Wireless World

ELECTRONICS, RADIO, TELEVISION

FEBRUARY 1964

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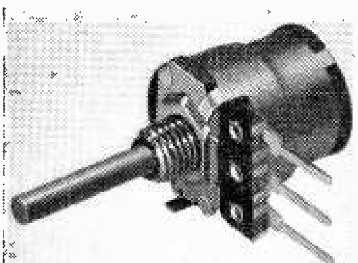
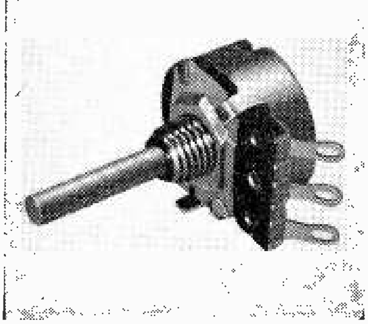
MINIATURE CARBON POTENTIOMETERS

Robustness and Reliability

Volume and tone controls of modern transistor portables and radios need to be very compact, and the Mullard range of miniature potentiometers—the EO88 range—make it possible for this requirement to be achieved.

These carbon potentiometers are fitted with soldering tags for wire connections, or with three terminal pins for use with





printed-wiring boards. Either version can be obtained with or without a single-pole rotary switch. The range of resistance values obtainable is 1 to 500kΩ, with either a linear or logarithmic law, and the potentiometers are stable over a temperature range of —10 to +70°C. Their diameter is 16mm and spindle lengths of 10, 15 and 20mm are available. These small Mullard potentiometers are outstanding among miniature components for their robust construction, reliability of operation and length of service life.

AC107 LOW-NOISE TRANSISTOR FOR TAPE RECORDERS

The Mullard AC107 low-noise junction transistor is now frequently used as a voltage amplifier in hybrid tape recorders. In this application, it offers the required amplification while introducing the minimum of hum and microphony. In addition to hybrid recorders, the AC107 is particularly suitable for battery-operated all-transistor tape recorders.

Use of the AC107 is not limited to the above equipment, however. Manufacturers of high-quality audio equipment who wish to employ transistor pre-amplifiers because of their inherently good microphony properties are making increasing use of the device. The Mullard AC107 is thus contributing greatly to the high standards attainable with the wide present-day range of audio equipment.

TEMPERATURE COMPENSATION PROLONGS EFFECTIVE BATTERY LIFE

AA129 bias stabilising diode

The AA129 Mullard junction diode is being used in the latest radios to provide compensation for changes in battery voltage and operating temperature.

In portables, the voltage of the batteries used will decrease with life, and the performance of the sets will deteriorate because of an increase in crossover distortion. This effect of decreasing voltage is accentuated as the operating temperature falls. To ensure good battery life, it is desirable

WHAT'S NEW IN THE NEW SETS

These articles describe the latest Mullard developments for entertainment equipment

that the rece vers should be designed to give acceptable performance when the voltage falls to about 50% of the nominal value.

If the AA129 is incorporated in the base-bias network of the output stage of the receiver, the necessary compensation can be achieved. With such an arrangement the voltage can fall well below the 50% limit without the performance of the receiver at extremely low temperatures falling below an acceptable standard. Use of the Mullard bias stabilising diode thus ensures less variation in performance with battery voltage decay and considerably prolongs the useful life of the batteries in a portable radio.

MVE 1500

5WW—090 FOR FURTHER DETAILS.

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The Physics Trade

A PLUMBER, called to attend to a blocked sink in a physical-chemistry laboratory and waiting for the return of his mate with a bigger pipe wrench, is watching through a forest of fractionating columns the dexterous manipulation of a burette by the research worker on the opposite side of the bench. After a time the scientist becomes aware that he is being watched. There is an awkward pause, and it is the plumber who breaks the silence: "Kind of a trade all on its own like, ain't it?"

We are reminded of this story (founded on fact) every time we visit the Physical Society Exhibition which, to give it its full sub-title is an "annual exhibition of scientific instruments and apparatus." It is here that the practical aspect of the scientific process—hypothesis tested by experiment—comes into its own and where as revolutionary changes have taken place in the past 50 years as in theoretical physics.

When we first reported this exhibition (in January 1912) the thermionic valve was still a curiosity and the exhibition was dominated, if not by string and sealing wax, by ebonite and lacquered brass. But by 1921 Prof. Fortescue and Dr. Bryan were able to assemble enough material to read a paper during the exhibition period on "Some of the Uses of the Thermionic Valve," one of many events which signalled the start of what we now term "electronics." Nowadays the kind of experiment required to verify advanced thought on the nature of the material universe requires all the resources of industry in making, mounting and monitoring the necessary giant particle accelerators. Physics must now call on the resources of finance, economics and commerce as well as on engineering.

Herein lies the origin of a dilemma which the Council of the Institute of Physics and the Physical Society has had to face in recent years—how far it should go in admitting or excluding the commercial element. It has always held that the Exhibition is "a scientific occasion rather than one for the display of ordinary commercial products," and it is important here to notice the use of the comparative "rather than" instead of an uncompromising "not." This has permitted flexibility in the interpretation of the rule.

One result of the Council's efforts to restrict commercial activities within the Exhibition has been to foster the growth of extra-mural trade shows of which there were many this year in hotels within easy reach of the Horticultural Halls. If industry can stand the expense we think this is probably the best solution of the problem. It should not be forgotten that physicists want to buy ordinary commercial products, and that the "Phys. Soc." Exhibition, whether the organizers like it or not, provides a powerful stimulus. Most of the research demonstrations by universities and Government establishments are mounted with the help of numerous production oscilloscopes, display units, etc., which would not otherwise qualify for admission, but which nevertheless may be new to some worker on his biannual emergence from the laboratory. It would be convenient if he could discuss the matter in detail at an adjacent trade show before returning to his ivory tower, particularly if he works in the provinces.

Next year the Exhibition will try the experiment of moving to Manchester under the new title of "The Physics Exhibition." We hope the hotel accommodation will be sufficient to house the many research workers who will travel north to see it, together with the firms who will be exhibiting outside as well as inside the exhibition.

Recent Developments in

AUTOMATIC ERROR CORRECTION

1.—ERROR CORRECTING CODES FOR RADIO TELEPRINTER CIRCUITS

By P. R. KELLER,* M.B.E., B.Sc., A.M.I.E.E.

MOST inland telegraph traffic is transmitted over line circuits between teleprinters using the 5-unit C.C.I.T.T. International Telegraph Code No. 2, and the start-stop mode of operation for maintaining synchronism between the transmitting and receiving apparatus.

When this method is used for transmission over an HF radio circuit a proportion of the received characters will often contain errors due to the distortion, noise and fading inherent in this propagation medium. This has led to the development of automatic error correcting equipment for use on radio teleprinter circuits. Before considering the modes of operation of various error-correcting systems, normal teleprinter operation will be reviewed.

The Teleprinter Code:—The code is shown in Table I. It is seen that each character is represented by five elements each of which is in one of two conditions. The use of all arrangements of a 5-element 2-condition code permits 32 different characters to be formed, and the number of symbols which can be printed is increased by using figure and letter cases. Some characters are allotted to machine functional operations which are the same in both cases.

Characters can be transmitted by transmitting all elements together on a 5-wire simultaneous basis (usually only over short distances) or, more generally, by transmitting the elements sequentially.

Start-Stop Operation:—In the start-stop method of transmission, illustrated in Fig. 1, the five information elements are of equal duration and are transmitted in order, preceded by a start element of the same duration, and followed by a stop element. The stop condition is maintained for a minimum period before the start element of the next character is transmitted. When an automatic transmitter is used, the stop period is often nominally $1\frac{1}{2}$ basic element periods, while, with manual keyboard transmission it may be longer and variable. When there is no traffic to be sent the circuit idles in the stop condition. The usual transmission speed is 50 bauds (50 elementary information units per second). At this speed the start element and the five information elements are transmitted for 20 milliseconds. each.

At the receiver, receipt of an element of start polarity prepares the apparatus to take note of the condition of the input wire at five examining points spaced at intervals of 20 msec and beginning 30 msec after the transition from stop to start polarity. As a result, the information elements are sampled at their mid-points and the receiver has maximum margin against distortion in the input signal. An electronic receiver can have a performance in this respect close to the ideal, and correctly interpret the signal with up to 50% distortion, i.e., when the transitions are displaced by up to 10 msec.

The advantage of start-stop operation is that receiver synchronism is accomplished in a simple manner relying only on a knowledge of the nominal transmission speed. Slight speed variations lead to small errors in the examining points, but these errors are not cumulative as the timing for the receipt of each character is reckoned only over the character period, and begins again from the timing of the next start element for the next character.

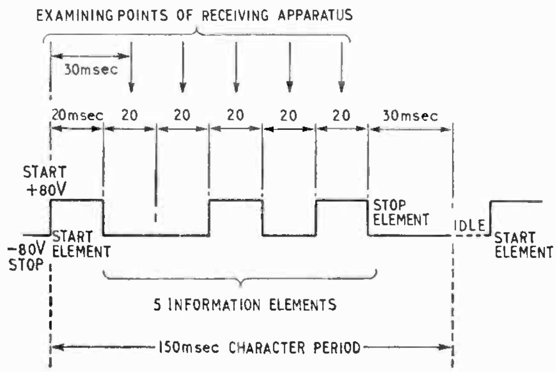


Fig. 1. Character J shown represented as MMSMS, ZZAZA or 11010, together with start and stop elements.

Signalling Conditions and Designations:—The two signalling conditions used to transmit characters in teleprinter code may be designated by several different systems of symbols, and presented physically in practical transmission systems in a further variety of ways. Since it is convenient at different times to use different terms and symbols some of those most commonly used are shown in Table II.

Transmission Over HF Radio Circuits:—Telegraph transmission over a radio circuit using the teleprinter code and start-stop operation can be effected quite simply by allowing two radio conditions to the start and stop telegraph signalling conditions. As examples, with on/off keying, "carrier off" can represent the start condition and "carrier on" the stop condition, while for frequency shift keying (F.S.K.) on frequency can be transmitted for start and another for stop, and so on.

The advantage of this method is that only simple

* *The Marconi Co. Ltd.*

terminal equipment is required and there is no compatibility problem in connecting to land line networks.

However, if traffic is transmitted in this simple manner direct from a teleprinter, or similar 5-unit apparatus, messages can be corrupted in two ways. Firstly, if one or more of the five information elements of a character is received incorrectly, a wrong character will be printed since all 32 possible arrangements of the five information elements are acceptable to the receiving teleprinter. Secondly, if a start or stop element is received incorrectly, the receiving teleprinter will lose phase temporarily and a number of characters will be printed incorrectly until phase is regained.

Synchronous Transmission:—Errors due to the incorrect receipt of a start or stop element can be overcome by synchronous working, which involves discarding the start and stop elements before transmission and re-inserting them correctly at the receiver, thus reconstructing a start-stop signal to drive the teleprinter. For synchronous working more complicated circuits are required, as the receiver must be synchronized, and phased correctly, to the incoming signal, but this method can reduce the printed error rate by about 75% even when the "unprotected" 5-unit teleprinter code is retained.

Protected Codes:—Further reduction in the printed error rate can be obtained by using a "protected" code, permitting error correction, in place of the teleprinter code, for transmission over the radio path. The error correcting terminals will generally provide automatic translation between the teleprinter code and the protected code to permit integration with normal teleprinter apparatus, or networks, at the ends of the radio link.

The protected codes have error detecting or error correcting properties, or both, depending on the other characteristics of the system. They always possess "redundancy" in the sense that only some of the possible arrangements of the elements of each character are transmitted and are acceptable to the receiver.

Error Detecting Codes:—For major point-to-point systems the method generally employed involves the use of an error detecting code in which individual 5-unit characters in teleprinter code are translated to 7-unit characters each of which contains three elements of mark polarity and four elements of space polarity. The code is shown in Table III. Of the 128 possible arrangements of the elements of a 7-unit code, 35 have this characteristic and are allocated to the 32 characters in teleprinter code and to 3 supervisory conditions. All errors affecting an odd number of elements in a character, and some errors affecting an even number of elements, can be detected at the receiver by inspection of the mark/space ratio. On detecting an error printing is stopped and a special signal requesting a repetition is returned to the transmitting terminal. Receipt of this signal causes a number of characters, which include the erroneously received character, to be re-transmitted automatically from a storage device. Printing is resumed at the end of the repetition process. Transpositions, involving a mark element interpreted as a space together with a space element interpreted as a mark in the same character, lead to undetectable

TABLE I
The Teleprinter Code
C.C.I.T.T. International Telegraph Alphabet No. 2

Permutation No.	Figure Case	Letter Case	5-Unit Code
1	—	A	ZZAAA
2	?	B	ZAAZZ
3	:	C	AZZZA
4	Who are you?	D	ZAAZA
5	3	E	ZAAAA
6	%	F	ZAZZA
7	@	G	AZAZZ
8	£	H	AAZAZ
9	8	I	AZZAA
10	Bell	J	ZZAZA
11	(	K	ZZZZA
12	)	L	AZAAZ
13	.	M	AAZZZ
14	,	N	AAZZA
15	9	O	AAAZZ
16	0	P	AZZAZ
17	1	Q	ZZZAZ
18	4	R	AZAZA
19	!	S	ZAZAA
20	5	T	AAAAZ
21	7	U	ZZZAA
22	=	V	AZZZZ
23	2	W	ZZAAZ
24	/	X	ZAZZZ
25	6	Y	ZAZAZ
26	+	Z	ZAAAZ
27	Carriage return		AAAZA
28	Line feed		AZAAA
29	Figure shift		ZZAZZ
30	Letter shift		ZZZZZ
31	Space		AAZAA
32	Unperforated tape *Error Symbol		AAAAA

A=Element of Start Polarity
Z=Element of Stop Polarity

TABLE II
Signalling Conditions and Designations For Teleprinter Operation

		One Condition	Other Condition
Designation	C.C.I.T.T. System	Start Space(S) A	Stop Mark(M) Z
	Mathematical Representation	0	1
Signalling Practice	U.K. Practice	+80V —80V	—80V +80V
	Loop Signalling	No Current	Current
	Tape Operation	No Hole	Hole
	Freq. Shift Operation	f1	f2

TABLE III

The Teleprinter Error Detecting Code

C.C.I.T.T. International Telegraph Alphabet No 2

<table>
<tr><th>Per-mutation No.</th><th>Figure Case</th><th>Letter Case</th><th>5-Unit Code</th><th>7-Unit Code</th></tr>
<tr><td>1</td><td>—</td><td>A</td><td>Z Z A A A | Z</td><td>Z Z A A Z A Z</td></tr>
<tr><td>2</td><td>?</td><td>B</td><td>Z A A Z Z · Z</td><td>Z Z A A Z Z A</td></tr>
<tr><td>3</td><td>:</td><td>C</td><td>A Z Z Z A | Z</td><td>A Z Z A A Z Z</td></tr>
<tr><td>4</td><td>Who are you?</td><td>D</td><td>Z A A Z A | Z</td><td>Z Z A A A Z Z</td></tr>
<tr><td>5</td><td>3</td><td>E</td><td>Z A A A A · Z</td><td>Z A A A Z Z Z</td></tr>
<tr><td>6</td><td>%</td><td>F</td><td>Z A Z Z A | Z</td><td>Z Z A Z Z A A</td></tr>
<tr><td>7</td><td>@</td><td>G</td><td>A Z A Z Z | Z</td><td>A A Z Z Z Z A</td></tr>
<tr><td>8</td><td>£</td><td>H</td><td>A A Z A Z · Z</td><td>A Z A Z Z A Z</td></tr>
<tr><td>9</td><td>8</td><td>I</td><td>A Z Z A A | Z</td><td>A A A Z Z Z Z</td></tr>
<tr><td>10</td><td>Bell</td><td>J</td><td>Z Z A Z A | Z</td><td>Z A Z Z Z A A</td></tr>
<tr><td>11</td><td>(</td><td>K</td><td>Z Z Z Z A | Z</td><td>Z Z Z A Z A A</td></tr>
<tr><td>12</td><td>)</td><td>L</td><td>A Z A A Z | Z</td><td>A A Z Z Z A Z</td></tr>
<tr><td>13</td><td>.</td><td>M</td><td>A A Z Z Z · Z</td><td>A Z A Z Z Z A</td></tr>
<tr><td>14</td><td>,</td><td>N</td><td>A A Z Z A | Z</td><td>A Z A Z A Z Z</td></tr>
<tr><td>15</td><td>9</td><td>O</td><td>A A A Z Z | Z</td><td>A Z Z Z A A Z</td></tr>
<tr><td>16</td><td>0</td><td>P</td><td>A Z Z A Z · Z</td><td>A Z Z A Z A Z</td></tr>
<tr><td>17</td><td>1</td><td>Q</td><td>Z Z Z A Z | Z</td><td>Z Z Z A A Z A</td></tr>
<tr><td>18</td><td>4</td><td>R</td><td>A Z A Z A | Z</td><td>A A Z Z A Z Z</td></tr>
<tr><td>19</td><td>!</td><td>S</td><td>Z A Z A A | Z</td><td>Z A Z A Z A Z</td></tr>
<tr><td>20</td><td>5</td><td>T</td><td>A A A A Z · Z</td><td>A Z Z Z A Z A</td></tr>
<tr><td>21</td><td>7</td><td>U</td><td>Z Z Z A A | Z</td><td>Z A A Z Z A Z</td></tr>
<tr><td>22</td><td>=</td><td>V</td><td>A Z Z Z Z · Z</td><td>A Z Z A Z Z A</td></tr>
<tr><td>23</td><td>2</td><td>W</td><td>Z Z A A Z | Z</td><td>Z A Z Z A Z A</td></tr>
<tr><td>24</td><td>/</td><td>X</td><td>Z A Z Z Z | Z</td><td>Z Z A Z A A Z</td></tr>
<tr><td>25</td><td>6</td><td>Y</td><td>Z A Z A Z · Z</td><td>Z Z A Z A Z A</td></tr>
<tr><td>26</td><td>+</td><td>Z</td><td>Z A A A Z | Z</td><td>Z A A Z Z Z A</td></tr>
<tr><td>27</td><td colspan="2">Carriage Return</td><td>A A A Z A | Z</td><td>A Z Z Z Z A A</td></tr>
<tr><td>28</td><td colspan="2">Line Feed</td><td>A Z A A A · Z</td><td>A Z A A Z Z Z</td></tr>
<tr><td>29</td><td colspan="2">Figure Shift</td><td>Z Z A Z Z | Z</td><td>Z A Z Z A A Z</td></tr>
<tr><td>30</td><td colspan="2">Letter Shift</td><td>Z Z Z Z Z | Z</td><td>Z Z Z A A A Z</td></tr>
<tr><td>31</td><td colspan="2">Space</td><td>A A Z A A | Z</td><td>A A Z A Z Z Z</td></tr>
<tr><td>32</td><td colspan="2">Unperforated Tape *Error Symbol</td><td>A A A A A · Z</td><td>Z Z Z Z A A A</td></tr>
<tr><td>33</td><td colspan="2">Idle Beta Signal Normally Cont. Stop Polarity</td><td>Z Z Z Z Z A</td><td>Z A Z A A Z Z</td></tr>
<tr><td>34</td><td colspan="2">Idle Alpha signal Normally Cont. Start Polarity</td><td>A Z Z Z Z A</td><td>Z A Z A Z Z A</td></tr>
<tr><td>35</td><td colspan="2">R Q Signal</td><td>A A Z Z Z A</td><td>Z A A Z A Z Z</td></tr>
</table>

A = Element of Start Polarity.
Z = Element of Stop Polarity.

errors and incorrect printing. However, the probability of such errors is low, and this system will reduce the error rate by orders of magnitude. Error detecting and correcting terminals of this type, operating on the principle of correcting errors by the automatic repetition of detected errors (ARQ), will generally also make provision for combining two or four teleprinter channels in time division multiplex. In this case the equipment characteristics have been internationally standardized.[4, 5]

ARQ systems can evidently only be operated on point-to-point circuits and where a return channel is available. For broadcast systems, or point-to-point circuits where a return channel is not available, some other method of error protection must be employed. In these cases an error correcting code can be used employing greater redundancy than a simple error-detecting code, as described above, and permitting the majority of errors to be corrected without reference back to the transmitting terminal.

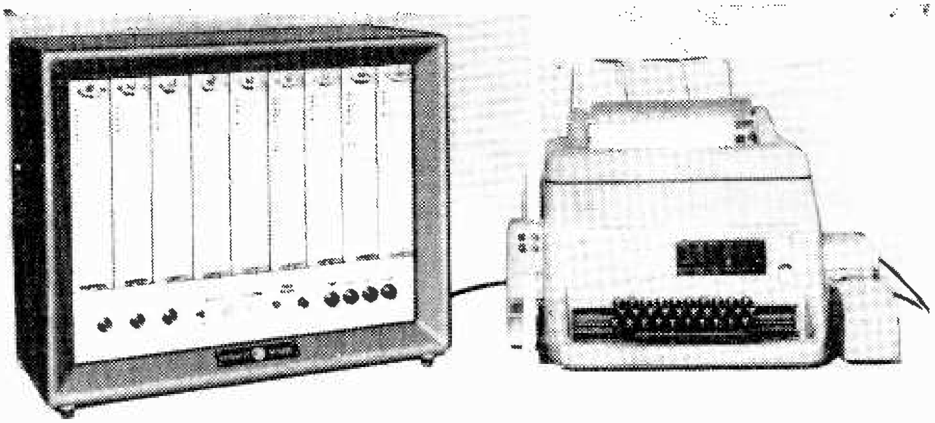
Error Correcting Code:—In a classic paper,[6] to which reference is often made, R. W. Hamming established basic rules for error detecting and error correcting codes, and indicated some of the ways in which such codes might be constructed by adding parity digits to groups of digits representing characters in a non-redundant unprotected code.

From these rules we know that in the case where the unprotected code has 5 elements, the minimum number of elements in the characters of a code permitting single-element errors to be detected is six, and the minimum number of elements in the characters of a code permitting single element errors to be corrected is nine, while at least ten elements are required in each character to permit single element errors to be corrected and errors affecting two elements to be detected.

In the latter case the characters of the new code have twice as many elements as the number of information elements in the characters of the original code. By grouping two or more teleprinter characters together, and operating on a group of ten or more digits, the proportion of parity or check digits will be reduced, but so will the effectiveness of single error correction on a circuit of given basic performance, while the complications of the terminal equipment will increase.

Practical System Requirements:—A system for transmitting teleprinter traffic over an HF radio circuit, and providing error protection by use of an error correcting code, should have the following characteristics:

(a) Any single element error in a character should be corrected automatically.
(b) Most multiple element errors in a character should be detectable, rather than result in a false correction, so that these uncorrectable errors may be indicated in the printed copy.
(c) As a corollary to (a) and (b), the number of undetectable errors, leading to the printing of an incorrect character, should be a minimum.
(d) Operation must be synchronous (if not, the performance would be little better than start-stop teleprinter code working).
(e) Phasing should preferably be automatic so that the equipment can be added to existing



Marconi "Autospec" error correcting equipment with receiving teleprinter.

networks with no change in operational procedure.

(f) A return channel should not be required.

A 10-Unit Error Correcting Code for Teleprinter Circuits:—It has previously been proposed to transmit 5-unit teleprinter characters twice as a means of obtaining an error detection facility by comparing the pairs of characters element by element. In certain cases, where the probabilities of mark and space errors are not equal, transmitting twice can give error correction, but for most modern transmission methods, F.S.K., F.M.V.F., etc., this is not possible.

A 10-unit error correcting code can be constructed by the Hamming method,[1] but for the special case where the unprotected code has 5 elements an equally effective 10-unit error correcting code can be devised, by an alternative method giving greater circuit simplicity in a practical equipment design, as follows:

Principles of Coding

In this method as many parity checks are made, each leading to the addition of a parity digit, as there are elements in the original character, each check covering the elements of the original character excluding one element at a time in turn.

The operation of the method is best seen by an example.

Take the case where the information elements of the 5-unit teleprinter character can be written as 01101, where 1 represents an element of mark (stop) polarity and 0 an element of space (start) polarity. Let us arrange that the first check digit is made 1 or 0 so that together with the four elements of the original character, excluding the first element, we obtain an odd number of 1 elements. The second check digit is made 1 or 0 so that together with the four elements of the original character, excluding the second element, we obtain an even number of 1 elements. The third check digit is made 1 or 0 so that together with the four elements of the original character, excluding the third element, we obtain an odd number of 1 elements. The fourth check digit is made 1 or 0 so that together with the four elements of the original character, excluding the fourth element, we obtain an even number of 1 elements. The fifth check digit is made 1 or 0 so that together with the four elements of the original character, excluding the fifth element, we obtain an odd number of 1 elements. The resulting character in error correcting code is then

0110100111

writing the original five elements in order in the first five element positions of the new character, and adding the check elements in sequence. In practice, of course, the ten elements can be transmitted in any order, provided that the receiver is programmed to take note of the order. Further it is evident that we could have arranged for any of the checks to give odd or even results, each different arrangement leading to a different set of 10-unit characters.

Principles of Reception:—At the receiving terminal similar checks are carried out on received characters. Five checks are made, each covering four elements from the first five together with the appropriate parity element from the last five. The results of the checks may be written in order in an electronic register expressing a correct check result as 0 and an incorrect check result as 1, so that for a character unmutilated in transmission the checks register shows 00000 and the first five elements for the character may be transmitted unaltered, but with start and stop elements added, to the receiving teleprinter. If a single error affects one of the first five elements the check register will contain only one 0 in the position corresponding to the faulty element, which can then be inverted before being transmitted to the teleprinter. If the single error affects one of the second five elements, the check register will contain only one 1, and the first five elements can be transmitted to the teleprinter unchanged. Any double errors, and many multiple errors, will result in the check register, containing 11111, or 111 with 00 in any arrangement, or 11 with 000 in any arrangement. In a practical system the teleprinter can be arranged to print an error symbol when these indications are given by the check register.

Examples:

Teleprinter signal	01101
Transmitted signal	0110100111
(a) Received signal (no errors)	0110100111
Check result	00000
5-unit output	01101

(b) Received signal (third element in error) 0100100111
Check result 11011
5-unit ouput 01101 (Third element in error and reversed as one 0 in third position of check result.)

(c) Received signal (ninth element in error) 0110100101
Check result 00010
5-unit output 01101 (First five elements accepted as check result shows only one 1).

(d) Received signal (double error affecting third and fourth elements) 0101100111
Check result 00110
5-unit output Error symbol (Because check result gives 11 with 000).

In this example it appears that the double error could have been corrected, but the same check result might have been obtained from a multiple error as in the next example.

(e) Received signal (quadruple error) 0000101101
Check result 00110
5-unit output Error symbol

(To be concluded)

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3. P. R. Keller and A. J. Wheeldon: "Recent Improvements in Automatic Error Correcting Systems for HF Telegraph Networks," *Point-to-Point Telecommunications*, Vol. 6, No. 2 (1962).
4. Recommendation No. 242 C.C.I.R. Green Book (Los Angeles 1959), Vol. 1, p. 130.
5. Report No. 108 C.C.I.R. Green Book (Los Angeles 1959), Vol. 3, p. 70.
6. R. W. Hammings: "Error Detecting and Error Correcting Codes." *Bell System Technical Journal*, April, 1950.
7. A. C. Croisdale: "Automatic Error Correcting Systems used on HF Radio Links," *I.E.E. Convention on HF Communication*, March, 1963, Fig. 15.

Books Received

Principles of Feedback Design by G. Edwin and Thomas Roddam. Essentially a working guide to the understanding and solution of feedback problems in electronic circuits, taking as a first example the step-by-step synthesis of the response of a three-stage valve amplifier, this book also affords an insight into the broader aspects of closed-loop systems and conditions for stability. Other topics discussed are signal-flow diagrams and feedback amplifiers as filters. Pp. 238. Iliffe Books Ltd., Dorset House, Stamford Street, London, S.E.1. Price 45s.

Principles and Practice of Radar, by R. S. H. Boulding, O.B.E., B.Sc., M.I.E.E., A.M.I.Mech.E., F.Inst.P. Seventh edition, revised and reset, gives a broad and comprehensive introduction to principles and practice. Pp. 851. George Newnes Ltd., Tower House, Southampton Street, London, W.C.2.

Dictionary of Modern Acronyms and Abbreviations, by Milton Goldstein, Ph.D. Over 6,000 coined words and abbreviations (chiefly American) in electronics and allied fields. Pp. 158. Howard W. Sams & Co. Inc., Indianapolis 6, Indiana, U.S.A. Price $4.95.

International Series of Monographs on Electronics and Instrumentation. (Pergamon Press, Headington Hill Hall, Oxford.)

Static Electromagnetic Frequency Changers, by L. L. Rozhanskii (translated from the Russian) discusses theory, layout, construction and design of devices based on non-linear inductance. Pp. 110. Price 35s.

Fundamentals of Microwave Electronics, by V. N. Shevchik (translated from the Russian). Broad general survey based on a series of lectures by the author at Sarator State University, of the interaction of electron streams with alternating electromagneic fields and of the practical devices which have emerged. Pp. 253. Price 70s.

Semiconductor Fundamentals, by A. H. Seidman and S. L. Marshall. A succinct course on semiconductor physics, transistor and diode (including tunnel diode) action and characteristics, and the application of these devices in amplifier, oscillator and logic circuits. Gives design formulæ and many worked examples. Pp. 278. John Wiley and Sons Ltd., Glen House, Stag Place, London, S.W.1.

The Physics of Magnetic Recording by C. D. Mee. A comprehensive survey of theories of the magnetic recording and reproducing processes and of the criteria for the specification of coating materials and tapes and their manufacture. Chapters are included on magnetic measurements and on experimental high-resolution recording systems. Features of this book are the emphasis on gap/coating relationships and the many diagrams of flux penetration and patterns of magnetization in depth. Pp. 270. North Holland Publishing Company, P.O. Box 103, Amsterdam. Price 60s., Fl. 30. or $8.40.

B.B.C. Engineering Training Manuals

Television Engineering. Vol. I. Fundamentals, camera tubes, television optics, electron optics. By S. W. Amos, B.Sc. (Hons.), A.M.I.E.E., D. C. Birkenshaw, M.B.E., M.A., M.I.E.E., and J. L. Bliss, M.I.E.E. Revised second edition now covers all line standards and deals more fully with image orthicon and vidicon tubes. Pp. 301. Price 45s.

B.B.C. Engineering Monograph No. 50. New Methods of Lens Testing and Measurement. Part I. A Photoelectric Lens Testing Bench, by W. N. Sprosen, M.A., and K. Hacking, B.Sc. Part II. A Method of Observing and Recording the Sources of Flare in a Lens. By K. Hacking, B.Sc., and J. C. Martin. Pp. 23. B.B.C. Publications, 35 Marylebone High Street, London, W.1. Price 5s.

