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Commentary

MOST of us when pressed to defend the scope of electronics would be a little vague and would, we think, be content to regard it as that branch of electricity which deals with thermionic emission. In other words, if there is a valve in the circuit, then it is electronics.

This definition would, however, scarcely satisfy the more precise minded scientist and it falls very short from the legal point of view.

The American Standard Definitions of Electrical Terms refers to electronics as "that branch of science and technology which relates to the conduction of electricity through gases or in vacuo", but these Standards were laid down as far back as 1941, and this when judged by the rapid development of the science is a long time ago.

It is an all embracing definition, yet by its very wide terms includes some branches of science and engineering, such as fluorescent discharge lighting, which are not generally accepted as electronics. Equally, of course, several new developments such as semi-conductors which are likely to have a most profound influence on electronics could strictly not be included in this definition.

We have been, therefore, very interested to see that our American contemporary, *Radio Electronics*, has been organizing a contest in an attempt to find a definition of the science and has just published what it considers are the best attempts.

The best definition in the opinion of the judges was the following:

"The science that deals with phenomena produced by electrons, and techniques for controlling electrons to generate, change, combine, program, display, apply or transmit energy or information".

Of the remaining entries published we prefer the one that won the second prize as approaching the correct definition:

"Electronics is the science and technology of the transfer of information or energy by electron emission, electromagnetic radiation, or devices employing the principle of semi-conduction in solids".

However, the judges go on to say, and we agree with them, that although some of the entries were excellent, the perfect definition is still to be written.

* * *

The recent Budget will have brought a sigh of relief to most taxpayers in this country, for the Chancellor of the Exchequer has, for the first time since the war, introduced a Budget which not only contains no new taxes, but gives some relief from the existing ones. Sixpence off the standard rate of income tax and a twenty-five per cent reduction in purchase tax will be a most welcome lightening of the burden as far as the individual taxpayer is concerned.

The need for this country to increase its production capacity and to be competitive in world markets has been repeatedly emphasized, but the crushing burden of taxation on industry has left little or nothing aside for the re-equipping of its factories with modern plant and machinery. It is too much to hope, of course, with rearmament and the costly maintenance of adequate armed forces, that there could be any large-scale reduction of taxation, but the present reliefs to industry in the form of allowances on capital expenditure for plant, and the removal of the excess profits levy should now provide the necessary incentive.

The reduction of purchase tax from $66\frac{2}{3}$ to 50 per cent on domestic radio and television receivers, will be most helpful for these products form a not inconsiderable proportion of the output of the British radio and electronic industry. The sales of television receivers in the new areas opened up by Kirk o'Shotts and Wenvoe has been particularly disappointing in spite of the stimulus provided by the Coronation and there is some evidence that there are a large number of receivers out of action due to the high cost of the replacement of worn-out valves and cathode-ray tubes.

* * *

During the middle of April two exhibitions of great importance to electronic engineers took place in London. These were the Radio and Electronic Component Manufacturers Federation's Exhibition at Grosvenor House and the Physical Society's Exhibition at Imperial College. Some of the exhibits at the former were described in our last month's issue, while the latter exhibition is dealt with elsewhere in this issue.

The holding of these two exhibitions at the same time is somewhat of a mixed blessing. For the visitor from overseas or the provinces it is obviously an advantage, since both can be seen during the same visit to London. On the other hand, it is impossible to do justice to both exhibitions in one day and there are many senior engineers and executives who must find it extremely inconvenient, if not impossible, to vacate their offices or laboratories on two days in the one week.

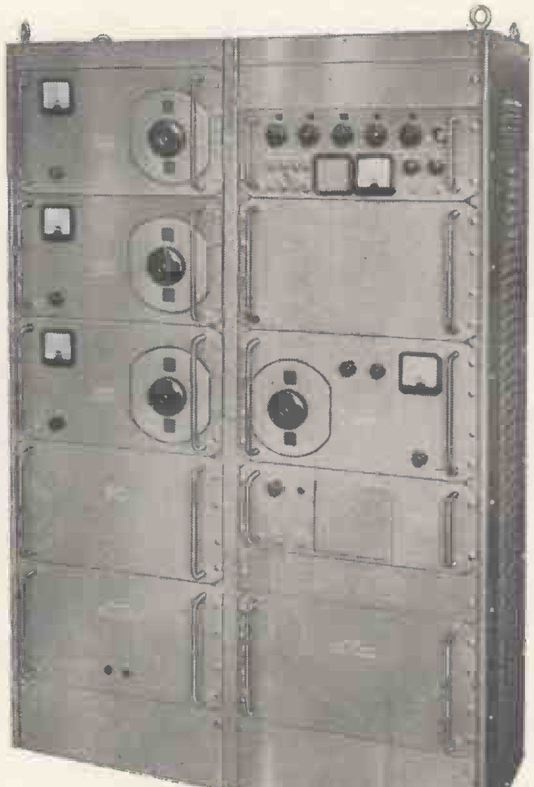
Developments in Frequency Synthesis†

By H. J. Finden*, M.I.E.E.

A method of generating frequency by synthesis of selected harmonics derived from a frequency standard is described. From a study of the products produced in a mixer system it is shown how to choose harmonics whereby near coincident frequencies to the required product are not present in the output. In this way it is possible to design filters to attenuate unwanted products to negligible amplitude. Details are given of a practical example whereby any one of a possible 100 000 frequencies is available between 1kc/s and 100Mc/s, controlled in accuracy by a single frequency standard. The use of a 1kc/s range free oscillator instead of harmonics in the synthesis process permits a continuous frequency coverage to be generated.

MEASUREMENTS involving frequency fall into three main groups. Firstly, there is calibration, and a typical example is the calibration of a wavemeter where scale readings are obtained for various frequencies. Secondly, the measurement of a frequency source may be required where the source may be remote and is almost certainly not an integral number, and finally measurements involving a known frequency source for the determination of the frequency characteristic of passive networks.

Frequency standards of very high precision have been available for a considerable time. When, however, an appreciable frequency spectrum is to be explored, existing methods are not generally satisfactory. Of the three groups of measurements, that of calibration is the easiest to make, and in the hands of a skilled observer a frequency standard controlling a harmonic series can be satisfactory. Nevertheless, in the war period it was obvious that new techniques were necessary, and in 1942 an equipment known as a frequency synthesizer was developed and described in a paper[1] presented at the Institution of Electrical Engineers in 1943. It was shown that in order to avoid ambiguity in the measurement it is desirable to produce a frequency of known value and close to the unknown under test. Moreover, the frequency produced should be locked to a frequency standard, and should be substantially a sine wave.



The complete synthesizer

Prior to the synthesizer approach, decades of frequency had been established to use an analysis method of measuring frequency. It was found that from harmonic series derived from multiplier and divider chains controlled from a frequency standard it was fairly easy to produce decades of frequencies of units, tens, hundreds and thousands of kc/s. Hence as substantially pure frequencies in nominated decades were available any unknown frequencies could be readily broken down until it could be determined by reference to a narrow range oscillator covering a 1kc/s range. Unfortunately there is a definite limit to the number of mixing stages which can be employed in the analysis process, as some distortion is produced in each mixing stage. Thus when the signal is reduced to lay between zero and 1kc/s it may have appreciable harmonic content. Nevertheless the method works quite well up to three stages of mixing.

Because there is a real need for a frequency source the opposite approach, i.e. that of synthesis, was explored. Thus the decades of frequency established were used to build up the frequency. From a combination of units and tens, simple selector circuits were used to enable any single frequency between 10 and 99kc/s in 1kc/s steps to be obtained substantially free of adjacent frequencies. The degree of purity of the output signal depends on the efficiency of the selector circuits and the presence of near coincident frequencies produced in the mixer system. By adopting the methods outlined, it is possible to generate an output with a maximum sideband component of 1 per cent amplitude for any one of a possible ten thousand frequencies in the spectrum 1kc/s to 10Mc/s. In this way the principle cause of ambiguity produced in measuring a frequency from a harmonic series is eliminated. Another common cause of uncertainty is due to incorrect frequency division within the equipment, but this possibility is also rejected as the highly selective circuits give no output for incorrect order of frequency divisions. Moreover, as the equipment can be set within 1kc/s of any frequency up to 10Mc/s it is only necessary to provide a means of interpolation over a 1kc/s range in order to determine any frequency in the spectrum.

Apart from simplifying the technique of frequency calibration and measurement, a locked frequency generator is provided by the equipment, thus justifying the complexity of the apparatus. During the past few years extensive user experience has shown that there is a real need for a

† *Based on a paper read at the Conference on High Frequency Measurements, Washington, D.C., January 1953.*

* *The Plessey Co. Ltd.*

source of greater purity and for a larger frequency coverage, and it is now proposed to describe the development of a frequency synthesizer to cover the spectrum 1kc/s to 100Mc/s capable of generating any one of a possible one hundred thousand frequencies with a maximum sideband component of 0·05 per cent.

In order to generate individual steps of frequency at a spacing which may be a small sub-multiple of a frequency standard, some method of mixing frequencies must be adopted. Unfortunately the mixing process produces many products other than the major sum or difference ones. Hence with an unsuitable choice of input frequencies one or more of these products may be nearly coincident to the wanted one. For this reason it was decided to undertake an investigation into the strengths of the various products produced in mixer systems.

Linear multiplication mixing appears to be the most profitable system to explore since we shall probably need several tuned circuits to select the wanted product and hence actual mixing efficiency (which is higher in other systems) is not the main consideration. If in an ideal linear multiplication system we apply signals of f_1 and f_2 to the g_1 and g_3 electrodes of a heptode valve, it can be shown that the current in the output consists of f_2, f_1, $(f_2 + f_1)$ and $(f_2 - f_1)$. The original terms f_2 and f_1 can be eliminated by using a balanced system as shown in Fig. 1.

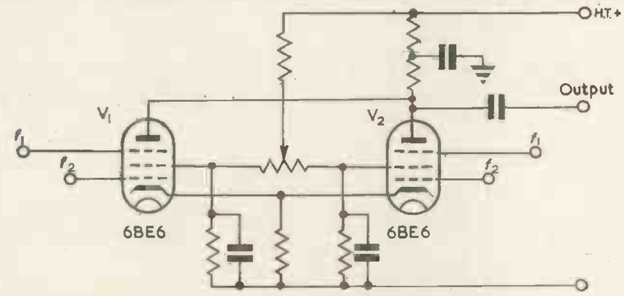


Fig. 1. Balanced linear multiplication system

In practice a linear system cannot be realized due to some curvature of the valve characteristic. To ascertain what resultant signals are produced in such a system a large number of readings were taken for varying levels of f_2 and f_1 on a balanced mixer fed with f_2 of 740kc/s and f_1 of 100kc/s, frequency values chosen as being non-harmonically related to ease the identification of the various products produced. Measurements were made by means of a heterodyne selective voltmeter, which permitted reliable readings up to -80db in relation to a 100mV sum or difference product. Table 1 shows values for minimum strengths of all products other than the first sum and difference ones. Examination of this table shows that in order to obtain a resultant output of $f_2 \pm f_1$ with any other product attenuated by at least 70db, it is necessary to consider fourth order harmonics of both input frequencies. The system was balanced most accurately for f_2 and in the simple method adopted gave -30db and -10db for f_1 over long periods after an initial ageing time.

TABLE 1

	740kc/s f_2–30db	1480kc/s $2f_2$–30db	2220kc/s $3f_2$–33db	2960kc/s $4f_2$–58db
100kc/s f_1– 8db	640kc/s– 0db 840kc/s– 0db	1380kc/s–37db 1580kc/s–37db	2120kc/s–49db 2320kc/s–49db	2860kc/s–68db 3060kc/s–68db
200kc/s $2f_1$–35db	540kc/s–38db 940kc/s–38db	1280kc/s–46db 1680kc/s–47db	2020kc/s–69db 2420kc/s–69db	2760kc/s–72db 3160kc/s–72db
300kc/s $3f_1$–42db	440kc/s–65db 1040kc/s–63db	1180kc/s–66db 1780kc/s–68db	1920kc/s–73db 2520kc/s–72db	2660kc/s–78db 3260kc/s–79db
400kc/s $4f_1$–57db	340kc/s–58db 1140kc/s–60db	1080kc/s–70db 1880kc/s–72db	1820kc/s–77db 2620kc/s–77db	2560kc/s–78db 3360kc/s–78db
500kc/s $5f_1$–71db	— —	— —	— —	— —

In an ideal equipment it is desirable that the only process required for obtaining a given frequency should be the setting of the required digits on the appropriate dials. It is necessary, therefore, to decide how the filtering of unwanted products in the output stage can best be accomplished. In the following treatment every frequency in the output of a mixer is considered even though it is coincident with the wanted one. This is essential because the unit 1kc/s steps used in the synthesis process may be replaced by a narrow range continuously variable oscillator to give a continuous frequency coverage and hence impossible filtering conditions would obtain for the very near coincident signals.

Examination of Table 1 shows that there are eight harmonics and thirty-two products to be considered, and if we make $(f_2 - f_1)$ the wanted product and $f_2 > f_1$, then the following statements can be made:

(a) f_2 will never be equal to f_1.

(b) The sign of the difference must be disregarded.

(c) Although $f_2 > f_1$ this does not imply that $2f_2 > 3f_1$ or that $3f_2 > 4f_1$ etc.

(d) All the sum frequencies $(mf_2 + nf_1)$ where m or n are 1, 2, 3 or 4 must be higher than f_2 and providing we can design filters to give the necessary discriminations between $(f_2 - f_1)$ and f_2, then there are sixteen products in Table 1 which need not be considered. Similarly we can ignore f_2, $2f_2$, $3f_2$ and $4f_2$.

(e) The second, third and fourth harmonics $(f_2 - f_1)$ can be eliminated by elementary filter design.

Table 1 can now be rewritten for the remaining seventeen products as shown in Table 2. The six products to the right of the diagonal are all higher than f_2 and can be ignored, leaving ten unwanted products to be considered.

TABLE 2

f_1	f_2–f_1	$2f_2$–f_1	$3f_2$–f_1	$4f_2$–f_1
$2f_1$	f_2–$2f_1$		$3f_2$–f_1	$4f_2$–$2f_1$
$3f_1$	f_2–$3f_1$	$2f_2$–$3f_1$		$4f_2$–$3f_1$
$4f_1$	f_2–$4f_1$	$2f_2$–$4f_1$	$3f_2$–$4f_1$	

Equating each of these products separately to the wanted one gives a relationship between f_2 and f_1, which must be avoided if the unwanted frequency is not to coincide with the wanted one.

If

$$f_1 = f_2 - f_1 \text{ then } 2f_1 = f_2 \quad (1)$$
$$2f_1 = f_2 - f_1 \text{ then } 3f_1 = f_2 \quad (2)$$
$$3f_1 = f_2 - f_1 \text{ then } 4f_1 = f_2 \quad (3)$$
$$4f = f_2 - f_1 \text{ then } 5f_1 = f_2 \quad (4)$$
$$f_2 - 2f_1 = f_2 - f_1 \text{ then } f_1 = 0 \quad (5)$$
$$2f_1 - f_2 = f_2 - f_1 \text{ then } 3f_1 = 2f_2 \quad (6)$$
$$f_2 - 3f_1 = f_2 - f_1 \text{ then } f_1 = 0 \quad (7)$$
$$3f_1 - f_2 = f_2 - f_1 \text{ then } 4f_1 = 2f_2 \quad (8)$$
$$f_2 - 4f_1 = f_2 - f_1 \text{ then } f_1 = 0 \quad (9)$$
$$4f_1 - f_2 = f_2 - f_1 \text{ then } 5f_1 = 2f_2 \quad (10)$$
$$2f_2 - 3f_1 = f_2 - f_1 \text{ then } 2f_1 = f_2 \quad (11)$$
$$3f_1 - 2f_2 = f_2 - f_1 \text{ then } 4f_1 = 3f_2 \quad (12)$$
$$2f_2 - 4f_1 = f_2 - f_1 \text{ then } 3f_1 = f_2 \quad (13)$$
$$4f_1 - 2f_2 = f_2 - f_1 \text{ then } 5f_1 = 3f_2 \quad (14)$$

$3f_2 - 4f_1 = f_2 - f_1$ then $3f_1 = 2f_2$.........(15)
$4f_1 - 3f_2 = f_2 - f_1$ then $5f_1 = 4f_2$.........(16)

Equations (1) to (16) inclusive can be expressed as forbidden ratios of $f_2/f_2 - f_1$ as follows :—

5/4, 4/3, 3/2, 5/3, 2, 5/2, 3, 4 and 5.