Wireless World OSCILLOSCOPE

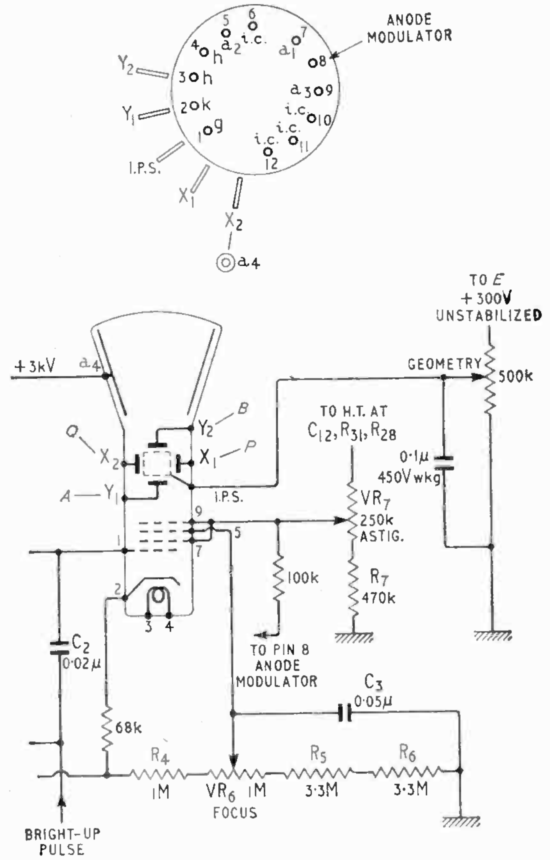


Fig. 3. Circuit modifications for Sylvania-Thorn SE3A tube. Tube base is obtained from Corr Fastener, Pinfold Lane, Stapleford, Notts.

7.—CALIBRATION

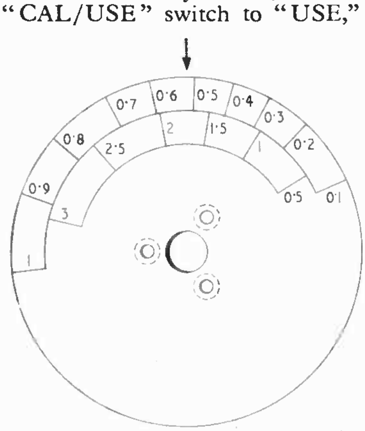
CONSTRUCTION of the oscilloscope is now completed, but before it can be used for voltage or time measurement, it must be calibrated. On this subject we must make the point that, while we will do our best in this series to keep to a minimum the equipment needed for test and calibration (for instance, the audio signal generator only required a meter and domestic radio and television), it is not possible to dispense with it entirely. We will try, as far as possible, to use test gear that we have already described, and the audio signal generator can be used for calibration of the oscilloscope.

One other point should be mentioned. When we publish a design it is as good as we can make it at a reasonable cost and in a reasonable development time. From this point on modifications occur to us, some are suggested, and price changes dictate others. In this way we describe the use of an alternative, cheaper tube and a rather more expensive, but more stable and efficient e.h.t. unit will come later.

Amplifier

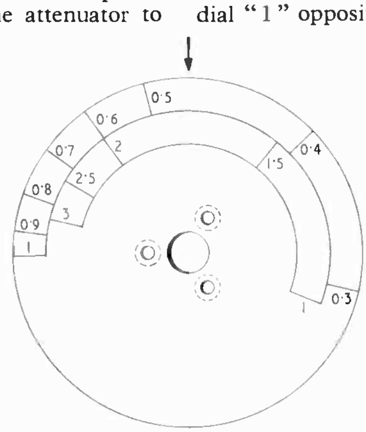
To return to the subject in hand, the y amplifier is probably the easiest unit to calibrate. A specimen dial is shown in Fig. 1. For this operation we need an audio signal generator with a calibrated output control (the "Wireless World" one will do very well, but so will many others). First set the amplifier "CAL/USE" switch to "USE," the attenuator to one of the "1" positions of the "1-3-10" sequence, and feed into the input socket a peak-to-peak signal of 100mV, 1V, 10V, etc. Set the y gain control to give a full-screen display. Switch to "CAL" and adjust the calibration waveform, by means of the "CAL VOLTAGE" dial, to fit between the same two cursor lines as the signal waveform. Mark on the dial "1" opposite the reference point. Switch back to "USE" and apply a signal of 90mV, 0.9V, 9V or any other 9 within the attenuator range. Switch to "CAL," adjusting the calibration voltage again and mark "0.9" opposite the reference point. Do this for all points from 0-1.

Repeat this procedure, on the other dial line, for signal inputs of 0-3 (30mV, 3V, 30V, etc.). This completes calibration of the y amplifier.



Y DIAL

Fig. 1. Specimen y amplifier dial

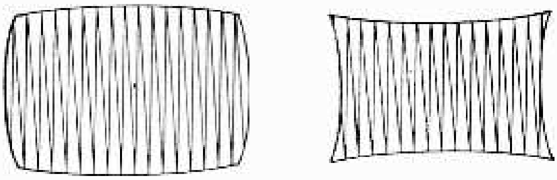


X DIAL

Fig. 2. Typical time-base dial

Timebase

Calibration of timebase sweep times is a little complicated by the fact that the amplitude and therefore frequency are slightly affected by the presence of a sync. pulse.



(a) (b)

Fig. 4. Distortion caused by tube. Borrel distortion shown at (a), pincushion at (b). Correct by adjustment of interplate shield voltage (see text).

We will therefore assume for the purposes of calibration, that the timebase is unsynchronized. If, in this condition, the length of trace is set by the "X gain" control to fill the ten screen divisions, then calibration will remain correct for any range if, when synchronized, the gain control is left untouched. This is the penalty one pays for simplicity. In later units, calibration will be carried out in a different way, as sweep times will not be continuously variable. Provision has already been made for this in the present x amplifier.

Once again an audio oscillator is used. As, in our sweep generator, the flyback time is negligible compared with the sweep time, a cycle of the sweep waveform can be considered as being equal in duration to the sweep time, and a Lissajous method can be used. Two dial scales are used as seen in Fig. 2, corresponding to the sweep time 1-3 and 3-10 multiples. If the timebase capacitors used are cheap types with wide tolerances, it may be wise to perform the following process for each range, giving eight scales on the dial. For most applications, it will be sufficient to assume that each range is a multiple of the next but one.

Switch the trigger selector to one of the external positions. Set the "Time per Division" range switch on the timebase unit to 3μsec. Adjust the x gain control to give ten divisions of scan. Inject 33.3kc/s into the y amplifier, adjusting attenuator and gain controls to give a conveniently-sized display. Adjust the timebase dial to give one cycle of the signal on the screen. It will be very difficult

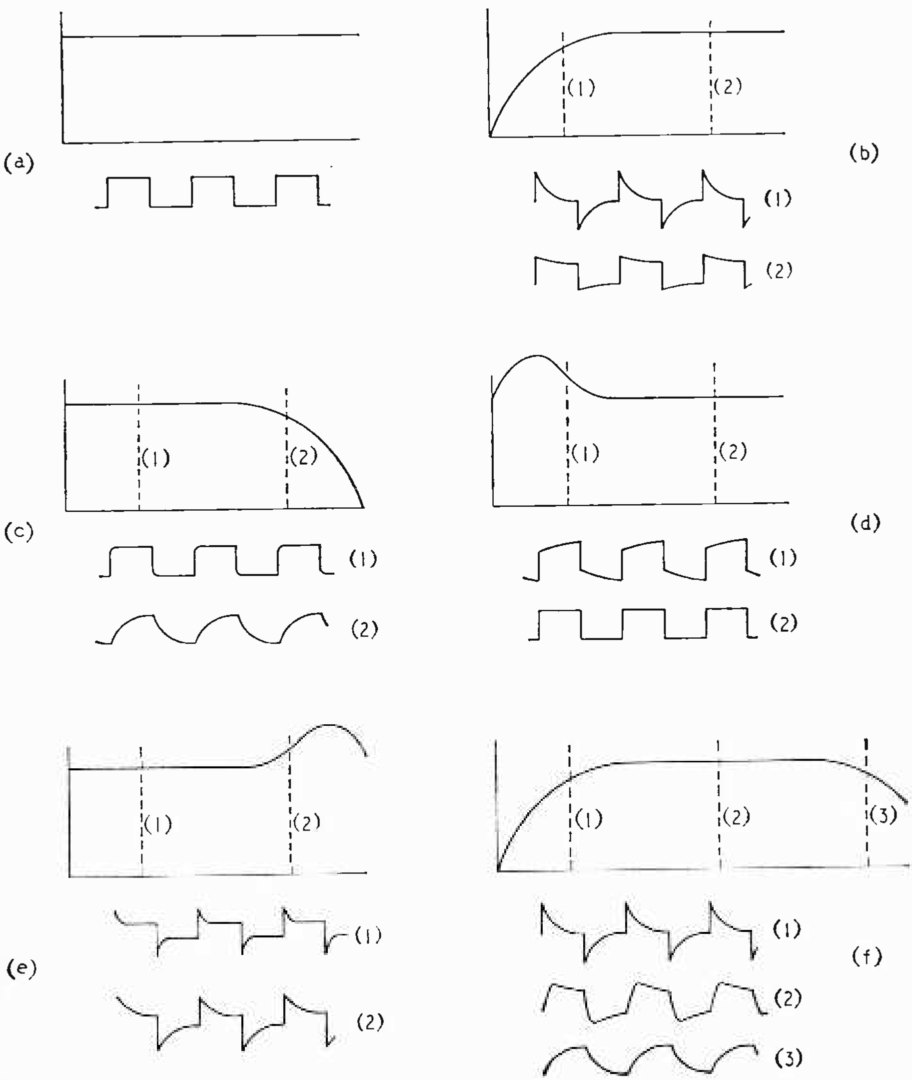


Fig. 5. Typical deformations of a square wave by amplifiers having different frequency characteristics. Square wave frequencies are shown as vertical lines on response curves.

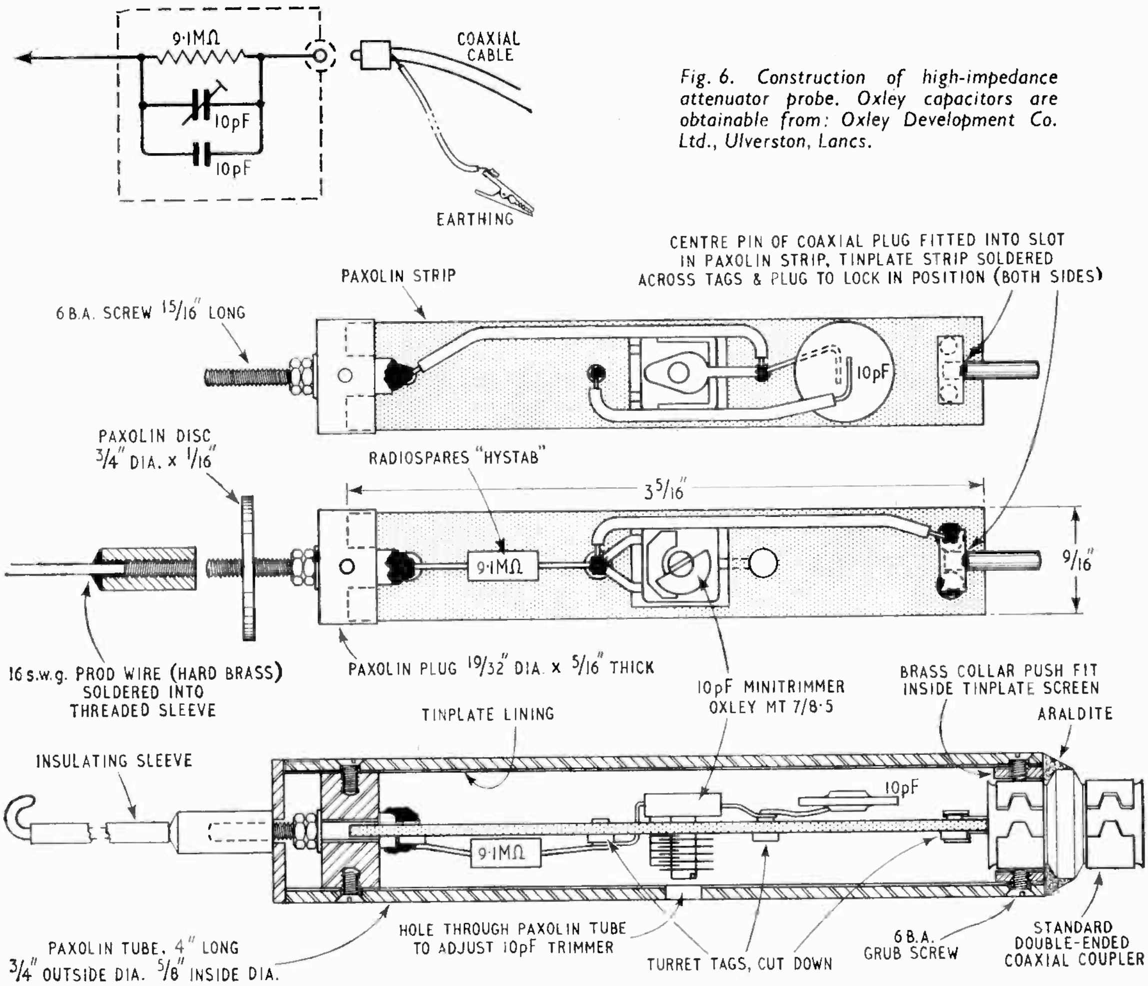


Fig. 6. Construction of high-impedance attenuator probe. Oxley capacitors are obtainable from: Oxley Development Co. Ltd., Ulverston, Lancs.

to obtain a stationary pattern, but a very small movement of the dial will make the pattern change quickly, which means that, if it moves only slowly, the two frequencies are near enough equal. When a steady or slowly-moving pattern is seen, mark the dial with "3." Repeat this process for dial markings from "1" to "3" and from "3" to "10." The signal applied to the y input should be $1/10t$ Mc/s where t is the time per division, in microseconds, being calibrated. For instance, on the second range, 10μsec per division, suppose that point "6" is to be marked. The frequency needed is $1/60$ Mc/s= 16.7kc/s. The highest and lowest input frequencies required are 100kc/s and 10c/s respectively.

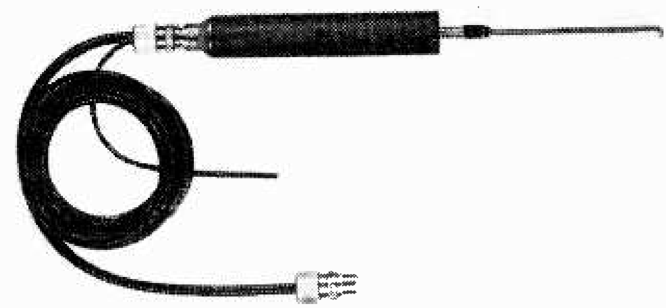
New Tube

As we mentioned earlier, many queries have been received on the subject of tube replacement, usually because of the cost of the DN7-78. Price changes since the oscilloscope was first published have led us to use a cheaper tube with roughly the same specification—the Sylvania-Thorn SE3A. Only slight modifications are needed for this tube, three of them being shown in Fig 3. The astigmatism control is now returned to h.t. at C_{12} and it was found that a geometry control was needed. This takes the form of a potentiometer across the h.t. line with the inter-plate shield of the tube taken to the wiper. This should not need frequent adjustment and is a preset control, or it can even be two fixed resistors. The wiper voltage should be adjusted until neither pincushion nor barrel distortion is shown on the screen. This is best displayed by feeding a high frequency to the y amplifier and running the timebase slowly, so that a raster is obtained. The display should almost fill the screen. A 68kΩ resistor should be inserted in the tube cathode circuit to prevent excessive beam current.

The Telcon Type SYLT3 Mu-metal screen should be used. The address of the tube makers is Thorn-A.E.I. Radio Valves and Tubes Ltd., Industrial C.R.T. Division, Millmarsh Lane, Brimsdown, Enfield, Middx. Telcon Metals are at Manor Road, Crawley, Sussex.

Uses

One of the main uses of the "No. 1" amplifier and timebase will be for audio testing. A quantitative frequency-response curve can be made by noting the output amplitude of an amplifier at different frequencies, but a quick, qualitative check is easily provided by using a square wave input at appropriate frequencies and examining the displayed output shape. In this context, one picture is worth two



High-impedance attenuator probe.

Frequency measurement by Lissajous figures has already been described in the time-base calibration, and this can be extended, although the time base is sufficiently accurate for most audio tests.

chapters of words, and Fig. 5 is therefore included.

Distortion measurement by oscilloscope is not easy. By simply gazing at an alleged sine wave, it is almost impossible to judge distortion of less than about 10 per cent, and less than 5 per cent is, to all practical purposes, invisible. Other methods must be used which would be out of place in this article, although we will possibly describe them later.

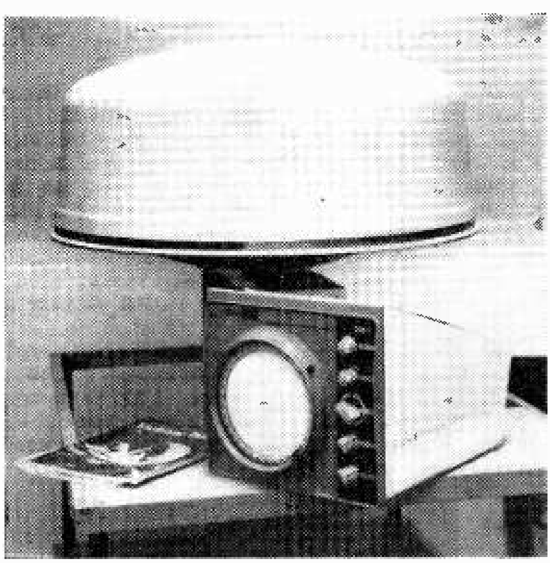
Probe

If a high-impedance source is to be examined, it may be found that the 1MΩ input impedance of the *y* amplifier is too low, and that the capacitance of a screened input cable is too high. For this reason, we have produced an attenuator probe which has an input impedance of 10MΩ in parallel with 10pF. It attenuates the signal by a factor of 10, and is therefore used on high-impedance, high-level signals. The trimmer is set up by looking at a square wave and adjusting the trimmer for no overshoot or rounding on the leading edge of the waveform. Construction is shown in Fig. 6.

YACHT RADAR

ALTHOUGH many compact and comparatively low-priced radars have been developed and marketed in recent months the majority of these have been for small coasters, or as second sets on ocean-going vessels. True there have also been mentions of yachts in the sales literature but implicitly these have been of the large luxury type.

A new radar (Model 1900) produced by Raytheon and distributed in the U.K. by Coastal Radio Ltd., sets



Radome and display unit of the Raytheon 1900 radar.

a new standard for compactness and low weight and opens up the wider field of small yachts and working boats.

Separate parabolic aerials, one for transmission and one for reception are mounted, together with their 3cm wavelength electronics and the rotation mechanism, inside a moulded one-piece radome 33in in diameter and 17in deep, weighing 43lb.

There are no waveguides and 50ft of video cable can be used between aerials and indicator units.

There are two other units, the display with 7in c.r.t. measuring $16 \times 12 \times 11$in (weight 30lb) and power supply $16 \times 9 \times 7$in (weight 15lb).

Range scales are provided for ½, 2, 6 and 12 miles (maximum range) and a resolution of 30 yards is claimed for the ½mile range.

Frequency is 9410 Mc/s (± 50 Mc/s), peak power 3.5kW, pulse length 0.14μsec and p.r.f. 2000. Beam width (3dB points) is 3° horizontal and 27° vertical with side lobes $<$-21dB.

The price of the Raytheon Model 1900 is £770.

5WW 337 for further details.

Telemetering Television Transmitters

TO extend the coverage of the island's television service the Cyprus Broadcasting Corporation has installed two additional stations on mountains (Mt. Olympus and Sina Oros). These two stations, each comprising two vision and two sound transmitters with their common programme input equipment, are to be controlled and supervised from the main station at Nicosia which is about 40 miles from each of the two "satellites." Duplex v.h.f. radio links are employed for the telemetry system which is being installed by Pye Telecommunications Limited. The system provides information on 23 points at each station and each of these is tested every 1.15 seconds.

Twenty controls covering the running up, shutdown, and if necessary the changeover of transmitters and associated equipment can be carried out from the main station. If the radio telemetry link should fail the "satellite" transmitter would be automatically transferred to a time-switch mechanism. If, on the other hand, the programme radio link failed the remote transmitter can be switched to rebroadcast "off the air" the transmissions from the other station.

LETTERS TO THE EDITOR

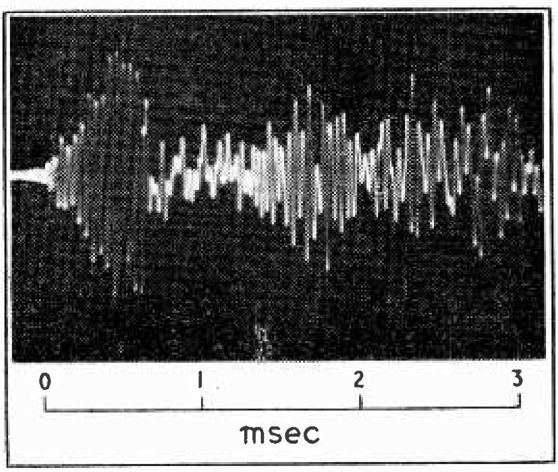
The Editor does not necessarily endorse opinions expressed by his correspondents

Hi-Fi by Numbers

I HAVE been reading with considerable interest the letter from Mr C. C. V. Hodgson, the B.B.C. reply and the correlated editorial, all of which appeared in your January, 1964 issue.

As regards the bandwidth of 10 kc/s for long-distance music lines mentioned by the B.B.C., it would be interesting to see a response curve showing the sort of roll-off that actually occurs. It seems unlikely that there could be a sharp termination at 10 kc/s like cutting the top off a stick of celery; I assume there would still be a few leaves hanging on in the 10 to 15 kc/s region.*

This question of frequency range and quality is of never ending interest but the emphasis should, as you say, always be placed on quality. Even with a bandwidth of 10 kc/s the reproduction of speech is cleaner and music is brighter on f.m. than on a.m. where the bandwidth is probably 2 to 3 kc/s narrower. On the other hand, line distortion shows up sooner on the f.m. transmissions and I occasionally find it necessary (in



Oscillogram of random frequencies produced by cymbal, showing as many as 24 vibrations in one millisecond.

Yorkshire) to change over to a.m. to avoid harshness, although this happens nowadays much less frequently than it did a few years ago. No doubt the quality of the lines has been improved and I suppose that still higher standards would be necessary with a bandwidth of 15 kc/s, otherwise complaints would be more numerous than compliments.

But how important is the 10-15 kc/s range in the reproduction of music? According to tests made by Snow, 14 out of 22 well known instruments require response up to 15 kc/s to avoid perceptible change in quality.

We have recently been making a few lab. tests at Wharfedale and we find that instruments such as the harp, Spanish guitar, harmonica and triangle reach 20 kc/s. The highest stepper seems to be the cymbal as it is possible to see quite strong vibrations at 24 kc/s in the oscillogram of Fig. 1.

Finally we come to the question: How important is the frequency range above 15 kc/s? I should be inclined to reply, not very, because few instruments are involved and the majority of adults hear very little at these very high frequencies. For my part, I should be happy to settle for the B.B.C. bandwidth of 10 kc/s because I suffer from presbyotia, due to anno Domini, eruditely described by "Free Grid" in the same *W.W.* January issue. I am stone deaf above 13 kc/s so, along with "Free Grid," I can enjoy a measure of immunity from attacks by shrieking sopranos.

Idle, Bradford, Yorks. G. A. BRIGGS
Wharfedale Wireless Works, Ltd.

*Do some people relish these excrescencies?—Ed.

IT was disappointing to note your reactionary and rather dusty opinion regarding the present broadcast frequency range put out on v.h.f. by the B.B.C.

The general tenor of your remarks suggests the Victorian father's "brush-off" to his children, that they are lucky to enjoy things as they are and should not be "greedy" in desiring an improvement.

It should be pointed out that an art is seldom furthered by the common denominator but rather that the "few" whom you appear to push on one side, are the real spearhead of advance.

The modern l.p. record has pushed on leaving radio a second best and also added stereo for good measure.

It is obvious that the backwardness of broadcast quality is not due to the engineers but to the politicians and it is all too easy to see that the engineers are being pushed up another street, i.e., Television Alley. Note how "sound" is now in very small type in the *Radio Times* and the high-powered advertising for the new TV channel all too strident.

In other words the politicians have chosen the painted harlot of colour TV as the end, rather than the twin virgins of pure stereo sound.

There are more Mr. Hodgsons than you imagine.

Welwyn Garden City. J. D. A. BOYD

[The small print could be the result of the longer hours and the greater variety of sound broadcasting?—Ed.]

I HAVE been most impressed by the B.B.C.'s spirited defence (January 1964 issue) of their policy of using landlines of only 7.5kc/s bandwidth to distribute the v.h.f. service to regional transmitters.

The money saved in G.P.O. rentals will no doubt help to finance the new programmes for BBC-2. Let us hope that when this achieves national distribution the same policy will be applied and the link bandwidth limited to an economic 3Mc/s.

Brentwood. JOHN NEATE

I READ with interest your comments on Mr. Hodgson's complaints regarding the restricted audio frequency band transmitted by the B.B.C.

For more than thirty-five years I have missed no opportunity of listening with careful attention to music, both live and reproduced. I am over fifty and my cut-off has descended from 17,000 to 12,500 c/s and I am not as discriminating as I used to be. This does not make me any less sensitive to distortion and this is the limiting factor in sound reproduction, and not frequency response.

There is no practical complete system of sound reproduction in which distortion does not become increasingly apparent as the reproduced bandwidth rises above about

7000 c/s. Only a handful of people have radio receivers in which the discriminator stage alone does not contribute sufficient distortion to make this statement obviously true.

There is no point in the B.B.C. spending large sums of money on raising the pass band until the overall transmitting system is capable of a much better fidelity than is feasible at present.

Until then Mr. Hodgson might be more content if he balanced his low- and high-frequency cut-offs, as recommended by Olson.

Whitby. E. W. ROYSTON

WHATEVER one's views on this matter, Mr. Hodgson's letter and your Editorial make welcome comment. I move, however, that the last paragraph of your leader be stricken from the records; if one must seek analogy with motor cars, surely Mr. Hodgson is pleading for greater refinement in everyday travel—from which most motorists should benefit most of the time.

The truth of many of your own comments is surely attested by the recent history of disc recording. Some years ago the disc recording companies threw open the window so wide that the amount of aural dirt admitted became distressing; we would have been happier with less "top" while enjoying the concurrent improvement in other directions that you mention. But the recording technicians proceeded to clear up the dirt, and in my opinion with a quite remarkable degree of success; whereas after reading Mr. Turner's letter one has the unhappy impression that the B.B.C. would have been only too content to close the window. I find it difficult to be certain that the greater satisfaction I now get from records as compared with f.m. at its best is due entirely to an extended top range; however, on a basis of some 35 years' aural—and often penal—servitude to domestic reproduction I maintain that those extra few thousand cycles *are* of more importance than you seem prepared to admit.

Even so, the issue at the moment must affect very, very few listeners. As to the future, I can see no evidence of this tiny minority increasing. Firms enter the quality market and fade away, and I judge Mr. Hodgson's opening paragraph overstates his case.

In spite of this, I find myself entirely on his side. In the first place, the struggle for the best is always worthwhile; secondly, the B.B.C. is avowedly wedded to the welfare of the estimable minority, as witness, for example, the amount of recondite music provided on the Third Programme. If Mr. Turner is really correct in presenting the problem largely as one of expense, let me assure him that the great majority of us would gladly waive the privilege of listening to the organ music of Clérambault if the saving would provide an extra couple of thousand cycles on our Mozart.

I think most of that small but important minority, the readers of *W.W.*, will share my opinion. Let us hope there is space in your correspondence columns to ventilate the subject.

Felixstowe. L. E. SMITH

IS your correspondent Mr. Hodgson sure that he can hear audio frequencies up to 15 kc/s as he appears to suggest? I used to think that my hearing extended up to 20 kc/s or so; however, recently at the Radio Communications Exhibition at the Seymour Hall I tested my acoustic response with the device provided and was surprised to find that my hearing cut off at 12 kc/s. As a matter of interest I am aged 39 years.

In 1939 the H.M.V. £100 Radio Gram had a band width of 8 kc/s and the manufacturers stated in their Service Manual that in the case of this high-quality model "that too much dirt had not been allowed to blow through the window." As the Editor correctly states, frequency response is not the only criterion in obtaining good sound reproduction and in my opinion the advantages of stereophony and resulting three-dimensional sound reproduction can more than make up for a frequency response which is not ideal, as was made evident by a stereophonic demonstration at the Seymour Hall.

The B.B.C. nowadays broadcasts a few stereophonic transmissions. Therefore, be of good cheer, Hi-Fi enthusiasts, because better things may yet come even with a limited frequency response.

Bromley. W. E. GARDNER

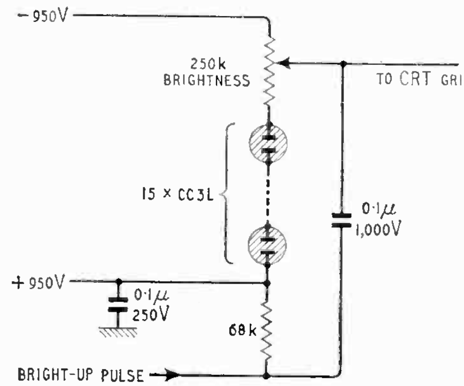
W.W. Oscilloscope

"WE have built a *Wireless World* oscilloscope which works well and promises to be a very useful instrument. As first built, it had for us a serious fault, which we have ameliorated by a simple modification, which we hope will interest other constructors.

Since the e.h.t. power supply unit is fed from the unstabilized h.t. supply, a change in the mains voltage affects the output of the floating c.r.t. grid bias supply, but does not similarly affect the neon-tube-stabilized e.h.t. negative supply. Hence the c.r.t. grid-cathode voltage depends on mains voltage, and the dependency is such that a 2-volt increase in mains voltage extinguishes the trace altogether.

Possibly in the *Wireless World* laboratories the mains are pretty steady and the effect is unimportant. In Cambridge, however, laboratory voltage is rather variable, and the effect is quite unacceptable.

We have stabilized the floating c.r.t. grid supply with



a second string of neons, 15 in all, as in the accompanying circuit.

The oscilloscope is now usable on any voltage between 185 and 230 (transformer on 200-210 volt tap) with small adjustments in brightness and focus.

Many thanks for this sponsored design. Let us see more of them!

P. E. K. DONALDSON
D. P. GRIFFIN
Physiological Laboratory, Cambridge

[Mr. Donaldson and his colleague have a valid point, although such extreme sensitivity to mains variations has not been our experience. However, we have in mind a new e.h.t. unit, occasioned by the use of a cheaper tube, which uses a valve stabilizer and does not exhibit this characteristic. —Ed.]

Colour Television Systems

IT is interesting to hear (Jan., p. 40) more of the background to the N.T.S.C. system from Mr. Macwhirter. There is evidence that the onset of crawling bars or "Venetian blinds" on simple PAL receivers with differential phase errors in the transmission path is relatively sudden, whereas an N.T.S.C. receiver will show progressive degradation. There may be an equivalent onset of flicker with field-rate switching which is objectionable on 50-field systems, but which was tolerable at that time on the 60-field system. Field-rate switching was no doubt adopted because at that time (1952-53) no practical one-line delay was available. A clamp pulse width of 1.4 μsec seems rather narrow and may make for a rather inefficient clamp, particularly with single-transistor clamp circuits, which are becoming increasingly used. I, too, would be interested to hear further comment on this point.

One must agree to a point with Mr. Macwhirter's final remark, although the absence of a tolerance on linear phase error and a far wider tolerance on differential gain and phase would have simplified instrumentation.

I would like to add two final points on the SECAM system which may have arisen since my article, published in the September 1963 issue, was written.

The first concerns the delay lines. These have now been manufactured from a grade of mild steel with adequate performance in terms of thermal stability and spurious responses for the SECAM system. The cost is estimated at 15 NF (approx. 22s) by the C.S.F.

The second point concerns the final cost of a SECAM receiver. C.F.T. have completed a design study for a complete receiver, and the cost of this receiver has been computed by the F.N.I.E., the French counterpart of B.R.E.M.A. They have put the cost at no more than, and probably less than, an N.T.S.C. receiver of equivalent performance.

Teddington. M. COX
A.B.C. Television, Ltd.

Generating Low Frequencies

THE letter by M. D. Armitage in the December issue of *Wireless World* commenting on the problems of producing very low frequencies prompts me to propose what I believe to be a novel approach.

The rotor of an induction motor has a current induced in it at slip frequency, i.e. a frequency which is mains frequency multiplied by the slip expressed as a fraction. The slip is, of course, dependant on the running conditions, e.g. the load on the motor.

Hence, if an induction motor drives a variable load, e.g. a magnetic brake, low frequencies from some 1% of mains (0.5 c/s) to full mains frequency (when the rotor is stationary) exist in the rotor.

The low frequencies, in the form of a small current, can be extracted from a slip-ring motor by connecting a suitable resistance between a pair of slip rings. In a squirrel cage motor, a low-frequency voltage usually exists between the two ends of the shaft.

An alternative approach is to use an induction motor to drive an alternator and to subtract the output of the alternator from a suitable mains voltage. This technique, however, requires voltage balancing circuits.

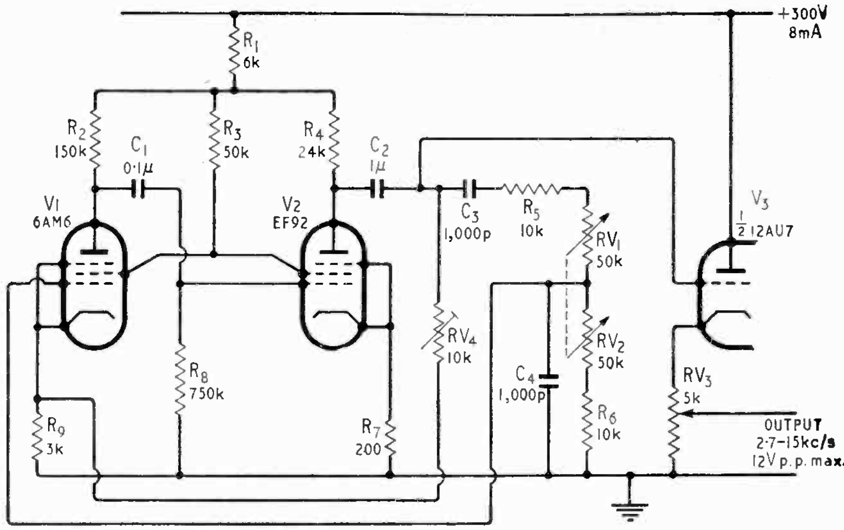
I would be interested to know whether this principle has ever been used for the generation of low frequencies.

Esher. ARTHUR GARRATT

Bridge Oscillator

PERHAPS your readers would be interested in a novel Wien bridge oscillator recently designed by me, which has certain rather unusual features.

The circuit at first looks fairly conventional, the unusual features being the common screen load R_3 and the fact that a preset potentiometer RV_4 takes the place of the conventional thermistor. Feedback stabilization is obtained via the common screen connection, though how it works is a mystery to me. The sine wave across R_3 is by far the largest in the circuit.



Unconventional bridge oscillator (J. P. Crean).

The waveform at V_1 anode resembles a cycloid and may in fact be an electronic analogue of the involute curve; the result of one circle rolling about another. The circles in this case being the grid and screen waveforms.

The cycloidal waveform from V_1 anode is corrected to a sine wave by the variable-mu characteristic of V_2.

The variation in output load provided by the Wien network is a necessary part of the circuit since the provision of a cathode follower in the feedback loop causes distortion.

If the resistor R_1 is omitted l.f. instability tends to occur when frequency is changed. Other circuits on these lines have been constructed by me, including one covering 150 c/s to 50 kc/s in two ranges.

From the stability point of view, variable bridge capacitors, and fixed resistors are preferable.

Marlborough. J. P. CREAN

Elements of Transistor Pulse Circuits

2.—LINEAR PULSE AMPLIFIERS

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

IN pulse work, an obvious need is for a circuit to amplify a pulse with as little change of shape as possible, i.e. a linear pulse amplifier. As it happens, this also turns out to be what most engineers know as either a video, wide-band, broad-band or base-band amplifier. What you call it depends on what field you work in, but it is basically an amplifier whose passband extends from a low audio frequency to an upper frequency many times the lower limit frequency. The high frequency limit is usually not less than 100kc/s. It may in special cases extend out to many hundreds of megacycles.

Transistors are smaller and more efficient than valves and have tended to replace them in general-purpose linear pulse amplifiers. Fortunately, most of the wide-band amplifier techniques developed for valves carry over into transistors. We will deal only briefly with these established techniques, leaving it to the interested reader to consult a standard text-book such as "Pulse and Digital Circuits," by J. Millman and H. Taub (McGraw-Hill). Special problems raised by the use of transistors we will examine more comprehensively.

General Design Problems

There are two ways you can approach linear pulse amplifier design. The first is to consider the response of the amplifier to a square-wave input and specify the performance in terms of (a) pulse gain, (b) pulse rise-time, and (c) pulse droop. The second is to examine its response to a continuous sine-wave input, and specify performance by (a) midband gain, (b) upper and (c) lower half-power bandwidth limits. It can be shown that the two approaches lead to the same practical results and we will generally adopt the more familiar continuous sine-wave approach.

Interstage Coupling:—Interstage coupling is the first problem. In theory, any of the three conventional methods—RC, direct or transformer coupling—is possible. In practice, linear pulse amplifiers are almost always RC-coupled. Direct or d.c. coupling brings in such problems of drift and of setting up bias voltage levels, that it is used only where the amplifier is specially required to operate down to zero or near-zero frequency.

Transformer coupling, too, raises difficult problems, mostly in the design of the transformer itself. With ferrite cores, a 30c/s-5Mc/s bandwidth is feasible. Bandwidths up to 200Mc/s have been produced experimentally with transformers, but, with these, optimum interstage matching is not usually possible due to the limited number of wire turns. Recent developments in wide-band transformer-coupled amplifiers employing transmission-line-type winding techniques have made possible bandwidths out to 1Gc/s at the high-frequency end, but poor low-frequency response restricts their use in linear pulse amplifiers. Quite apart from the design difficulties, transformer coupling is relatively the most expensive coupling method.

Because of all this, we will confine ourselves to the design of RC-coupled pulse amplifiers only.

Transistors in Linear Pulse Amplifiers:—The transistor is normally considered as a current, rather than a voltage, amplifier, and the design of transistor linear pulse amplifiers usually works in terms of current gain. This contrasts with valve designs which are usually worked in terms of voltage gain.

In a linear pulse amplifier, the transistor could be used in any of the three basic configurations shown in Fig. 22: (a) common-base; (b) common-emitter, and (c) common-collector. However, the common-emitter connection is normally used, because with

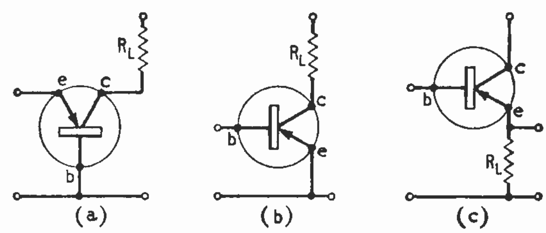


Fig. 22. Transistor configurations. (a) common-base, (b) common-emitter, (c) common-collector.

RC coupling it can provide both voltage and current gain. Without a matching transformer the common-base arrangement has no current gain and the common-collector no voltage gain. The common-collector and common-base connections will mainly be found used only as terminal stages. The common-collector may start or end a chain to give high input resistance or low output resistance. The common-base may be used as a final stage where high voltage is required.

Pulse Characteristics:—As noted earlier, one way of specifying the small-signal performance of a linear pulse amplifier is in terms of pulse properties such as rise and fall times. Fig. 23 illustrates the terms used for a typical pulse waveform. AXYS represents the input pulse, and ABCDEFGH the amplified output pulse. The *pulse gain* is the ratio of RD, the output pulse peak amplitude, to AX, the input amplitude. The *rise time*, T_R, is the distance PQ along the time axis where PB represents 10% and QC 90% of the peak amplitude, RD, i.e. the time for the output pulse to rise from 10% to

* Newmarket Transistors Ltd.

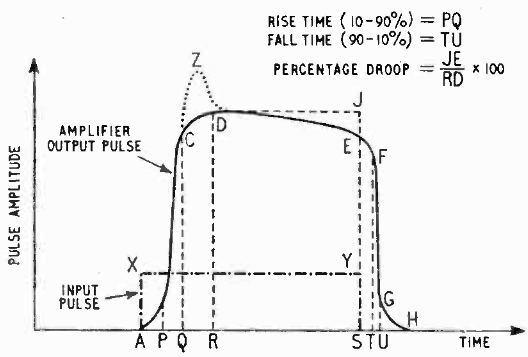


Fig. 23. Pulse response characteristics.

90% of the peak. At the end of the input pulse, S, the output pulse will have "drooped" to the point E, and the *pulse droop* is the fall JE expressed as a percentage of the peak amplitude, RD. Finally the *fall time*, T_F, is the distance TU along the time axis corresponding to the fall from point F (10% below point E) to point G (90% below point E). In the diagram, we have also shown in a "dotted" curve, CZD, the "overshoot" that sometimes occurs when inductive compensation circuits are used. Here the vertical distance from D to Z, expressed as a percentage of RD, is a measure of the overshoot.

As we are considering small-signal operation, the transistor operates only in its active region, neither cutting off nor bottoming. The droop of the pulse top then depends on the relation of the pulse length to the time constants of the coupling and by-pass RC networks. Also, provided the droop is small (as is usually the case), the fall time can be taken as equal to the rise time.

The pulse performance is then normally specified by (a) gain, (b) rise time, and (c) percentage droop. (For the present we are disregarding overshoot.)

It can be shown that to a good approximation, the response to a train of square waves is related to continuous response characteristics as follows:

Pulse gain = midband gain .. .. (1)
Pulse rise (and fall) time = $1/3f_B$ .. .. (2)
Percentage pulse droop = $300f_o/f$ .. .. (3)

where f_B = amplifier continuous response upper 3dB turnover frequency,
f_o = lower 3dB turnover frequency, and
f = repetition frequency of input square wave.

Frequency Characteristics:—In a linear pulse amplifier, the primary circuit requirement is to keep the gain constant over the amplifier design bandwidth. For various reasons, apparent later, gain tends to fall off at both low and high frequencies.

At low frequencies, the transistors themselves present few problems. Their parameters are real and constant in this region. Input and output resistances can be easily calculated from simple formulae and conventional audio-frequency design techniques used. Low-frequency response falls off mostly due to the limitations of finite coupling and bypass capacitors. The main difference from valve designs will be found in the values of the coupling capacitors. Transistor input impedance being low compared with a valve, coupling capacitors generally come out orders of magnitude higher. The actual physical size of the capacitors does not increase, however, because the transistor works at a much lower voltage level than a valve and capacitors with lower voltage ratings can be used.

At high frequencies, amplifier response falls off mainly due to the fall off in transistor gain, and to transistor internal capacitances or circuit external stray capacitances shunting the signal or introducing feedback.

In the transistor itself, the common-emitter short-circuit current gain falls off to unity at a characteristic frequency f_1 (practically the same as the frequency f_T sometimes quoted instead by manufacturers). This behaviour is illustrated in Fig. 24. It will be seen that above f_{hfe} (the frequency at which h_{fe} is 3dB down on its low frequency value, h_{feo}) the transistor current gain follows the approximate law:

h_{fe} (at frequency f) = f_T/f .. .. (4)

and that f_{hfe} is therefore given by

$f_{hfe} = f_T/h_{feo}$ .. .. (5)

In this context, we should note a concept often used in amplifier design—the "gain-bandwidth" product, GB. This is the product of the midband gain and the 3dB upper frequency limit. For the transistor itself,

$GB = h_{feo} \times f_{hfe} = h_{feo} \times (f_T/h_{feo}) = f_T$ .. (6)

This gain-bandwidth product, f_T, is often used as a figure of merit for a transistor to be used in a linear pulse amplifier. Clearly, the higher f_T, the less the current gain fall-off will restrict the upper frequency response of the amplifier.

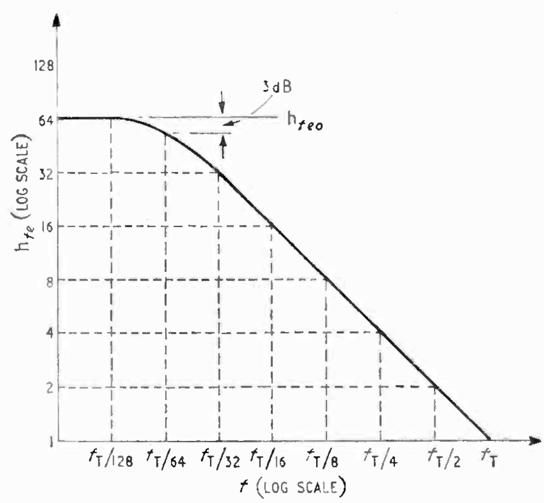


Fig. 24. Variations of common-emitter current gain (h_{fe}) with frequency.

Equivalent Circuits:—There are several equivalent circuit models that could be used for considering transistor high-frequency performance in a linear pulse amplifier. At the approach level adopted here, the simplified hybrid-pi circuit developed in Fig. 25 has some advantages. Fig. 25(a) shows a simple RC-coupled common-emitter stage. At the high-frequency end of the bandwidth we can consider the coupling and bypass capacitors, C_1, C_2, C_3, as a.c. short circuits. Also we can lump the source resistance, R_1, and the two base-bias resistors,

R_2, R_3, into one equivalent resistance, R_s. Finally we can lump the collector resistor, R_4, and the load resistor, R_6, into an equivalent resistance, R_L. Using the full hybrid-pi equivalent circuit, this leads to the arrangement of Fig. 25(b), where each of the elements is independent of frequency.

In linear pulse amplifiers, R_L is usually small compared with $r_{b'c}$ and r_{ce}, and C_T is relatively small compared with $C_{b'e}$. Ignoring these high-impedance items, we get the simplified hybrid-pi circuit of Fig. 25(c). As the load resistance is usually small, $C_{b'c}$ does not shunt it appreciably. Moreover, the direct transmission through $C_{b'c}$ is small compared with the output of the current generator $g_m v_{b'e}$, and may be ignored on the output side. Because of the Miller effect, the effective capacitance looking into $C_{b'c}$ towards the load can be shown to be approximately $g_m R_L C_{b'c}$ (which is effectively in parallel with $C_{b'e}$). Finally, in practical circuits, $r_{bb'}$ is usually small compared with R_s and $r_{b'e}$, so that the equivalent circuit can be further simplified to Fig. 25(d), where $C = C_{b'e} + g_m R_L C_{b'c}$.

Looking at the equivalent circuit of Fig. 25(d), we can see that the voltage, $v_{b'e}$, across $r_{b'e}$ will fall off at high frequencies due to the shunting effect of C. This means that the corresponding amplifier output current, $g_m v_{b'e}$, also falls off at high frequency.

Amplifier Gain and Bandwidth Without Compensation:—For the simplified circuit of Fig. 25(d), which has no frequency compensation circuit included, the current gain is given by

$$A_i = \frac{i_o}{i_s} = \frac{g_m v_{b'e}}{v_{b'e}/(R_s//r_{b'e}//X_c)}$$

$$= g_m(R_s//r_{b'e}//X_c) \quad .. \quad .. \quad (7)$$

At low (midband) frequencies, X_c, the reactance of C, can be disregarded as very high, and the midband amplifier current gain is then given by

$$A_{io} = g_m(R_s//r_{b'e}) = g_m \times \frac{R_s r_{b'e}}{R_s + r_{b'e}} .. \quad (8)$$

As frequency rises, the current gain A_i in equation (7) falls to a 3dB-down point at a frequency given by

$$f_B = \frac{1}{2\pi C(R_s//r_{b'e})} = \frac{R_s + r_{b'e}}{2\pi C R_s r_{b'e}} .. \quad .. \quad (9)$$

From (8) and (9), the amplifier gain-bandwidth product is given by

$$GB = Ai_o f_B = \frac{g_m}{2\pi C} = \frac{g_m}{2\pi(C_{b'e} + g_m R_L C_{b'c})} \quad (10)$$

If in Fig. 25(d) we make R_s very large and R_L very small, we get the circuit for measuring the short-circuit current gain of the transistor itself. From equation (8) this gives

$$h_{feo} = g_m r_{b'e} \quad .. \quad .. \quad .. \quad .. \quad (11)$$

and, from (9)

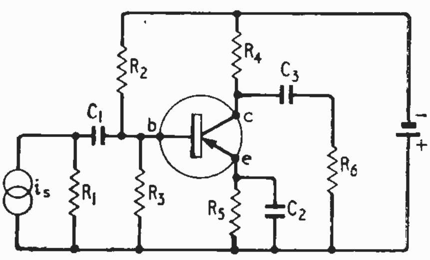
$$f_{hfe} = \frac{1}{2\pi C_{b'e} r_{b'e}} \quad .. \quad .. \quad .. \quad .. \quad (12)$$

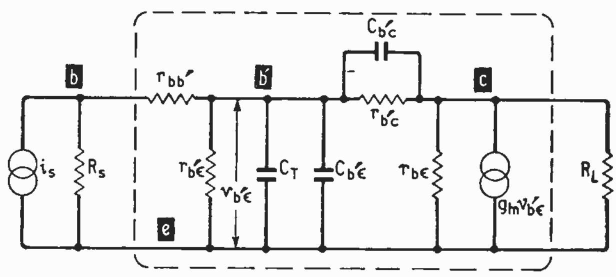
Thus the transistor gain-bandwidth product referred to in (6) is given by

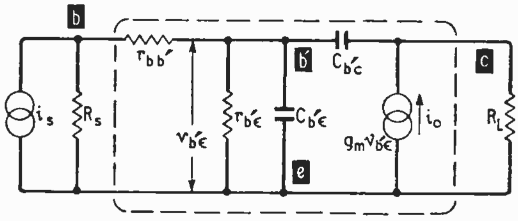
$$f_T = h_{feo} \times f_{hfe} = \frac{g_m}{2\pi C_{b'e}} \quad .. \quad .. \quad (13)$$

Typical Uncompensated Linear Pulse Amplifier Stage:—To put real values to all this, let us consider a modern germanium alloy r.f. transistor, for which typically, $g_m = 39 \times 10^{-3}$ mho, $r_{b'e} =$ 2,500 ohms, $C_{b'e} = 530$ pF, and $C_{b'c} = 10$pF. Substituting these values in (11), (12) and (13) we get $h_{feo} = 100$, $f_{hfe} = 125$kc/s, and $f_T = 12.5$Mc/s. (Note that in alloy r.f. transistors, it can be shown that $f_{co} = 1.2 f_T$, and we can thus derive the more familiar $f_{co} = 15$Mc/s.).

If we now take a typical source resistance $R_s =$ 1,000 ohms and a typical load resistance $R_L =$ 800 ohms, and substitute these values in (8), (9) and (10), we get achievable characteristics of an actual single-stage uncompensated linear pulse amplifier as follows: Midband current gain = 28, 3dB bandwidth = 280kc/s and gain—bandwidth product = 7.8Mc/s. In terms of pulse response,







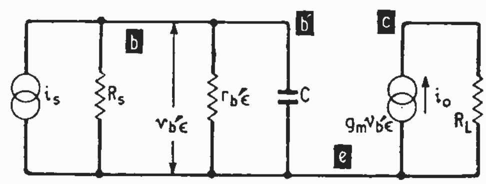


Fig. 25. Derivation of simplified equivalent circuit for high-frequency linear pulse amplifier, showing (a) actual common-emitter amplifier, (b) full hybrid-pi equivalent circuit, (c) partially-simplified equivalent circuit and (d) fully-simplified equivalent circuit.

this gives from (1) and (2) earlier, a peak pulse gain of 28 and a pulse rise (and fall) time of $1.2\mu S$.

Collector Capacitance Effect:—In all the above, we have ignored the possible shunting of R_L by the collector capacitance. That this is justified we can see as follows: It can be shown that the collector-emitter capacitance is approximately given by $A_i \times C_{b'c}$. This shunts the load R_L, and the half-power frequency cut off of the combination in the numerical example given is:

$$f_c = \frac{1}{2\pi R_L(A_i C_{b'c})} = 710\text{kc/s.} \quad .. \quad .. \quad (14)$$

which is well beyond the 280kc/s. bandwidth of the amplifier arrived at above, when we ignored the shunting of R_L.

High-frequency Compensation

Four main techniques are used to extend the high-frequency response of linear pulse amplifiers: (1) negative feedback, (2) shunt inductance peaking, (3) series inductance peaking and (4) positive feedback

Negative Feedback H.-f. Compensation:—Simple negative feedback can be used in two ways as shown in Fig. 26. In the first case, Fig. 26(a), the unbypassed emitter resistor R_E, lowers the mid-band gain and pushes out the bandwidth limit, because the gain-bandwidth product is not much affected. It can be shown that the method is effective for R_E in the range:

$$R_s/h_{feo} < R_E < R_s \quad .. \quad .. \quad .. \quad (15)$$

Approximate formulae for the compensated amplifier current gain and bandwidth are then:

$$A_{io}(F) = \frac{A_{io}}{1 + kh_{feo}} \quad .. \quad .. \quad .. \quad (16)$$

and

$$f_B(F) = f_B\left(1 + \frac{kh_{feo}}{1+k}\right) \quad .. \quad .. \quad (17)$$

where $k = R_E/R_s$.

In the typical numerical example given earlier, we had $A_{io} = 28$, $f_B = 280$kc/s, $R_s = 1{,}000$ ohms and $h_{feo} = 100$. If we now take $k = 1/100$, this gives $R_E = 10$ ohms, and we find that with feedback A_{io} drops to 14 and f_B widens to 560kc/s.

A second method of applying simple negative feedback for gain-bandwidth trading is shown in Fig. 26(b) where feedback is from collector to base via the resistor R_F. It can be shown that this method is effective for R_F in the range

$$R_L < R_F < h_{feo}R_L \quad .. \quad .. \quad .. \quad (18)$$

However the technique is of limited application for very wide bandwidths because the feedback resistor R_F eventually becomes so low that it materially loads both input and output circuits with a consequent loss of gain-bandwidth product.

The two simple negative feedback circuits of Fig. 26, can be modified for high-frequency peaking by introducing frequency conscious elements in the feedback path as shown in Fig. 27. Shunting of the emitter resistor by a small capacitor C_E as in Fig. 27(a) reduces the feedback at high frequency and thus increases the amplifier high-frequency gain. The value of C_E is often selected initially so that its reactance at f_{hfe} is equal to R_E, i.e.

$$C_E = 1/(2\pi f_{hfe}R_E) \quad .. \quad .. \quad .. \quad (19)$$

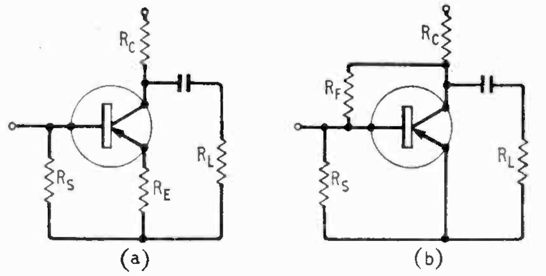


Fig. 26. H.-f. compensation by resistive negative feedback using (a) unbypassed emitter resistor and (b) collector-base feedback resistor.

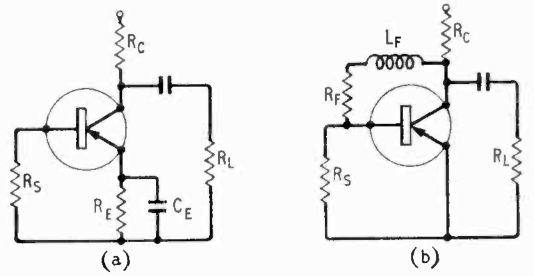


Fig. 27. High-frequency peaking by selective negative feedback, derived by (a) shunting emitter resistor by small capacitor and (b) inserting small inductance in series with feedback resistor.

With this as a starting value, C_E can be adjusted experimentally for the desired results.

The simple collector-base feedback of Fig. 26(b) can also be modified for high-frequency peaking by padding out the feedback resistor R_F with a series inductor or L_F as shown in Fig. 27(b). This inductor tends to reduce the effect of the feedback resistor R_F at high frequencies and thus extends the bandwidth. It can be shown that an approximate value for this inductor is:

$$L_F = R_F\frac{(1+R_F/R_L)}{2\pi f_T} \quad .. \quad .. \quad .. \quad (20)$$

Shunt-inductance H.-f. Compensation:—Shunt-inductance peaking can take several forms as illustrated in Fig. 28. The basic arrangement is an inductive impedance in parallel with the load, R_L, as in Fig. 28(a). Signal current is drawn off from the load through R and L in series. At low frequencies, the reactance X_L of L is low and the current diverted from the load is $R_L/(R + R_L)$ of the total available. At high frequencies, X_L increases and the current diverted from the load is reduced; i.e. the current into the load increases, compensating for the fall-off occurring otherwise.

In practical circuits, the shunt compensation is often achieved by padding out the collector resistor, R_c as shown in Fig. 28 (b). Although the value of L is usually set by "cut and try" methods, a useful starting point is to select L so that its reactance at the transistor common-emitter cut-off frequency, f_{hfe}, is equal to R_c, i.e.

$$L = R_c/(2\pi f_{hfe}) \quad .. \quad .. \quad .. \quad .. \quad (21)$$

The value of L to be expected in this case for the typical alloy r.f. transistor described earlier with

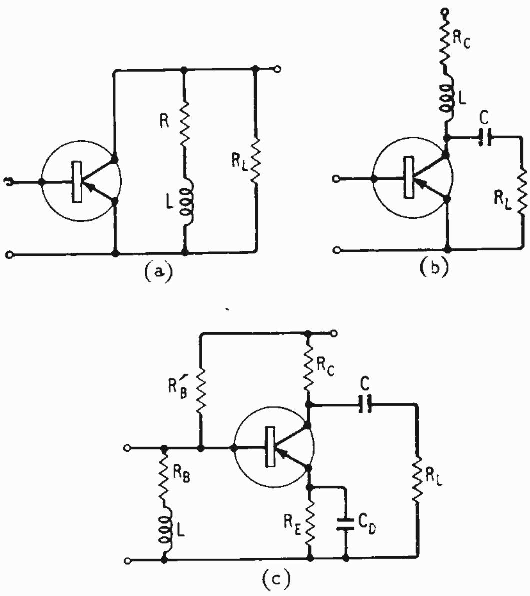


Fig. 28. Shunt high-frequency peaking circuits. At (a) is shown load-resistor padding, (b) padding of collector-load resistor and at (c) base-bias-resistor padding.

$f_T = 12.5$ Mc/s, $h_{feo} = 100$ and $R_e = 1{,}500$ ohms is then about 2mH.

The compensating inductor may be inserted in some other parallel network such as the base-bias potentiometer as illustrated in Fig. 28 (c). Here the same starting rule of thumb—making the reactance of L at f_{hfe} equal to R_B—can be used.

Shunt peaking is useful for compensating the current-gain fall-off of the transistor, but another method, series peaking, is usually adopted for dealing with signal shunting by the transistor output capacitance.

Series-inductance H.-f. Compensation:—Series inductance peaking is illustrated in its basic form in Fig. 29, and consists of inserting an inductor L in series with the transistor output. This inductor is approximately chosen initially to resonate with the collector output capacitance, $A_{io} \times C_{b'c}$, at the collector cut-off frequency:

$$f_C = \frac{1}{2\pi A_{io} R_L C_{b'c}} \quad \cdots \quad \cdots \quad \cdots \quad (22)$$

It is then adjusted by cut-and-try methods. The practical circuit takes the form of Fig 29 (b) where

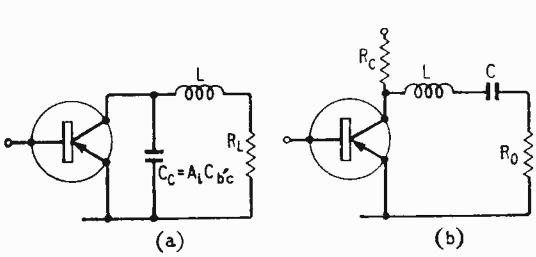


Fig. 29. Series-inductance high-frequency peaking, showing the basic circuit (a) and at (b) the practical circuit.

the effective load resistance is R_c and R_o in parallel, and the large coupling capacitor C has such a low reactance that it can be ignored in the calculations. The optimum inductance value is difficult to compute because of the many variables involved, but in practice, designers often start from the empirical assumption that its reactance at the cut-off frequency of the unpeaked amplifier is equal to the transistor short-circuit input impedance at that frequency (usually obtainable from the manufacturer's data sheet).

Other H.-f. Compensation Techniques:—Positive feedback at high frequency is sometimes introduced by design to push out the upper frequency limit of the amplifier. This should be done with caution, because spreads of transistor characteristics can easily lead to instability.

Finally, it can be shown that the gain-bandwidth product of an uncompensated transistor wide-band amplifier is relatively independent of the emitter bias current, I_e. However, the transistor gain varies directly with I_e, so that it is possible to trade gain and bandwidth by varying I_e. This method has the disadvantage that the gain-bandwidth can vary widely between units because of the spread of transistor gain.