In the synthesis of any frequency spectrum such as 10 to 99, 100 to 999, etc., the choice of the value of f_2 is limited by harmonic selection of frequencies derived from the divider and multiplier chains controlled from the frequency standard. To meet the ideal conditions specified, static filters must be used to accept the wanted signal $(f_2 - f_1)$. Although low-pass filters are easier to construct than band-pass sections, it is obvious that the low-pass wanted spectrum must be less than an octave. Band-pass filters are probably best treated on an approximately logarithmic basis of about 1·1/1. If we consider a spectrum of 10 to 99 units examination of Table 3 shows three low-pass bands of 1·6/1 where the lowest possible values of f_2 are seen by inspection to be 90, 130 and 210, i.e. the 9th, 13th and 21st harmonics of ten.

In the original work published on the frequency synthesizer[1] it was shown that the tenth harmonic of a series could be selected by two tuned circuits to give at least 60db attenuation of adjacent harmonics. However, bands of 10 to 16 and 16 to 25 can be covered with two low-pass filters, providing we can obtain the 13th harmonic with at least 70db attenuation of the 12th and 14th harmonics. It should be noted, however, that the values of f_1 are not low order harmonic multiples of the units harmonic series, and steps must be taken to produce these frequencies; this will be considered later.

Band-pass ratios of approximately 1·1/1 are shown in Table 4 for frequency spectrums of 25 to 29, 29 to 34, 34 to 37, 37 to 41, 41 to 45, 45 to 50, 50 to 55, 55 to 60, 60 to 66 and 66 to 73. As $(f_2 - f_1)$ is expressed as a ratio it may be necessary to check by substitution that the value of f_2 chosen is suitable. No solutions are given for the top two spectrums assuming the 13th harmonic of ten is the highest practical value. However, the spectrum 25 to 50 can be covered by six band-pass sections.

In a similar manner we can consider the case where

TABLE 3

	$f_2 - f_1$		
	FILTER A	FILTER B	
	10 – 16	16 – 25	25 – 40
$\frac{f_2}{f_2-f_1}$ 5/4	12 – 20	20 – 31·33	31·33– 50
4/3	13·33– 21·33	21·33– 33·33	33·33– 53·33
3/2	15 – 24	24 – 37·5	37·5– 60
5/3	16·67– 26·67	26·67– 41·67	41·67– 66·67
2	20 – 32	32 – 50	50 – 80
5/2	25 – 40	40 – 62·5	62·5–100
3	30 – 48	48 – 75	75 –120
4	40 – 64	64 –100	100 –160
5	50 – 80	80 –125	125 –200
Lowest possible value of f_2	90 (9 × 10)	130 (13 × 10)	210 (21×10)
Chosen value of f_2	110	130	—
Values of f_1	100–94	114–105	—

TABLE 4

	$f_2 - f_1$									
	FILTER C	FILTER D	FILTER E	FILTER F	FILTER G	FILTER H	FILTER I	FILTER K		
	25–29	29–34	34–37	37–41	41–45	45–50	50–55	55–60	60–66	66–73
$\frac{f_2}{f_2-f_1}$ 5/4	31·25–36·25	36·25–42·5	42·5 –46·25	46·25–51·25	51·25–56·25	56·25–62·5	62·5 –68·75	68·75–75	75–82·5	82·5–96·25
4/3	33·33–38·67	38·67–45·33	45·33–49·33	49·33–54·67	54·67–60	60 –66·67	66·67–73·33	73·33–80	80–88	88–97·33
3/2	37·5 –43·5	43·5 –51	51 –55·5	55·5 –61·5	61·5 –67·5	67·5 –75	75 –82·5	82·5 –90	90–99	99–109·5
5/3	41·67–48·33	48·33–56·67	56·67–61·33	61·33–68·33	68·33–75	75 –83·33	83·33–91·67	91·67–100	100–110	110–128·33
2	50–58	58–68	68–74	74–82	82–90	90–100	100–110	110–120	120–132	132–146
5/2	62·5 –72·5	72·5 –85	85 –92·5	92·5 –102·5	102·5–112·5	112·5–125	125–137·5	137·5 –150	150–165	165–192.5
3	75 –87	87 –102	102–111	111–123	123–135	135–150	150–165	165–180	180–198	198–219
4	100–116	116–136	136–148	148–164	164–180	180–200	200–220	220–240	240–264	264–292
5	125–145	145–170	170–185	185–205	205–225	225–250	250–275	275–300	300–330	330–385
Possible values of f_2 below 130	90 120 —	110 — —	80 100 ? 120 130	90 ? 110 ? 130 —	80 ? 100 ? 120 ? —	110 — —	120 — — —	130 — — —	— — — —	— — — —
Chosen value of f_2	120	110	130	130	100	110	120	130	No Solution	No Solution
Values of f_1	95–91	81–76	96–93	93–89	59–55	65–60	70–65	75–70	—	—

$f_1 > f_2$ and $(f_1 - f_2)$ is the wanted product. The forbidden ratios of $f_2/(f_1 - f_2)$ turn out to be 1/4, 1/3, 1/2 2/3, 3/2, 2, 3 and 4. If the spectrum is again divided into 1·1/1 ratio sections it is found that where solutions are given that $f_1 > 76$ hence there is a disadvantage in making $f_1 > f_2$.

It is now necessary to consider how f_1 can be produced for the solutions given in Tables 3 and 4. Values of f_1 of 55 to 114 are necessary and it is because of this that we cannot produce an equipment to generate from static selection only. However, the necessary frequencies can be produced in an initial mixing stage by using a combination of 5, 6, 7, 8 or 9 with 50, 60, 70, 80, 90, 100 or 120. This is most easily achieved by using the sum product of the unit and tens digits fed to a mixer when the second or units digit is 5 or more and the difference product where the second digit is 4 or less. Thus to produce 79 we would select 70 + 9, but to produce 71, 80 − 9 would be selected. It is important to note that where a continuously variable spectrum is required it is essential to have a manually operated selector circuit to give the necessary discrimination against the 2nd, 3rd and 4th order harmonic when the continuously variable input frequency covers 5 to 10 units. Thus a complete spectrum of 10 to 99 units requires two mixing stages. The first mixer is used in all cases, but when the desired frequency is less than 50 a second mixing stage is employed.

Table 5 shows the input frequencies required for the two mixers used in a typical section of the complete spectrum of 10 to 99. It will be seen that f_3 has been considered as being continuously variable from 5 to 10 and expressed as four significant figures, hence if these units are kc/s, frequencies are expressed to the nearest 1c/s. It is necessary to have five calibrations for the manual selector scales if they are to be direct reading in terms of the final output frequency.

Fig. 2 shows a block diagram of the method used to synthesize a frequency of 31kc/s. Signals f_4 of 70kc/s, and f_3 of 9kc/s, are fed to mixer 1 with the manual selector tuned to the sum product of 79kc/s designated 31kc/s on Y_{10} calibration. An output f_2 of 110kc/s and f_1 of 79kc/s derived from mixer 1 are fed to mixer 2 when the band-pass D_{10} filter will accept the difference product of 31kc/s.

To synthesize a three-digit spectrum of 100 to 999kc/s, we can use a frequency representing the least two significant figures generated as described above. Thus to produce 293kc/s the 93kc/s representing the least two digits is obtained by feeding signals f_2 of 100kc/s and f_1 of 7kc/s to mixer 1 and manually tuning the selector for the difference product of 93kc/s. As this two-digit synthesized frequency is more than 50kc/s, the output is then routed to mixer 3 where it is mixed with a signal f_3 of 900kc/s. The second manual selector is tuned to accept the difference product 807kc/s designated 293kc/s on Y_{100} scale calibration. The 807kc/s signal is then fed to mixer 4 in conjunction with a signal f_4 of 1 100kc/s when the band-pass filter D_{100} will accept the difference product of 293kc/s, i.e. the required frequency. The above sequence of operations is shown in Fig. 3.

Fig. 4 (page 183) shows a block diagram of a frequency synthesizer which has been produced on the principles outlined. The output is manually variable in amplitude over a ratio of more than 10/1 to give a maximum of 10mW for all frequencies up to 10Mc/s and of 1mW for frequencies between 10Mc/s and 100Mc/s. Fixed level outputs at

TABLE 5 Two Digit Synthesis

FREQUENCY SPECTRUM	1ST MIXER f_4 f_3	MANUAL SELECTOR	2ND MIXER f_2 f_1	OUTPUT FILTER
10 to 14·999	90 + (10 to 5·001)	100 to 95·001 Cal. Y 10 to 14·999	110 − (100 to 95·001)	LOW-PASS FILTER A
15 to 15·999	100 − (5 to 5·999)	95 to 94·001 Cal. Y 15 to 15·999	110 − (95 to 94·001)	LOW-PASS FILTER A
16 to 19·999	120 − (6 to 9·999)	114 to 110·001 Cal. Z 16 to 19·999	130 − (114 to 110·001)	LOW-PASS FILTER B
20 to 24·999	100 + (10 to 5·001)	110 to 105·001 Cal. Z 20 to 24·999	130 − (110 to 105·001)	LOW-PASS FILTER B
25 to 28·999	100 − (5 to 8·999)	95 to 91·001 Cal. V 25 to 28·999	120 − (95 to 91·001)	BAND-PASS FILTER C
29 to 29·999	90 − (9 to 9·999)	81 to 80·001 Cal. Y 29 to 29·999	110 − (81 to 80·001)	BAND-PASS FILTER D
30 to 33·999	70 + (10 to 6·001)	80 to 76·001 Cal. Y 30 to 33·999	110 − (80 to 76·001)	BAND-PASS FILTER D
34 to 34·999	90 + (6 to 5·001)	96 to 95·001 Cal. Z 34 to 34.999	130 − (96 to 95·001)	BAND-PASS FILTER E
35 to 36·999	100 − (5 to 6·999)	95 to 93·001 Cal. Z 35 to 36·999	130 − (95 to 93·001)	BAND-PASS FILTER E
37 to 39·999	100 − (7 to 9·999)	93 to 90·001 Cal. Z 37 to 39·999	130 − (93 to 90·001)	BAND-PASS FILTER F
40 to 40·999	80 + (10 to 9·001)	90 to 89·001 Cal. Z 40 to 40·999	130 − (90 to 89·001)	BAND-PASS FILTER F
41 to 44·999	50 + (9 to 5·001)	59 to 55·001 Cal. W. 41 to 44·999	100 − (59 to 55·001)	BAND-PASS FILTER G
45 to 49·999	70 − (5 to 9·999)	65 to 60·001 Cal. Y 45 to 49·999	110 − (65 to 60·001)	BAND-PASS FILTER H

10mW are available for 100c/s, 1kc/s, 10kc/s, 100kc/s, 1 000kc/s and 10Mc/s, and at 1mW for 100Mc/s with the output referred to 75 ohms in all cases.

From a 100kc/s G.T. cut crystal controlled frequency standard, thermostatically controlled at 60°C, harmonic series are derived at 100kc/s fundamental, by division at 10kc/s and 1kc/s fundamentals, and by multiplication at 1 000kc/s and 10Mc/s fundamental frequencies. Alternatively the internal frequency standard can be replaced by an external standard to control the same harmonic series. Because further expansion of the frequency range of the equipment was envisaged, considerable care has been taken in the frequency division and multiplication process to reduce jitter. 100kc/s pulse amplifiers are used for deriving

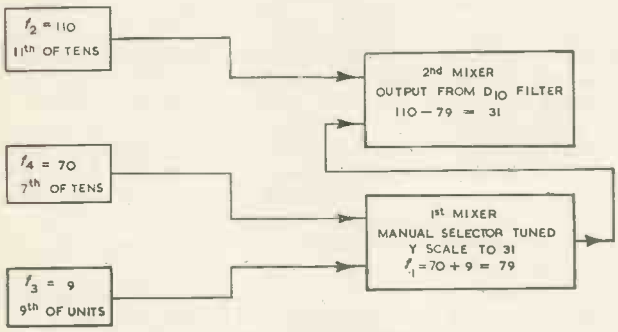


Fig. 2. Method used to synthesize 31kc/s

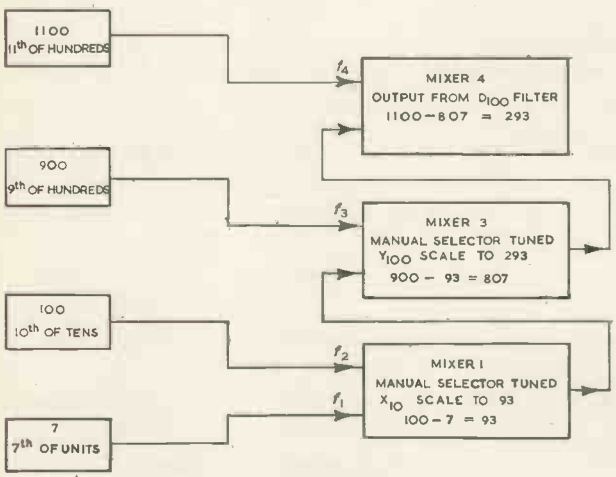


Fig. 3. Synthesis of three-digit spectrum

the 100kc/s harmonics and for locking the 10kc/s multivibrator. By means of well stabilized power supplies and very short rise times of the locking signals, the phase stability in the output frequency is better than 1 part in 10^9. Four pairs of three-stage selector circuits are employed to select the 5^{th}, 6^{th}, 7^{th}, 8^{th}, 9^{th}, 10^{th} and 12^{th} harmonics and the 10^{th}, 11^{th}, 12^{th} and 13^{th} harmonics of tens, hundreds, thousands and ten thousands. The 1^{st} to the 10^{th} harmonics inclusive of the units are selected in a further three-stage selector. Thus a total of 54 harmonics are available locked by the frequency standard.

A manual digit dial control comprising five sets of multiway bank switches is employed to control the selection of the desired harmonics employed in the synthesis process. The control is by means of a 24V D.C. potential applied to a series of motor driven switches which drive the selector switches through Geneva mechanisms. Fig. 5 shows one of these three-stage selectors. The digit control switches also select one of five calibrations on the various manual S.P.F. continuously variable selectors, select one of eight static filters in each of four stages following the second mixing of each synthesis process and route the output through the correct mixing stages and finally to the output socket. In this way the complexity of the operations is reduced to the setting of the frequency required on the manual digits dials and the tuning of one, two, three or four S.P.F. manual selectors for two, three, four or five figure frequencies respectively—a perfectly logical operation. Resonance indicators are provided at each mixer stage involving manual tuning and a fixed output meter is calibrated at 10mW F.S.D.