We have been concentrating on the transistor aspects of high-frequency compensation, but the reader is reminded that the valve technique of gain-bandwidth trading by varying interstage resistance loading is applicable also to transistors. The only limitation is that the resultant interstage shunt resistance R_s must lie between $r_{bb'}$ and $r_{b'e}$.

Another point not to be forgotten is that the overall amplifier gain must remain stable, i.e. not break into oscillation. Rigorous theoretical examination of possible instability can be made, but is very difficult, and, transistor characteristic spreads being so wide, this aspect is usually covered by experimental testing.

A practical aspect of high-frequency compensation is the method of testing bandwidth characteristics. We have been thinking in terms of conventional sine-wave response measurements, but, with modern fast oscilloscopes available, it is often more convenient to inspect and measure the pulse response visually. This is where the " overshoot " mentioned earlier becomes significant, because the appearance of an overshoot on the output pulse leading edge gives an indication of impending instability that might not be evident from a continuous-signal bandwidth measurement. Usually a few per cent of overshoot is allowable to sharpen the leading edge of the output pulse before instability becomes a significant problem.

The analysis of high frequency compensation techniques given has been very approximate, ignoring many second order effects and making severe practical simplifying assumptions. However, the results will be found correct to a first order of magnitude. In general, it will be found that by judicious use of peaking techniques, bandwidths can be approximately doubled for any specified gain. Anyone seeking a more rigorous treatment should consult standard textbooks such as "Transistors—Principles, Design and Applications" by W. G. Gartner, Van Nostrand, 1960, or "Transistor Circuit Analysis" by M. V. Joyce and K. K. Clarke, Addison-Wesley Publishing Co. 1961.

Low-frequency Compensation

The low-frequency cut-off (or percentage droop—see (3)) of a linear pulse amplifier is not usually much dependent upon the characteristics of the transistors; it is determined by the same considerations as apply to extending the low-frequency bandpass limit of a conventional RC-coupled audio amplifier. The main limiting factors are the inter-stage coupling capacitor, C_K, shown in Fig. 30 (a), and the emitter decoupling capacitor, C_D, in Fig. 30 (b). The design values of C_K and C_D are usually chosen to give not more than 1dB attenuation each at the lower bandwidth limit, f_o, aimed at, so that in combination they give less than 3dB attenuation. A formula for the interstage coupling capacitor on this basis is:

$$C_K = \frac{3}{2\pi f_0(R_C + R_L)} \quad \ldots \quad (23)$$

and for the emitter bypass capacitor

$$C_D = \frac{3h_{fe0}}{2\pi f_0 R_s} \quad \ldots \quad (24)$$

Another method of low-frequency compensation well known from valve practice can also be used with transistors as shown in Fig. 30(c). Here R_C and C_V

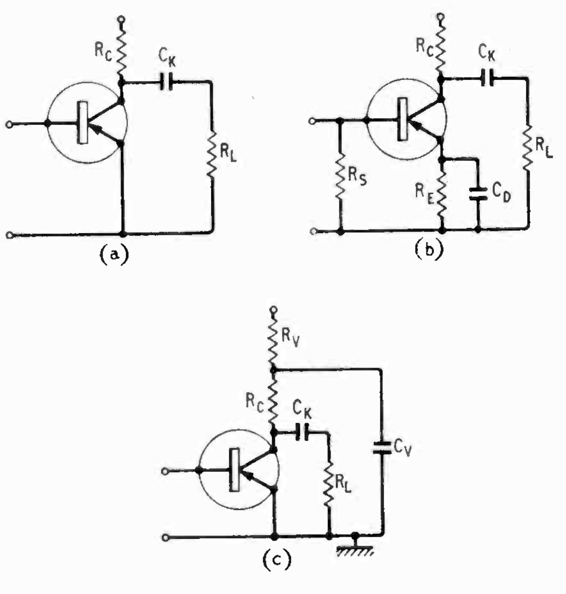


Fig. 30. Low-frequency response considerations. C_k in (a) and C_d in (b) both cause a fall-off at low frequencies. Circuit at (c) is one method of correction.

in parallel give bass boost, provided R_V is chosen as high as possible consistent with the supply voltage, and a value of C_V is selected:

$$C_V = R_L C_K / R_c \quad \ldots \quad (25)$$

Transistors For Linear Pulse Amplifiers

When we use a transistor with a gain-bandwidth product, f_T, in a practical linear pulse amplifier stage, we generally find that due to various unavoidable losses in bias resistors, etc., it is not easy to attain an amplifier gain-bandwidth much more than 2/3 of f_T. Now transistors used in linear pulse amplifier fall into two main types: alloy and diffused base. The best commercially-available alloy types give a guaranteed minimum gain-bandwidth, $f_{T min}$, of about 6Mc/s, and these can be used to produce a stage with a gain-bandwidth of about 4Mc/s in practice, e.g. to produce a gain of 10 and a bandwidth of 400kc/s.

For higher gain-bandwidth requirements than this, recourse has to be made to diffused-base transistors, where a minimum f_T of 60Mc/s is now obtainable almost as cheaply as the 6Mc/s alloy type. Although the analysis given earlier applied primarily to alloy r.f types, it still holds substantially true for diffused types, so that gain-bandwidths of some 40Mc/s are easily obtainable in practice. In some of the ordinary linear pulse requirements, indeed, it may be found necessary to add circuit elements to restrict rather than to enlarge the amplifier bandwidth. Some diffused types with $f_{T min}$ of 300Mc/s are now commercially available so that amplifiers with gain bandwidth products of 200 per stage are feasible.

Multistage Linear Pulse Amplifier

Where the desired amplifier gain cannot be obtained with one stage, it is possible to cascade linear pulse amplifier stages effectively. The gain of a single stage of the type discussed in detail above is given by

$$A_i = \frac{A_{io}}{1 + jf/f_b} \quad \ldots \quad (26)$$

The gain of n identical stages would then be

$$A_{in} = A_i^n \quad \ldots \quad (27)$$

It can be shown that the overall bandwidth of n such stages is given by:

$$F_B = f_B/(1.2n^{\frac{1}{2}}) \quad \ldots \quad (28)$$

if n is greater than 3. Thus we can see that the overall bandwidth shrinks as the square root of the number of stages. It will be found also that as n increases the overall gain-bandwidth increases at first, but finally falls off. This means that a point is ultimately reached where adding an extra stage merely reduces the total gain-bandwidth product.

Readers looking for more information on multi-stage linear pulse amplifiers should consult "Handbook of Semiconductor Electronics" by L. P. Hunter, McGraw-Hill, 1962.

High-level Linear Pulse Amplifiers

Linear pulse amplifiers are often required to furnish large peak-to-peak voltage swings with bandwidths of many Mc/s for such applications as driving the grid or deflection plates of a cathode ray tube. Maximum output may be limited by the transistor voltage ratings or by useful range of currents over which the transistor retains its high frequency performance. For a discussion of the practical problems involved the reader should consult "Transistor Television Receivers," by T. D. Towers, Iliffe Books Ltd., 1963.

In high-voltage linear pulse amplifiers with very wide bandwidths (over 25Mc/s), unavoidable wiring capacitances and transistor output capacitances forces the use of small resistance loads. The maximum output will then be limited by the maximum permissible current swing (or in other words, the maximum dissipation). Where circuit strays, and not C_c, are the major frequency limiting factor, higher peak-to-peak load current can be obtained by parallelling transistors.

For frequencies less than 5Mc/s, the voltage rating of the transistor tends to be the main limiting factor at present. In this case the use of the common-base configuration is advantageous, since common-base usually permits higher collector current excursions before distortion or breakdown. Common-base has the further advantage that wide alpha bandwidth permits the collector voltage to swing closer to zero without distortion than is the case with common-emitter. Typical practice is to drive the common-base output stage from a high output-impedance common-emitter stage.

If a voltage swing greater than the transistor rated voltage is desired, it is possible to connect transistors in a stack employing signal feedback to ensure all transistors share the output voltage equally. Such a configuration is shown in Fig. 31.

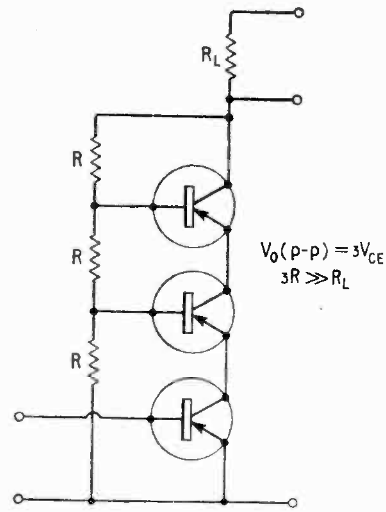


Fig. 31. Stacking transistors to give output swing greater than voltage ratings of individual transistors.

Conclusion

Modern transistors with gain-bandwidth products up to hundreds of megacycles make possible the use of transistors in most linear pulse amplifiers that are commonly required. Special cases requiring gain-bandwidths beyond this may require recourse to more exotic circuits such as transistor distributed amplifiers.

Commercial Literature

Evershed & Vignoles Ltd., of Devonshire Works, Dukes Avenue, London, W.4, have now issued the second in their series of coloured educational wall charts. This chart, in poster size, shows the insulation, continuity and voltage testing circuitry of the **Battery "Megger" Tester,** and in diagrammatic form illustrates the main principles of operation. The chart is available to training schools from the publicity manager and the company will also supply, on request, small educational leaflets supplementing the wall charts.
5WW 301 for further details.

A 28-page catalogue supplement (No. 135) describing recently introduced **switches and signal indicator lamps** is now available from Arcolectric Switches Ltd., of Central Avenue, West Molesey, Surrey. General and technical information is included together with dimensional diagrams.
5WW 302 for further details.

"**Nickel Alloy Permanent Magnets in U.K. Electronics**" is the title of a new illustrated publication produced by the International Nickel Company (Mond) Ltd. This publication deals with applications and copies are available from the Company's publicity department, 20 Albert Embankment, London, S.E.1.
5WW 303 for further details.

Catalogues covering a new range of **plugboard programming systems and accessories**—some of which are manufactured by the Virginia Panel Corp. of America —are now available from Jenkins Fidgeon Ltd., Linley Road, Talke, Staffs.
5WW 304 for further details.

A multi-range **frequency/tachometer** covering 3.f. to 500 kc/s is described together with a frequency deviation unit and a voltage deviation unit in a leaflet sent to us by Ledon Developments Ltd., of 76-78 Deptford High Street, London, S.E.8.
5WW 305 for further details.

"**A New Construction Technique for the Hi-Fi Enthusiast**" is the title of a leaflet giving details of Martin Audiokits. A 5-stage matching input selector unit, a pre-amplifier with master volume control, a 3-channel mixer with plug-in adaptors and a 10 watt amplifier are among the described kits. Copies of the leaflet are available from Martin Electronics Ltd., 154 High Street, Brentford, Middx.
5WW 306 for further details.

A brochure describing the newest addition to the E.M.I. range of **measuring oscilloscopes,** the WM26, is now available from the instrument division of E.M.I. Electronics Ltd., Hayes, Middx. Also included in the brochure is a range of plug-in pre-amplifiers and a full complement of accessories for the WM26.
5WW 307 for further details.

"**Storage Equipment in Steel**" is the title of the latest N. C. Brown Ltd. catalogue. It covers several types of shelving, cabinets, component bins, storage units, etc. Steel office furniture is also included. Copies of the catalogue are obtainable from N. C. Brown Ltd., Eagle Steelworks, Heywood, Lancs.
5WW 308 for further details.

The Addison Electric Company, of Belmont Road, London, W.4, has started to publish a quarterly house journal titled "Addison News." It is freely distributed to the **wire and cable industry**, which it serves, and other potential readers are invited to be put on the company's mailing list.
5WW 309 for further details.

Automatic graph plotting instruments, from analogue or digital sources, are described in a recent leaflet from the electronics division of Bryans Ltd., of Willow Lane, Mitcham, Surrey. A digital data translator, a function generator and automatic XY plotters are among the described instruments. Technical specifications of some models are included.
5WW 310 for further details.

WORLD OF WIRELESS

B.B.C. Licence Renewed

THE "British Broadcasting Corporation (Licence and Agreement)," which covers the next 12 years and came before Parliament during December, has now been approved by the House of Commons. A number of detail changes have been made in some of the technical clauses of the 1952 licence (amended in 1961) and some have been deleted.

An interesting new clause (5) is that which deals with the reciprocal obligations of the B.B.C. and the I.T.A. in the sharing of aerial masts for the new u.h.f. television services. Mr. Mawby, Assistant P.M.G., stated in the House that the present "give and take between the two organizations" in the planning of the u.h.f. network has been remarkable. The I.T.A.'s obligations regarding the co-siting of stations are laid down in the Television Act, 1963.

The financial clause (17), which in the 1952 Licence and Agreement stipulated that the Corporation should receive an amount equal to 85% of the net licence revenue, now provides for it to have 100%, less Post Office expenses.

The B.B.C.'s income from licences during the past financial year, to March, 1963 (as taken from the B.B.C.'s 1964 Handbook), totalled £37,972,143, after deducting the Post Office expenses of £2,783,331. The Corporation also paid the Post Office nearly £1.75M for line, cable and telephone hire. After finding £20.9M for programmes, £10.7M for engineering and some £2.5M for capital expenditure plus general overheads, the B.B.C.'s reserves dropped to under £200,000.

The P.M.G., Mr. Bevins, again refused to increase the combined radio and television licence fee. However, the Government has increased the borrowing powers of the B.B.C. to £20M, for capital expenditure, which with the nation-wide introduction of BBC-2 will be considerable.

The question of local sound broadcasting was raised several times in the House during the debate. Mr. Bevins answered "I confess that before I came into the Chamber today I did not realize that the consensus of opinion here was so much in favour of local sound as it has appeared to be during the debate. The House knows that on earlier occasions the Government dismissed this recommendation of Pilkington. My mind is not closed on this subject. I would like to study the matter further in the light of what has been said, without giving any undertaking or promise to the House at this stage."

John Martin, who lost his sight during the war when serving in the Merchant Navy as a radio officer and is now an amateur transmitter (G3NTE), is featured in the St. Dunstan's Annual Report.

B.B.C.-2 Masts and Aerials

THE B.B.C. has ordered the aerials for its first two u.h.f. transmitters outside London. They will be mounted on top of the existing 750-ft masts at Sutton Coldfield, in the Midlands, and Wenvoe, South Wales. The aerials are the first of their kind to be used in this country and consist of a 5-ft diameter glass fibre cylinder 30 to 40ft in length on the inside of which the dipoles will be mounted. Although initially they will be used only for BBC-2 these aerials have been designed by Marconi's to radiate up to four programmes simultaneously.

In preparation for the co-siting of B.B.C. and I.T.A. transmitters at two existing I.T.A. stations—Winter Hill, Lancs., and Emley Moor, Yorks.—the Authority has ordered two new masts to replace the existing 450ft masts. That at Emley Moor will be 1,250ft tall and that at Winter Hill 1,000ft. Each mast will be capable of carrying four aerials for Bands IV and V, two for Bands I and III and one for Band II. A third mast, 1,250ft tall, is to be erected by the I.T.A. at Belmont, Lincs., where there will be a B.B.C./I.T.A. station. All three masts are to be built by B.I. Callender's Cables and will consist of a 9ft diameter steel tube, the top 350ft section being of open lattice steel construction. This longer topmast will be enclosed in glass fibre on which will be mounted the dipoles. Initially, only a Band III aerial, supplied by E.M.I., is to be fitted on each of these masts.

U.R.S.I.—The next triennial General Assembly of the International Scientific Radio Union will be held in September 1966 in Munich. This meeting will be preceded by a symposium on radio wave propagation to be held in Belgrade. The new president of the Union in succession to Dr. R. L. Smith-Rose is Professor I. Koga of Japan. The Union has published a volume recording progress during the 50 years since its formation. U.K. contributors include Dr. R. L. Smith-Rose, Sir Harry Massey, Dr. L. Essen, Dr. J. A. Saxton, Dr. W. J. G. Beynon and J. A. Ratcliffe. The 165-page volume costs 29s.

British Gift to Skopje TV Station.—In answer to a request to members of the European Broadcasting Union from the Yugoslav Radio and Television Service for help in providing equipment for the Skopje television station, which was a victim of last year's earthquake disaster, a three-camera outside broadcast unit has been dispatched from London. It is a joint gift from Associated-Rediffusion and Associated Television and has been converted—by Pye Ltd.—to operate on the 625-line standards.

The B.B.C.'s new television and v.h.f. sound **relay station for Pembrokeshire** comes into service on February 15th. Situated near Haverfordwest, the television transmitter will radiate in channel 4 and the sound transmitters on 89.3, 91.5 and 93.7Mc/s. All transmissions are horizontally polarized.

BBC-2 Test Card.—As a temporary measure the B.B.C. is using a modified test card "C" for the BBC-2 trade test transmissions, which were recently resumed with increased power on Channel 33. The five frequency gratings, which on the standard card indicate resolutions of 1, 1.5, 2, 2.5 and 3Mc/s, have been changed to indicate 1.6, 2.3, 3.1, 3.9 and 4.7Mc/s.

New I.T.A. Trade Test Schedule.—In order to achieve an adequate standard of maintenance the Independent Television Authority has announced that trade test transmissions from its parallel operated stations will be radiated at reduced power on two days a week, instead of one, during the hours of 10.0 a.m. to 1.0 p.m. The five stations concerned are:—

Black Hill (Central Scotland) Caradon Hill (Cornwall) Durris (near Aberdeen)	Wednesdays and Fridays
Mendlesham (Suffolk) Stockland Hill (Devon)	Tuesdays and Fridays

B.S.R.A.-B.K.S. Merger.—Negotiations have now reached an advanced stage for the amalgamation of the British Sound Recording Association and the British Kinematograph Society. The name of the joint society has not yet been decided and each organization is continuing its programme of meetings under its own name for the remainder of this session. Members of either society may now attend any of the other's ordinary meetings.

Commercial TV for Liberia.—A commercial 625-line v.h.f. television station operating on Channel 6, Band III, has been set up in Monrovia, Liberia, by Overseas Rediffusion Ltd. Negotiations to establish the station were concluded with the Liberian government on 6th December, 1963, and the station became operational one month later with an e.r.p. of 2.5kW. Pye T.V.T. Ltd. supplied all the transmitting and studio equipment.

U.H.F. 'phone-only licences are to be issued to amateurs as a result of discussions between the Post Office and the Radio Society of Great Britain. The new licence will permit the holder of a radio amateur examination certificate to operate on 'phone-only above 420 Mc/s. He will not have to pass a morse test.

The word "electronic" has been added to the title of the Department of Electrical Engineering at the **University of Birmingham.** Of the 68 postgraduate students, in what will now be known as the Department of Electronic and Electrical Engineering, 60 are concerned with electronic engineering.

Amplivox Ltd. are providing a **research bursary** in the Physics Department of Imperial College under the supervision of Dr. R. W. B. Stephens. The research will be concerned with the transmission of sound and vibrations in a variety of materials, and the behaviour of sub-miniature mechanical-acoustical systems embodying such materials.

Henry's Radio Ltd. ask us to inform readers who may have sent orders with money between 10th November and 31st December to 303, Edgware Road, London, W.2, that if they have not yet received acknowledgment, a claim should be lodged with the Post Office, who have the matter in hand. Henry's regret this inconvenience which has arisen through no fault of their own.

"Acoustic Noise Measurement and Analysis."—In the first equation, on p. 51 of this article in the January issue, it is regretted that multiplcation signs were set in error. The equation should read

$$N = 10 \log_{10}\left(\frac{p}{p_0}\right)^2 = 20 \log_{10}\left(\frac{p}{p_0}\right)$$

WIRELESS WORLD INDEX

The Index to Volume 69 (1963) is now available price 1s (postage 3d). Cloth binding cases with index cost 9s, including postage and packing. Our publishers will undertake the binding of readers' issues, the cost being 30s per volume including binding case, index and return postage. Copies should be sent to Associated Iliffe Press Ltd., Binding Department, c/o 4 Iliffe Yard, London, S.E.17, with a note of the sender's name and address. A separate note, confirming despatch, together with remittance should be sent to Dorset House, Stamford Street, London, S.E.1.

"The Physics Exhibition" is in future to be the title of the annual exhibition of scientific instruments and apparatus organized by the Institute of Physics & Physical Society. For the first time the 1965 exhibition is to be held in the provinces; the venue is the Manchester College of Science and Technology and the date 5th-8th April.

To celebrate the 75th anniversary of the **Electrical Inspection Directorate** of the Ministry of Aviation its headquarters and laboratories at "Aquila," Golf Road, Bromley, Kent, are to be opened to the public on the 6th, 7th and 8th May.

A two-day course on recent advances in **semiconductors applications** is to be held at Slough College, Bucks, on 18th and 18th March. Eight lectures will be delivered by specialists from Ferranti, G.E.C., Mullard and S.T.C. (Fee, including meals, £3 10s.)

P.A. Symposium.—The Association of Public Address Engineers is planning to hold its third symposium in Manchester on 20th September.

A two-day symposium covering the principles and applications of **digital and analogue computers** is to be held at the Norwood Technical College, Knight's Hill, London, S.E.27, on 24th and 25th March. (Fee £2 12s 6d.)

The tenth **v.h.f./u.h.f. convention** organized by the London U.H.F. Group of the Radio Society of Great Britain is to be held on 16th May at the Kingsley Hotel, London, W.C.1.

The **Technical Publications Association** is holding an exhibition "on technical publications as an aid to industry" in Birmingham on 4th April. Further details may be obtained from the Association's new address 17 Bluebridge Avenue, Brookmans Park, Herts. (Tel.: Potters Bar 55392.)

CLUB NEWS

Dorking.—The February 11th meeting of the Dorking & District Radio Society at 8.0 at the "Wheatsheaf," Dorking, will take the form of a discussion on receivers. On February 25th J. Green, of Decca, is to give a talk and demonstration on "Wiring techniques, printed circuits, etc." at 8.0 at the "Star & Garter," Dorking.

Halifax.—The subject of the talk to be given by F. C. Luxton to members of the Northern Heights Amateur Radio Society on February 19th is "Accidents in the shack, including electrical faults." Meetings are held on alternate Wednesdays at 7.30 at the Sportsman Inn, Ogden.

Plymouth.—Meetings of the Plymouth Radio Club are held each Tuesday at 7.30 at Virginia House, Bretonside. On February 4th a Mullard film show will be presented.

Spen Valley.—February's meetings of the Spen Valley Amateur Radio Society includes talks on "Noise Problems" (6th) by W. Dougherty and on "Colour Television" (11th) by Dr. G. N. Patchett. The meeting on the 6th will be held at 7.15 at the Heckmondwike Grammar School and that on the 11th at the Bradford Technical College.

PERSONALITIES

Martin Ryle, F.R.S., professor of radio astronomy at Cambridge University, is the first recipient of the van der Pol gold medal of the International Scientific Radio Union (U.R.S.I.). The medal, donated by Mrs. van der Pol in memory of her late husband, is to be awarded at each triennial general assembly "to an outstanding radio scientist who, during the three-year period preceding the year of the General Assembly, will have made a valuable contribution, in one of the fields of activity of the Union, either by his research work, discoveries, achievements, or by any other activity." Professor Ryle, who received the medal at the U.R.S.I. meeting in Tokyo in September, has been at Cambridge since the end of the war, initially as lecturer in physics at the Cavendish Laboratory and latterly at the University's Mullard Radio Astronomy Laboratory. He has occupied the University's chair of radio astronomy since it was established in 1959.

F. E. Jones, M.B.E., B.Sc., Ph.D., M.I.E.E., M.Brit.I.R.E., has been appointed managing director of Mullard Ltd. in succession to **S. S. Eriks,** K.B.E., who has headed the Mullard company since 1929. Dr. Jones, who is 49, joined the staff of the Telecommunications Research Establishment in 1940 after graduating from King's College, London. For his work on the wartime blind bombing system "Oboe" he was awarded the M.B.E. in 1945. Dr. Jones was appointed deputy director of the Royal Aircraft Establishment, Farnborough, in 1953. He resigned from the Civil Service three years later to join the board of Mullard Ltd. Dr. Jones was a member of the Radio Research Board of the D.S.I.R. until 1962. Mr. Eriks will remain a director of Mullard Ltd.

Bertram V. Bowden, M.A., Ph.D., M.I.E.E., principal of the Manchester College of Science and Technology and Dean of the Faculty of Technology at Manchester University since 1953 was appointed a life peer on December 23rd. Dr. Bowden, who is 53, spent three years in the Cavendish Laboratory, Cambridge, under Lord Rutherford and several years teaching before joining the Telecommunications Research Establishment, Malvern in 1940. He took a team from T.R.E. to the Naval Research Laboratory, Washington, to work on an aircraft identification system. From 1945 he was for a short time at the Massachusetts Institute of Technology, then with Sir Robert Watson-Watt's consulting organization for three years, and in 1950 he joined Ferranti's computer group.

H. V. Beck, B.Sc., M.A., A.M.I.E.E., who joined Marconi Instruments in January, 1962, as chief of advanced development, has been appointed research manager. Mr. Beck, who is a graduate of King's College, London, was from 1957 at the Cavendish Laboratory as head of the electronics section having previously been with the Cambridge Instrument Company. He is chairman of the I.E.E. Professional Group for Electronic Measuring Instruments and Techniques. **A. G. Wray,** M.A., M.Brit.I.R.E., the deputy chief engineer of the company since 1960, has been appointed engineering manager. Mr. Wray graduated at Emmanuel College, Cambridge, and joined the company in 1944 being appointed company physicist eight years later, He is a member of several committees of the British Standards Institution dealing with electronic measuring techniques and is chairman of the Programme and Papers Committee of the Brit.I.R.E.

Brigadier E. I. E. Mozley, M.A., A.M.I.E.E., has relinquished the post of Director of Telecommunications at the War Office and retired from the Army. Prior to his appointment in 1961 Brigadier Mozley was, for three years, commander of the Royal Signals Planning Wing at Catterick where he was concerned with advance planning in both the technical and tactical aspects of army communications. The new Director of Telecommunications is to be **Brigadier R. H. E. Robinson,** O.B.E., who was, until recently, Chief Signals Officer H.Q. Far East Land Forces, Singapore. Brigadier Robinsón, who is 50, served in the Mediterranean area in 1943/4 where he commanded the 8th Army Signals. During 1951/52 he was with the British Joint Services Mission in the United States.

Gilbert A. Briggs, well-known founder of Wharfedale Wireless Works, has retired from the managing directorship of the company and has become chairman of the board. Mr. Briggs, who is 73, founded, in 1933, the company which has been a subsidiary of the Rank Organisation since 1958. He is well known for his many books on audio topics and for his enterprise in demonstrating recorded *versus* live sound as he did with such outstanding success on several occasions in the Royal Festival Hall, London, and on the other side of the Atlantic.

Brigadier J. D. Haigh, O.B.E., M.A., M.I.E.E., has been appointed planning manager of the Swindon Group of the Plessey Company. Before joining the Plessey Group in 1958, Brig. Haigh was director of electronics and development (telecommunications) at the Ministry of Supply.

Dr. F. E. Jones

H. V. Beck

A. G. Wray

Brig. J. D. Haigh

Professor P. M. S. Blackett, F.R.S., has resigned the headship of the Department of Physics at Imperial College, London, but is continuing as professor of physics and as pro-rector. Professor Blackett, who joined the staff at Imperial College in 1953, has served as a part-time member of the National Research Development Corporation and as a member of the Research Council of the Department of Scientific and Industrial Research. The new head of the Department of Physics is **Professor C. C. Butler,** F.R.S., who joined the college staff as a reader in physics in 1953 and has been professor of physics since 1957. Professor Butler, who is 41, and a graduate of Reading University, where he also received his Ph.D., was on the staff of Manchester University from 1945 until 1953.

R. J. Clayton, O.B.E., M.A., M.I.E.E., the new managing director of G.E.C. (Electronics) Ltd., joined the G.E.C. Research Laboratories in 1937 after graduating in physics at Cambridge University. He transferred to the G.E.C. Applied Electronics Laboratories at Stanmore in 1950 and later became manager. In 1958 he was appointed general manager of the group of three G.E.C. Applied Electronics Laboratories and after a short period in which he was additionally deputy director at the Hirst Research Centre he became a director and general manager of G.E.C. (Electronics) Ltd. in 1961. Mr. Clayton is chairman of the Research Advisory Committee of the Electronic Engineering Association and a member of the D.S.I.R. Radio Research Board. He has also served as chairman of the Guided Weapons Technical Committee of the Society of British Aircraft Constructors.

J. P. Engels has relinquished his position as managing director of Philips Electrical Ltd. to become vice-chairman of Philips Electrical Industries Ltd. **A. L. Sutherland,** director and general sales manager of Philips Electrical Ltd. has been appointed commercial director of the company. Mr. Sutherland joined Philips in 1933 and became a director of Cossor Radio & Television following its acquisition by Philips in 1959. The new general sales manager of Philips Electrical is **R. H. Pengelly,** M.B.E., who has been general manager of Cossor Radio & Television for the past two years.

Following Mr. Pengelly's appointment, **David Holmes,** Cossor's sales manager, has become general manager and a director of Cossor Radio & Television Ltd. He has been with the company for 12 years. His successor as sales manager is **F. N Filby,** who has been with Cossor since 1935.

John Clarricoats, O.B.E. (G6CL), retired at the end of the year after 36 years' service with the Radio Society of Great Britain. He had been general secretary since December 1932. When "Clarry" joined the Society its membership was under 1,000 but now stands at nearly 12,000. He is secretary of the European Area of the International Amateur Radio Union and has been a member of British delegations to many international radio conferences, the most recent being the Space Communication Conference in Geneva in October.

John Rouse, who joined the H.Q. Staff of the R.S.G.B. in 1952 as assistant editor of the *Bulletin*, has been appointed general manager. (The post of general secretary has been discontinued.) He served in Royal Signals during the war and from 1945-47 was instructor at the signal officers' training school at Mhow, India. While in the Services in India he operated as an amateur with the call VU2AD. His present call is G2AHL.

John Powell, M.A., D.Phil., assistant managing director of Texas Instruments Ltd., at Bedford, is to succeed **A. N. Provost** as managing director of the company. On leaving the R.A.F. in 1945, Dr. Powell spent three years at Queen's College, Oxford, followed by three years' post-graduate research at the Clarendon Laboratory. He then received a three-year research fellowship to the National Research Council, in Ottawa, Canada, to investigate the properties of semiconductors. On his return to England in 1954, he spent three years with the Marconi Company before joining Texas Instruments. Dr. Powell was appointed vice-chairman of the Group B management committee of V.A.S.C.A. in 1961. Mr. Provost has become semiconductor group manager for Europe, the Middle East and Africa, and is to take up residence in Geneva. He spent some time with Sylvania Electric Products before joining Texas Instruments Inc., in Dallas.