In order to obtain a continuous frequency coverage the 5^{th}-10^{th} unit harmonics can be replaced by a narrow range oscillator covering a 1kc/s continuous range. An oscillator whose frequency can be varied between 91kc/s and 90kc/s is adjusted for maximum frequency stability. The tuned circuit is placed in a resistance bridge stabilized oven controlled at 60°C. The overall short period stability is $\pm 0{\cdot}1$c/s and ± 1c/s for long term period stability. This oscillator is mixed with 96, 97, 98, 99 and 100kc/s, and the difference products of 5 to 6kc/s and 6 to 7kc/s are passed by a low-

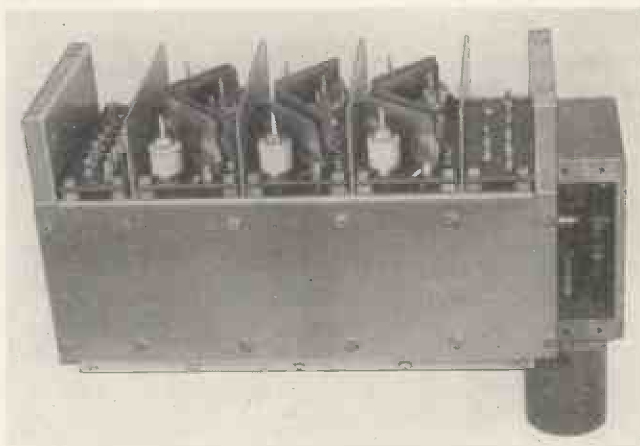


Fig. 5. Geneva operated selector switch

pass filter *P* and of 7 to 8kc/s, 8 to 9kc/s and 9 to 10kc/s by the low-pass filter *Q*. The frequencies 96, 97, 98, 99 and 100kc/s are derived from a 3-stage selector which passes the sum products of 90 + 6, 7, 8, 9 and 10 respectively. It is possible to use the unit's harmonics for this number which have already been selected since they will not be required in the synthesis of the required output. Although all the kc/s steps in the complete spectrum are controlled by the frequency standard, the resultant output when derived from a free running oscillator has an additional inaccuracy of the short period stability of the oscillator. Correction for long-term drift from calibration can be made by reference to a built-in dekatron cold-cathode counter. To economize in the number of valves used in this checking process, only the least two significant figures are counted over a 1 second and 10 second period to determine the nearest 1c/s and 0·1sec respectively. The frequency range used in this connexion is 1-2kc/s, obtained by deriving 92kc/s in a mixing stage fed by 100kc/s and 8kc/s and mixing in a further stage.

To enable the complete equipment to be used as a frequency measuring device a mixer No. 11 is provided, and in conjunction with a low frequency amplifier resultant beats between the synthesizer output and the unknown can be adjusted to be seen visibly on an indicator tube or heard

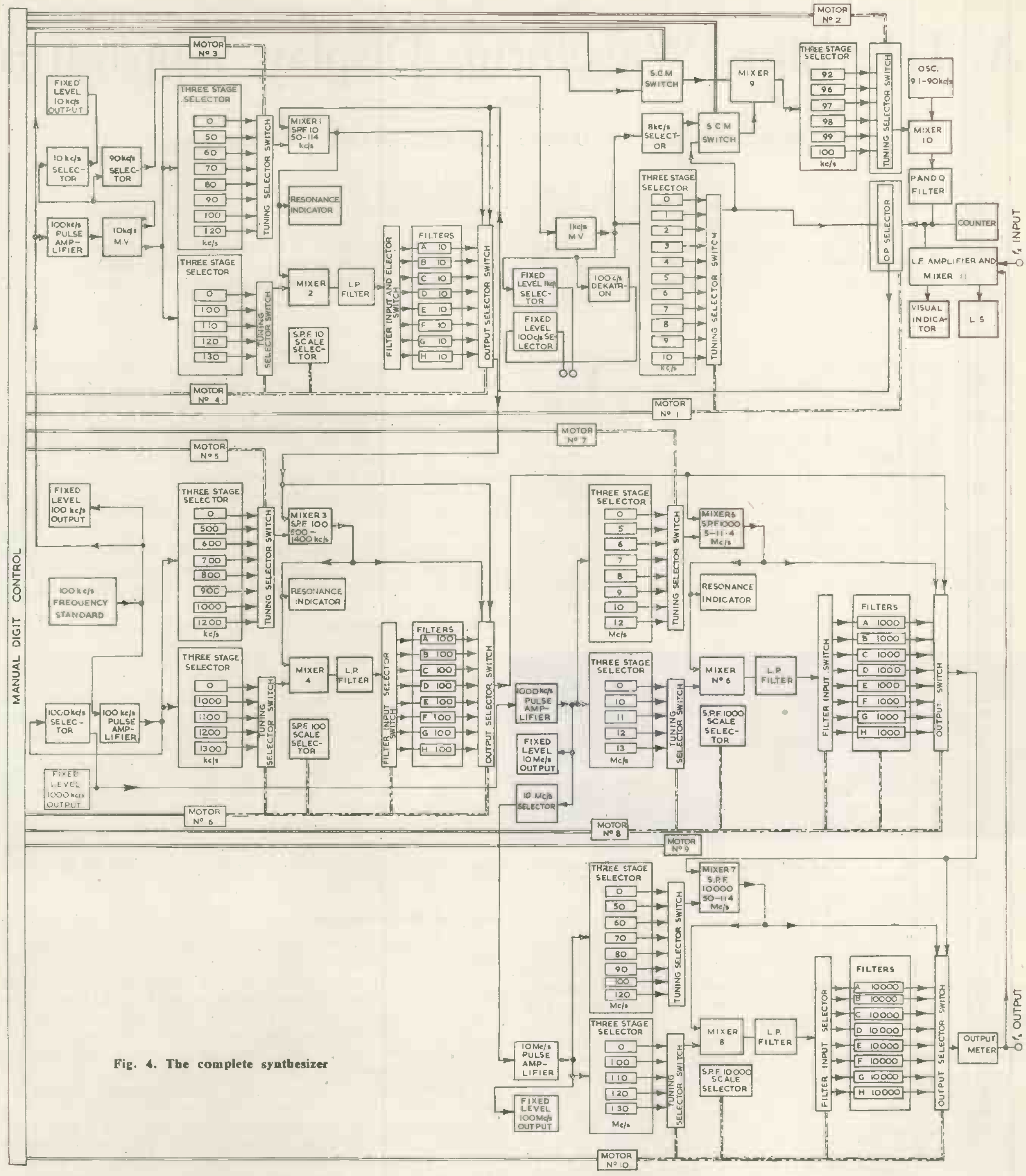


Fig. 4. The complete synthesizer

on a loudspeaker. The 1-2kc/s band can be used in the usual double beat measuring technique method.

Among the many features in the use of the equipment is the ability to check to at least 1 part in 10^6 accuracy within 1 second. For instance several of the BBC transmissions are of at least this accuracy in the medium waveband and by feeding a signal from the synthesizer set 1kc/s low of the transmission to which the receiver is tuned an instantaneous check can be carried out.

Acknowledgment

In conclusion, the author wishes to acknowledge permission of the Directors of the Plessey Co. Ltd., and the Ministry of Supply, to publish this work, which is the result of a development contract carried out for Telecommunications Research Establishment.

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A Television Waveform Display Apparatus

(Part 1)

By G. N. Patchett*, Ph.D., B.Sc., A.M.I.E.E., M.I.R.E., A.M.Brit., I.R.E.

It is well known that it is difficult to see any detail of the frame synchronizing period of a television signal on a normal cathode-ray oscilloscope. The present apparatus is designed to select any number of lines from two upwards so that detail of the frame synchronizing period or any other portion of the waveform may be examined easily. The apparatus is self-contained and may be synchronized to the 50c/s supply or suitable frame synchronizing pulses. A number of results showing the waveform of various lines in a picture are given, together with the picture showing the particular lines.

THERE are many cases, both in television servicing and research, where it is desirable to examine the waveform of a television signal as it passes through a section of a television receiver, particularly in the synchronizing separator circuits. The normal television signal consists of a picture signal portion and a synchronizing signal portion, and the latter may be divided into line and frame synchronizing signals. The line pulses are at a frequency of 10 125c/s and may be viewed on a cathode-ray oscilloscope with the time-base operating at 10 125c/s, or a sub-multiple of this frequency. This does not result in a clear waveform (except in the case of very simple test patterns) since all the different lines are superimposed on each other. A typical result obtained on a normal picture (with a 1/5th second exposure and the time-base running

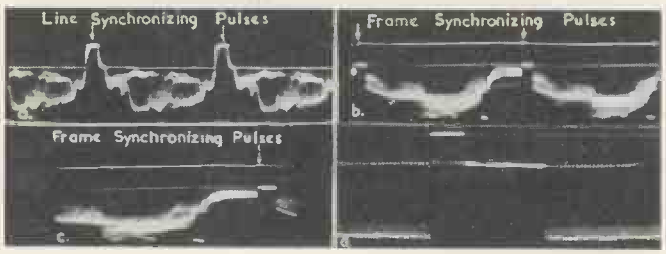


Fig. 1. Oscillograms taken on normal oscilloscope of typical television waveforms. All negative picture signal, positive synchronizing pulses

(a) Time-base frequency 3375c/s ($\frac{1}{3}$ line frequency).
(b) Time-base frequency 25c/s (picture frequency).
(c) Time-base frequency 50c/s (frame frequency).
(d) Time-base frequency 25c/s expanded about nine times.

at 3 375c/s) is shown in Fig. 1(a). This shows the pulses clearly, but the vision portion is blurred, due to the superimposition of the different lines. In this oscillogram the signal is a negative picture signal.

When we come to try and view the frame synchronizing signal greater difficulties are encountered. Although the frame frequency of a television set is 50c/s, odd and even frames are different and, therefore, the picture only repeats 25 times a second. In order to obtain a clear single trace the time-base must be run at 25c/s (or a sub-multiple of this frequency). The frame pulses only occupy four lines (in a BBC transmission) and since a whole "picture" (i.e. two frames) is viewed, the frame synchronizing signals only occupy a small section (1 per cent of the complete waveform and no detail can be seen with a normal cathode-ray oscilloscope. A typical result on a BBC transmission is shown in Fig. 1(b) which is taken with the time-base running at 25c/s. The frame synchronizing periods have been marked, but are only just visible. A slight improvement is obtained if the time-base is run at 50c/s, but then the odd and even frame waveforms are superimposed and cause some confusion. A typical result is shown in Fig. 1(c). An improvement is possible if the trace can be expanded to 5 or 10 times the screen diameter, but this feature is normally only incorporated in expensive oscilloscopes. A typical result obtained, using a pattern generator, on a 25c/s time-base, expanded about 9 times is shown in Fig. 1(d) and some detail is now visible. In this case some means is often required to alter the phase of the synchronizing signal fed to the oscilloscope or the desired portion of the waveform is not visible, it being expanded off the screen. Although this is an improvement, since the frame synchronizing signals only occupy four lines, the frame pulses only occupy (when the waveform is expanded five times) $\frac{4 \times 5}{405}$ i.e. approximately 5 per cent of the screen trace, and are difficult to see unless the oscilloscope has a very fine trace.

For many purposes it is essential to be able to view one line, or a few particular lines, of a picture in detail. The most important lines are probably those lines corresponding to the frame synchronizing period. On some oscilloscopes fitted with a triggered time-base it is possible to "fire" the time-base from the frame synchronizing pulse and so see some of the lines associated with the pulse. It is not possible to see the whole of the frame synchronizing period in this way since the flyback of the time-base is normally triggered and, therefore, a portion of the pulse is lost in the flyback.

General Requirements

Before dealing with an actual apparatus for viewing a few lines the requirements of such a device will be briefly considered. On a television set the frame frequency is, of course, 50c/s, but it must be remembered that alternate frames are different (being termed odd and even frames) so that an interlaced picture is built up. This means that the television signal only repeats 25 times per second. Hence any apparatus for selecting a line (or a few lines) for viewing must operate with a fundamental frequency of 25c/s. If a line is selected every 1/50th second then two lines become superimposed (and displaced half a line relative to each other) and, although this may be of use in certain applications, it is not usually desirable. Suppose that we wish to view one line. It is necessary for the time-base to traverse the screen in the time of one line 1/10 125th second) and remain at one or other side of the screen until the same line occurs again, 1/25th second later, or after the passage of 404 lines. Since the stationary spot at either end would cause burning of the screen and the flyback of the spot (which may be longer than the scan) would confuse the trace, it is necessary to black out the spot except during the actual scan or period of the line. Since it is desirable to be able to select any line it is necessary to be able to shift the phase of the scan relative

* *Bradford Technical College.*

to the picture signal throughout the whole picture time or 360°. In order to do this the time-base must be of a special type, which can be triggered by a 25c/s pulse, and, at the same time a pulse must be generated to brighten the spot on the cathode-ray tube. In order to be able to view more than one line the speed of the time-base and the width of the brightening pulse must be variable.

The difficulties of obtaining the above depend on whether the television waveform being viewed is synchronized, reasonably rigidly, to the 50c/s mains or not. If it is, the mains may be used as the source of the 25c/s triggering pulse (by frequency dividing). If the signal is not synchronized then the source of the 25c/s triggering pulse must be the frame synchronizing pulses or the frame time-base of a television set. When the mains is used it is comparatively easy to shift the phase before frequency dividing and forming a pulse. When a 50c/s pulse is the source it is not as easy to obtain the required phase shift.

When the signal from a pattern generator is being viewed it is usually satisfactory to obtain the triggering pulse from the mains, since the pattern generator can usually be locked to the mains and the lock is fairly rigid. In the case of the BBC transmissions, although the signal is normally synchronized to the mains the lock is not rigid (being slow acting) and there is a variable phase shift in the supply between the source of transmission and the receiving point (particularly when situated far from London). The result is that the waveform viewed on a display apparatus synchronized to the mains, drifts slowly backwards and forwards. Although the lines can be viewed, it becomes a nuisance as, particularly when only one, or a few lines are being viewed, continual adjustment is required to keep the same line or lines on the screen.

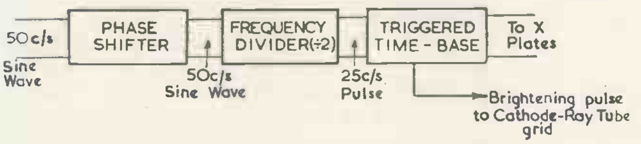


Fig. 2. Block diagram of one type of waveform display apparatus fed with with a 50c/s sine wave voltage

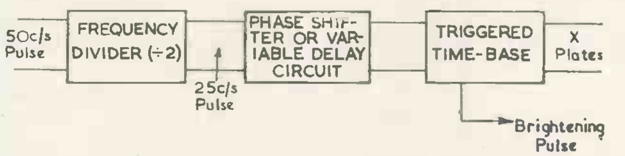


Fig. 3. Block diagram of a waveform display apparatus operated by 50c/s pulses

Principles of Operation

There are various ways in which a waveform display apparatus may be constructed and some of these will be briefly described. Fig. 2 shows an arrangement using the 50c/s supply as the source of the pulses. The 50c/s supply is first fed through a phase shifter. This may consist of a resistance-capacitance bridge network but, since a single network gives a maximum phase shift of rather less than 180°, three such networks are required (usually separated by valves) with a three gang variable resistor. A simpler arrangement is the use of a phase shifting transformer or a magslip connected as described by the author[1], where a continuous phase shift (with the actual angle indicated by a pointer) over any number of degrees is possible. Alteration of the phase shifter alters the phase of the triggering pulse relative to the signal and so enables any line (or lines) to be selected.

The output from the phase shifter is fed to a frequency divider where the 50c/s is converted to 25c/s. Since most frequency dividers require a pulse input, the sine wave output of the phase shifter must first be converted to a pulse. The frequency divider may take several forms such as a synchronized multivibrator, synchronized time-base or the blocking oscillator type described later. The 25c/s output from the frequency divider is now used to trigger the special time-base, one type of which will be described later.