G. A. G. Rowlandson has succeeded **R. Roper** as the senior sales engineer of the merchandising division of the Solartron Electronic Group. After spending several years in the Royal Corps of Signals, Mr. Rowlandson joined the staff of the radio department of the Royal Aircraft Establishment at Farnborough. Four years later he became a division engineer with Southern Instruments and before joining Solartron in 1959, spent two years with Honeywell Controls and two years at King's College, London. Mr. R. Roper has become general sales manager (communications) of Cossor Communications Company.

G. C. Pope, M.Eng., A.M.I.E.E., who joined Advance Components Ltd. of Hainault, Essex, in March 1963, and became general manager, has been appointed a director and joins the Board. He specialized in electronics at Liverpool University and then spent 12 years with the A.E.I. Group becoming sales manager of the Radio and Electronic Components Division in London. **A. W. Stapleton** formerly chairman and joint managing director has become chairman of Advance Components; **H. E. Howard** is now deputy chairman, and **E. G. Wakeling,** A.M.I.E.E., formerly joint managing director has become managing director. Mr. Wakeling joined Advance in 1959 having formerly been manager of the servo division of Elliott Bros. at Lewisham.

Peter Jones, A.M.Brit.I.R.E., who was engineer-in-charge of test and development with Leevers-Rich Equipment Ltd. until a few years ago, has rejoined the company as general manager in succession to **E. D. Parchment,** A.M.Brit.I.R.E., who has left the company. Mr. Jones was, for a short time, with Tape Recorders (Electronics) Ltd. and latterly as an assistant editor with Heywood & Co. Mr. Parchment joined Leevers-Rich in 1959, as technical sales manager, and became a director the following year.

OBITUARY

Sir Reginald Payne-Gallwey, Bt., Comp.I.E.E., a well-known figure in the councils of the British radio industry, died on 12th January, aged 74. Sir Reginald, who succeeded to the baronetcy on the death of his cousin in 1955, was for 28 years associated with the Erie Resistor Company as a sales consultant until his retirement last year. He had been a member of the Council of the Radio Industry Club for many years and was an associate vice-president of the London Chapter of the Armed Forces Communications and Electronics Association.

David N. H. Lambert, B.Sc., A.M.I.E.E., resident engineer at the B.B.C's Far Eastern broadcasting station at Tebrau, Malaya, died at Johore on 18th December, aged 57. He had been with the Corporation since 1934 and was, for ten years or so, in the Research Department before being appointed assistant engineer-in-charge of the Burghead, Scotland, medium-wave transmitting station in 1951. Four years later he was seconded to Radio Belize, British Honduras, as chief engineer. He returned to this country in 1958 and was for three years engineer-in-charge of the Clevedon, Somerset, transmitting station prior to his Far Eastern appointment.

NEWS FROM INDUSTRY

Group Trading Profit of **Radio Rentals Ltd.,** of which Baird Television is a subsidiary, totalled £7,781,544 in the year ended 31st August 1963. This represents an increase of over £1M on the previous year's results. After deducting £4,651,742 for depreciation, £1,357,382 for tax and £16,870 for minority interests, the net profit of the group totalled £1,755,550.

S.T.C.-Eimac Klystrons.—As a result of an agreement signed between the American companies Eitel McCullough Inc. and the International Telephone and Telegraph Corporation, Standard Telephones and Cables Ltd.—British subsidiary of I.T.T.—is to manufacture the Eimac range of u.h.f. television klystrons at its Paignton, Devon, plant. Initial production at Paignton for the U.K. and export markets will concentrate on klystrons with power outputs of 25kW.

Invac Data Equipment.—Associated Automation Ltd., a member company of the Elliott-Automation Group, has signed a licensing agreement with the Invac Corporation of Waltham, Massachusetts. The agreement allows Associated Automation to manufacture and market the Invac range of equipment in the United Kingdom, the British Commonwealth (excluding Canada), Europe and the Middle East. This includes the new range of peripheral equipment for data processing, data logging and data communications applications.

An intercommunication system has been installed by the Marconi International Marine Co. at Esso Petroleum's oil terminal at Purfleet, Essex. The system which has an integrated fire alarm system is similar to that recently installed at Esso Petroleum's new terminal at Tynemouth and comprises a main control unit installed in the despatching office block, and a number of loudspeaker/microphone units located at strategic points in the terminal. At each of the outstation positions there is a "break glass to operate" watertight fire call switch. The breaking of the glass automatically brings the fire circuits into operation and broadcasts an interrupted 1,000c/s tone over all loudspeakers.

Radio Towers for Cyprus.—British Insulated Callender's Construction Co. has received an order, valued at £74,000, from the Marconi Company for the supply of 16 radio communication towers. They are to be erected in Cyprus.

Elliott Airborne Radio Equipment.—Two recent contracts placed with the airborne communications division of Elliott-Automation for "Series 21" navigation and communications equipment brings the total value of orders for this equipment to well over £1,500,000. The "Series 21" installations which are priced at about £20,000 each comprise a dual v.h.f. communications and a dual v.h.f. navigation (V.O.R./I.L.S.) system with an additional glide path receiver—to comply with the requirements of the automatic landing regulations. The R.A.F. already have a number of these installations in operational use in their Argosy, Comet IV and Heron aircraft.

British Relay Ltd. have installed a communications system in the recently completed New Ambassadors Hotel in London. The installation comprises two intercommunication systems linking each bedroom with the hotel reception and room service. A four-programme radio distribution system is integrated in the intercom system.

The research branch of the Engineering Department of the Post Office has placed a contract, to the value of £28,000, for two data logging systems with the **Solartron Electronic Group,** Farnborough, Hants. The equipment will be used for the measurement and recording of the electrical parameters of planar type transistors.

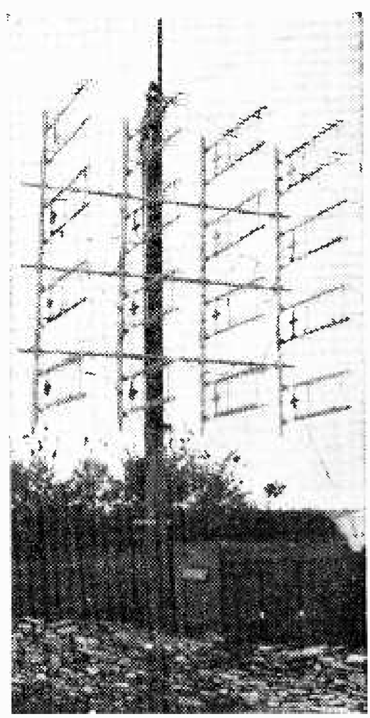
The Marconi Company is to supply the transmitting equipment for a new **broadcasting station** at **Dar-es-Salaam,** Tanganyika. This will form part of an extension to the Tanganyika broadcasting service and will include two Marconi 50-kW medium-wave transmitters, together with programme input equipment and ancillaries. The associated aerial system will also be supplied by the Marconi Company.

Erie Resistor Ltd., of Great Yarmouth, Norfolk, has acquired a 31,300 sq. ft. factory at Arminghall, near Norwich.

Handley Page Ltd. are operating an **analogue computer service** from their Cricklewood works, London, N.W.2. The equipment on hire comprises four Short & Harland general-purpose consoles; each of which may be hired for £15 per day. Further details can be obtained from R. S. Skelton, Analogue Computer Department. Tel.: GLAdstone 8000.)

Elliott-Automation has opened a second **computer workshop** in the London area at Snow House, 103/109 Southwark Street, S.E.1 (Tel.: WATerloo 7640 and 7561). It is equipped with an Elliott 803 computer with a magnetic core store and a floating point arithmetic unit. The computer can be hired, together with accessories, on an hourly basis and operating and programming assistance is available. The workshop is open 24 hours a day, five days a week.

A new company to be known as **Export Engineering Services Ltd.** has been formed to provide a technical representation service for engineering companies in overseas markets. The managing director, P. E. M. Warden, A.M.I.E.E., was previously with the B.T.H. Company. The new Company will operate from Greystones, Cavendish Road, Weybridge, Surrey (Tel.: Weybridge 45202).



All this and parametric amplification too ... Using this array, with parametric amplifiers to boost the signal level, Rediffusion are planning to relay BBC—2 to their Southampton subscribers immediately the service comes into operation in the London area—20th April. The aerial is sited four miles outside the town and a cable connects it to the Company's distribution centre.

B.O.A.C. using Cossor Transponders.—The British Overseas Airways Corporation has purchased a number of "SSR 1600" airborne transponders from Cossor Electronics Ltd. This type of secondary surveillance radar transponder, which has full 12-bit encoding facilities, is installed in VC10, BAC111 and Trident aircraft.

Amphenol-Borg (Electronics) Ltd. has been formed to carry on the business previously conducted by the electronics division of Amphenol-Borg Ltd. of which it is a wholly owned subsidiary. It will operate from Thanet Way, Whitstable, Kent. (Tel.: Whitstable 4345.)

Ten trawlers now being built in British shipyards for Irvin & Johnson Ltd., of Cape Town, are to be fitted with **Marconi Marine equipment.** The installations, which will be identical, will include radiotelephone, direction finding and fish-finding equipment. Marconi Marine are also supplying and installing communications equipment in the new British built 8,000-ton passenger-cargo vessel *Centaur*.

Gertsch Products Inc., of Los Angeles, whose equipment is handled in the U.K. by Wayne-Kerr Laboratories Ltd., of New Malden, Surrey, has been acquired for $3,503,510 by the Singer Company, Connecticut, U.S.A.

Racal Electronics Ltd. have received over £1M worth of orders for their 7½kW single-sideband transmitter-receiver installations in recent months. The equipments are automatic in operation and provide over 250,000 alternative channels, by means of a synthesizer driven from a precision frequency source. The installations, which are being used for ground-to-air communication by the R.A.F., can be controlled over a single pair of Post Office lines.

The southern area office of **Acheson Colloids Ltd.** has moved from Richmond, Surrey, to 1 Finsbury Square, London, E.C.2. (Tel.: MONarch 5813.)

W. H. Sanders (Electronics Ltd.) and its associated companies Arrow Ltd. and Sanders Overseas Microwave Agency Ltd. have opened a northern sales office close to Manchester Airport. The full address is: Office B2, Haletop, Civic Centre, Wythenshawe, Manchester, 22. (Tel.: Mercury 1703.)

Sound Coverage Ltd., the audio equipment company formed 18 months ago, has moved to larger premises at 7-9 Kew Green, Kew, Surrey. (Tel.: RIChmond 5438/9.) E. Trevor Thomas has joined the company as joint managing director, with responsibility for mechanical design, from Pamphonic Reproducers Ltd.

Hebrides Radio Equipment.—The Ministry of Aviation has placed an order with A. T. & E. (Bridgnorth) Ltd. for v.h.f. communications equipment to be installed at Stornoway and Mangersta on the Isle of Lewis, in the Outer Hebrides. Multichannel duplicated radio terminals, with automatic changeover facilities are being provided, together with aerials, ancillary and test equipment. The Mangersta station will be remotely controlled from Stornoway and the link will, in one direction, carry audio and control switching signals for modulation and control of the transmitters, and in the other, the audio output of the receivers. A two-way engineering circuit is also being provided.

British Oxygen Cryoproducts has been set up by the British Oxygen Company to concentrate, as its name implies, on deep low temperature techniques and engineering. Among the company's products is liquid helium which is used in masers, for superconductive magnets and in the production of very high vacua.

Rank Cintel, a division of The Rank Organisation, has received an order for about £6,000 worth of industrial electronic metal detection equipment from Sidwell Timbers of South Africa. The equipment is to be installed into production lines processing blockboard from second-hand timber.

NEW YEAR HONOURS

AMONG the recipients of awards in the New Year Honours List were the following in the world of radio and electronics:—

Knighthoods

Jules Thorn, chairman and managing director, Thorn Electrical Industries.
John Toothill, C.B.E., Comp.Brit.I.R.E., director, Ferranti.

K.C.M.G.

Hugh Carleton Greene, O.B.E., director general, British Broadcasting Corporation.

C.M.G.

I. K. Mackay, director general, Nigerian Broadcasting Corporation.

C.B.E.

Brig. J. F. Mc L. Mellor, O.B.E., D.F.H., M.I.E.E., Corps of Royal Electrical and Mechanical Engineers.
R. E. Sainsbury, director general of guided weapon and electronic production, Ministry of Aviation.
J. A. F. Somerville, Government Communications Headquarters.
Brig. T. R. Warburg, late Royal Signals.

O.B.E.

D. W. Bushe, lately engineer-in-charge of radio station, Berbera, Sudan.
Col. D. Dibsdall, B.Sc., A.M.Brit.I.R.E., late Royal Signals.
E. W. Hayes, M.I.E.E., head of planning and installation department, B.B.C.
K. I. Jones, Assoc.I.E.E., chief engineer, Ferguson Radio Corporation.
Lt Col. J. H. Mansfield, Royal Signals, T.A.
E. Potts, M.I.E.E., assistant director (engineering), head of radio design staff, Headquarters, Signals Command, Air Ministry.
L. A. Robinson, engineer-in-chief, Posts and Telecommunications Department, British Guiana.
E. C. Slow, B.Sc., A.M.I.E.E., senior principal scientific officer, Royal Radar Establishment.
R. W. White, B.Sc., F.Inst.P., A.M.I.-E.E., assistant staff engineer, Post Office Research Station, Dollis Hill.

M.B.E.

Major J. S. Birch, Royal Signals, T.A.
A. A. Coker, engineer-in-charge (sound), B.B.C., Bristol.
E. A. Davis, station radio officer, Government Communications H.Q.
J. B. L. Foot, A.M.I.E.E., research engineer, G.E.C. (Electronics) Ltd.
W/O. J. D. Francis, Royal Signals.
J. C. Mann, 1st radio officer (Marconi Marine), *S.S. Empress of Britain.*
J. R. M. McNally, general manager, Beckman Instruments, Ltd.
C. Nicolson, B.Sc., senior experimental officer, D.S.I.R. Radio Research Station.
E. D. Northcott, Directorate of Electronic Production (Telecommunications), Ministry of Aviation.
Capt. R. Prendergast, Royal Signals, T.A.
Major G. Proudman, Royal Signals.
F. L. Reed, Government contracts manager, E.M.I. (Electronics) Ltd.
E. P. Sim, assistant director, engineering division, Australian Post Office.

B.E.M.

Acting Chief Radio Electrical Artificer (Air) E. S. Barrett, R.N.
R. T. Bedford, inspector (radio line plant), Australian Post Office.
O. E. Cooper, supervising technician, Paddington Terminal, Overseas Telecommunications Commission, Australia.
Chief Radio Supervisor J. D. Foster, R.N.
T. W. Goford, lately supervising technician (radio), Department of Civil Aviation, Alice Springs, Australia.
W/O B. G. Green, Royal Signals.
Leading Radio Electrical Mechanic P. W. M. Griffioen, Royal Australian Navy.
Cpl. R. D. Holdsworth, Royal Signals.
A. Lee, technical officer, Post Office Research Station, Dollis Hill.
Chief Radio Supervisor (W) L. McWalter, R.N.
Sgt. A. F. Moon, Royal Signals.
Chief Radio Electrician T. G. Rennie, Royal Naval Reserve.
Sgt. J. K. Roberts, Royal Signals.
Chief Radio Supervisor V. J. Stuart-St. Clair, Royal New Zealand Navy.
C. Xerri, technical assistant, 234 Signal Squadron, War Office, Malta.

Royal Victorian Medal

Chief Communications Yeoman R. W. Fisher, R.N.

POINT-TO-POINT REVIEW: 1963

By P. A. C. MORRIS,* B.Sc., A.M.I.E.E.

IN reviewing the practice and performance of point-to-point communications systems during 1963 one is obliged to begin with mention of submarine coaxial cables. For, in the last month of the year, the most challenging route to the long-distance communicator, London-Australia, was spanned with a high-performance 80-channel link. For the first time a continuous telephone service became available between the antipodes. Nor was this the only achievement for, earlier in the year, a 128-channel cable was laid between Jamaica and Miami, whilst a fourth telephone cable was laid across the Atlantic—from New Jersey to Cornwall.

Although the h.f. radio system that has linked Australia to Britain for 37 years is now relegated to a stand-by role, this should not be taken as being typical of a fate universally befalling radio. A recent study by Lee and Cannon† of the growth of h.f. telex and leased telegraph channels on routes not served by coaxial cables shows an expansion rate of about 60% per annum—a remarkable figure for any undertaking and certainly not indicative of decline. What this means is that there is a great deal of difference between the types of system that are appropriate to routes requiring more than about 20 kc/s of aggregate bandwidth capacity and those requiring less. For large areas of the world the lower capacity is sufficient at present and so there is considerable interest in securing the most efficient use of the h.f. band.

This fact was emphasized by publication during 1963 of the Report of the Panel of Experts which was set up by the International Telecommunication Union to study ways of reducing congestion in the band. Many of its 33 technical recommendations underline the principles of good practice, which very often hinge upon the use of modern and efficient installations. Others cover the frequency tolerance of transmitters and spurious emissions, whilst great importance is attached to the abandonment of d.s.b. operation in favour of s.s.b. However, 11 recommendations cover the provision, wherever possible, of alternative systems ranging from line-of-sight microwave links, tropospheric scatter, and satellites, in addition to submarine coaxial cables. One would scarcely take issue with the Panel on the wisdom of providing these alternative methods of communication, but it is

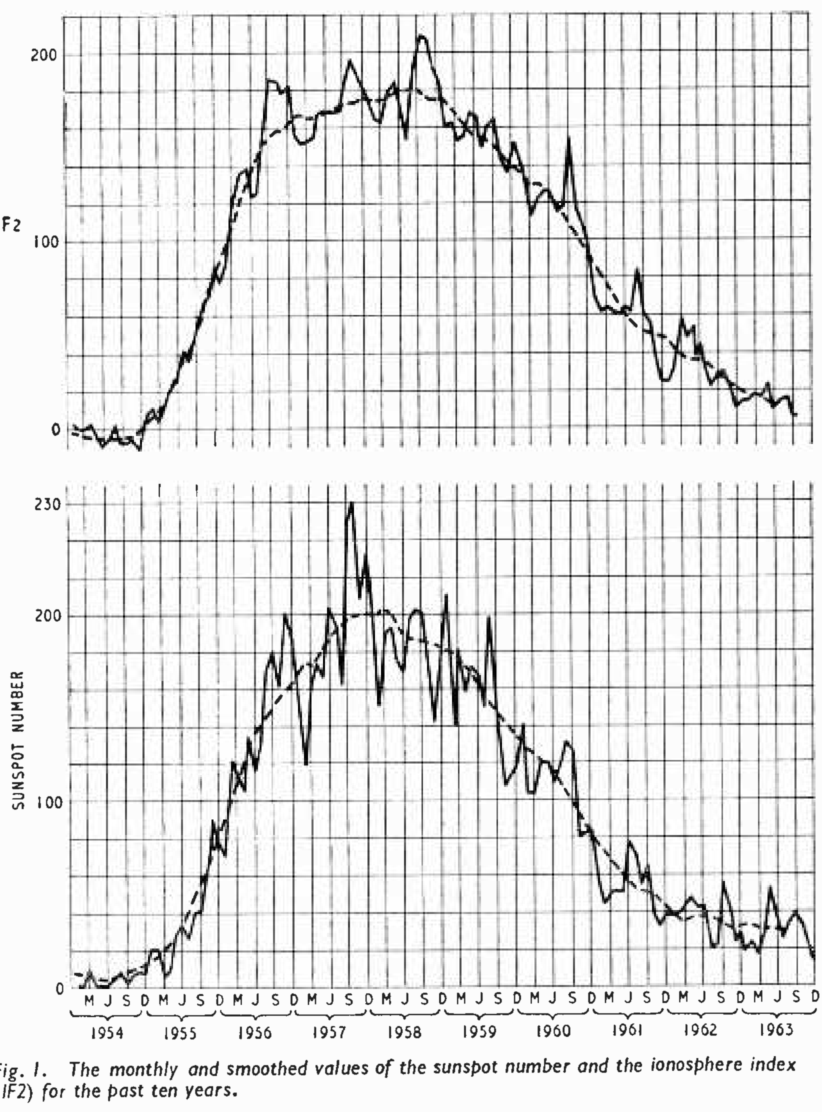


Fig. 1. The monthly and smoothed values of the sunspot number and the ionosphere index (IF2) for the past ten years.

* Cable & Wireless Ltd.

† Lee, W. H., and Cannon, R. W. Documents of I.E.E. Convention on H.F. Communication, March, 1963.

nevertheless, true that most organizations have been installing them just as soon as they can be shown to be economically justified.

Why is it that h.f. radio remains so attractive for lower capacity routes? The quick answer is that it is the cheapest system. Even when thoroughly well engineered, an h.f. link is far cheaper than a coaxial cable on a cost-per-channel-mile basis. On this basis one could afford to double the expenditure on a radio system and produce considerably higher circuit efficiencies since the amount of lost time per day on a radio link varies inversely with the expenditure on its provision. But at root the reason is the complex variability of the propagation medium and the strong diurnal influence in this variability. This is quite unlike the characteristic of, say, v.h.f. propagation in which, while the path attenuation often varies within the same order of magnitude, it does so with no certainty of communication within any given period. If an h.f. radio system works at all one can practically guarantee that it will work at some time within *any* 24 hours. The simplest of equipment will provide some sort of service at the optimum time of day, whilst it is only when continuous service is required that massive installations are required. As an example, during June, 1963, the yacht *Rehu Moana* operated a radiotelephone over a range of 1,000 miles into the G.P.O. network using only 75 watts, whilst a continuous commercial service might require 10 kW for the same distance.

The question of the proper level of expenditure on h.f. systems became a topical one during the year on account of further progress in the field of oblique-incidence sounding equipment. In the review of 1962 mention was made of the potential value of sounders in giving an instantaneous measurement of propagation conditions over a radio path: the system uses a synchronized sweep-frequency pulse transmitter and receiver at either end of the circuit. In June representatives of many organizations witnessed a demonstration of this equipment working across the Atlantic and a number of them were impressed with the possibility it opened up of matching the usage of radio frequencies to the *measured* maximum usable frequency. Test equipment is normal in radio stations to monitor the performance of transmitters and receivers and here was the apparatus to monitor the propagation path.

The snag, of course, is the cost which amounts to the equivalent of a high-power transmitter itself. But it is in this sort of context that the foregoing discussion on the cost of operating a radio link has relevance.

However, to continue our review of developments in 1963, we shall now turn to the longer-term influence of the solar cycle on h.f. communications.

The surprising fact to be reported is that there has been practically no change in the general level of solar activity during the year. After a steady decline from the maximum in 1958 the running average sunspot number has remained around 30 throughout 1962 and 1963. This is quite unlike the last cycle ending in 1953, and indeed one has to go back to the mimimum of 1876 to find anything at all similar. It is tempting to suppose that the sunspot number will not fall any lower and that the new cycle will appear at any moment: the fact that a sunspot characteristic of the beginning of a new cycle was observed in August lends some support to this view. However, past records show that the smoothed sunspot number invariably drops below 10 so that a further fall must be expected yet. Fig. 1 shows the monthly and smoothed values of both the sunspot number and the IF2 index; the latter gives the measured variation in ionization of the F-layer and is published by the D.S.I.R. Radio Research Station, Slough. It is interesting to note that this index reveals the decline of solar ionizing radiation which is not shown by the sunspot number.

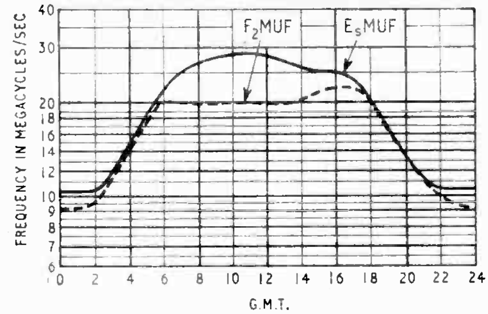


Fig. 2. London-Nairobi predictions for June 1963 showing sporadic-E(E_s) enhancement.

In general the performance of radio circuits has been maintained at the same level as in 1962. There were nevertheless events worthy of note such as the severe interruptions to services during ionosphere storms in September and October: during the latter half of September there were several flares which led to storms causing Dellinger-type fades and the same active area of the solar disk returned a month later after the sun's rotation causing similar disturbances. Examination of circuit logs for the period of these storms draws attention to the fact that only routes traversing high latitudes are seriously affected.

The expected influence of sporadic-E ionization on propagation during the summer period duly appeared. Operating frequencies around 15% higher than the predicted F2 MUFs were consistently used, especially on easterly routes from London. Normally no account of sporadic-E is taken in drawing frequency prediction curves because of its variable nature. However, the U.S. Central Radio Propagation Laboratory does publish forecast data which can be used to draw predictions of the median MUF due to sporadic-E. The appropriate curves have been drawn in Fig. 2 for the route London-Nairobi and it will be noted that the full-line sporadic-E MUF matches up very well with the actual frequency usage of 21 Mc/s in daytime.

It is during the solar minimum years, when F2 MUFs are depressed, that the sporadic-E effect is important and during next summer it will be especially valuable to have the use of higher frequencies which these curves indicate will be available.

Finally, in the field of satellite communications the event of the year was the successful launching of the experimental synchronous satellite Syncom II in July. From a quasi-stationary position over the Atlantic it has demonstrated the possibility of a relay in the 22,000-mile orbit.

Physical Society Exhibition Review

Highlights as seen by the Staff of *Wireless World*

THE Exhibition Committee have for several years been fighting what appeared to be a losing battle to subdue the purely commercial aspects of the exhibition. This year, however, a considerable measure of success was achieved, and new equipment was not diluted by all the old models in makers' catalogues. A welcome innovation was the section devoted to educational exhibits; much more attention is being paid to instruments specifically intended for teaching purposes, perhaps as a result of the Nuffield committee interim report.*

Measuring Instruments

Oscilloscopes:—Transistor oscilloscopes have, until fairly recently, been somewhat thin on the ground, possibly because the length of the tube means that size cannot be significantly reduced, and because either a mains supply or large batteries are needed, largely nullifying the advantages of transistor working. Two instruments were seen this year, however, the Cossor CD100 and the E.M.I. WM41.

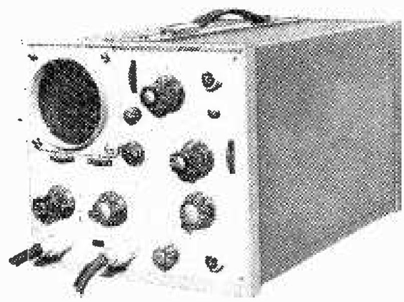
The CD100 is a modular oscilloscope, consisting of a main frame, carrying power supplies and tube, and a large aperture to accept separate or combined *y* and *x* deflection units. An advanced specification is offered and units are available for bandwidths up to 35 Mc/s and sensitivities up to 500μV/cm. Swept-frequency oscillator heads and u.h.f. sampling units are also designed for the instrument. Nuvistors are used to obtain high-input impedance amplifiers, and bootstrap circuitry is used in the timebase units. Y-delay is 153 nsec, achieved by means of a remarkably simple delay line. This is an example of the "why-has-no-one-thought-of-it-before" category of devices and consists simply of two lengths of p.v.c.-covered wire closely wound in opposite directions round a flexible former, which plays no part in the operation. The characteristic impedance is 220Ω, bandwidth up to about 50 Mc/s and delay about 20 nsec per foot. There is no cross-talk between adjacent coils when it is folded into a small space.

E.M.I. showed the prototype of their WM41 10 Mc/s instrument, which again uses valves in the input stages of the *y* amplifier. Several novel features were noted, among them being the power supply. When powered by a 12-V battery, the main supply, e.h.t. line and calibrating square wave are all derived from a transistor 7 kc/s inverter. Considerable economy is achieved in this way. The timebase, which sweeps at a maximum rate of 0.2/μsec/cm, is a bootstrap, constant-speed, triggered type in which the flyback time is variable to obtain locking. A tunnel diode is incorporated in the trigger circuit. No *y* delay is used. The unit is very compact and two can be fitted side-by-side in a 19-in rack.

Current Measurement:—The properties of bismuth telluride have been employed by A.M.F. in a copper/bismuth telluride thermoelectric ammeter. The alternating or direct current is passed through a metal strip in thermal contact with the junction. The bismuth telluride is in the form of a pointed slug, narrow copper foil being used to reduce heat loss, the junction thus having a short response time. The relation between current and junction voltage is approximately a square law.

Testmeter:—An electronic equivalent to the well-known "AVO" was shown by Avo Ltd. This comprises two completely separate transistor amplifiers for a.c. and d.c. measurements. The d.c. amplifier is a long-

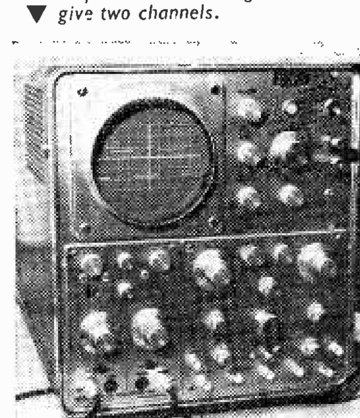
*"The Teaching of Modern Physics."

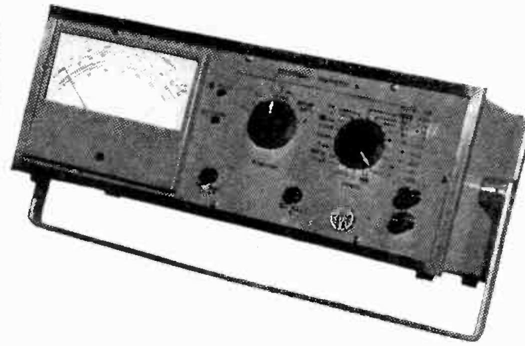


▶ *E.M.I. 10Mc/s transistor oscilloscope.*

◀ *A.M.F. thermojunction ammeter in display box.*

Cossor 35Mc/s transistor oscilloscope. Beam-switching is used to give two channels. ▼





Avo electronic testmeter for R, I and V measurements.

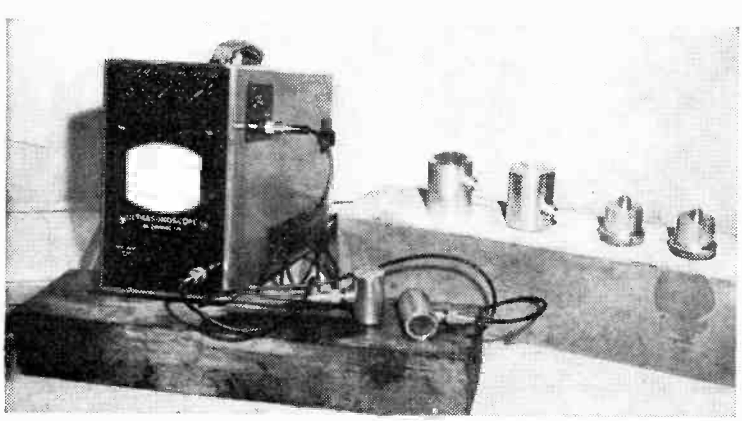
A.E.I. dielectric test set.

tailed pair with additional negative feedback, and a dual transistor at the input for temperature stability. Negative feedback is also used in the a.c. amplifier to stabilize the meter reading. Current, voltage and resistance measurements may be made. Full-scale readings of 100 mV and 30μA are provided, and resistance is indicated between 200Ω and 20MΩ.