Where the synchronizing source is a 50c/s pulse (obtained from say the frame time-base of a television set) the same method may be used by integrating the pulses so as to obtain a sine wave. This is arranged to feed a power amplifier which, in turn, feeds the phase shifter and the remainder of the circuit shown in Fig. 2. This arrangement has been described by Sturley[2]. The alternative to converting the pulse into a sine wave is to keep it as a pulse, frequency divide it and then feed the resulting 25c/s pulse into a pulse phase shifter (or delay circuit) as shown in Fig. 3. This method is used in the apparatus to be described later and has been used by other authors. The phase shifter or delay circuit is not easy to design if "dither" is to be eliminated and a large phase change is to be obtained. One method of reducing the "dither" is to trigger the time-base from line pulses and this is used in the Television Line Selector or Analyser[3] made by Messrs Murphy Radio Ltd. This unit will only show one line since the time-base is run at line frequency.

Davies[4] uses a delay circuit in which the termination of the delay is precisely at line intervals by injecting line pulses into the delay circuit. This greatly reduces the "dither" due to variations in the delay time of this circuit. Fisher[5] and Green[6] both use circuits where the triggered time-base (or brightening pulse in the case of Green) is triggered by line pulses. One line pulse is selected by a gate circuit which allows only one pulse to pass during the period of the 25c/s (actually 30c/s in the U.S.A.) pulse from the phase shifter or delay circuit. These arrangements have the disadvantage that both line and frame synchronizing pulses are required.

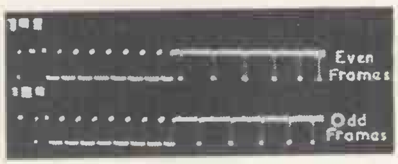


Fig. 4. Oscillogram obtained using 50c/s scan and 25c/s square wave to separate the two frame waveforms. Positive picture signal from pattern generator

An alternative arrangement to the use of a 25c/s time-base has been described by Sturley[2], in which a 50c/s time-base is used, but the position of the trace on the cathode-ray tube is moved up and down by a sawtooth waveform (or square wave) at 25c/s, so that two traces result, one showing the odd frame and the other the even frame. A photograph taken in this way is shown in Fig. 4. In this particular case a 25c/s square wave oscillator was used to deflect the trace up and down. Although this was not synchronized, when once adjusted, the waveform remained steady apart from an occasional interchange of the two waveforms as the frequency drifted. This was taken on the waveform display apparatus to be described, but the frequency divider was adjusted so as to operate on each pulse.

Detailed Description of Apparatus

Having dealt with various methods of obtaining the required result the apparatus developed by the author will now be described in detail. The apparatus was originally constructed for demonstrating the operation of synchronizing separators and for experiments on synchronizing separator circuits in television servicing classes. It is considered that it would also be most useful to those engaged on research in television, and since developed has been used in some research on interlacing by the author[7]. The apparatus was designed to show on a cathode-ray tube screen a portion of a television signal, the section required being selected at will and the number of lines viewed could be varied from about two to about 250 lines. (More could be shown if desired, but it is not likely that this would be required as the whole number may easily be shown on a normal oscilloscope). As the apparatus may be used for several purposes it was designed so that it could be driven from the 50c/s mains or from positive or negative pulses (at frame frequency).

A block diagram of the apparatus is shown in Fig. 5. If the driving signal is a pulse it is first limited (and reversed in phase if necessary) so that the apparatus will operate over a large range of pulse amplitudes without adjustment. If a 50c/s sine wave (from the mains) is used it is squared (by limiting) so as to produce a 50c/s square wave. The square wave (or pulse) is fed to a frequency divider so as to obtain a 25c/s pulse which is converted into a 25c/s sawtooth waveform in the sawtooth generator. A pulse is now obtained from this sawtooth waveform which is continuously variable in phase over nearly 360° in a manner described later. This pulse is then used to trigger a modified sanatron time-base which gives a variable speed scan starting at the leading edge of each pulse. The output from this time-base is fed to a push-pull amplifier which feeds the X-deflecting plates. The time-base also generates a pulse during the period of scan which is used to brighten the spot of the cathode-ray tube, being fed to the grid. Since the speed of the trace is rapid and the repetition rate only 25c/s, a cathode-ray tube with a high E.H.T. voltage is required to obtain a satisfactory picture, particularly when viewed by a number of people in normal illumination. For this reason a larger deflecting voltage is required and a push-pull amplifier is included to feed the Y-deflecting plates.

Circuit Description

A circuit diagram of the apparatus is shown in Fig 6 (page 187). With the switches S_1. S_2 and S_3 (ganged) in position (1) a 50c/s sine wave (from the 6·3 volt heater supply) is fed to the grid of V_1 which roughly squares the sine wave, the

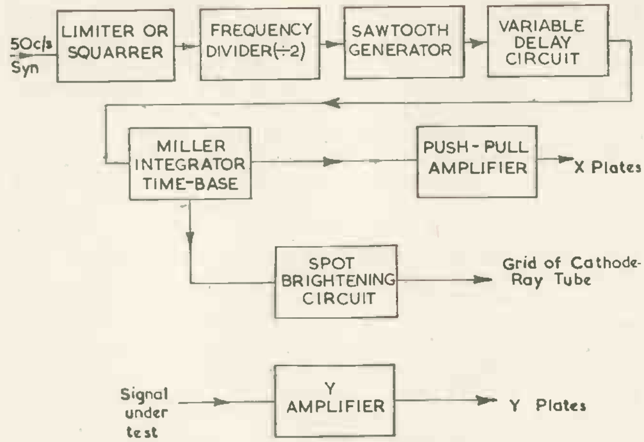


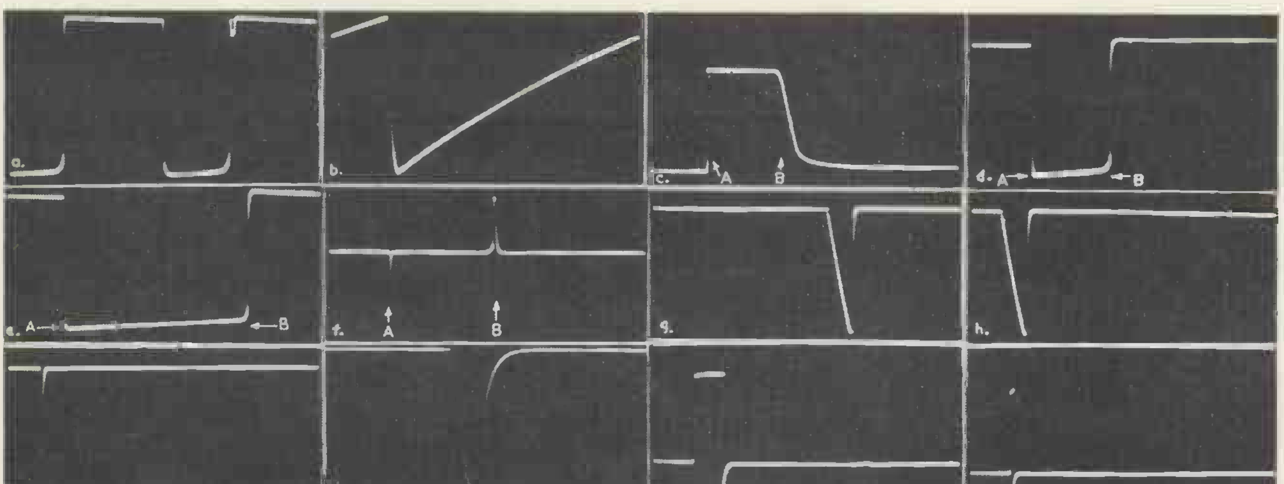
Fig. 5. Block diagram of waveform display apparatus

process being completed by valve V_2. The output from V_1 is shown in Fig. 7(a), taken on a 25c/s time-base. When it is desired to operate from pulses the "pulse input" terminal is used which feeds through C_1 and S_1, S_2 and S_3. With positive pulses the switch is placed in position (2) and the signal is fed to V_1. With negative pulses the switch is placed in position (3) and the signal is fed to V_2. In both cases the pulse is limited in amplitude so that a constant amplitude positive pulse is fed to the frequency divider circuit.

The next section is the frequency divider composed of valves V_3, V_4 and V_5. When the positive pulse from V_2 is applied to V_3 and V_4 the latter conducts and C_3 and C_4 are charged to voltages depending on their capacitances. At the end of the pulse the potential of V_2 falls and C_3 is discharged through V_3, but C_4 remains charged, as V_4 is non-conducting. On the next pulse C_3 is recharged and another charge (not equal to the first) is given to C_4, increasing its potential. This potential is arranged (by suitable adjustment of the cathode potential of V_5 by potentiometer R_8) to make V_5 conducting. Valve V_5 is connected as a blocking oscillator so that once conduction starts the grid

Fig. 7. Waveforms at various points in waveform display apparatus. The oscillograms are taken with a 25c/s time-base

(a) Anode voltage of V_2.
(b) Cathode voltage of V_7.
(c) Anode voltage of V_8. A fixed side of pulse, B variable side of pulse.
(d) Anode voltage of V_9.
(e) Anode voltage of V_9, different setting of line selector R_{16}.
(f) Grid voltage of V . A fixed pulse and B variable pulse.
(g) Output voltage from V_{15}, lowest speed setting on high-speed range.
(h) As (g) but different setting of line selector R_{16}.
(i) Output voltage of V_{15}, highest speed setting on high-speed range. Line selector setting as (g).
(j) As (i) but time-base expanded about nine times to show shape of "pulse".
(k) Brightening pulse output from V_{21}, lowest speed setting on high-speed range (as g).
(l) Brightening output from V_{21}, highest speed setting on high-speed range (as i).



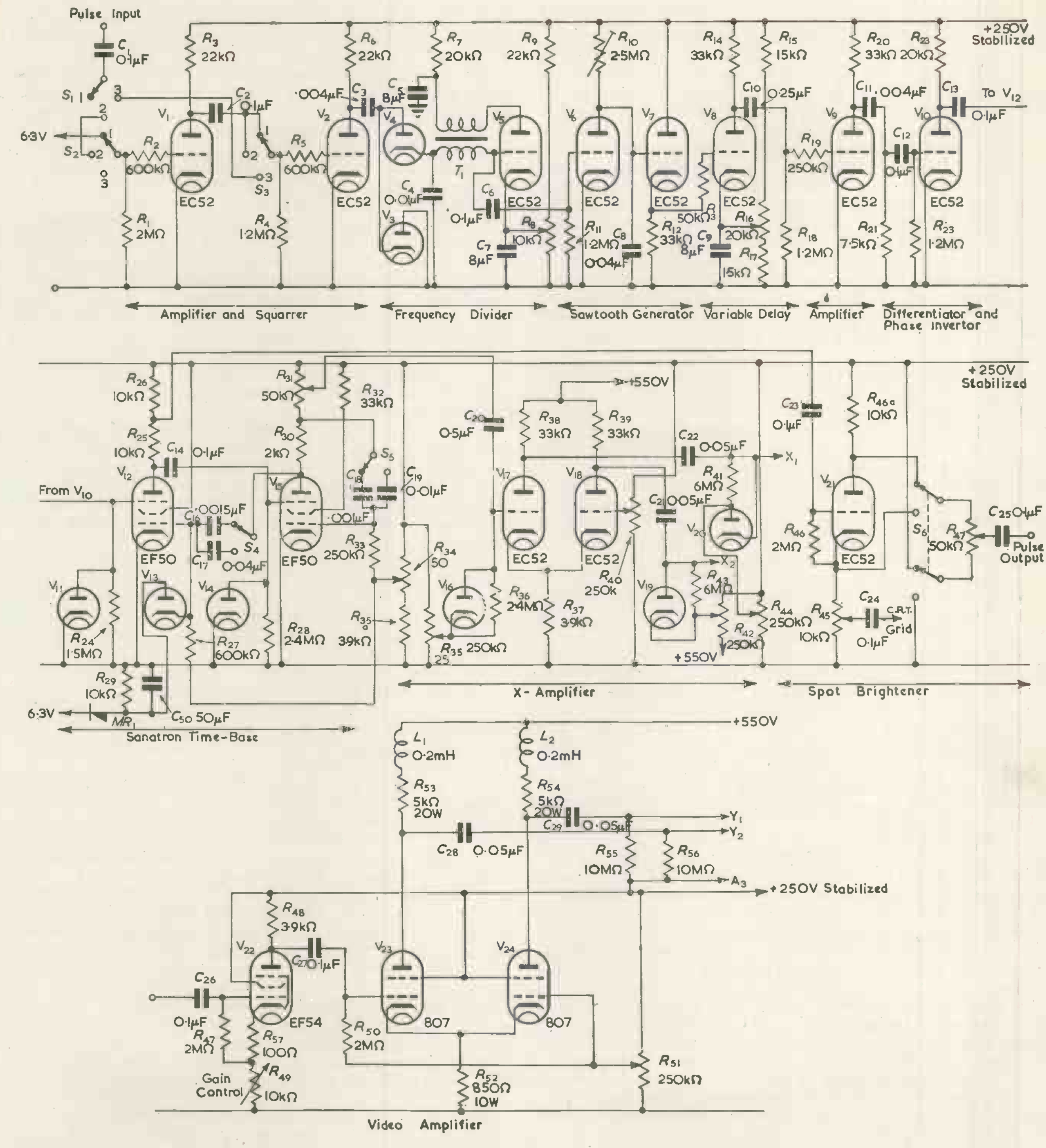


Fig. 6. Circuit of waveform display apparatus

is driven positive by the action of transformer T_1, and capacitor C_4 is discharged, ready to receive the next pulse. The result is a pulse through V_5 every other pulse of the input. The positive pulses on the grid of V_5 (at 25c/s) are fed through C_6 to the grid of valve V_6, which acts as a driven time-base. During the period between pulses C_8 is charged through R_{10} but when the positive pulse is applied to the grid of V_6, C_8 is rapidly discharged. The result is a sawtooth waveform (25c/s) across C_8 which is fed to V_7 which acts as a cathode-follower, producing a similar waveform across R_{12} (see Fig. 7(b)).

The voltage across R_{12} is fed to the grid of V_8 (through resistor R_{13}). The cathode of V_8 is biased by the potential divider R_{15}, R_{16} and R_{17} and this bias can be varied by R_{16}. At the start of the sawtooth waveform, V_8 will be non-conducting and will not conduct until the sawtooth voltage is approximately equal to the bias from R_{16}. After this V_8 will conduct and act as an amplifier of the sawtooth waveform until the grid goes positive, when the anode current will remain approximately constant. The result is a portion of the waveform on the anode of V_8 (reversed in phase), the portion depending on the bias from R_{16}. An oscillogram of the anode voltage of V_8 is shown in Fig. 7(c). Edge A of the pulse corresponds to the flyback and edge B can be varied by variation of the bias on V_8 by R_{16}. This circuit, therefore, produces the variable delay. The resistor R_{16} acts as the line selector, selecting the line (or lines) required. The maximum phase shift is not quite 360° due to the flyback, but it is sufficient for most purposes. The variable edge of the pulse is now sharpened by amplification and limiting in V_9. The output from V_9 for two different time delays (two positions of R_{16}) is shown in Fig. 7(d) and 7(e). The output from V_9 is now differentiated, by C_{11} and R_{21}, giving the result shown in Fig. 7(f), the positive pulse (B) being variable in phase. The negative pulse (A) is removed and the positive pulse reversed in phase by valve V_{10}, the result being a sharp negative pulse which can be varied in phase.

The variable phase negative pulse is now used to trigger a special time-base (modified sanatron) composed of V_{12} and V_{15}, together with the diodes V_{11}, V_{13} and V_{14}. The time-base operates in the following manner:—

At the end of a negative pulse on g_3 and g_1 of V_{12} the valve becomes conducting and its anode potential falls. This fall of potential is communicated to g_3 of V_{15} cutting off its anode current. Valve V_{15} acts as a Miller integrator and, with no anode current flowing C_{18} or C_{19} charge up to full H.T. potential due to grid current (g_1) of V_{15}. The negative pulses from V_{10} are fed to g_3 of V_{12}, the pulses being D.C. restored by V_{11}. The negative pulse cuts off the anode current of V_{12} causing its anode potential to rise, this rise of voltage being fed to g_3 of V_{15} (V_{14} acting as a D.C. restorer) causing the valve to conduct. The initial drop in the anode potential of V_{15} is fed to g_1 of V_{12} (through C_{16} or C_{17}) so maintaining V_{12} cut off independent of the pulse on g_3. The fall in anode potential of V_{15} causes its own grid g_1 to go negative (due to C_{18} or C_{19}) and so the sudden rise of anode current is checked. The anode potential now falls as C_{18} (or C_{19}) discharges through R_{31}, R_{33} and R_{34} in an approximately linear manner (the normal Miller run-down of anode potential). During this fall of anode potential g_1 of V_{12} is maintained negative and cut off, but g_1 is prevented from going more than about 10 volts negative by the diode V_{13} which has its anode returned to a point of potential about 10 volts negative. Eventually the anode current of V_{15} cannot increase further and its anode ceases to go in a negative direction. This causes the bias of V_{12} to disappear, V_{12} conducts and its anode potential drops. This causes the anode of V_{15} to be cut off due to the negative pulse fed to g_3. This causes C_{18} or C_{19} to recharge and constitutes the flyback. The anode of V_{15} now remains at full H.T. until the next negative pulse on g_3 of V_{12}. It should be noted that the pulse starts the scan and not the flyback of the time-base. The speed of the scan is determined by the setting of R_{34} (which controls the voltage discharging C_{18} or C_{19}) and the position of switches S_4 and S_5 (ganged) which select two values of capacitance. The output from R_{31} is now used to feed the X plates, after passing through a push-pull amplifier. The output waveform from V_{15} is shown in Fig. 7 (g-j). Fig. 7(g) and (h) are taken with the maximum number of lines (approximately 35) on the high-speed position of S_4 and S_5, but with two different settings of the line selector R_{16}. Fig. 7(i) is the output corresponding to the minimum number of lines on R_{34} (approximately 2) where it will be seen that the flyback is longer than the scan, the scan being only 2/405 of the total time. Fig. 7(j) shows the same waveform on an expanded time scale where it will be noted that the scan is practically linear. The X amplifier consists of valves V_{17} and V_{18} with diodes V_{16}, V_{18} and V_{19}. Valve V_{17} is fed from V_{15} and cathode coupled to valve V_{18}. Since the width of the "pulse" fed from V_{15} varies (with the setting of R_{34}) it is D.C. restored by V_{16} to reduce the grid swing which V_{17} and V_{18} must handle. R_{35} and R_{40} are used to give suitable bias voltages to V_{17} and V_{18} respectively. The output from these valves is fed to the X-deflecting plates, through blocking capacitors C_{21} and C_{22}. Since the X plates are A.C. coupled, the varying width of "pulse" from V_{15} causes the picture to drift sideways on variation of the scan speed. This trouble is eliminated by D.C. restoring diodes V_{19} and V_{20}. R_{42} and R_{44} are used for picture centring and maintaining the mean potential of X_1 and X_2 at final anode potential to prevent distortion of the spot.

As mentioned earlier, it is necessary to brighten the spot during the scan period. This pulse is obtained from the anode of V_{12} (since its anode goes positive during the scan period), being fed to the cathode-follower V_{21}. The variable output from the cathode resistor R_{45} is fed through the high voltage blocking capacitor C_{24} to the grid of the cathode-ray tube. The normal brilliance control is set so that the spot is just extinguished and then R_{45} adjusted to give sufficient brilliance. Fig. 7(k) shows the pulse obtained with a setting corresponding to 7(g) and 7(l), the pulse corresponding to 7(i).

In many cases it is desirable to brighten or darken the corresponding lines on the television set or monitor, which are being selected by waveform display apparatus. This may be done by feeding this same pulse to the grid (or cathode) of the television tube. Such a pulse of variable magnitude is obtained from R_{47}, its polarity being determined by the position of switch S_6.

The remaining portion of the equipment is the video amplifier to feed the Y-deflecting plates. This amplifier is required to give a large output and have good frequency response. V_{22} acts as a preamplifier with variable gain by means of R_{49}. This valve then feeds V_{23} and V_{24} as a cathode coupled amplifier with inductance compensation in the anode. On the maximum sensitivity position a 0·25 volt R.M.S. input gives a trace 1 inch high (peak-to-peak) and the gain can be reduced by a factor of approximately 80 by the gain control R_{49}. This amplifier is flat to 1Mc/s and drops to about 30 per cent at a frequency of 2Mc/s. This is quite sufficient for most purposes.

As has already been stated a high voltage tube is required unless the tube is to be viewed under weak illumination by a single person. Accordingly an ACR1 tube with about 5kV final anode potential is used. The tube power supply is conventional and not shown on the diagram. In order to reduce the "jitter" on the screen a conventional 2 valve stabilizer feeds H.T. to all the valves, except those in the X and Y amplifiers, which are fed with the input to the stabilizer. The power supply and stabilizer are not shown on the diagram. For simplicity in the diagram single valves have been shown. Apart from the diodes, single valves were actually used (as they were available) but the size of the equipment could be reduced by using miniature double triode valves. Most of the valves are not critical and any triode of similar characteristic is suitable.

With this equipment it is possible to view from two to about 250 lines and to pick out any portion required. Since the phase delay circuit does not cover quite 360° it would appear that there would be a dead section which could not be viewed. This is overcome by operating switch S_1, S_2 and S_3 for a brief instant, so that the frequency divider operates on the "other" cycle. It is pure chance which cycle the divider operates on.

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(To be continued)

The Investigation of Ionospheric Absorption by a New Automatic Method

(Part 2)

Measurements on Oblique-Incidence Broadcast Signals

By J. B. Jenkins*, M.Sc.

The method of ionospheric investigation using oblique-incidence broadcast signals is discussed, and it is shown that certain parts of the equipment described in Part 1 may also be used to make automatic measurements of this type. The equipment produces greatly improved records. Its use in the investigation of ionospheric winds is forecast and its general value as a curve-smoothing device is anticipated.

IN Part 1 equipment was described which automatically measures pulse amplitudes and produces a record consisting of discrete recordings at one minute intervals, each recording being proportional to the summation of all pulse amplitudes received during that minute period.

Observations are carried out on the variation of signal strength from a distant broadcast station to obtain information on the ionosphere; experiments have been carried out using parts of the new equipment to see whether they might also be used in this type of measurement. These experiments have been successful and it is shown that records are obtained which are superior to the records obtained using the existing method of measurement.

An important problem in ionospheric research is concerned with the determination of the correlation existing between echo amplitude measurements by the vertical-incidence pulse method, and measurements of signal strength at oblique-incidence from a distant broadcast station. It is shown that if the complete equipment described in Part 1 is applied to vertical-incidence pulse measurements and if simultaneous measurements, using equipment to be described, are made of signal strength from a broadcast station, then the nature of presentation of the results is such that the discrete recordings obtained from both equipments may be directly compared.

It is foreseen that the method described in this article may be applied to measurements of winds in the ionosphere and a brief description of its possible application in this field is included.

The Present Method of Measurement of Signal Strength Variations Received from a Broadcast Station

In order that oblique-incidence measurements may be related to vertical-incidence pulse measurements it is necessary that the frequencies are also related. Thus:

If f_o is the oblique-incidence broadcast radio frequency,
f_v is the radio frequency of the vertical-incidence pulse-modulated signals,
and θ is the angle of incidence of the oblique wave at the reflecting layer,
then, $f_v = f_o \cos\theta$.

It is usual to tune a receiver to a broadcast station at which strong signals are received, i.e. to a frequency f_o, and then knowing the location of the broadcast station and the height of reflexion, θ may be calculated and the equivalent vertical-incidence frequency f_v may be determined. Vertical-incidence measurements are then made at a frequency f_v as described in Part 1.

To measure the variations of oblique-incidence signals a receiver tuned to frequency f_o has its D.C. fluctuating output continually recorded on a pen recorder. A typical record is shown in Fig. 11.

In analysing this record an operator would divide it into small intervals of time of say one minute, and he would then estimate the mean values over these short periods. However, the variations might be so rapid that an operator could not approach the analysis of such a record with the confidence that the results he obtains would be accurate. The method of analysis is obviously tedious and the results derived may suffer from error.

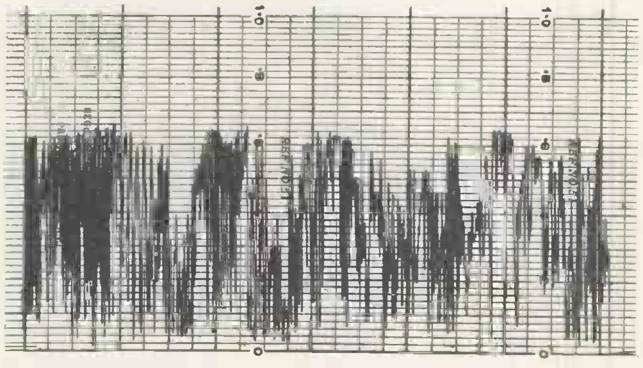


Fig. 11. A typical record obtained by continuously recording the receiver output

The New Method

Since an operator is not interested in the short term variations that occur, much of the information presented on the record will be unwanted.

If, however, the fluctuating D.C. signal from the receiver is fed into an integrator circuit whose output is recorded at one minute intervals (with provision made for resetting the integrator after the recording has been made), discrete recordings are obtained which represent the summation of all the D.C. levels fed to the integrator over a minute period. The integrator thus functions as a smoothing circuit producing an output at minute intervals which represents the mean receiver output over that minute period.

In order to carry out these new automatic measurements the appropriate circuits required are:

1, the receiver; 2, the integrator circuit; 3, the integrator supply circuit; 4, the timing circuit.

The corresponding units are described in Part 1 and were shown in Figs. 4(a) and 4(b).

Figs. 12(a) and 12(b) are typical records obtained simultaneously using the new method of measurement and the

* *University College, Swansea.*

original continuous method of measurement respectively.

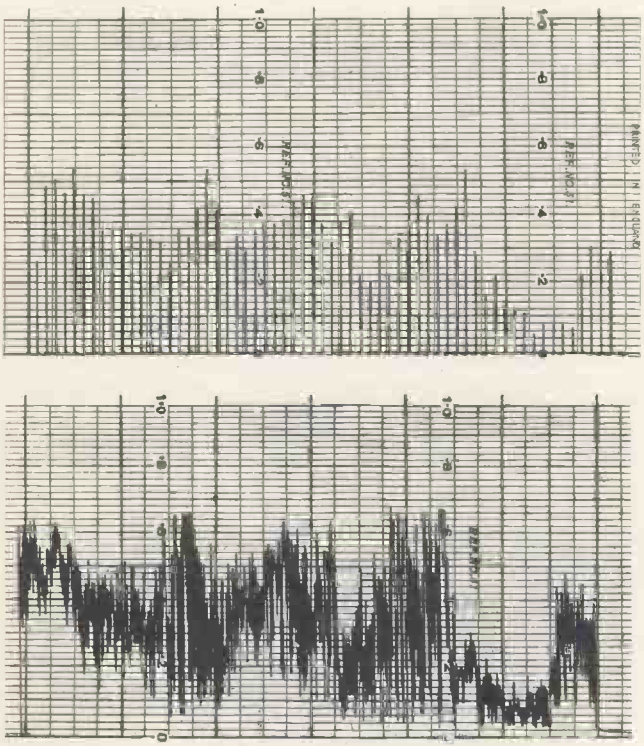
It will be seen that Fig. 12(a) is far simpler to analyse than Fig. 12(b) and no skill at interpretation of the mean value is necessary. The accuracy of analysing the new type of record is only limited by the accuracy with which each recording may be measured.

Correlation Between Vertical-Incidence Pulse Measurements and Oblique-Incidence Broadcast Signal Measurements.

In order to determine the correlation existing between the two methods, two instruments are necessary. These are:

(a) the apparatus described in Part 1 for the vertical-incidence pulse measurements.

(b) the appropriate circuits, as explained previously, for the oblique-incidence measurements.



Figs. 12(a) and 12(b). Simultaneous records using the new method of measurement and the continuous method of measurement respectively

The same time switch may be used to operate both equipments.

Two records are then available and simultaneous recordings on each record may be compared. Since the two instruments are synchronized by the same time switch, this obviates the necessity for making frequent timing indications. If mean values over a long period are to be compared, the mean values for the longer period may easily be deduced arithmetically from the records.

The Measurement of Ionospheric Winds

Investigations of ionospheric winds may be carried out using either vertical-incidence pulse measurements or measurements of broadcast signals at oblique-incidence. In either case it is usual to record signal strength at three sites. A steady wind giving rise to a uniform drift of the ionosphere will cause time displacements between the three records. If time displacements between peak signals on the three records are measured, the direction and velocity of the wind may be calculated. The calculation is simplified if the sites are at the corners of a right-angled triangle.

It is possible that the new method described will find application in this field of measurements, and this would involve the use of three instruments. The method would be particularly useful where the displacement times involved are long compared with an integration period of one minute. For shorter displacement times the integration period could well be reduced below one minute. The method allows instantaneous observation and the recordings can be synchronized by a time switch common to the three instruments.

Conclusions

In Part 2 the automatic measurement of signal strength from a distant broadcast station has been described and it is shown that the method might be extended to measurements of ionospheric winds.

Although this article is concerned chiefly with problems relating to radio propagation, the method described can be applied to any problem related to the recording of a continuously varying D.C. signal. The method has definite advantages where the mean value of a variable quantity is required (assuming this quantity can be resolved as an electrical voltage).

Acknowledgments

Mr. Jenkins would like to thank the Council of the University of Wales for the award of a post-graduate studentship. The authors are indebted to Dr. W. J. G. Beynon and Mr. K. Davies for their helpful discussions on radio propagation. They would also like to thank Dr. Beynon for his generous granting of facilities for testing the equipment.

A Pile Period or Reactivity Meter

By T. E. Burnup* and J. H. Bowen*

THE density of neutrons at a particular point within an atomic pile changes with time unless an exact balance is maintained between the rate of reproduction of fresh neutrons, and the rate at which neutrons are absorbed in control rods inserted in the pile for that purpose. The error existing in this balance is known as the pile reactivity, being positive or negative according to whether the resulting rate of increase of neutron density is positive or negative. It is denoted by the symbol "δk" and the measurement of δk is of some importance in pile control.

If δk has a constant value for a period of time, say about a minute, the resulting neutron density follows the law:—

$$n = n_0 e^{\omega t}$$

where n = neutron density at the point under consideration at time t,

n_0 = neutron density at initial instant,

ω = a function (invariant with time) of the reactivity δk.

Thus δk is measured by experimentally determining ω in the above equation. This may be accomplished continuously, so that ω, and thus δk through a conversion chart, is continuously displayed. This is most convenient for normal operating practice; but for special purposes, e.g. checking the relative absorbtion powers of different materials, a "spot check" method is more accurate. The

* *Atomic Energy Research Estab., Harwell.*

procedure then is to measure the time taken for n/n_0 to achieve some convenient ratio, say "a".

Then $a = e^{\omega t}$ or $\omega = 1/t \log_e a$.

If a is chosen equal to e, then we simply have $\omega = 1/t$. If a more conveniently set up ratio of 2 is chosen,

$$\omega = 1/t \log_e 2 = \frac{0{\cdot}692}{t}$$

The "discontinuous period meter" thus falls into three parts:—

(a) The primary measuring element for determining the neutron density at a point.
(b) The instrument for measuring the time interval.
(c) The device for measuring the neutron density ratios, which need only give a single indication when the ratio achieves the set value "a".