Material Testing:—Equipment for the determination of material parameters was displayed by A.E.I. Research and S.T.C. The dielectric loss analyser shown by A.E.I. is intended not only to assess capacitance and loss tangent but to separate solid-dielectric loss and that caused by ionization of gaseous discharges in the small cavities in the material. Advantage is taken of the fact that below a certain voltage gaseous discharges do not occur. Below this "inception voltage", capacitance and loss tangent are obtained by balancing a capacitance bridge and supply the y deflecton circuit of an oscilloscope with specimen charge storage and the x system with applied voltage. At balance, the display is a horizontal line, control settings to obtain this giving the C and loss. Above the inception voltage, the horizontal line opens out vertically to take the form of a rhomboid. The included area gives total discharge loss per cycle, height gives charge transfer per cycle, length of a horizontal the inception voltage and the projected length of the whole is the test voltage. The instrument is extremely simple to operate compared with older systems and interpretation of the result is rapid.

The S.T.C. resistivity test set is intended to measure the resistivity or the thickness of slices of semiconductor without the necessity for contacts of any kind. The principle is that of damping a tuned circuit by the resistance of the specimen. A tuned circuit is loosely coupled to a swept oscillator and the voltage across the tuned circuit at resonance measured by a peak-reading voltmeter. The slice of semiconductor is then placed in the coil and the new reading measured. Reference to a calibration chart gives specimen resistivity or, if resistivity is known, the thickness. Discontinuities in large samples can be detected. The problem of measuring the peak of an extremely narrow resonance curve is lessened by modulating the sweep speed, by means of a feedback circuit, so that the peak is broadened. Automatic level control is applied to the oscillator to keep the output constant over the 90-100 Mc/s band.

B-H Loop Plotter.—The sight of a conventional x-y plotter drawing a hysteresis loop was sufficiently interesting to cause one to dig the heels in and defy the course of enforced motion down the alleyways. Telcon Metals with the aid of this now familiar piece of equipment demonstrated their dynamic hysteresis loop plotter which was used to draw, on paper, the major and minor B-H loops of soft magnetic materials (at frequencies from 50-5,000 c/s). The method adapted is to sample simultaneously H and B waveforms over a short period of time. D.c. levels are then obtained which are fed to the x and y inputs of the plotter. The voltage signal proportional to H is obtained across a non-inductive resistor in series with the magnetizing current. The voltage signal proportional to B obtained via a search coil is integrated electronically. The signals as they now stand are easily displayed on an oscilloscope but are too fast for a plotting table. However, a sampling technique is used to supply the



Prototype ultrasonic concrete testing set Type NHM/I shown with transmitting and receiving heads. (Ultrasonoscope Co.)

plotter drive. Pulses of 2μsec duration generated by switching a square-loop core wound with Mumetal tape are used to open a gating circuit during which the "B-H" signals are sampled. The pulse generator is triggered by a signal of the same frequency as that used in testing the core, but slowly changed in phase over a full 360°. The pen of the plotter describes a complete B-H loop. (Telcon Metals apparently do not intend to manufacture this apparatus on a commercial basis; they will, however, be pleased to pass circuit information on to would-be users.)

Compression Testing.—Ultrasonic testing of inhomogenous absorbent materials such as concrete, stone and wood was demonstrated by a prototype instrument Type NHM/1 manufactured by Ultrasonoscope. In these materials there is sometimes a correlation between the velocity of propagation of ultrasonic energy and compressive strength. The instrument has a high-power transmitter, a relatively low frequency generating and detecting system to minimize absorption in the specimen and a timing device so that the time of travel of a wave in the specimen can be measured. Transistors are used and the equipment is battery powered. The operating frequencies are 50, 100, 200 and 500 kc/s. Sweep speeds are 10μsec, 100μsec and 1msec. The sweep delay is calibrated from 0 to 10msec in 10μsec steps. The smallest resolvable time difference is 0.1μsec in any 10μsec steps up to 10msec.

Materials

The Advanced Research Group of Rolls-Royce showed examples of their current research projects on metal-coated glass fibres and fibre-reinforced metals. In association with the former case, pure fused silica had been coated with an aluminium alloy thus conferring a measure of resistance to damage to the fibres at temperatures of up to 300°C. In the case of the latter project, demonstrations showed that silica fibres continuously coated with aluminium can be compressed to form a fibre-reinforced metal. The material showed an increase in strength over ordinary aluminium at temperatures in excess of 200°C. The Research and Development Group of the Sperry Gyroscope Company showed their latest developments in the field of catalytic reduction and what is now termed "electroless" chemical plating. This enables the deposition of metal coatings on non-metallic substrates. The range of substrates now includes ceramics, ethyl silicate refractory mouldings, fused silica, resin-bonded boards and, to a more limited extent, p.t.f.e. Metals which have been found to be suited to this process are phospho-cobalt and nickel. Copper, gold, palladium, and platinum have also been deposited successfully. A layering process is possible whereby successive strata of different metals can be built up.

Though, at present, applications are somewhat obscure, the magnetic properties of an iron-rhodium alloy demonstrated by Johnson Matthey and Company were interesting enough to be noted. An alloy containing approximately equal numbers of iron and rhodium atoms was shown to have anti-ferromagnetic properties at room (and even exhibition) temperatures. However, when the alloy was heated to approximately 60°C it became noticeably ferromagnetic. Recent work indicates that the ordered structure of these alloys below the transformation temperatures changes when this temperature is reached and the magnetic and crystallographic cells coincide.

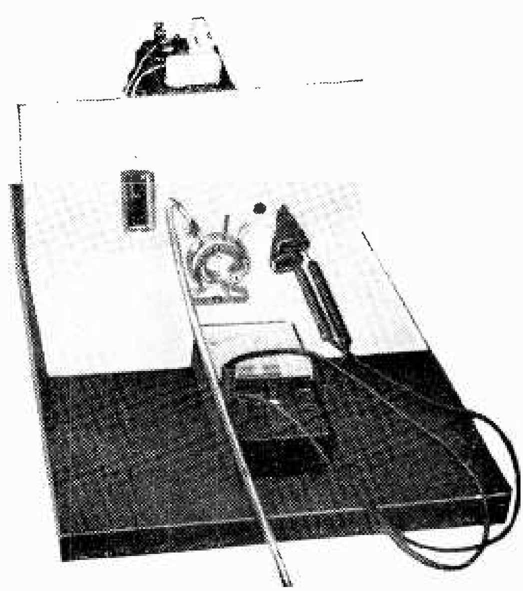
Industrial Electronics

Manometry.—For the measurement of very small pressures, Mercury Electronics have introduced a micro-manometer which is sensitive down to 1mm water, and will register the pressure obtained from a pitot head at 0.1 m.p.h. The pressure capsule has an optically coated diaphragm acting as a concave mirror which varies its focal length according to the pressure inside the capsule. It is mounted in an optical system in which are two photosensitive semiconductors wired in a bridge. The output is therefore proportional to pressure over a wide range and drift is kept to less than 0.1mm water per hour.

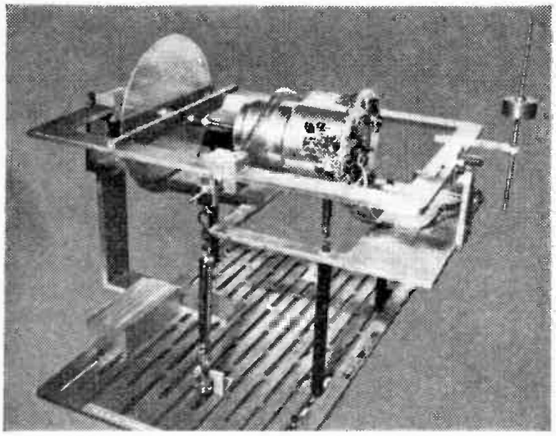
Telemetry:—The formidable problems of measuring the blade vibrations of a power-generating turbine in the presence of copious quantities of steam, heat and centrifugal force have been solved by the Central Electricity Research Laboratories. A strain-gauge bridge is fixed to a turbine blade, its output being applied to a voltage-sensitive semiconductor capacitor, which frequency-modulates a 30Mc/s transmitter. Power is fed to the transmitter and its power circuit at 50kc/s from a stationary coil.

Communications:—For the transmission of control information and speech between a gantry crane and a fixed station, the British Iron & Steel Research Association have developed an inductive loop system. The crane carries toroidal windings through which a loop, carrying the signal, is threaded. The transmitter consists of two square-wave oscillators running at 4.8 and 5.6kc/s respectively, one frequency corresponding to a digital "ONE" and the other to a "ZERO." The oscillators are gated by a pulse train and the signal to be transmitted. Filters allow only the fundamental to be transmitted. At the receiver, the signals are separated by filters and passed to amplitude discriminators to avoid circuit noise. The signals are then detected, and passed through trigger stages to the teleprinter.

Brushless D.C. Motor:—Because of the very short life of carbon brushes when used in high-flying aircraft, it



Mercury Electronics micro-manometer.



University College of North Wales transistor-commutated motor.

was decided by the University College of North Wales that semiconductors should be suitable for use under these conditions in d.c. machines. The exhibit was a d.c. motor whose rotor is a permanent magnet, the armature being a three-coil system. A shutter is coupled to the rotor, and allows the light from a lamp to illuminate each of three phototransistors in turn. The outputs of the phototransistors are used to drive silicon transistor switches connecting each coil in turn to the supply. The efficiency is claimed to be rather better than that of the conventional brush type of motor.

Angular Measurement:—The use of optics for rotation measurement is not new, but the laser provides a means of measuring directly the rotation of a system with respect to inertial space. The ring laser designed by the Services Electronics Research Laboratory takes the form of three mirrors arranged on a ring, with a gas discharge tube between each pair of mirrors, the whole forming a triangle. Transitions in the gas atoms in the tubes provide sufficient gain to overcome losses in the optical system, and oscillation takes place, the wavelength being 6328Å. No preferred direction of propagation is inherent, and two contra-rotating oscillations are produced. If the ring is stationary, the oscillation wavelengths are identical, but if the ring rotates with respect to space, the oscillation propagated in the same direction as the ring rotation needs a longer wavelength to keep the propagation path a whole number, and the frequency of oscillation decreases. The opposite state of affairs exists for propagation in the other direction. If samples of the two frequencies are applied to a photodetector, the beat note is a measure of rotation rate. The rotation of the earth should in theory give a beat of 46c/s, but the two oscillations tend to pull one another, and this small difference is not measurable. The system has possibilities in inertial navigation.

Television Microscope:—The Watson television eyepiece with pointer enables a horizontally-positioned camera to be used in conjunction with any microscope. The pointer, whose controls are on the eyepiece, can be brought into sharp focus on the monitor screen and ranged freely over the entire field of view. When used with a binocular microscope the television eyepiece is fitted over one of the optical eyepieces, allowing the other eyepiece to be used conventionally. At the exhibition a trinocular microscope was used so that binocular and monitor vision of the specimen was possible simultaneously. The magnification on the monitor screen is determined by the magnification factor of the objective in use × 1.25 × screen diagonal (when screen diagonal is measured in inches).

Semiconductors

Light.—It took many people long enough to accept the concept of holes moving about in a piece of semiconductor, but it would now appear that photons are the latest thing in current carriers. Mullard had a device called the transluxor, which is a light-operated amplifier. A gallium arsenide diode is biased into its forward region and emits light at about 9100Å at room temperature or, considerably more efficiently, at 77°K. The input current produces the light, which is transmitted at its customary high velocity (no transit-time effects) to a p-n junction between gallium arsenide and another unspecified material. Current gain between input and output approaches unity. The responses of emitter and collector to current and light stimuli are such that light modulation of the order of 1Gc/s is expected to be possible.

A gallium arsenide emitter shown by Mining and Chemical Products produces infra-red radiation at a wavelength of about 9000Å. Typically, the diode requires between 50 and 400mA at about 1.25V to produce up to 15μW of infra-red power. Greater output for the same current can be obtained by cooling the emitter to 77°K, the temperature of liquid nitrogen.

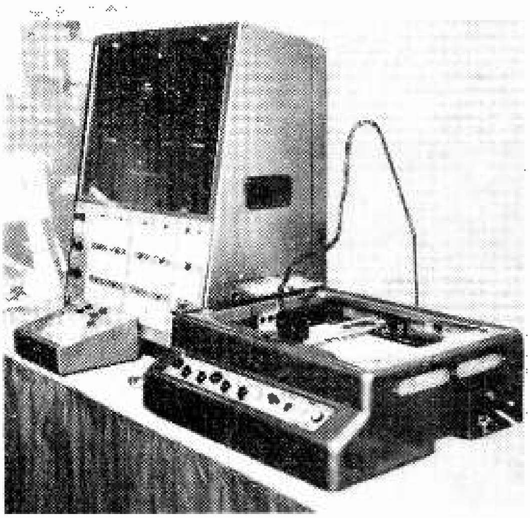
Gallium phosphide is used in a similar device shown by the Services Electronic Research Laboratory. Depending on the material used to dope the GaAs, the colour of the light is either green or red, and others are possible. The response time of the device is of the order of 0·2μsec. Drive conditions are 25mA at 2V to give between 10 and 40 foot-lamberts. If the drive is applied in short pulses, very bright flashes of light can be obtained.

Watson television camera microscope eyepiece used with a trinocular microscope.

Computers and Data Processing

Recent developments in the computer and data processing fields, if this year's exhibition was to be taken as indicative of trends, showed a leaning towards a speeding up of data processing.

Bryans presented a formidable display with their Series 20017 digital data translator. Essentially the equipment is a digital-to-analogue converter which selects and processes data representing the x and y co-ordinates of a graph from digital data on punched cards or tape and converts them to analogue form suitable for feeding into an x-y plotter. Transistors are used throughout the equipment. A keyboard is also provided for testing or for keying-in additional data. A large neon display panel allows visual input checking of polarity, numeric value and channel number.



Bryans digital data translator.

The Admiralty Research Laboratories demonstrated a new voltage digital recorder, designed to record a transient voltage signal by sampling at a high rate, converting to digital form and recording on magnetic tape. On replaying the tape the information is transferred to 5-hole paper tape for subsequent processing by computer. Compared with the conventional system of photographing an oscilloscope trace to record a transient signal this method, though costing more, represents a considerable saving of time.

An analogue-to-digital converter demonstrated by J. Langham Thompson changes analogue input voltages between 0 and 10 volts to an equivalent binary digital output suitable for feeding to a paper-tape punch machine or directly to a computer. The converter, which has an input impedance of 100kΩ, is triggered by a 10V positive-going pulse so that the input voltage can be converted to a digital output at any given instant. Thus, with a suitable pulse generator the converter can be used to produce digital outputs corresponding to the input voltage at regular time intervals.

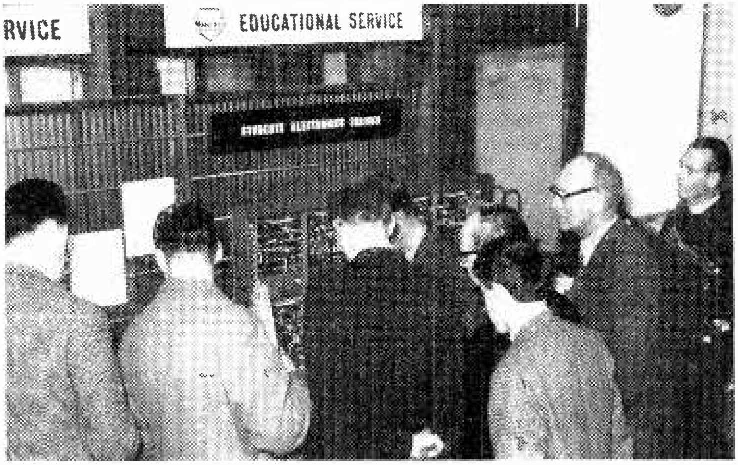
The Data Processing Research Laboratories of Elliott-Automation gave a foretaste of things to come by showing units of a prototype tunnel-diode digital computer based on Goto-pair logic. The computer uses a 3μsec cycle store time and a 40-digit word length. Electromagnetic delay lines are used for serial storage while conventional ferrite cores are used as a parallel bulk storage medium.

Microwaves

Many difficulties in variable-tuned circuit design at u.h.f. are associated with variable capacitors. The use of a variable inductor often provides a solution. One possibility is the use of an inductor with a saturated core. A ferrite variable inductor working up to about 800Mc/s was demonstrated by the Caswell Research Laboratories of the Plessey Company. It consisted of a coil wound across the diameter of a soft ferrite disc about which a saturating static field, parallel to the plane of the disc, can be rotated. When the static field and the alternating field generated in the coil are parallel the permeability is unity but when they are perpendicular a permeability of approximately four may be obtained. The losses are reasonably low, and in practice a Q of between 50 and 75 has been achieved in a circuit with a tuning range of 275 to 390Mc/s.

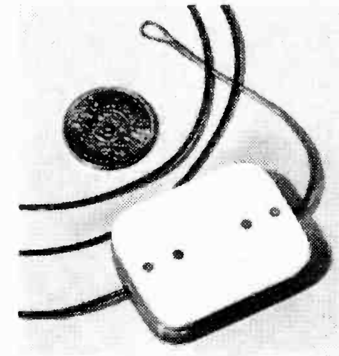
Flann Microwave Instruments demonstrated a new microwave oscillator Type PCLX which covered the range 4 to 12Gc/s. The instrument uses a plug-in klystron valve in a coaxial line cavity and the reflector voltage is automatically adjusted for the frequency of operation. Frequency is shown on a direct-reading dial and since the load conditions can pull the frequency and invalidate the critical reflector potential derived by the tracking system, a trimming potentiometer allows a small measure of readjustment. Over the frequency range the maximum power available varies from 4 to 100mW. The levels are adjustable by withdrawing the coupling probe into the cut-off tube. The output impedance is 50Ω. A transistor power supply drives both the klystron oscillator and the modulator circuits. Square-wave or saw-tooth modulation can be applied.

When the applications to which lasers can be put are considered it was surprising that so few lasers were ex-



Typical of the interest shown in exhibits in the Educational Section.

▲ *Klystron oscillator for 4 to 12 Gc/s manufactured by Flann Microwave Instruments.*



▶ *Devices pacemaker Mk II shown with a florin for size comparison. Major chest surgery is avoided.*

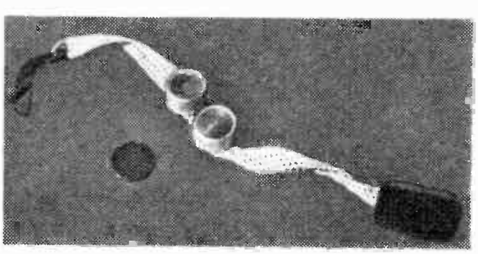
hibited. Some three gas and one ruby laser were demonstrated at the exhibition together with a few applications. Elliott-Automation in their educational display demonstrated a bench-mounted helium neon laser. With this equipment the use of confocal mirrors external to the tube simplifies alignment and the change-over from infra-red to visible operation was easily performed. Other demonstrations in this field included rotation measurement (described elsewhere in this report), micro-welding by ruby laser devices and Raman spectroscopy.

Miscellaneous Exhibits

Delay line: A parametric delay line designed by University College of North Wales uses back-biased junction diodes as the capacitive elements. The velocity of propagation along the line, and therefore delay, is variable by altering the diode bias. If this is done while a pulse is in transit along the line, stretching or compression of the pulse is obtained, the frequency components of the pulse being scaled up or down.

Medical Electronics: Many stands showed that medical physics and electronics had not stood still over the past year. The miniature radiotelemetering device for cardiac monitoring shown by the University of Edinburgh and the South-Eastern Regional Hospital Board was inconspicuously conspicuous by the degree of miniaturization attained when one considered that the battery which was contained in the apparatus gave a working life of 250 hours. The equipment consisted of a metal reed tuned to about 180c/s (which is found to be the optimum frequency) and forming one plate of a tuning capacitor of a one-transistor v.h.f./f.m. transmitter. Impulses causing vibration of the reed therefore result in the modulation of the frequency of the transmitter. No electrodes are needed, and by strapping the monitor on the chest a clear indication of heartbeats can be heard remotely from the patient.

The St. George's implantable pacemaker Mk. II manufactured by Devices was an interesting development of an established technology in that the need for major surgery has been avoided. The pacemaker, consisting of a two transistor and a diode conventional blocking oscillator together with four Mallory batteries, is enclosed in a silicone-rubber case. This is implanted subcutaneously in the armpit region. The platinum-tipped electrodes are taken to the heart via the jugular vein. A 1msec pulse 5V in amplitude is produced and is then differentiated to minimize polarization and hence corrosion, of the electrodes. The pulse repetition rate is variable for use in patients of widely differing age groups.



V.h.f./f.m. cardiac monitor and battery case developed by the Department of Medical Physics, Royal Infirmary, Edinburgh (combined with a 3d piece).

Radio Microphone: A complete radio microphone system was shown by Labgear of Cambridge. The system has an audio-frequency response of 50 c/s to 12 kc/s ±2 dB and although the receiver unit has a mains power supply, provision is made for battery operation. The transmitter, which is frequency modulated, has an output power of 50 mW. The spurious radiation level is less than 100 μW. Power is provided by an internal rechargeable nickel-cadmium cell. The frequency stability is within ±5 kc/s of the nominal carrier frequency. The receiver provides an output of 1V into 600Ω and has a frequency range of 174.6 to 175 Mc/s. A special feature of the receiver is the provision of a battery charger output for recharging the transmitter battery.

Stabilizer: When the input voltage to a series regulator is varied over a wide range, trouble can be experienced due to excessive power dissipation in the series transistor. To avoid having up to three power transistors in parallel, Transitron Electronics employ a silicon planar type to pre-stabilize the supply to the series regulator. A free-running multivibrator is fed from the pre-stabilized supply, the square-wave output being fed back to a 2N1722 chopper transistor, which features 0.15Ω saturation resistance and a cut-off frequency of 20 Mc/s. The feedback loop tends to keep the voltage across the series regulator constant and reduces the power dissipation.

Combination Lock: Purely for amusement, A.E.I. invited clearer-minded visitors to try to operate their electronic combination lock. A deceptively simple block diagram was displayed behind the lock, but, in our case, to no avail. The lock could be operated by switching the inputs to a series of AND gates, the outputs of which were fed back in a devious way. The reward for success was the lighting of a lamp, which seemed a bit miserly.

MANUFACTURERS' PRODUCTS

NEW ELECTRONIC EQUIPMENT AND ACCESSORIES

Voltage Stabilizer

A TOTALLY enclosed, mains voltage stabilizer, Type 126 produced by Servomex Controls, Crowborough, Sussex, has been designed to meet severe environmental conditions. Enclosed in a heavy-gauge mild-steel case without orifices, the equipment can be used in excessively dusty and damp atmospheres. It will withstand shocks of up to 40g and can be immersed in up to 18in of water (from its base).

The input voltage is within the range 200 to 250V. The correction range with an output of 7kVA is −20% to +10% or −15% to +15%. At 14kVA the correction ranges are −10% to +5% or −7½% to +7½%. The harmonic distortion introduced is claimed to be negligible. The case is mounted on castors and the top cover is easily removed for servicing.

5WW 311 for further details

Wide-range Signal Generator

TWO attenuators, 50Ω and 600Ω are provided in the E.H. Research Laboratories signal generator Model 410. The 50Ω control provides 50dB attenuation in 10dB steps. Together with the amplitude control, the output, over the whole frequency range of 10 c/s to 10 Mc/s, is variable from 3 V to 3 mV into 50Ω. The 600Ω attenuator provides up to 50dB attenuation also in 10dB steps and it is calibrated in volts and dBm. With the amplitude control the output voltage can be varied continuously from 1.5 V to 1 mV. Both attenuators are accurate to within ±1dB.

When correctly terminated the output from the instrument is level to within ±0.5dB from 10 c/s to 1 Mc/s and ±1 dB from 1 Mc/s to 10 Mc/s. The long-term frequency stability is within ±1% after a warm-up time of 15min. The output can be taken via a type B.N.C. coaxial connector or from a pair of screw terminals. The output level is monitored on a voltmeter calibrated in volts and dBm. The reading when the instrument is correctly termir ted is accurate to within ±5% of full scale. The distortion is claimed to be less than 1% from 20 c/s to 100 kc/s, less than 2% from 100 kc/s to 1 Mc/s and better than 3% from 1 to 10 Mc/s.

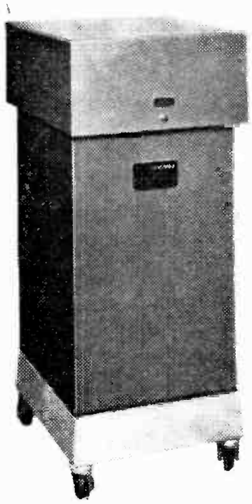
Rack-mounting and bench versions can be obtained at £226 and £234 respectively (exclusive of duty) from Livingston Laboratories, Camden Road, London, N.W.1.

5WW 312 for further details

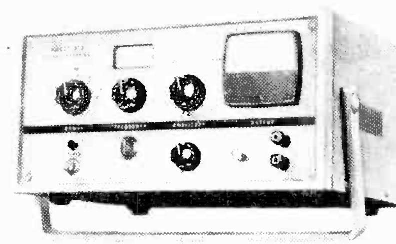
Battery-powered Millivoltmeter

EIGHT voltage ranges, with a minimum full scale deflection of 1mV and a maximum f.s.d. of 3V, are provided by the PM2453 millivoltmeter recently introduced by Philips and available in the U.K. from Research and Control Instruments Ltd., King's Cross Road, London, W.C.1. The accuracy of measurement is within 5% over the frequency range 50 c/s to 1Mc/s. Over the range 10c/s to 5Mc/s the accuracy is reduced to within 9%. With the attenuator probe, which is supplied with the voltmeter, the measurement range can be extended to 300V.

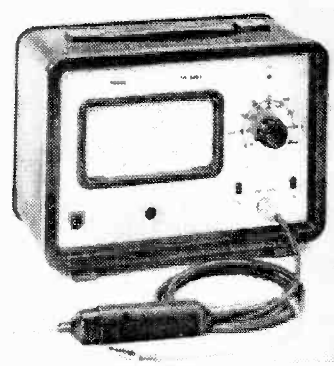
Powered by five rechargeable batteries and weighing 4½lb, the instrument is usable at all times. The batteries may be recharged 300 times

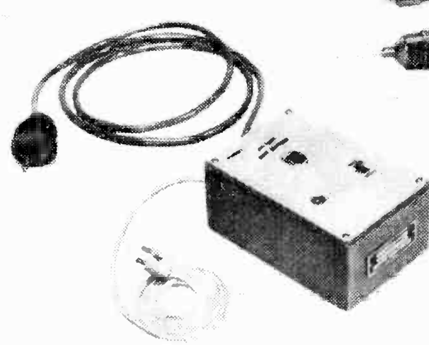


▲ *Voltage stabilizer Type 126 manufactured by Servomex Controls.*



▲ *E-H Model 410 wide-range signal generator.*





▲ ◀ *Type PM2453 transistor battery-powered millivoltmeter shown with the battery charger PM9000. Both equipments are manufactured by Philips.*

and provide 40 hours operation per charge. The millivoltmeter has a battery self-check facility. An accessory, a battery charger Type PM9000, is available for recharging the batteries from a mains supply without the need for their removal from the instrument.

The input impedance of the instrument is 1MΩ in parallel with 35pF. An internal oscillator provides a 10kc/s calibrating signal. The cost of the instrument is £70.

5WW 313 for further details

Silicon Rectifier and Heat Sink

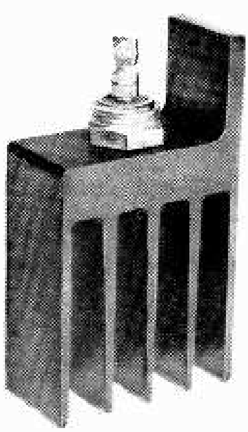
INTERNATIONAL Rectifier announce a new range of silicon rectifiers rated at 60A with stud temperatures of 115°C. Components from this new 25G range are available over a wide voltage range and the maximum pulse overload is 850A for 10msec. The rectifiers are made with a welded glass-to-metal seal and are tin plated. An alloy-extruded heat sink has been developed by the International Rectifier Co. of Oxted, Surrey, for use with this series of rectifiers.

5WW 314 for further details

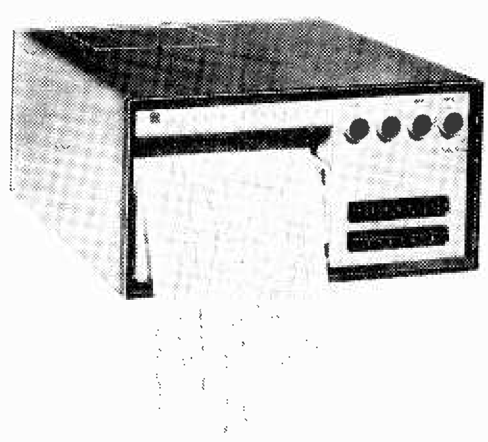
Wobbulator

TELEVISION Bands IV and V are covered by the Metrix u.h.f. wobbulator Type 240. The frequency range of this instrument extends from 470 to 870 Mc/s (channels 21 to 68) and over this range the wobbulator can be used as a "single-signal" generator. When used as a sweep generator the sweep can be varied continuously from less than 2% of the centre frequency up to 23 Mc/s (±11.5 Mc/s) at a repetition frequency of 50 c/s. The maximum output level is 1V peak to peak at an impedance of 50 ohms. Internal markers are provided and these have a rectangular wave shape. A horizontal sweep output (for oscilloscope applications) 10V in amplitude at 50 c/s is available variable in phase through 120°. The wobbulator can be powered from a 115 to 250V 50 c/s mains supply. Costing £296 approximately it is obtainable in the U.K. from Bemax Instruments Ltd., 54 Victoria Road, Surbiton, Surrey.

5WW 315 for further details



▲ International Rectifier Type 25G rectifier mounted on a Type E heat sink.



▲ 24-channel Visicorder Oscillograph manufactured by Honeywell Controls.