In addition to the equilibrium accuracies of these three sections of the instrument, the dynamic characteristics must also be discussed.

The primary measuring element normally takes the form of an ion chamber.

The equivalent circuit may be represented as shown (Fig. 1), in which a constant current generator produces a current i instantaneously proportional to the local neutron density in which the chamber is immersed. C represents the chamber capacitance together with associated cables and H.T. supply. R is the signal resistor, and V the signal voltage.

$V = i\dfrac{R}{1 + pT}$ in transfer function form, where $T = CR$.

or, if i is a step-function of current,

$V = i/R\ (1 - e^{-t/T})$

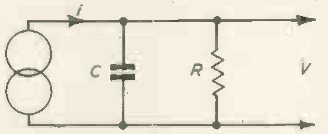


Fig. 1. Equivalent circuit

Appropriate values are:—

$R = 10^6\Omega$, $C = 1\,000$pF, $T = 10^{-3}$sec.

For the time being, we simply note that the lag in this circuit is of the order of milliseconds.

The interval timer should measure periods of up to 100sec with an accuracy of 1/100sec. This can be accomplished by:—

(a) Mechanical stopclocks. The requirement can be met by having a continuously running constant-speed section, with a clutch to engage and disengage the indicating hands as required. The lags for engagement and release of such a clutch are inherently different.
(b) A recording device such as photographing a C.R.O. trace using a reference waveform as a strobe. The inconvenience of this approach for operational use is obvious.
(c) A highly successful all-electronic clock has now been made using a Muirhead tuning fork type D418D as the reference source, and the dekatron (CV2199) as the combined counter and indicator.

Four dekatrons are used, counting scales of 10, the fastest showing intervals of 1/100sec and the slowest, 10sec periods, the longest period measurable thus being 99·99sec.

The dekatron circuit has been described elsewhere[1].

The ratio measuring device may take several forms.

(a) The ion chamber signal may be displayed on a pen recorder. Two contacts may be positioned along its scale to give the desired ratio. Now a dynamic relationship naturally exists between the input signal to a pen recorder, V_i say, and its actual reading V_o. This may be represented in a simplified form by

$\dfrac{V_o}{V_i} = \dfrac{1}{1 + pT_1}$ where T_1 is related to the friction and inertia of its component parts. Neglecting ion chamber lag, we have $V_i = kn_0 e^{\omega t}$ where k is some constant.

Solving the differential equation for V_o gives

$$V_o = \left[\frac{1}{1 + \omega T_1} e^{\omega t} + e^{-t/T_1}\left(1 + \frac{1}{1 + \omega T_1}\right)\right] n_0$$

so that, a sufficiently long time after connecting the recorder to V_i, we have

$$V_o = \frac{1}{1 + \omega T_1}\, e^{\omega t}$$

(By a sufficiently long time is meant, of order $2T_1$ say. T_1 for a typical commercial pen recorder having full-scale travel in about 2sec, would be about ⅓sec.)

Thus the ratio

$$\frac{V_o \text{ at time } t}{V_o \text{ at time } o} = n/n_0\ \frac{1}{1 + \omega T_1}$$

However, this difficulty is easily overcome, since

$$\frac{V_o \text{ at time } (t + t_1)}{V_o \text{ at time } (t_1)} = e^{\omega t} = n/n_0$$

which simply means that if both the contacts are positioned sufficiently far up the scale for the initial transient to be avoided, although the absolute values of the readings are in error, the ratio is correct for our purpose. The lag described previously may also be incorporated in this effect, and is similarly immaterial for the present purpose.

We must now take account of lags in making and breaking the contacts. If the lags of make and break are equal, then exactly as above, their effects are cancellatory. If, however, a difference exists, equal say to T_d, then the error in ω is given by T_d/t^2 approximately, i.e. it is greatest for small values of t.

To avoid an excessive increase in the neutron density while these measurements are being made, t is made small when the reactivity δk is greatest; thus larger values of δk are more liable to errors of measurement, which is unsatisfactory. Every effort must be directed therefore either to minimizing those lags or to making them consistent and equal.

(b) The ion chamber signal voltage may be compared with a reference voltage derived from a potentiometer. By taking two such reference voltages in the required ratio, the time interval may be measured between achieving equality with each. The relays, however, which detect this equality have a certain operating voltage, and a finite time lag. Since the rate of change of voltage is greatest at the higher reference level, the lag is not the same at both operations, with the same result as mentioned in (a).

(c) A comparison of voltages may be made as in (b), then the ion chamber signal resistor (R, Fig. 1) may be changed in the required ratio. The time interval is now measured between the voltage V twice achieving the same value. Thus the comparison relay is working under the same conditions at each switching operation, and should have consistent lags. Using a high-speed relay the lag is less than 10 milliseconds. The ratio of the signal resistors can be accurately predetermined, and they are chosen to have similar temperature characteristics and are mounted together in the same box. The reference voltage is derived from a neon stabilizer (85A1) which is adequate to give the required stability for a 100sec period. The error voltage actually passes through a D.C. (chopper-bar) amplifier before entering the comparison relay, this amplifier having an output of 10 volts for less than 100 microvolts input, and a long-term stability of better than 10 microvolts. The purpose of this amplifier is to make the rate of change of voltage at the relay sufficiently high, even for the slowest rates of change of pile power normally encountered.

Operational experience of using the equipment here described shows that time intervals up to 100sec may be consistently measured to an accuracy of 1/100sec, with a corresponding accuracy of measurement of δk.

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Stability in Negative Feedback Time-Bases

By A. B. Starks-Field*, B.Sc.

Negative feedback, being a useful means of ensuring linearity in time-bases, is often used. It does, however, sometimes cause some curious forms of instability, in addition to the more usual oscillation at high frequencies associated with negative feedback amplifiers.

This article deals with the tendency to produce a sequential operation in that alternate scans cover different ranges (double stroking). In a mild form it can destroy the interlace in a television raster even though the timing of the frame time-base may be perfect.

NEGATIVE feedback is becoming more and more frequently used to achieve the necessary linearity for many applications of time-bases as well as amplifiers. Many of these can be classed as direct integrating types in that the voltage or current required for the application is the integration of some constant voltage used in the system. There are several forms of instability which can occur in these systems, the most obvious being the case where, at some frequency, due to stray capacitances, the loop gain of the circuit treated as an amplifier becomes positive and exceeds unity, when the circuit oscillates at the frequency so defined. This type of instability is well known and can be dealt with by the standard methods applicable to amplifiers. There is, however, another type of instability which is much more obscure and takes the form of a sequential operation. This article is concerned with the discussion of this latter type.

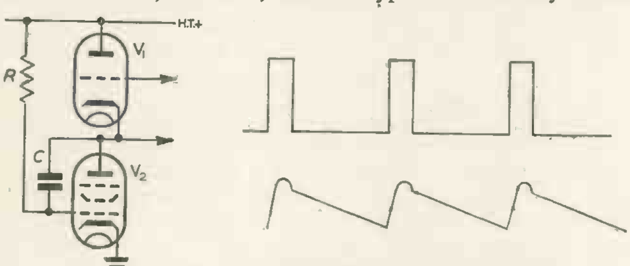

Fig. 1. Basic Miller integrator time-base with discharge valve V_2

As an example of the general type of circuit Fig. 1 shows a simple case. V_1 is a familiar form of Miller integrator which is arranged to provide a voltage function which is an integral with respect to time of the H.T. supply voltage, while V_2 is a charge valve, arranged so that it charges the feedback capacitor C during flyback, and establishes the initial conditions for the integration. During the flyback the capacitor C is charged through V_2 and the grid current of V_1, while during the scan it is discharged through the resistor R and the anode current of V_1. Since during the scan the grid voltage of V_1 alters by only a small amount, the voltage across R is constant and the capacitor current is constant, being approximately equal to E_o/R, where E_o is the H.T. supply voltage.

Therefore, since $E_a \approx 1/C \int I_o dt + V_g + K$

where E_a is the anode voltage of V_1

and V_g is the grid voltage of V_1

and K is some constant,

then $E_a \approx 1/C \int E_o/R \, dt + V_g + K$

$\approx E_o t/RC + K_1$

* *Marconi's Wireless Telegraph Company Limited.*

In the above equation, since E_a is defined at the start of the scan by the conditions dictated by V_2, K_1 can be evaluated (and therefore E_a) for any point on the scan.

This is the valuable point about this circuit; i.e. that the initial conditions of the scan are defined by V_1 and therefore the starting voltages of all the scans are equal.

Now considering any circuit in which the output voltage V_o is an integral of the reference voltage E_o, as expressed below:

$$V_o = K \int E_o dt - K_1$$

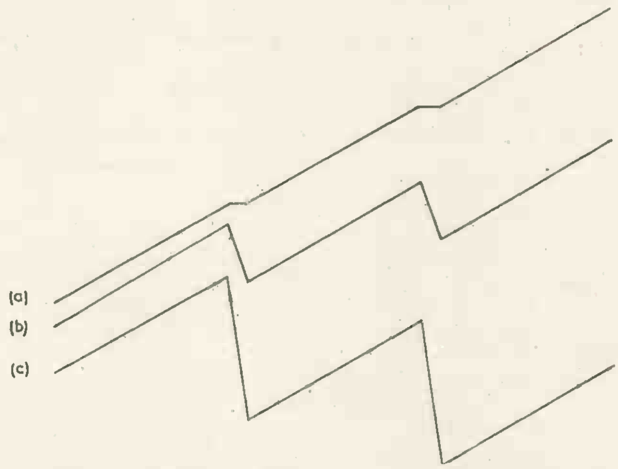

Fig. 2. Effects of interrupting the integration of a constant term by certain specified functions

(a) *Mere interruption,* (b) *return function less than result of integration,* (c) *return function greater than result of integration*

The value of K_1 can be anything without altering the fact that the output is an integral of the input. It is conceivable therefore that if a circuit were designed to evaluate the integral of a constant voltage and the process interrupted periodically to carry out some other ill-defined operation, then there are several possibilities which mathematically satisfy the problem, some of which are shown in Fig. 2. Fig. 2(a) shows the effect of merely interrupting the integration periodically and then allowing it to continue from the value attained. Fig. 2(b) shows a case where the integration is interrupted and a return operation carried out which is less than the amplitude of scan, while Fig. 2(c) shows the result of the return operation being greater than the amplitude of scan. In many circuits this sort of operation can occur during the first few cycles of scan, but in a stable system the circuit adjusts itself until the return function is numerically equal to the scan amplitude. There are, however, one or two unpleasant cases which can occur. For instance, stability may be reached only when the integrating ampilfier is running to a limit and is then violently non-linear. Another, and probably the most common, form occurs when the return function is itself a function of the final value which the integration attains, in which case sequential operations become possible. This sort of operation is sometimes present in television frame time-bases and the author has used the terms double or triple stroking for the sequences shown in Fig. 3(a) and (b) respectively. In case (a), after completing two successive

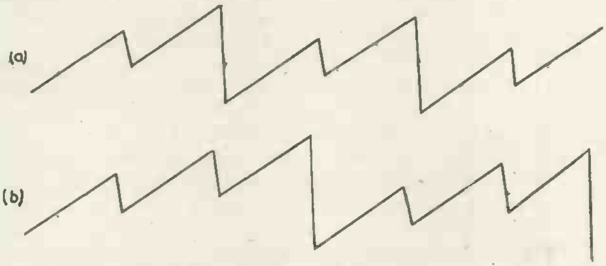

Fig. 3. Double and triple stroking waveforms, where return function is a funcion of the result of integration

dissimilar scans, the starting conditions of the third are equal to those of the first, and it is therefore evident that the circuit will continue to work in this condition. Fig. 3(b) shows the same thing happening for a sequence of three scans.

Any circuit which can be shown to have a stable sequence of this form, even though it may also be possible for normal operation to remain stable, must be regarded as a risky one to use because any slight disturbance may change the operation from one mode to the other, and very often circuits show a preference for the least desirable mode.

Fig. 4 shows an idealized schematic circuit for a magnetic deflexion time-base. It is assumed that the amplifier is capable of supplying current to the load in either direction. The issue is therefore not confused by the impossibility of a reverse current.

The following symbols will be generally used in the subsequent mathematical arguments.

$p = d/dt$
E_0 = The reference voltage for integration
I_c = current in the deflector coils
R_c = resistance of deflector coils
L_c = inductance of deflector coils
A_0 = internal magnification of the amplifier
V_c = voltage across deflector coils
E_p = voltage across primary of a transformer
E_s = algebraic sum of the voltages around secondary loop of transformer including load circuit.
i_1 = primary current
i_2 = secondary current
L_1 = primary inductance of a transformer
L_2 = secondary inductance of a transformer
M = mutual inductance between windings
T_s = period of scan in seconds
T_f = period of flyback in seconds

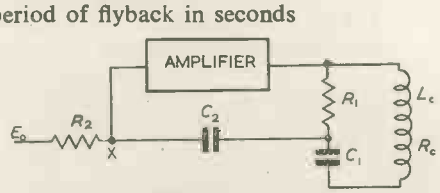

Fig. 4. Basic circuit for producing a deflexion current which is the integral of a constant input voltage E_0

Appendix 1 gives the mathematical argument which indicates that under certain conditions the deflector coil current can be the integral of E_0.

Now suppose we introduce at point x, in the circuit shown in Fig. 4, a voltage from a low-impedance source which is capable of cutting off the final valves and thus rendering the deflector coils with their associated stray capacitances free from the amplifier. (This assumption may require some justification when considering practical cases.) A further assumption is that C_1R_1 are chosen such that their damping influence on the deflector circuit is negligible. When this voltage is applied to the point x, the deflector circuit will start to execute a damped oscillation, and normally we will assume that the voltage is applied for a period equal to half the natural period of the deflector circuit. If the current value attained at the end of scan is I', then after the application of the voltage the current in the deflector circuit will become $-\alpha I'$, where α is the decrement ratio of the deflector circuit. If at this instant integration continues normally, then at the end of the next scan the coil current will be:

$$\frac{R_c}{C_2R_2}E_0T_s - \alpha I'$$

After the next one the current will be:

$$\frac{R_c}{C_2R_2}E_0T_s - \alpha\left[\frac{R_c}{C_2R_2}E_0T_s - \alpha I'\right]$$

and therefore, after n scans,

$$I_c = I_s[1+(-\alpha)+(-\alpha)^2+(-\alpha)^3 \;\ldots\; (-\alpha)^{n-1}]+(-\alpha)^nI'$$

where $I_s = \dfrac{R_c}{C_2R_2}E_0T_s$.

As n tends to infinity $(-\alpha)^n$ tends to zero, and thus I_c, at the end of the scan, tends to $I_s/1+\alpha$.

Fig. 5. Starting conditions of deflector-coil current which will occur in circuits of the type shown in Fig. 4. *Double stroking occurs, but the waveform eventually settles down*

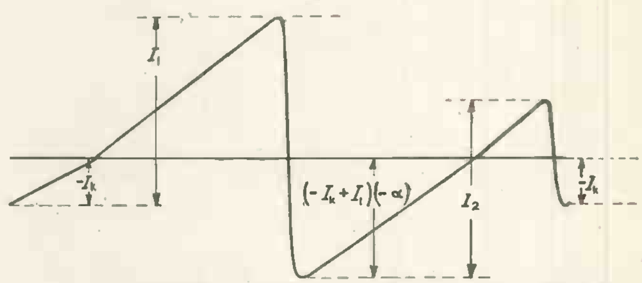

Fig. 6. Waveform produced by the circuit shown in Fig. 4 if non-linearity is present. *This will double stroke indefinitely*

If the circuit is started operating from zero, then it will be seen that the waveform starts according to that shown in Fig. 5, and if the conditions stipulated above are satisfied then the circuit is stable. It is, however, significant that the early scans exhibit double stroking, and it is possible therefore that if there is any dissimilarity between the pulse applied to x from one scan to the next a degree of double stroking may quite conceivably occur. A practical example of this is in television, where the phasing of the line and frame time-bases differs on alternate scans and a small amount of interference from the line circuit modifies the nature of the pulse. It may be an explanation why a frame time-base can be accurately synchronized in time and yet fail to interlace well.

Now consider the case where the process of integration is non-linear over its range of output, e.g. the multiplication term in front of the integration sign is a function of output voltage. This type of non-linearity is similar to that produced by the curvature of the valve characteristic, and is different from the case where the non-linearity is a function of time. Appendix 2 gives an approximate analysis of the problem.

Fig. 6 shows the waveforms which can result from such an arrangement. Let us consider a starting condition (i.e. after the previous flyback) such that the coil current $I_c = -I_k$. For the purpose of this argument it is assumed that the slope for negative coil current will be less than that for positive currents. In practice this would usually take the form of a steady curvature and not two discontinuous

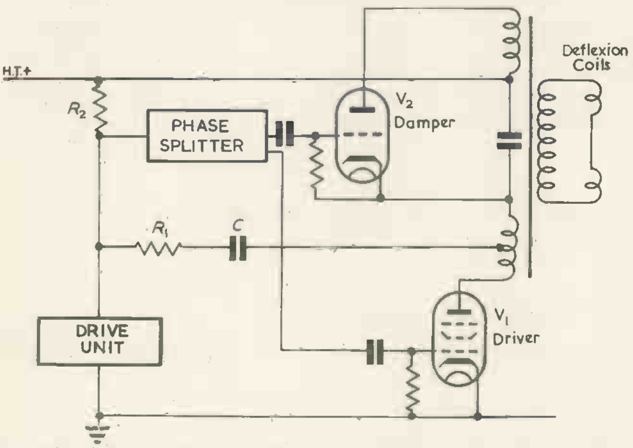

Fig. 7. Practical circuit which can, under certain conditions, double stroke indefinitely

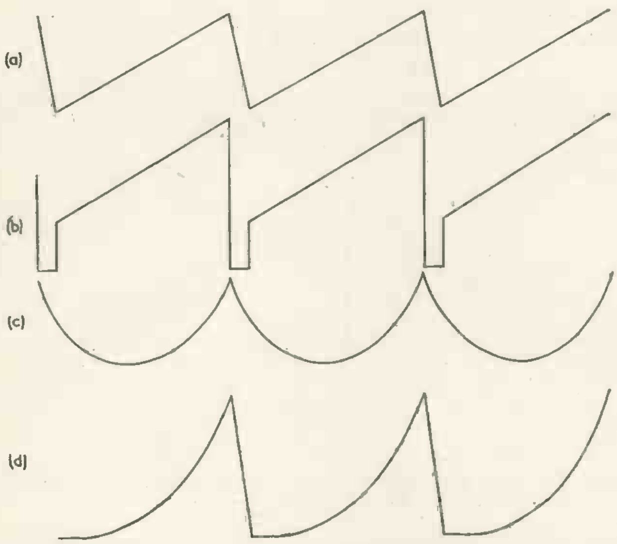

Fig. 8. Waveforms which occur in a transformer coupling to the deflector coils

(a) *Load current*, (b) *secondary voltage*, (c) *magnetizing current*, (d) *primary current*

linear portions. After the first scan under consideration the current would change to zero and then, at a greater rate, to some positive value $(-I_k + I_1)$, executing a total amplitude change of I_1. At this point the driving valves are entirely cut off and the deflector circuit is allowed to execute a half-cycle of free oscillation. If α is the decrement ratio (i.e. second half-cycle amplitude is α times the first; $\alpha < 1$), then after flyback the coil current $I_c = (-I_k + I_1)(-\alpha)$, and this may well have a larger numerical value than I_k. Therefore the coil current I_c is negative for a longer period of the second scan, and as a result the total current change (say I_2) will be less than I_1. I_c at the end of the second scan is then $(-I_k + I_1)(-\alpha) + I^2$. After the second flyback I_c would then become $[(-I_k + I_1)(-\alpha) + I_2](-\alpha)$.

If after this process $I_c = I_k$ (as may well be the case) then the process may be repeated indefinitely. This is a critical condition; it can be shown that it is possible for such a circuit either to run normally or to double stroke, and once it starts to double stroke it will continue to do so. Appendix 2 puts this more rigorously in mathematical form.

A practical line time-base which exhibits this tendency under certain conditions is shown in Fig. 7[1,2]. It consists of a booster-damper line time-base using a triode damper valve, with an overall magnetic Miller feedback loop consisting of C, R_1 and R_2. In this circuit, the integrating feedback is operative whether the driver valve V_1, the damper valve V_2, or both, are carrying current, since the feedback is fed via the phase splitter. Referring to Appendix 1 and Fig. 4 it will be seen that if the loop gain is large then the current in the deflector coils will be linear, for the feedback circuit is similar in theory except that the shaping components, corresponding to C_1, R_1 and C_2 in Fig. 4, are now included in the form of a series combination R_1C. If, however, the loop gain is inadequate, and the gain via the driver valve is less than that via the damper valve, then it can be shown the integral function has the type of non-linearity referred to above and the circuit may double stroke.

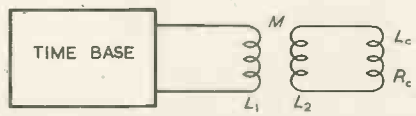

Fig. 9. Equivalent circuit of a coupling transformer and deflector coils

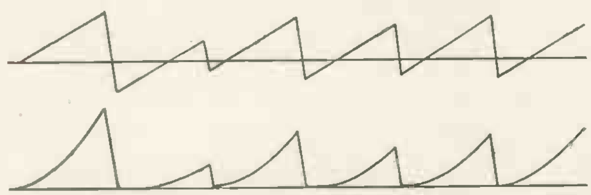

Fig. 10. Waveforms produced in a coupling transformer, for starting conditions, illustrating initial double stroking which may or may not disappear.

(a) *Secondary current*, (b) *primary current*

Another component which can cause trouble is the transformer coupling the valve circuit to the deflector coils. As this component has one or two properties apart from its influence on the stability of a circuit, a short analysis of its behaviour is desirable.

Fig. 8(a) shows the current waveform required in the deflector coils, (b) shows the corresponding voltage waveform required across the deflector coils, and (c) shows the magnetizing current in the primary of the transformer required to produce the necessary voltage waveform. The larger the primary inductance the less will be the magnetizing current, and therefore the total primary current will approach more and more the shape of the load-current waveform. Since this current must be supplied in most cases by a single-ended stage the current can never reverse and therefore the least average current supplied to the stage must be such that the waveform just touches the zero line. Under these conditions the average power fed to the stage is equal to half the peak-to-peak load current referred to the primary multiplied by the H.T. supply voltage. If, however, the magnetizing current is arranged to be one-half of the peak-to-peak load current referred to the primary the total primary current takes the form shown in Fig. 8(d). The peak-to-peak value of this waveform is little greater, and the average value is very much lower, than before. This results in an improvement in efficiency and is a desirable condition, but unfortunately in many cases such a design used in a negative-feedback circuit is prone to double stroking, as will be subsequently shown.

Appendix 3 gives an approximate mathematical treatment of the problem, showing how the tendency to double stroke is a function of the transformer parameters. The method of approach is to assume that the feedback circuit will ensure that the coil current increases linearly from whatever initial value exists at the start of scan, and that during flyback the primary current is made to decay according to a definite law to a small value. The waveforms shown in Fig. 10 give an indication of the process, (a) being the coil current and (b) being the primary current. The result is that, during the scan, from an initial value of zero, the load current builds up to the specified peak and the primary current then has to be built up to the referred value plus the necessary magnetizing current. At flyback, however, nearly all the primary current is cut off, with the result that the current change in the secondary circuit is that of the load current plus the magnetizing current referred to the secondary. This means that the next scan starts from a current value in the coils which may be equal to and of opposite sign to that which existed at the end of the scan. In a similar way to that of the previous case a sequence of two dissimilar scans can result in a starting condition for the third scan being equal to that of the first.

In the result of Appendix 3 $(R_c T_s)/(L_c + L_2)$ must be made less than unity. In practice it has been found that many circuits are stable which do not pass the above test, but this is probably due to the fact that the approximations are only partially justified. The inclusion of the neglected

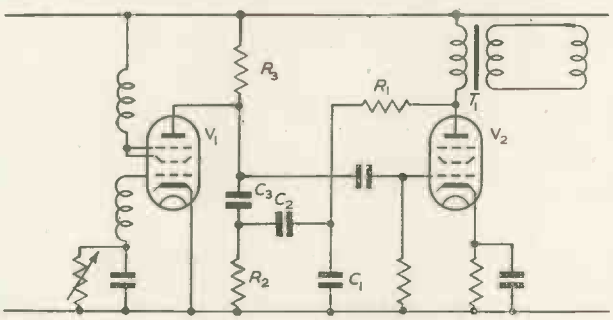

Fig. 11. A conventional fed-back transformer-coupled time-base circuit

terms in the equations result in very complicated series which are difficult to interpret. Other factors such as hysteresis and eddy-current loss may also contribute to stability as their effect can often be simulated by resistance included in the primary circuit. It is interesting to note that the only significant assumptions that have been made are that the feedback will ensure that the coil current is linear while during flyback the primary current shall decay to zero. No sources of non-linearity such as valve or magnetization characteristics enter into the question.

The circuit shown in Fig. 11 is given as an example of a frame time-base which is feedback controlled, and will be used to justify some of the assumptions made. It can be shown that to a first order the primary voltage of the transformer T_1 is a reasonably accurate replica of the voltage across the secondary. If then R_1 and C_2 have a time-constant equal to that of the deflector coils the waveform appearing at the junction of R_1 and C_1 is similar to that appearing across the resistive component of the deflector coils. If the junction of R_1 and C_1 were connected directly to C_3 then the circuit would take the form of a Miller integrator, except that the feedback ensures that the sawtooth wavetorm is produced at the junction point of R_1 and C_1. Since this waveform is similar to that of the voltage across the resistive component of the deflector coils, and therefore that of the deflector-coil current, then this latter current would also have a sawtooth form. This argument, however, is only true if the gain of the stage is large, when the voltage across R_3 is constant and the charging current is constant. However, with most television frame time-bases the variation of grid voltage over the scan is quite appreciable and therefore the voltage across R_3 (and thus the rate of change of deflector-coil current) decreases towards the end of scan. By including R_2 and C_2 it can be arranged that the effective amount of feedback decreases towards the end of scan and thus ensures linearity[3]. It is reasonable to suppose therefore that the feedback circuit will ensure that the secondary current is linear with respect to time so long as the output valve is working within its capabilities. Also when the blocking oscillator valve V_1 conducts the output valve is cut off for the period of the flyback and therefore the primary current must be zero except for any current in R_1C_1. It is indeed unfortunate that this type of circuit has the characteristic of instability because apart from the danger of double stroking it is well capable of ensuring adequate linearity with a comparatively small transformer, with the corresponding reduction in cost and, paradoxically, an improvement in efficiency. Probably the solution lies in some form of limiting circuit on the secondary side such that double stroking is discouraged. The author has known several circuits which behaved quite well until some interfering pulse caused them to change their mode, and they could only be returned to normal either by turning the amplitude to maximum or by desynchronizing.

By increasing the scan amplitude to maximum, the driving stage is operated to both limits, thus ensuring that both the starting and finishing scan currents are well defined and equal from scan to scan, and causing double stroking to cease. Desynchronizing has a very similar effect in that the scan time is longer, and therefore the scan amplitude is greater. The time-base cannot normally be run under these conditions, however, because of non-linearity at the beginning and end of scan, and because the maximum scan available must exceed that normally used, to allow for valve ageing, etc.

In general, it would appear that double stroking can, and almost certainly will, occur during starting in any circuit in which the flyback function is dependent for its starting conditions on those existing at the end of scan, and is maintained linear irrespective of starting conditions. The methods of establishing whether or not the circuit constants are such that it will occur are very complex, and in most cases approximate, but the general process of carrying out complete cycles from points of equal starting conditions seems to be the only logical method of showing that double stroking can occur, and it may well give a clue as to what must be done to prevent it. The problem, as was pointed out earlier, will obviously have a bearing on the accuracy of interlace[4,5].

Acknowledgment

In conclusion, the author wishes to express his thanks and appreciation to Marconi's Wireless Telegraphy Company Limited for permission to publish this article.

Appendix 1

Analysis showing that the deflector-coil current is the integral of a constant input voltage E_0.

Referring to Fig. 4:

$$I_c = \frac{V_c}{R_c + pL_2} \qquad \ldots\ldots\ldots\ldots (1)$$

$$V_c = \frac{V_c\ 1/pC_1}{R_1 + 1/pC_1}$$

where V_{c1} is the voltage across C_1.

$$\therefore V_c = \frac{V_{c1}\,(R_1 + 1/pC_1)}{1/pC_1} \qquad \ldots\ldots\ldots\ldots (2)$$

From Equations (1) and (2):

$$I_o = \frac{V_{o1}(R_1 + 1/pC_1)}{1/pC_1(R_c + pL_o)}$$

$$= \frac{V_{o1}(pC_1R_1 + 1)}{R_o(p\,L_o/R_c + 1)}$$

If then C_1R_1 is made equal to L_o/R_o then:

$$I_o = \frac{V_{c1}}{R_c} \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

Let V_x be the voltage point at x, then $V_o = -A_oV_x$.

From (2):

$$-A_oV_x = \frac{V_{o1}(R_1 + 1/pC_1)}{1/pC_1} \quad \ldots\ldots\ldots\ldots (4)$$

Assuming that the amplifier does not load the point x, i.e. I_2, the current in R_2, flows into C_2.

$$I_2 = \frac{E_o = V_x}{R_2} = \frac{V_x - V_{o1}}{1/pC_2} \quad \ldots\ldots\ldots\ldots (5)$$

Substituting Equation (4) in Equation (5):

$$\frac{E_o + \dfrac{V_{o1}(R_1 + 1/pC_1)}{A_o\,1/pC_1}}{R_2} = \frac{-\dfrac{V_{o1}(R_1 + 1/pC_1)}{A_o\,1/pC_1} - V_{o1}}{1/pC_2}$$

$$E_o/R_2 = pC_2V_{o1}\left[1 + \frac{(pC_1R_1 + 1)}{A_o}\left(1 + \frac{1}{pC_2R_2}\right)\right]$$

if A_o is large.

$$\text{Then } V_{o1} \approx \frac{E_o}{pC_2R_2}$$

$$\therefore I_o \approx \frac{E_o}{pC_2R_2R_o}$$

or in classical notation:

$$I_c = \frac{1}{R_2R_oC_2}\int E_o\,dt \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Appendix 2

Illustrating the possibility of continuous double stroking in a feedback line time-base. In this case let

$$I_c = (K_1 + K_2I_o)\int E_o dt$$

$$\therefore \frac{I_c}{K_1 + K_2I_o} = E_ot$$

Proceeding as previously indicated from the condition where $I_o = 0$.

After scan (1)

$$\frac{I_c}{K_1 + K_2I_c} = E_oT_s$$

Putting $E_oT_s = B$

$$I_c = K_1B + K_2BI_c$$

$$= \frac{K_1B}{1 - K_2B}$$

After flyback (1)

$$I_c = -\frac{aK_1B}{1 - K_2B}$$

After scan (2)

$$I_c = \frac{BK_1}{1 - BK_2} - \frac{aBK_1}{(1 - BK_2)^2}$$

After flyback (2)

$$I_c = \frac{aBK_1}{1 - BK_2} - \frac{aBK_1}{(1 - BK_2)^2}$$

and in general after scan $(n + 1)$:

$$I_c = \frac{BK_1}{1 - BK_2}\left[1 + \frac{(-a)}{(1 - BK_2)} + \frac{(-a)^2}{(1 - BK_2)^2} \ldots + \frac{(-a)^n}{(1 - BK_2)^n}\right]$$

if $(1 - BK_2) > a$ this series is oscillating and convergent
$(1 - BK_2) = a$ this series is oscillating
$(1 - BK_2) < a$ this series is oscillating and divergent

Appendix 3

Analysis of the conditions likely to cause double stroking due to the use of a transformer coupling in conjunction with a feedback time-base. The feedback is assumed to ensure that the deflector-coil current is linear during the scan and the flyback function is assumed to reduce the primary current according to an exponential law.