Recording Oscillograph

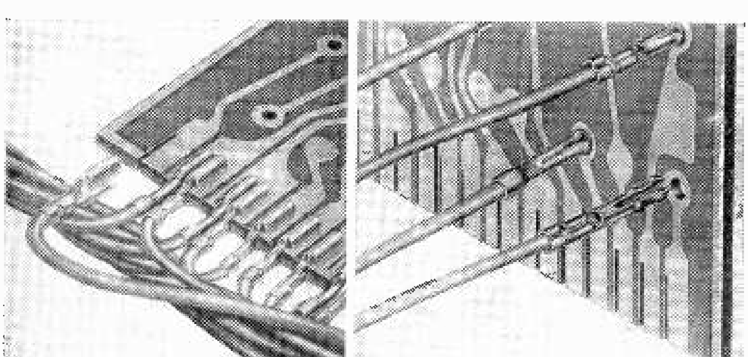
TWENTY four channels are provided on an 8-in wide paper by the Model 1508 Visicorder Oscillograph manufactured by Honeywell Controls, Greenford, Middlesex. Each channel can record at frequencies ranging from z.f. to 5kc/s. All operating controls are on the front panel of the instrument, which is only 7in high. Any of 12 recording speeds may be selected before or during recording by pushbutton control. Deflections of 8in peak to peak are possible and traces are recorded at writing speeds in excess of 125 cm/msec. The recorder's optical system, magnet assemblies and drive systems are mounted on a single metal casting. The main light source is a high-pressure mercury vapour lamp. A number of accessories are also available. Rack or bench mountable, the instrument weighs approximately 50lb.

5WW 316 for further details

Printed-board Terminals

TWO PRODUCTS introduced recently by Aircraft Marine Products facilitate connections to printed-board circuitry. The AMP-EDGE terminal provides a simple connection using slots cut into the edge of either single- or double-sided circuit boards. The AMP-IN terminal enables lead connection to any point on a printed board. It consists of a tubular jack with a shoulder which fits into a hole 0.072in diameter. The connecting wires to both types of terminal can be machine or hand crimped. The address of the manufacturer is 87-89 Saffron Hill, London, E.C.1.

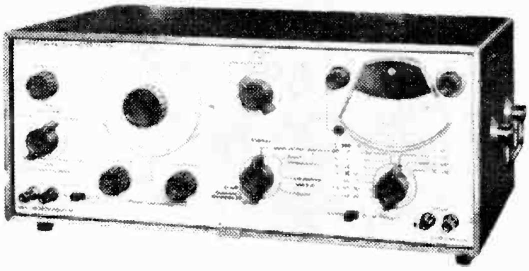
5WW 317 for further details



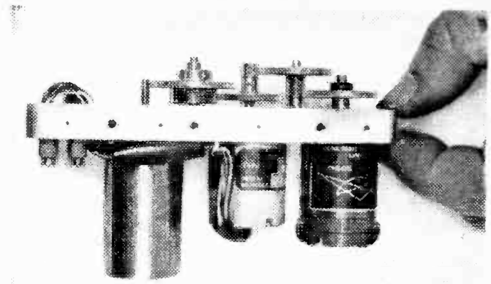
▲ AMP-EDGE and AMP-IN printed board terminals manufactured by Aircraft-Marine Products.

Distortion Factor Meter

A NOTABLE feature of the new distortion factor meter Type TF 2331, manufactured by Marconi Instruments, is that the fundamental frequency-rejection filter is tuned by a calibrated dial with fine control so that almost complete fundamental rejection can be obtained over a frequency range of 20 c/s to 20 kc/s. Transistors are used throughout the instrument, which is normally powered by an alternating mains supply, but provision is made for

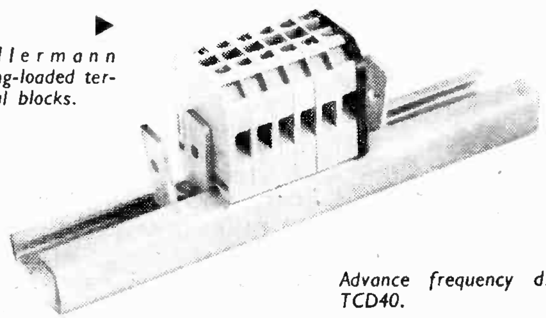


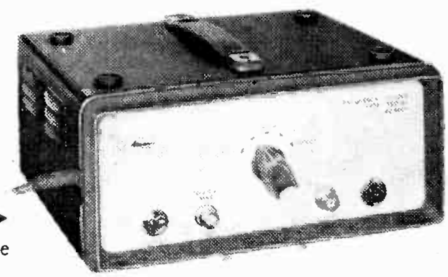
▲ *Marconi Instruments distortion factor meter Type TF 2331.*



▲ *Moore Reed analogue-to-digital converter designed to meet the requirements of M.o.A. Av. P.24*

▶ *Hellermann spring-loaded terminal blocks.*





▶ *Advance frequency divider Type TCD40.*

battery supply. Distortion measurements down to a factor of 0.05% may be made over an input voltage range of 0.775V to 30V (r.m.s.) The internal voltmeter, besides being used for d.f. measurements, can be used for voltage measurements over the range 1mV to 30V and up to a frequency of 100 kc/s. The input resistance can be switched from a 600-Ω resistance to a high-impedance input. Other facilities include an l.f. cut for the elimination, if required, of mains hum and an amplifier output from the voltmeter section for oscilloscope examination of the signal. The instrument weighs 15lb and is available in bench or rack-mounting versions.

5WW 318 for further details

Terminal Blocks

A SPRING-LOADED terminal block that permits the use of 46 terminals per foot is available from Hellermann Terminals, Crawley, Sussex. The terminals are mounted in a rail and are locked with screws. The blocks are manufactured from Melamine and are rated at 25A, 230V.

5WW 319 for further details

Frequency Divider

THE range of existing 1 and 10Mc/s counters may be extended by the use of the Model TCD40 frequency divider manufactured by Advance Components Ltd., Hainault, Essex, Operating over the range 1 to 40 Mc/s, division factors of 100, 40, 10 and 4 may be selected. When frequency division is not required a direct connection of input to output can be made. Both input and output sockets are 50-Ω BNC types. The maximum input sensitivity is 50 mV r.m.s. The output pulses provided by the unit are greater than 2V peak-to-peak. The divider can be used over the temperature range 0 to 40°C and a 45 to 65 c/s mains supply is required.

5WW 320 for further details

Switching Diode

A HIGH-SPEED, planar epitaxial diode, designated the Type ZS142 is available from Ferranti Ltd., of Hollinwood, Lancs. The component was developed principally for computer applications and at an ambient temperature of 25°C is rated at a maximum peak inverse voltage of 25V. The maximum power dissipation is 275mW. At 1Mc/s the capacitance at 1V is 1.4pF and at 10V, 1.25pF. The length of the diode is 0.300in and the diameter is 0.106in. Connections are made by flexible leads.

5WW 321 for further details

Analogue-to-Digital Converter

AN analogue-to-digital converter system comprising a 6-pole, 400 c/s servo motor, a gear train driving a digital shaft encoder and a high-accuracy control transformer synchro having a maximum error of

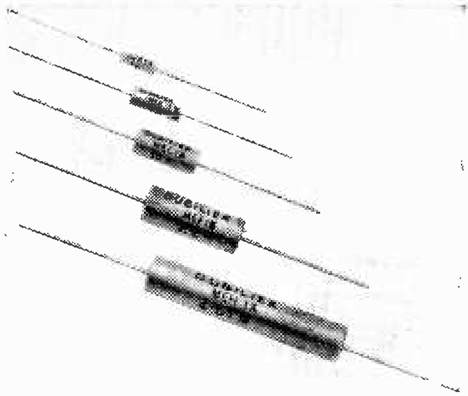
INFORMATION SERVICE FOR PROFESSIONAL READERS

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 40 and 43.

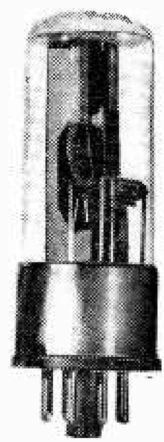
We invite readers to make use of these cards for all inquiries dealing with specific products. Many editorial items and all advertisements are coded with a number, prefixed by 5WW, and it is then necessary only to enter the number(s) on the card.

Readers will appreciate the advantage of being able to fold out the sheet of cards, enabling them to make entries while studying the editorial and advertisement pages.

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.

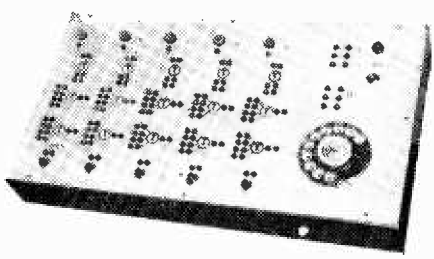


▲ *Components from the Dubilier ME range of metal film resistors.*



▲ *Thermal-delay switch Type S45 C/ID manufactured by Standard Telephones and Cables.*

▲ *"Micro-6" radio receiver distributed in kit form by Sinclair Radionics.*



▲ *"Lan-Dec" Type L.D.-15 digital computer designed primarily for educational establishments.*

±3 minutes has been introduced by Moore, Reed and Company, Durnsford Road, London, S.W.19. It accepts a standard control-transmitter synchro-output signal for conversion into digital form. The system provides a digital readout in Gray code at a resolution of 2^{11} or 2^{12} per revolution of the synchro shaft or up to 2^{12} in a binary code. The synchro rotates at 20 r.p.m. at full motor voltage. Measuring $1\frac{7}{16}\times3\frac{1}{16}\times5$in the unit fits into a standard ARINC case.

5WW 322 for further details

Metal Film Resistors

THE Dubilier Condenser Company announce that metal film resistors designated ME Types are available in five wattage ratings and resistance values from 30Ω to 10MΩ. The standard tolerance is $\pm1\%$ but tolerances of 0.5, 0.25 and 0.15% can be obtained dependent upon temperature coefficient.

The outer casing for the lower wattage sizes is a moulding of moisture-resistant, high-temperature plastic material and for the 1 and 2 watt components, a porcelain tube with hermetically sealed ends. All five sizes have low noise levels which are independent of the resistance values. The level is normally less than $0.1\mu V/V$. The voltage coefficient measured between one-tenth and full-rated voltage is less than 5 p.p.m./V for all values. However, on low and medium value resistors the voltage coefficient is essentially zero. Resistors from the ME series can be supplied in five different temperature coefficients from ±150 parts per million/°C down to ±15 parts per million/°C. They are non-inductive up to approximately 100Mc/s excepting for the low-value, high-wattage types.

5WW 323 for further details

Miniature Radio Receiver

A SIX-STAGE transistor radio receiver measuring $1\frac{4}{5}\times1\frac{3}{10}\times\frac{1}{2}$in, is available from Sinclair Radionics, Histon Road, Cambridge. Designated the Micro-Six it contains an internal ferrite-rod aerial and operates in the medium waveband. A.g.c. is applied to the r.f. stage and negative feedback to the a.f. stages. The receiver is powered by a mercury cell. All parts, including an earpiece, are available at a cost of 59s 6d.

5WW 324 for further details

Thermal-delay Switch

ALTERNATING currents of up to 5A at 250V can be switched by the Type S45 C/ID thermal-delay switch manufactured by S.T.C. Valve Division, Footscray, Kent. The switch is a single-pole, change-over device with a nominal delay time of 42 sec.

5WW 325 for further details

Educational Digital Computer

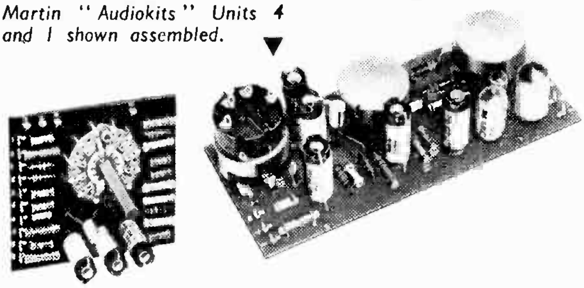
MANY digital computer applications can be demonstrated with the "Lan-Dec" digital computer manufactured by Lan-Electronics Ltd., Farnham Road, Slough, Bucks. The "Lan-Dec" is basically a large patch board with standard computer logic symbols representing each of the 15 NOR gate transistor logic circuits which are wired directly to the underside in five vertical columns of three gates each. Connections to each of the NOR gates are duplicated. Demonstrations possible include Boolean algebra, half and full adders, subtraction and shift registers and binary counters. Each instrument is supplied with the cords necessary for patching and a comprehensive instruction manual. The current consumption of the equipment is 300 mA. A low-voltage power supply which is capable of powering two "Lan-Dec" computers is also available.

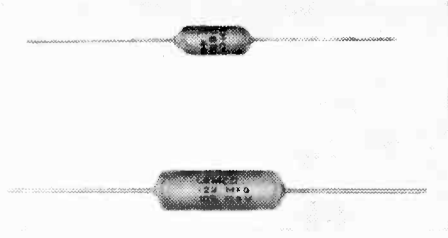
5WW 326 for further details

Audio Construction Kits

TRANSISTOR audio kits manufactured by Martin Electronics of Brentford, Middlesex, are so designed that further units can be added at any time to increase the scope of the equipment without replacing existing units. All the units of the series are on printed boards and transistors are used throughout the range. The main amplifier, designated Unit 5, is available as a 3W or 10W version and the sensitivities of both versions enable them to be matched to the outputs of Unit 2 (pre-amplifier with volume control) or Unit 4 (combined pre-amplifier

Martin "Audiokits" Units 4 and 1 shown assembled.

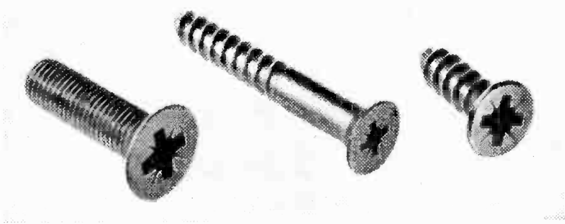




Capacitors from the Lemco polyester range.

and tone control unit). The main amplifier has a transformerless 3-Ω output stage. Unit 1 is a 5-input, matching selector unit. Unit 2, the pre-amplifier, is claimed to have a frequency response of 45 c/s to 20 kc/s ±2dB and a harmonic distortion of 0.25% at 10W output when used with other units of the series. Unit 3 is a 3-channel mixer unit, the versatility of which is increased by the availability of plug-in adaptors to enable the unit to be used with a variety of audio transducers. The combined pre-amplifier and tone-control unit (No. 4) has a base control operating over the range −16 to +10dB and a treble control from −16 to +12dB. A power supply unit is available with 24V output, tapped for supplies to the units. Front panels are available for all the units with controls. Unit 1 kit costs 47s 6d, Unit 2—37s 6d, Unit 3—79s 6d, Unit 4—62s 6d and Unit 5, which is based on the Mullard AB transformerless design, £5 12s 6d. The power supply costs 52s 6d.

5WW 327 for further details



"Pozidriv" recessed-head screws.

Television-signal Pre-amplifier

A NUMBER of television-signal pre-amplifiers are available from Gordon J. King of Brixham, Devon. The equipments amplify Band I and Band III frequencies and switching from one channel to the other on the pre-amplifier is unnecessary. Power is provided by a 9V battery contained within the case and the only connections necessary are from the aerial to the pre-amplifier and from the pre-amplifier to the television set: both input and output impedances are 75Ω. A v.h.f./f.m. version is available. The television units are designated "Telebooster" and the f.m. version F.m.-booster. The voltage gains of the former pre-amplifiers are 18dB for the channel tuned to in Band I and 14dB for the channel tuned in Band III. The f.m. version has a 16dB gain over a group of 3 to 4 channels. The bandwidth of the "Telebooster" is quoted as being approximately 1.5dB down on the channels adjacent to that tuned. The dimensions are $3\frac{1}{2} \times 3\frac{1}{2} \times 2$in and the weight $\frac{1}{2}$lb (including battery). The cost of each amplifier is 75s 6d.

5WW 328 for further details

Polyester Capacitors

THIRTY standard values of capacitance are available in a new range of polyester capacitors manufactured by the London Electrical Manufacturing Company. Values range from 0.01μF to 1μF (125V working) and 0.001μF to 0.47μF (400V working). The capacitance tolerance is within ±10% of all values and the power factor at 1kc/s is better than 60×10^{-4}. The components may be used over a temperature range of −40 to 100°C. The dimensions vary from 7mm diameter and 21mm length to 19.5mm diameter and 35mm length. The London Electrical Manufacturing Company, Bridges Place, Parsons Green Lane, London, S.W.6, now produce ceramic, mica, polystyrene, electrolytic and polyester capacitors.

5WW 329 for further details

Improved "Phillips" Screws

DESIGNED to reduce assembling times and to lengthen the life of power screwdriver bits, the new "Pozidriv" recessed head announced by G.K.N. Screws & Fasteners Ltd. is based on the well-known Phillips cruciform slotted head, but has nearly parallel driving faces which eliminate the "lift" experienced when driving the original type. The difficulties experienced earlier in producing economically the ideal slot have now been overcome and machine, self-tapping and wood screws in a wide range are now available to industry. Retail sales are promised for the autumn.

Complementary screwdrivers and bits for power tools will be available from Stanley Works (Great Britain) Ltd.

5WW 330 for further details

Stereo Cartridge

A CERAMIC, stereo cartridge introduced recently by The Goldring Manufacturing Company of Leytonstone, London, E.11, has a frequency response which extends from 30c/s to 20kc/s. The output is 50mV per channel (1kc/s) and the signal to cross talk ratio is specified as −20dB at 1kc/s and −10dB at 10kc/s. A replaceable diamond stylus is provided with a tip radius of 0.005in. The cartridge can be tracked at 2gm, the lateral compliance being 10×10^{-6} cm/dyne and the vertical 8×10^{-6} cm/dyne. The recommended load impedance is from 1 to 2MΩ. The cartridge, including purchase tax, costs £4 17s 8d.

5WW 331 for further details

Transistor Pads

NYLON transistor mounting pads, suitable for use with both TO5 and TO18 can sizes, are available from the Telecommunications Division of

Associated Electrical Industries, Woolwich. The pads are suitable for use at temperatures in the range -50 to $+175$°C and moulded-in bosses hold both pad and transistor clear of the printed board. This allows free circulation of air between pad and board. Other features of these components are the prevention of movement of, and possible damage to, transistor leads after assembly, a reduction in the risk of damage to the transistor during soldering, and the fact that transistors are more easily mounted in a consistent pattern.

5WW 332 for further details

Precision Resistors

A STABILITY of better than $\pm 0.003\%$, measured against standards of $\pm 0.001\%$ tolerance, is claimed for resistors in the "J" series introduced recently by Alma Components of Diss, Norfolk. Loose-winding techniques are used in the construction of these components. The resistance wire is wound on an epoxy-resin former and sealed under "dry" conditions in an epoxy-resin tube. Seven types are available, ranging from $\frac{1}{8}$W up to 2W with values from 300kΩ to 3MΩ. Matched sets can be supplied to resistance tolerances of $\pm 0.005\%$ with temperature coefficient matching to $\pm 2\frac{1}{2}$ parts per million/°C. The cost of resistors from this "J" series is said to be only slightly higher than that of the normal precision resistors.

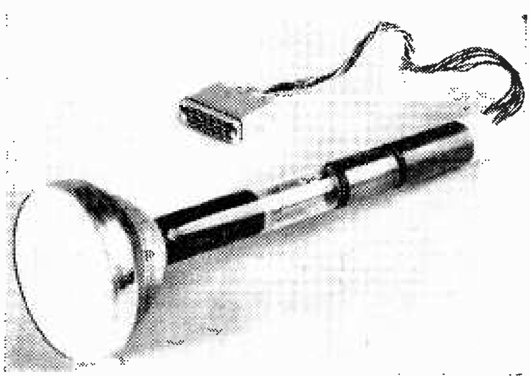
5WW 333 for further details

Electrostatic-focus Cathode Ray Tubes

ELECTROSTATIC focusing at near-cathode potential and low-power magnetic focusing techniques are combined in a new series of high-resolution cathode ray tubes developed by Ferranti of Hollinwood, Lancs. Tubes of this series which are available at present, Types 5E/12 and 3C/12, achieve a minimum spatial frequency response resolution of 150 cycles per centimetre. (Other types in development are capable of a spatial frequency response of 200 c/cm). Large electrostatic lenses are used, which, when operated at cathode potential act as the primary lens and only small degrees of spherical aberration and astigmatism are produced. Astigmatism-correction coils mounted on the neck of the tube reduces this latter effect. E.h.t. variations of up to 2% do not appreciably deteriorate focus. A small, low-power electromagnetic lens is employed as a secondary correction lens in the tube.

The maximum anode voltage is 20 kV while that of the electrostatic lens or second anode is 500V. The nominal grid voltage for usual cut-off is Va/300. The tubes have 6.3V heaters and the maximum resistance of the dynamic focus coils is 50Ω. Different phosphors are available and screen thicknesses are optimized for either 7kV or 15kV operation.

5WW 334 for further details



◀ *A 5-in version of the new Ferranti high-resolution cathode ray tubes.*

Colour Bar Generator

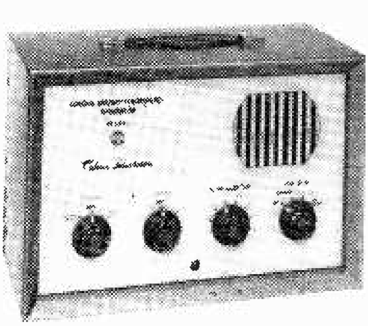
THE first in a range of British-manufactured R.C.A. colour television instruments, the colour bar generator Type WR-L64A is a portable unit providing colour bars, dots or cross-hatch pattern modulated on a r.f. carrier. A colour beam selector enables single colours to be displayed to facilitate colour-purity adjustments. The generator was designed for N.T.S.C. colour television receivers and is manufactured by R.C.A., Great Britain Ltd., Windmill Road, Sunbury-on-Thames, Middlesex. The picture carrier frequency is 55.25 Mc/s and that of the sound, 61.25 Mc/s; both are factory preset but are tunable. The picture carrier voltage is approximately 50 mV. The r.f. output impedance is 70Ω. The power requirement of the instrument is 40W (200-250V, 50 c/s). The generator costs £75.

5WW 335 for further details

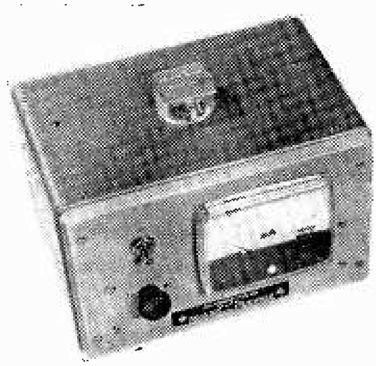
Contactless Bulk Resistivity Measurement

AN interesting feature of a resistivity test set Type 74711, manufactured by S.T.C., is that samples of the material under test are not placed in electrical contact with the instrument which is designed to measure the damping effect of the sample on a lightly-loaded tuned circuit. This feature makes the test set particularly useful for production-line testing of thin slices of semiconductor material in the manufacture of transistors. If the resistivity of a semiconductor material is known, then the thickness of the sheet can also be measured. The instrument uses transistors and its dimensions are $8\frac{1}{4} \times 5\frac{1}{2} \times 6\frac{3}{8}$in; the weight is 5lb. The test coil projects $\frac{3}{4}$in above the top of the case.

5WW 336 for further details



▲ *Colour bar generator Type WR-L64A. Single colours may be selected to facilitate colour purity adjustments.*



▲ *S.T.C. contactless, bulk resistivity test set, with a sample in the test position.*

THE BODE FILLET

TO WHAT EXTENT SHOULD IT BE TAKEN INTO ACCOUNT IN AMPLIFIER DESIGN?

By THOMAS RODDAM

ONE of the major problems in life is the problem of communication. If a sufficiently general view is taken this need not be limited to the transmission of information but can be expressed as the problem of converting one ordered structure into another. This choice of definition enables the philosophy of the Second Law of Thermodynamics to be applied to political problems as well as to information theory. Maxwell's demon becomes the Minister for Colonial Reconstitution; a party in opposition tends to maximum disorder: these are two applications of the scientific method to everyday affairs.

This opening paragraph was produced by the interaction of two apparently unconnected matters. The first was a book review in which some unlucky author was taken to task for flippancy: the second was some material, which I propose to examine in detail, on the Bode ideal loop-gain characteristics in a recently published text. There can be no doubt that flippancy has no place in a serious and advanced text. One should "reject all amplification, digressions and swellings of style." If the aim is to convey new information to those who can understand it there is nothing like "the primitive purity and shortness" recommended by Thomas Sprat.

It is true that in a perfect communication channel we need no redundancy and we can use highly efficient coding systems properly adapted to the information to be transmitted. With some diffidence I suggest that the reader is not an ideal receiver. He has not stored, for immediate access, all the information which has been sent to him previously: the noise level is high, for as he reads this the children are watching "Cosh," the do-it-yourself television series for juvenile delinquents, his wife is reporting on the strange events in the supermarket, while thoughts of the gas bill and the odd rattle inside his motor car come creeping in. The writer of "texts of interpretation" is seeking a method of coding information which will carry it past these obstructions. Often, I believe, the main obstruction is that the reader cannot believe that he can understand what is being said. Of course he can, and in a couple of weeks he is explaining it all, at tedious length, to the author from whom he learnt it. Right now, however, he is on the verge of collapse. Flippancy is a great aid in making the reader relax, in making him realize that if the author, who is so obviously stupid, understood what he wrote it must be within the comprehension of any normal reader.

Many readers have been frightened off by the rather formal sections at the beginning of Bode's "Network Analysis and Feedback Design" (D. van Nostrand Company). If you are to tackle the more advanced problems of amplifier design, however, there is a vast amount of material here which you cannot afford to ignore and which is too extensive to absorb if it is watered down. Mr. Edwin has recently reminded us of the basics and essentials of the subject but, valuable as Basic English is, the student cannot stop there. The day will come when someone says "Agenbite of inwit" to him and two of these three words are not among the most common one-thousand words of the English language.

The idea of an ideal cut-off characteristic for single-loop amplifiers is a plausible one. Let us consider the simple form first. The initial assumption is that the loop gain should be constant over the whole working band. Outside this band the gain should fall as rapidly as possible so that the loop gain will reach unity quickly in order to reduce the frequency range over which the characteristic must be controlled. This aspect of the problem becomes more important as we use transistors, since the delay-line effect of the diffusion process gives us an excess phase shift at high frequencies. The lumped

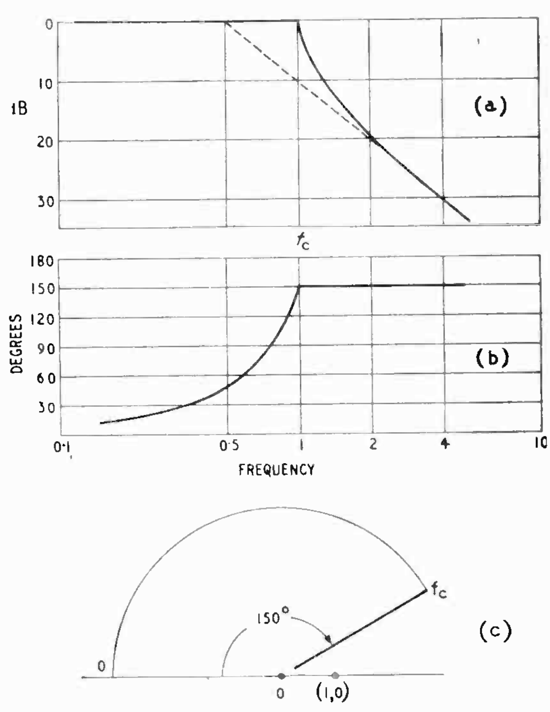


Fig. 1. Typical amplitude (a) and phase (b) characteristics, and (c) the corresponding Nyquist diagram. The area between the dotted and solid lines in (a) has been termed the "Bode fillet".

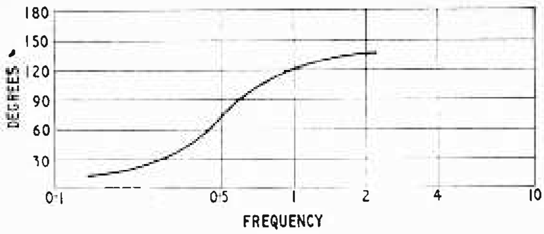


Fig. 2. Phase characteristic corresponding with a gain characteristic following the asymptote in Fig. 1 (a).

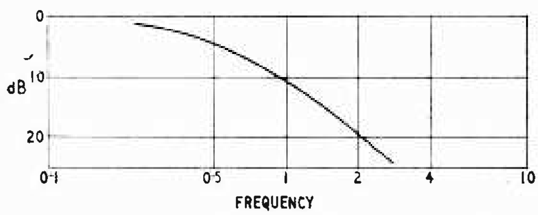


Fig. 3. Amplitude response in an amplifier with inter-electrode and stray capacitance.

elements of normal amplified circuits are almost invariably minimum-phase networks and so we can say that the amplifier phase-shift will be proportioned to the local average rate of cut-off.

The phase shift, for an unconditionally stable amplifier, must not exceed 180° until the loop gain has fallen below unity. In a practical design it is usual to call for a margin of some 30° or more. The Bode basic ideal cut-off assumes a constant 150° phase shift at all frequencies above the maximum working frequency. It is a straightforward problem to solve the equations connecting phase and amplitude with these conditions and to derive the amplitude and phase response shown as Fig. 1(a) and (b). The Nyquist diagram is the extremely simple form shown in Fig. 1(c).

The features of interest here are the asymptotic slope of the amplitude characteristic, 10dB/octave, and the relationship of this asymptote to the cut-off frequency. The slope is determined by the phase shift in the cut-off region and the relationship is a very simple one, most conveniently written as a statement that the slope of the asymptote in dB/octave is equal to (phase shift)^{0}/15. This, of course, only applies when the effects of discontinuities have been excluded. The asymptote cuts the low-frequency gain line at $f_c/2$, one-half the cut-off frequency. There is thus a region in which the gain exceeds the asymptotic gain filling the gap between $f_c/2$ and f_c. If it were not for this the phase characteristic would take the form shown in Fig. 2 and, of course, the amount of feedback available at f_c would be 10dB. It is this area above the asymptote which I have recently seen described as Bode's fillet.

In spite of the theoretical charm of this ideal characteristic, I have never been too happy about its utility. There is no doubt that it is seminal, but the ideas are dangerous in the hands of the unwary. Suppose that we assume 20dB of feedback. The $\mu\beta$ effect at low frequencies will be about -0.8dB but at cut-off frequency the $\mu\beta$ effect is $+0.8$dB and it rises to a maximum of $+6$dB when the $\mu\beta$ gain is $+1$dB. The overall response will thus show a peak of about 7dB at $2f_c$.

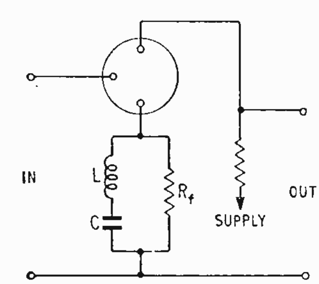
This peak represents some 6dB of positive feedback. Any distortion produced by the amplifier at this frequency will be doubled. Any signal entering the amplifier at this frequency will not emerge at an amplitude reduced by the effect of the negative feedback but at an amplitude increased by the positive feedback. I have pointed out before that it is not enough to say that musical instruments do not produce much high-frequency energy and that, therefore, if there is no cross-over distortion there can be no distortion at all. The low-frequency sounds can be considered to pre-empt most of the amplitude range, holding the high frequencies in the overload region for much of the time. Pimonow's results (*W.W.*, Oct., 1962, p. 493) lead one to wonder how a boy who can detect cut-off in the region of 45 kc/s will react to harmonics in this region. Fortunately most of our loudspeakers will dispose of any energy up here without finding it necessary to radiate it as sound.

The reader who has not studied Bode's own writing may be surprised at the form given in Fig. 1 for the ideal gain characteristic. In some references a jump is made directly to the more sophisticated form given later by Bode which incorporates a step of flat gain near the critical point. The treatment of this is extremely interesting, progressing through the system having a phase shift of 180° up to the frequency at which the step takes charge and on to the safer solution providing both gain and phase margins before the final high-slope asymptote is reached. The effect of making the step a sloping one is considered, but only in terms of stability. Since we can never produce a practical circuit which follows the ideal characteristics exactly it is very valuable to know how deviations from the theoretical solution will affect the stability.

My chief concern here is with the Bode fillet. It may be that you feel like a tax inspector, that there is a lot of expense-account lunch to very little business, but one half-pennyworth of bread to this intolerable deal of sack. I can only hope that you go on to add "we'll read it at more advantage." (Henry IV, Pt. 1, Act II, Scene IV.)

A practical amplifier circuit which contains no transformers will usually have a response determined

Fig. 4. Circuit to provide the Bode fillet when it is missing.



by a number of RC circuits and the capacitance will be the inter-electrode and stray capacitances. The sort of response we might find is shown in Fig. 3. This has not been worked out in any details but is intended to serve as a typical shape for a system with, for example, two or three staggered cut-off frequencies. Here there is no trace of the Bode

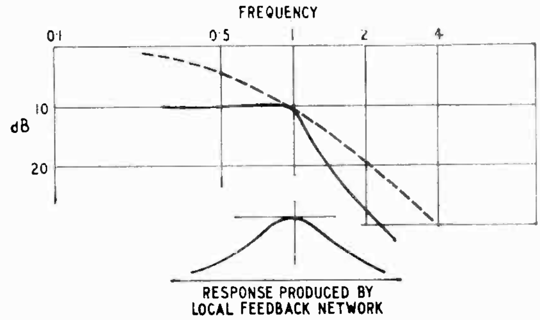


Fig. 5. Response of Fig. 3 modified by a resonance.

fillet, and in fact this particular curve is stretched to be below the 10dB/octave asymptote. It has been suggested, and it was this suggestion which prompted me to write this article, that we should add the network shown in Fig. 4 as L, C, R_f to provide the Bode fillet. The curious symbol for the amplifying device represents either a common-cathode valve or a common-emitter transistor of either polarity. I do not believe there is a standard symbol for this, possibly because the symbol seekers are so committed to keeping negative and north apart on their page (no mnemonic needed) that they cannot draw a circuit in this general form.

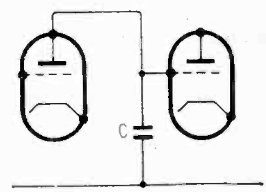
This network will provide local negative feedback at all frequencies except in the neighbourhood of the resonant frequency of the LC circuit. The rough shape of this is shown in the lower curve of Fig. 5 and the effect of combining it with the smooth roll-off of Fig. 3 has been sketched in above. The resulting form is a response held well up to the corner frequency and then dropping sharply before flattening away to run parallel to the original characteristic. This is, indeed, just what the doctor (H. W. Bode, Ph.D.) ordered. Well, my doctor has ordered a prescription containing oil of cajuput, but he does not expect me to swallow it: apply by massage it says on the box. I refuse to swallow this negative feedback device either.

In a desire to achieve an ideal-looking response a large amount of local negative feedback has been applied over most of the working band We know this is a very extravagant way of using negative feedback and that we get a much better overall performance by applying the feedback right round the loop. Even formally it is not correct, since Bode has limited his study to single-loop systems and this local feedback converts the amplifier into a multiple-loop circuit. In producing the Bode fillet the local feedback has dropped the gain of the amplifier substantially, a figure of 10dB is typical, in the low-frequency region. There is little benefit in return, for the stability conditions are fixed by the behaviour well beyond the influence of this circuit. The loop feedback may, in theory, remain the same, but in that event we must find another 10dB of gain from somewhere. In my experience not only are we already rather short of gain but we could find better uses for any spare gain, if we had it.

Let us see why the Bode fillet crept in at all. The real object of the exercise was to concentrate the available gain-bandwidth into the region where the gain would be useful. The more gradual the cut-off slope, the more gain there is at frequencies where, we have decided, there is no signal. Furthermore, the more gain there is at frequencies at which the performance is getting less and less under no control and more under the control of stray effects. There are, I know, gentlemen who devote a good deal of energy to snatching pay-rolls in order to make up for their losses at the races. Using local feedback in the way just described seems quite illogical. The correct approach, surely, is to design the Bode fillet into the response. For this we need what used to be called the Wheeler network (*Proc. I.R.E.* July, 1939).

The basis of all the theory is the fact that an interstage coupling, and this includes the cases where one or other "stage" is either generator or load, cannot avoid the presence of the capacitance C shown in Fig. 6. I do not propose to recapitulate the theoretical difficulties which we encounter in the absence of this capacitance, nor do I propose to show that if you cut out one parasitic capacitance at one place by a circuit trick it will return to plague you elsewhere. Some aspects of this problem were discussed in *Electronic Technology,* March, 1960,

Fig. 6. The unavoidable capacitance.



pp. 127-9. However, once this capacitance is introduced, as physically we know it must be, it can be shown that the average gain over the whole frequency spectrum cannot be greater than that given when we have only the capacitance there. An interstage network can reduce the average gain, it can redistribute the gain within the spectrum, but it cannot increase it.

Performance limit theorems of this kind are of very great practical importance because they tell us just how near to the ideal we have reached and save us wasting time in what is really a quest for perpetual motion. This, indeed, is not a far-fetched simile, because if you integrate Johnson noise produced by a resistance without introducing the stray capacitance you will find you have a power source,

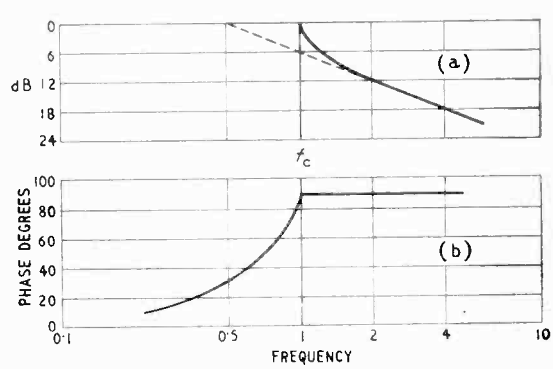


Fig. 7. Characteristics using the Wheeler networks and limiting phase shift to 90°.

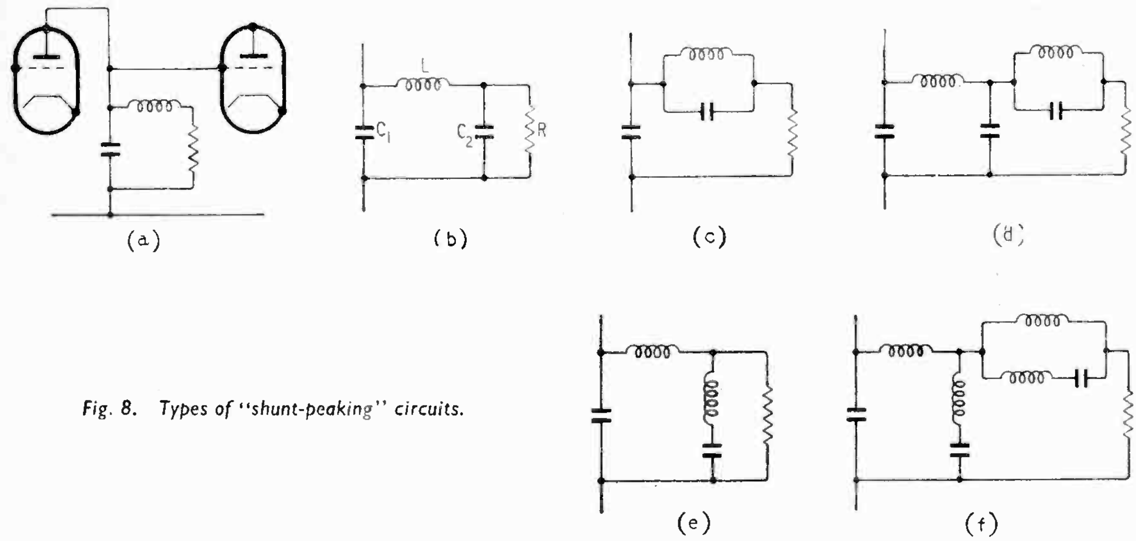


Fig. 8. Types of "shunt-peaking" circuits.

as van der Pol has shown. The theory also leads to the conclusion that any conductance at infinite frequency in parallel with the capacitance reduces the average gain.

The Wheeler networks are circuits which have zero conductances at infinite frequency and which perform the task of concentrating the gain as far as possible into the working band. The formal mathematics of the situation bears a close resemblance to the formal mathematics of the ideal loop characteristic. The limiting phase shift of the stage is 90°, since at a sufficiently high frequency one capacitance must take charge. To get maximum gain the 90° phase shift should extend over the whole spectrum outside the working band, in which the gain should be constant. The resulting amplitude and phase characteristics are shown in Fig. 7. The amplitude response is asymptotic to the 6dB/octave slope fixed by the capacitance, but instead of there being a smooth curve lying below this, as we should have with a resistance as the interstage network, the ideal interstage network gives us the 6dB lift at the edge of the working band and shows the characteristic shape of the Bode fillet.

It is very tempting to suspect that the use of local feedback to produce the wanted shape should lead to the same end result and that is only a difference in circuit configuration which conceals this fact. This is not so and I think that its falsity can be demonstrated quite simply. When a resistance is used alone as the coupling element some energy must be lost in this resistance and the useful average gain is thereby diminished. The negative feedback can only redistribute this reduced average gain. The discussion should, indeed, be a little more subtle, dealing with the average gain outside the working band, but then we approach the point when we might just as well carry out a formal analysis.

The Bode fillet is something very real in this context: it is useful gain which has been rescued from the part of the frequency spectrum beyond the working band. How are we to get the required response from a practical circuit? The answer is that we must make use of the fact that the required total band impedance which gives us a gain characteristic g_mZ shown in Fig. 7 must be the input impedance of a low-pass filter. One-half of the capacitance is then absorbed in the filter and this factor of one-half accounts for the 6dB advantage which you can see we have at the cut-off frequency in Fig. 7(a).

The simplest practical structure used in this way is the so-called shunt-peaking circuit shown as Fig. 8(a), but more complex networks based on the use of full sections and on the use of m-derived and double m-derived sections to provide better matching are given by Bode with their response curves and are shown in Fig. 8: the double m-derived system in Fig. 8(f) matches the required response so closely that Bode does not draw the response but merely inserts some calculated points.

For general purposes the netwok of Fig. 8(b) is probably the most important. It uses only the same number of extra components as the circuit of Fig. 4 and it has a response which is about 3dB down at the band edge. By changing definitions a little we might say that at a cost of about 1dB in gain inside the working band we can provide a flat response which is defined by an ideal cut-off frequency of 1.1 times the upper working frequency. In practice, however, we should not use a succession of flat response circuits. When the inductance in Fig. 8(a), for example, is made to have a higher value than the flat-response value we find that the response will peak upwards before cutting off in very much the same way as we can get a mismatch at the edge of a filter response. The rising slope of such a peaked response forms a convenient way of compensating for the gentle droop of a pure RC network. Very often we find that this compensation can be made by using the leakage inductance of the output transformer so that we need add no physical inductor at all.

Whatever means are adopted to produce the Bode type of response in an amplifier we must accept the fact that we are making trouble for ourselves. The sharp cut-off associated with the flat gain inside the working band gives us a rapid approach to 90° phase

(*Continued on page 105*)

shift in each stage. Even a two-stage amplifier will need a very distinct step in the response in the region where the Nyquist plot is near the danger point (1, 0) and the loop round this point must be large enough to allow for all the gain tolerances. As far as I can make a generalization I would say that sophistication in stage design breeds sophistication in feedback network design. Readers who have recently bought Rolls-Royces may have noted that they feel an urge to be better dressed. When we turn to three-stage amplifiers, which are probably the most common of our feedback problems, we are usually too preoccupied with the problem of limiting the initial slope, and thus the phase-shift of the cut-off characteristic, to be concerned with the few decibels at the corner. I am inclined to wonder whether we have made sufficient use here of inductive compensation. In Fig. 9 we have the response of the network of Fig. 8(b) when $C_2=2C_1$ and $L/C=R^2/4$. This gives us a step some 9dB below full gain and the correspondingly slow run of the phase angle. Normally we should produce a step of this kind by adding an RC network, but the whole response would then be moved in under the basic RC roll-off. The step we have here is out beyond the frequency fixed by the low frequency load and the circuit capacitance. Thus although the roll-off appears to be unpleasantly gentle it does not start at nearly such a low frequency: for the factor of 8-9dB at which the step occurs we must allow a factor of 3 in the frequency scale, so that this response is 1dB down where the conventional CR step would be 3dB down.

A rough calculation, based on a capacitance of 50pF and a resistance of 20,000 ohms leads to an inductance value of 5mH. There are some difficulties, since I suspect that we shall need to allow for the effect of the self-capacitance on the inductor. This art, however, appears to be a technique deserving rather more attention than it has received. The

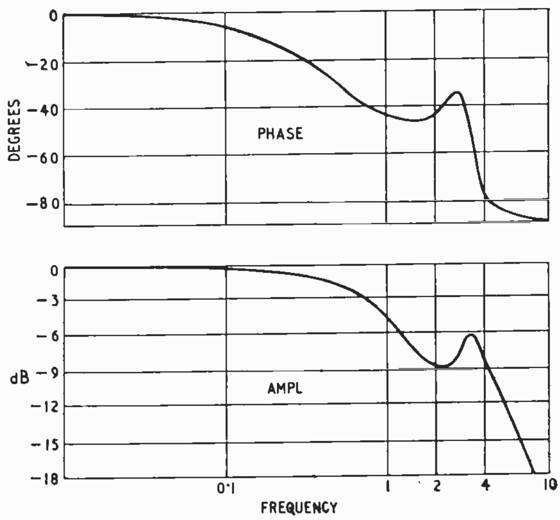
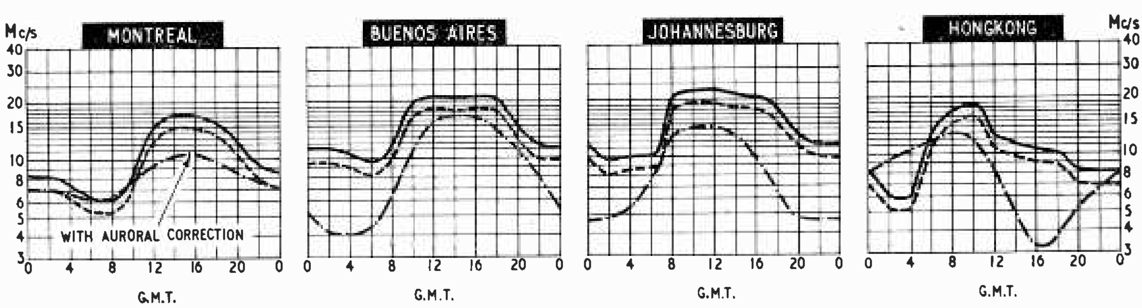


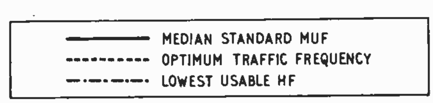
Fig. 9. Response of the network of Fig. 8(b).

curves shown in Fig. 9 are typical of a large set given by Bode (pp. 445-450) which can be used for marrying-up shapes to get what we need in a particular design.

There is, I think, a general moral to be drawn. Simple solutions to complex problems are not necessarily good. A feedback amplifier design can proceed very well without using the idea of the Bode fillet and the problem becomes relatively simple, since we can adopt the rather rough and inefficient RC network solutions. If we try to make an efficient amplifier design we must go right to the heart of the matter, it is the designer's choice, fish or cut bait.

H. F. PREDICTIONS — FEBRUARY





The prediction curves show the median standard MUF, optimum traffic frequency and the lowest usable high frequency (LUF) for reception in this country. Unlike the MUF, the LUF is closely dependent upon such factors as transmitter power, aerials, local noise level and the type of modulation; it should generally be regarded with more diffidence than the MUF. The LUF curves shown are those drawn by Cable and Wireless, Ltd., for commercial telegraphy and they serve to give some idea of the period of the day for which communication can be expected.

FEBRUARY MEETINGS

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

LONDON

5th. I.E.E.—"Recent developments in radar modulation systems" by R. Benjamin at 5.30 at Savoy Place, W.C.2.

5th. Brit.I.R.E.—"The Omnitrac II computer" by J. A. Ashton at 6.0 at the London School of Hygiene, Keppell Street, W.C.1.

5th. Brit. Kinematograph Soc.—"Synchronous tape sound systems" a survey by five speakers of some ¼in tape systems used for television at 7.30 at the Central Office of Information, Hercules Road, Westminster Bridge Road, S.E.1.

7th. Television Society.—"Television service planning for overseas" by D. Law, A. A. McKerrell & T. D. Barritt at 7.0 at the Conference Hall, I.T.A., 70 Brompton Road, S.W.3.

12th. I.E.E.—"Newton and Heaviside in control" by G. G. Gouriet at 5.30 at Savoy Place, W.C.2.

12th. Brit.I.R.E.—"Correlation techniques in studio testing" by A. N. Burd at 6.0 at the London School of Hygiene, Keppell Street, W.C.1.

13th. Radar & Electronics Assoc.—"Radar meteorology" by R. F. Jones at 7.0 at the Royal Society of Arts, John Adam Street, W.1.

17th. I.E.E.—Discussion on "Factors affecting the quality of pictures read off camera tubes and storage tubes" at 5.30 at Savoy Place, W.C.2.

18th. I.E.E.—Discussion on "Teaching active network theory" at 5.30 at Savoy Place, W.C.2.

20th. Institution of Electronics.—"Developments in electronic telephone exchanges" by K. A. T. Knox at 7.0 at the London School of Hygiene, Keppell Street, W.C.1.

21st. Institute of Navigation.—"Lasers" by P. G. R. King at 5.30 at the Royal Institution of Naval Architects, 10 Upper Belgrave Street, S.W.1.

21st. Television Society.—"The testing of mass-produced television receivers" by D. W. Maguire at 7.0 at the I.T.A., 70 Brompton Road, S.W.3.

21st. B.S.R.A.—"The subjective assessment of noises" by D. W. Robinson at 7.15 at the Royal Society of Arts, John Adam Street, W.C.2.

26th. Brit.I.R.E.—"High definition radar" by J. M. G. Seppen at 6.0 at the London School of Hygiene, Keppell Street, W.C.1.

ABERDEEN

26th. I.E.E.—"From graduate to professional engineer" by J. E. C. McCandlish at 7.30 at Robert Gordon's Technical College.

BASINGSTOKE

6th. Brit.I.R.E.—"Solid-state switching" by A. C. Savage at 7.30 at the Technical College.

BIRMINGHAM

10th. I.E.E.—"Harmonics and transients in relation to static converters" by R. A. Hammond at 6.0 at the College of Advanced Technology.

24th. I.E.E.—"Post Office colour television network" by J. B. Sewter and P. J. Edwards at 6.0 at the College of Advanced Technology.

BOLTON

6th. Brit.I.R.E.—"Some aspects of the use of radio telemetry in small vehicle research and development" by M. A. Millward at 7.0 at the Technical College.

BOURNEMOUTH

19th. Brit.I.R.E.—"Electronic techniques in the study of the sea" by M. J. Tucker at 7.0 at the Municipal College of Technology and Commerce.

BRISTOL

11th. Brit.I.R.E. & R. Aero. Soc.—"Redundancy techniques for reliability in aviation electronics" by R. K. Barltrop at 6.30 at the University Engineering Lecture Rooms.

19th. Society of Instrument Technology.—"Introduction to digital instrumentation" by Dr. M. J. White at 7.30 at the University, The Royal Fort.

CAMBRIDGE

18th. I.E.E.—"The colour performance of the Secam system" by G. B. Townsend at 8.0 at the Engineering Laboratories, Trumpington Street.

CARDIFF

5th. Brit.I.R.E.—"Semiconductor integrated circuits" by M. S. Alderson at 6.30 at the Welsh College of Advanced Technology.

CHELTENHAM

3rd. Society of Instrument Technology.—"Industrial applications of digital read-out systems" by G. Rigby at 7.30 at the Belle Vue Hotel.

28th. Brit.I.R.E.—"A practical method of implementing a step towards full automation" by F. S. Ellis at 7.0 at N. Gloucestershire Technical College.

CHRISTCHURCH

12th. I.E.E.—"Present state of colour television" by S. N. Watson at 6.30 at the Kings Arms Hotel.

DUBLIN

20th. I.E.E.—"Telecine systems" by T. J. Murphy at 6.0 at the Physics Laboratory, Trinity College.

DUNDEE

27th. I.E.E.—"From graduate to professional engineer" by J. E. C. McCandlish at 7.0 at the Electrical Engineering Department, Queen's College.

EDINBURGH

5th. Brit.I.R.E.—"Numerical control of machine tools" by D. F. Walker at 7.0 at the Department of Natural Philosophy, The University, Drummond Street.

11th. I.E.E.—"Radio astronomy techniques," by H. Gent at 7.0 at the Carlton Hotel.

FARNBOROUGH

25th. I.E.E.—"Recent developments in components for computers" by W. Renwick at 6.15 at the Technical College, Boundary Road.

27th. Brit.I.R.E.—"An introduction to the theory and application of piezo-electric transducers" by R. F. J. Orwell at 7.0 at the Technical College.

GLASGOW

4th. I.E.E.—Discussion on "The Robbin's report" opened by Sir David Anderson at 7.30 at the University.

6th. Brit.I.R.E.—"Numerical control of machine tools" by D. F. Walker at 7.0 at the Institution of Engineers and Shipbuilders, 39, Elmbank Crescent.

10th. I.E.E.—"Radio astronomy techniques" by H. Gent at 6.0 at the Royal College of Science & Technology.

LEEDS

4th. I.E.E.—"Stereophonic broadcasting systems" by Dr. G. J. Phillips at 6.30 at the Electrical Engineering Department, the University.

25th. I.E.E.—"Optical masers" by I. L. Davies at 6.30 at the Department of Electrical Engineering, the University.

LEICESTER
11th. Television Society.—" Some factors affecting the choice of a colour television system " by R. N. Jackson at 7.15 at the New Vaughan College, St. Nicholas Street.

LIVERPOOL
17th. I.E.E.—" Parametric amplifiers " by Dr. F. J. Hyde at 6.30 at the Royal Institution, Colquitt Street.
19th. Brit.I.R.E.—" Automatic marshalling yards " by J. M. Howe at 7.30 at the Walker Art Gallery.

MANCHESTER
11th. I.E.E.—"Mathematics as an educational discipline for the engineer " by P. L. Taylor at 6.15 at Reynolds Hall, College of Science and Technology.

MIDDLESBROUGH
5th. I.E.E.—" Lasers: principles and applications " by Dr. R. P. Howson at 6.30 at Cleveland Scientific and Technical Institute.

NEWCASTLE-UPON-TYNE
12th. Brit.I.R.E.—" The role of the engineer in medicine " by W. J. Perkins at 6.0 at the Institute of Mining and Mechanical Engineers, Westgate Road.
20th. Society of Instrument Technology.—" Telecommunications " by R. Taylor at 7.0 at the Conference Room, Roadway House, Oxford Street.

NEWPORT, I.o.W.
7th. I.E.E.—" Communication satellites " by Dr. K. Milne at 6.30 at the Technical College, Hunnyhill.

PLYMOUTH
20th. I.E.E.—" Satellite communications " by D. Wray at 3.0 at the Continental Hotel, Millbay Road.

PORTSMOUTH
12th. I.E.E.—" A survey of magnetic tape and ferrite core storage systems " by P. P. A. Calvert and J. H. Streeter at 6.30 at the College of Technology.

RUGBY
25th. I.E.E.—" Global communications " by R. J. Halsey at 6.30 at the Rugby College of Engineering Technology.

SHEFFIELD
20th. I.E.E.—" The ultra-sound image camera " by Dr. C. N. Smyth at 6.30 at the University.

SWANSEA
20th. I.E.E.—" Pulse techniques in line communication " by R. O. Carter at 6.0 at College House, University College, Singleton Park.

TORQUAY
5th. Brit.I.R.E. & I.E.E.—" The principles and technology of lasers " by Dr. R. C. Smith at 6.30 at the South Devon Technical College.

WEYMOUTH
14th. I.E.E.—" The field-effect transistor and its applications " by C. S. den-Brinker at 6.30 at the South Dorset Technical College.

WOLVERHAMPTON
12th. Brit.I.R.E.—" Mathematical training for engineers " by N. Bright and F. J. Hawley at 7.15 at the College of Technology.

UNBIASED

By "FREE GRID"

"Hi-Res"

I WAS very interested to read the Editor's *ex-cathedra* remarks in the January issue on what, in his very first sentence, he terms "high-quality sound reproduction." We all know what he means, and yet the question arises at once whether it is etymologically possible for reproduction to be of high or low quality, or whether it is possible to have "hi," "lo" or any other sort of "fi."

It is clear, I think, that things described by the words "reproduction" and "fidelity," like the word "unique," either are or are not. They can have no qualifying adjectives of degree and so phrases like the all-too-common one "rather unique" are meaningless. However, the O.E.D. does allow "reproduction" to be used loosely in certain cases such as in connection with birth. Our children are not really reproductions of ourselves, and perhaps both the Editor's family and my own may find in this a cause of rejoicing as neither of us resembles Adonis.

We are all equally guilty in the misuse of certain words, but the Editor, by virtue of his position, does speak, like a bishop or a king, from the height of his *cathedra,* and that is why his words carry so much more weight than those of us lesser folk, and if he puts his foot in it he makes a much louder squelching noise when pulling it out.

The snag is I just cannot imagine what other phrase the Editor could have used to convey the meaning he intended. There is really no such thing as "reproduction" in the sense that the noise which comes out of our loudspeaker is exactly the same as that which went into the microphone.

I can only suggest rather faintheartedly the phrase "high degree of resemblance" to take the place of "high-quality reproduction." We could abbreviate it to "hi-res." I merely put it forward as a suggestion for you learned ones to get your teeth into.

Wireless for the Deaf

PROBABLY a great number of you listened to the annual appeal for the Wireless-for-the-Blind Fund which was made so effectively by Richard Dimbleby in the B.B.C.'s Home Service on Christmas Day.

We were informed, among other things, that a special set for a totally blind person costs only £10 as there is no purchase tax charged on it. As I listened I could not help wishing that some similar sort of thing could be done for those who have the misfortune to be deaf, or at any rate very hard of hearing.

Naturally I shall be told what I know already, namely that there are special attachments for coupling the earpiece or earpieces of a hard-of-hearing person direct to a suitable part of the circuit of a receiver. Particulars of these are readily obtainable from the Royal National Institute for the Deaf, 105, Gower Street, London, W.C.1.

My point is, however, that to the best of my belief there is no special receiver, free of purchase tax, which is available to those who are hard of hearing, corresponding to the one obtainable by the blind. There is certainly no annual appeal for wireless for the deaf.

Of course, I may be quite wrong. If so please don't hesitate to tell me. I am pachycephalous and pachydermatous—as well as being a married man—so hard words have little, if any, effect on me.

I have no particular axe to grind as my eyesight is only 2 or 3 dioptres down (or should I say up?) and my hearing only a few decibels down in the upper register, but I like to help people less fortunate than myself, more especially in the matter of hearing.

Philological Philistinism

IN the December issue I mentioned the lamentable errors made by a lady writer in an Essex newspaper giving biographical details of the famous scientist of palæo-Elizabethan days whom she and I both referred to as Dr. William Gilbert of Colchester. Mr. E. A. Payne, of Little Baddow, Essex, has written to the Editor, more in sorrow than in anger, to point out that the proper spelling of his name, as shown on his tombstone is Gilberd, the name by which he is always known by Colcestrians.

I am, however, not quite so steeped in philological Philistinism as Mr. Payne may think. When I first mentioned this famous Colcestrian savant in these pages just over thirty-three years ago on 31st December, 1930—when I also published a sketch showing his famous personal demonstration to the first Queen Elizabeth—I made a gallant attempt to get the name printed correctly as Gilberd. However, the Editor of those days, whose motto was *suaviter in modo, fortiter in re,* would have none of it, but trod firmly on my spelling in that charmingly disarming manner for which he was so well known. However, many years later when I made a brief reference to the learned doctor, I substituted a "d" for the "t." I should add that this was in the reign of a different Editor—not the present one—whom I successfully persuaded.

I deliberately wrote the name as Gilbert in the December issue solely because the scribe whom I was castigating wrote it thus, and I wanted her, if she read my words, to be in no doubt that we were both talking about the same person.

Spelling is sometimes very confusing, and I am afraid that except in Colchester, although incorrect, the spelling "Gilbert" has come to stay, just as has the use of the words "ions" and ionosphere, despite the fact that I once received a letter from a kindly Hellenic reader at the Greek Embassy chiding me for not using the correct plural for the word ion, which is, of course, ionta and for not writing correctly of the iontosphere instead of omitting the "t" which I am afraid we all do and shall continue to do although we never drop the "t" in pantomime.

Electronic Sleep Inducer

ALL of us like to sleep occasionally, and I see in the magazine *Japan Electronics* an interesting description of what is known as an electronic sleep inducer. This has interested me greatly although I have always found television a first-class sleep inducer.

The Japanese electronic sleep inducer runs from three 9-volt batteries or, by means of an adapter, from a.c. mains. The instrument is said to send 19-volt pulses lasting 1mm/sec (*sic*) into the brain by means of saline-saturated pads applied over the eyes and at the back of the neck, "and the repeating rate is 100 cycles," says the writer of the article.

The device is conveniently small; its case measures only $5 \times 3\frac{1}{2} \times 2$in and it weighs 350 grammes.

The great thing about this instrument to my mind is that the restorative effect to our overwrought nerves of two hours of induced sleep is said to be equal to a full night's normal sleep. Obviously this will leave us ample time out of the 24 hours of the day to burn the candle at both ends or to burn the midnight oil as I am doing now while writing my monthly contribution.