Referring to Fig. 9:

$$E_p = pL_1i_1 + pMi_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$E_s = 0 = p(L_2 + L_c)i_2 + R_ci_2 + pMi_1 \quad \ldots\ldots (2)$$

From (2)

$$i_1 = \left[\frac{L_2 + L_c}{M} + 1/p\,R/M\right]i_2$$

$$= \frac{L_2 + L_c}{M}\left[1 + 1/p\,\frac{R}{L_c + L_2}\right]$$

writing $\dfrac{L_2 + L_c}{M} = \sigma$ the effective transformer ratio

and $\dfrac{R}{L_2 + L_c} = \beta$ the secondary time-constant.

$$i_1 = \sigma(1 + \beta/p)i_2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$i_2 = \frac{i_1}{\sigma(1 + \beta/p)} \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

If at the start of the scan $I_c = I_o$ and it is assumed that the feedback circuit merely ensures that the deflexion current increases linearly, then we may say that during the scan:

$I_c = I_c = I_o + Kt$, where K is a constant giving the rate of change of current in amperes/second .... (4a)

$\therefore$ From Equation (3)

$$i_1 = \sigma[(I_o + Kt) + \beta(I_ot + Kt^2)] + K_o \quad \ldots\ldots (5)$$

where K_o is the initial primary current.

Postulating that the primary current must decay according to the law $A_1e^{-K_1t}$ during flyback, A_1 being the initial value and K_1 the time-constant decay, then applying Equation (4):

$$i_2 = 1/\sigma(1 + \beta/p)^{-1}A_1e^{-K_1t} \quad \ldots\ldots\ldots\ldots (6)$$

The solution of Equation (6) is in two parts:

the complementary function:

$$i_2 = A_2e^{-\beta t}$$

where A_2 is the arbitrary constant to satisfy the initial conditions,

and the particular integral:

$$i_2 = \frac{A_1}{\sigma(1 - \beta/K)}e^{-K_1t}$$

$$\therefore i_2 = \frac{A_1e^{-K_1t}}{\sigma(1 - \beta/K)} + A_2e^{-\beta t}$$

$\therefore$ at the end of flyback, time T_f

$$i_2 = \frac{A_1 e^{-K_1 T_f}}{\sigma(1 - \beta/K)} + A_2 e^{-\beta T_f} \quad \ldots\ldots\ldots (6a)$$

Writing $e^{-\beta T_f}$ as K_s

and $e^{-K_1 T_f}$ as K_p

at the end of flyback:

$$i_1 = A_1 K_p \quad \ldots\ldots\ldots (7)$$

$$i_2 = 1/\sigma \frac{A_1}{(1 - \beta/K)} K_p + A_2 K_s \quad \ldots\ldots\ldots (8)$$

Carrying out one complete cycle of scan and flyback and putting $KT_s = I'$, using Equation (4a):

$$i_2 = I_o + I' \quad \ldots\ldots\ldots (9)$$

using Equation (5),

$$i_1 = \sigma[(1 + \beta T_s)(I_o + I)] + K_o \quad \ldots\ldots (10)$$

At the start of flyback using Equations (6a) and (9),

$$i_2 = I_o + I' = 1/\sigma \frac{A_1}{(1 + \beta/K_1)} + A_2$$

using Equations (7) and (10),

$$i_1 = A_1 = \sigma[(1 + \beta T_s)(I_o + I')] + K_o$$

for conditions at start of flyback must equal those at end of scan.

$$\therefore I_o + I' = \left[\frac{(1 + \beta T_s)}{(1 + \beta/K_1)}(I_o + I') + \frac{K_o}{\sigma(1 - \beta/K_1)}\right] + A_2$$

$$\therefore A_2 = (I_o + I') - \left[\frac{(1 + \beta T_s)}{(1 + \beta/K_1)}(I_o + I') + \frac{K_o}{\sigma(1 - \beta/K)}\right]$$

At the end of flyback

$$i_2 = \left[\frac{(1 + \beta T_s)}{(1 - \beta/K_1)}(I_o + I') + \frac{K_o}{\sigma(1 - \beta/K_1)}\right] K_p$$

$$+ \left\{(I_o + I') - \left[\frac{(1 + \beta T_s)}{(1 - \beta/K_1)}(I_o + I') + \frac{K_o}{\sigma(1 - \beta/K_1)}\right]\right\} K_s$$

$$= \left\{\frac{(1 + \beta T_s)}{(1 - \beta/K_1)}(I_o + I') + \frac{K_o}{\sigma(1 - \beta/K_1)}\right\} K_p - K_s)$$

$$+ (I_o + I')K_s \quad \ldots\ldots (11)$$

and $i_1 = \sigma\left\{[(1 + \beta T_s)(I_o + I')] + K_o\right\} K_p \quad \ldots\ldots\ldots (12)$

For the following cycle start with:

$I_o = i_2$ as in Equation (11)

and $K_o = i_1$ as in Equation (12)

In most cases it is reasonable to assume that the primary current decays very nearly to 0, i.e. K_p is small and therefore K_o can be neglected as far as the subsequent scan is concerned.

Equation (11) may then be written:

$$i_2 = -\left[\frac{(1 + \beta T_s)}{(1 - \beta/K_1)}(K_p - K_s) + K_s\right](I_o + I) \quad . (13)$$

and Equation (12) may be written:

$$i_1 = \sigma[(1 + \beta T_s) K_p (I_o + I')] \quad \ldots\ldots\ldots (14)$$

$\left[\frac{(1 + \beta T_s)}{(1 - \beta/K_1)}(K_p - K_s) + K_s\right]$ may be written K'

$\therefore$ Equation (11) becomes

$$i_2 = K'(I_o + I') \quad \ldots\ldots\ldots (13a)$$

Starting then with $I_o = 0$

after the first cycle

$$i_2 = K'I'$$
$$i_1 = \sigma(1 + \beta T_s) K_p I'$$

after the second cycle

$$i_2 = K'I'(1 + K')$$
$$i_1 = \sigma(1 + \beta T_s) K (K' + 1)$$

after $(n + 1)$ cycles

$$i_2 = K'I'[1 + (K') + (K')^2 + (K')^3 \ldots + (K')^n] \quad \ldots (15)$$

$$i_1 = \sigma I'(1 + \beta T_s)K_p[1 + (K') + (K')^2 + (K')^3 \ldots + (K')^n] \quad \ldots\ldots (16)$$

Similarly at the end of the $(n + 1)^{th}$ scan

$$i_2 = I'[1 + (K') + (K')^2 + (K')^3 \ldots + (K')^n] \quad \ldots\ldots (17)$$

$$i_1 = I\sigma(1 + \beta T_s)[1 + (K') + (K')^2 + (K')^3 \ldots + (K')^n] \quad \ldots\ldots (18)$$

In the above equations

$$K' = \left[\frac{(1 + \beta T_s)}{(1 - \beta/K_1)}(K_p - K_s) + K_s\right]$$

Since K_s is small and may be neglected,

$$K' \approx \left[1 - \frac{1 + \beta T_s}{1 - \beta/K_1}\right]$$

K_1 is normally large compared with β since the flyback is short, and K' is therefore generally negative.

Referring back to Equations (15), (16), (17) and (18):

if $|K'| < 1$ the series will be oscillating and convergent

if $|K'| > 1$ the series will be oscillating and divergent.

A further approximation may be made by neglecting

$$\beta/K_1, \text{ when } K' \approx \left[1 - \frac{1 + \frac{R_o T_s}{L_c + L_2}}{1}\right] = -\frac{R_o T_s}{L_c + L_2}$$

$$\text{So for stability } \frac{R_o T_s}{L_c + L_2} < 1$$

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RADIO EQUIPMENT FOR PAKISTAN

Telecommunications equipment, made in Australia at a cost of £A600,000, is being supplied to Pakistan by the Australian Government in accordance with the Colombo Plan, under which Australia is assisting the development of Asian countries.

The radio communication apparatus, which will be used for the extension of the communications network between East and West Pakistan, as well as on overseas services, will shortly be shipped from Melbourne. Included are radio transmitters and receivers for the maintenance of traffic with ships at sea for both East and West Pakistan.

Made in Melbourne by Amalgamated Wireless (Australasia) Ltd., the equipment comprises five 30kW transmitters, 17 single sideband receivers, together with monitoring and test apparatus, and associated aerial systems; two 100 watt high frequency transmitters, and two 3 000 watt medium frequency transmitters, and associated equipment for communication with ships, are other specified units.

In addition Australia is also supplying broadcasting transmitters and ancillary equipment to Radio Pakistan at a cost of £A350 000. This equipment will be used for extension of general programme facilities, and particularly for broadcasting between East and West Pakistan. It will provide special interception facilities for Radio Pakistan, enabling the East Pakistan network to re-broadcast transmissions intercepted from West Pakistan. The items comprise two 10 000 watt short-wave transmitters for Lahore and Peshawar; three 10 000 watt medium frequency transmitters for Lahore, Dacca and Quetta; and two 1 000 watt transmitters for satellite stations.

Electrical Telemetering and Automatic Process Control

(Part 2)

By J. R. Boundy*, B.Sc., M.I.E.E.

ONE of the first large-scale plants to be completely controlled by the automatic process control equipment described in Part 1 of this article was an SO_2 extraction plant for the production of premium grade kerosene. The plant is in the Llandarcy National Oil Refinery of the Anglo-Iranian Oil Co., and it has been in operation for 18 months. This installation was the first plant to be controlled completely electronically in the world, and has run successfully since the initial commissioning, and is now operating well above the designed daily throughput.

The physical quantities being controlled are levels, pressures and flows. There are 17 controllers for the maintenance of a constant liquid level in the various columns and vessels, four controlling the flow of liquids and gases and three controlling pressures.

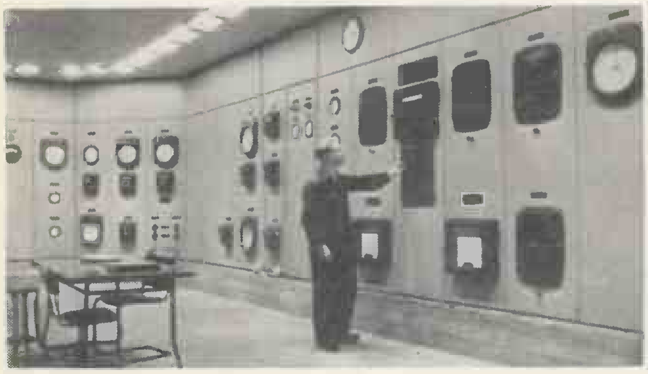


Fig. 8. Control panel for SO_2 extraction plant, Llandarcy

The standard practice in oil refineries up to the moment has been to use pneumatically operated control equipment. In these pneumatic equipments, the signals from the measuring point to the controller and from the controller out to the regulating unit, are air pressures. As plants have become larger and the need for centralized control becomes more obvious, the lag in transmission of these air pressures, as signals, becomes serious. Resort has therefore been made to a method of remotely setting these controllers; thus leaving the actual controllers locally on the plant, and bringing only the remote setting equipment into the control room. The replacement of these pneumatic signals and controllers by electrical equivalents obviously eliminates these difficulties and thereby reduces the number of units required.

This elimination of signal lags, due to transmission over a distance, gives the plant designer freedom to place the various control equipments in positions which are most suitable for the daily operation of the plant without adversely affecting the efficiency of the automatic control. This normally means that the designer will bring all his controls into a centralized control room, of which Fig. 8 is an example, leaving on the plant only those units which are essentially part of it, such as the measuring units and the control valves.

The designer may, with advantage, go one step further. He may wish to take advantage of the fact that one may divide the actual individual controllers themselves into two or more sections. In other words, because there are no mechanical linkages between various parts of the controllers, then one may, for example, divorce the control setting dials from the main components of the controller itself. An example of this was shown in the control console illustrated in Part 1. Here the setting dials are placed on the front of a console desk, while the main body of the controllers themselves placed in the back and wings of the unit. (See Fig. 9.) One may, of course, go further still, and place the controller main equipment in an adjacent apparatus room and rack mount the equipment. This "telephone exchange" technique is of great help in the maintenance of the equipment. Obviously once the freedom of design has been given, all sorts of combinations of layouts of equipment can result, such as graphic wall panels with setting dials in the diagram, etc.

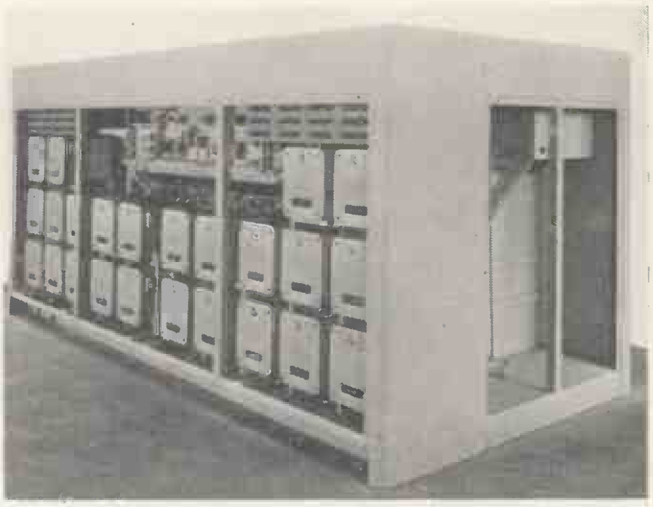


Fig. 9: Rear view of console control desk

This flexibility of the electronic equipment was of great advantage on the first large plant because it permitted compliance with all the accepted practices of pneumatic equipment and thus made the change of technique less obvious. The only really visual difference was the use of multicore telephone type cable, instead of the usual air lines of copper piping. The use of telephone type cable instead of copper piping does, of course, bring with it the further advantage of being able to wire completely the control panel or desk in the manufacturer's works. The panel or desk can then be taken to the site complete, lowered into position, and then the incoming cables terminated on the terminal blocks. This makes the work left to do on site

* *Evershed and Vignoles Ltd.*

very small indeed, and has, of course, very many advantages.

This plug-in technique is used on the main controller equipment itself; as will be seen in Fig. 10, the individual controller trays are slid into the controller boxes along the guides and carry on them a plug which mates with sockets at the rear of the controller case. This has two main advantages. When the equipment arrives on site, the trays can be plugged in at the last minute, minimizing the risk involved in the general handling of these large panels and desks. Secondly, during normal running, if a fault occurs in a controller, the mechanic need not attempt to locate the fault, he merely pulls out the suspected trays and replaces with spare trays, thus restoring the plant to normal operation in the minimum possible time. The suspected controller trays can then be taken to the quiet of the maintenance shop and repaired without interference by operating staffs, etc.

Fig. 10. Removal of trays of process controller

Simulator Unit

In order to assist the maintenance mechanic, a small electrical analogue was designed, Fig. 11, so that the controller trays when repaired can be fully tested under working conditions in the maintenance shop. This analogue simulates the conditions found on an actual plant. The operator can therefore return his repaired trays to the plant, knowing that they will be satisfactory in operation.

The standard regulating unit on the plant is simulated by using the moving-coil, shutter, and double photocell arrangement, described in Part 1. The simulation is reasonable because the photocell unit is a current bridge, and the magnitude of the current is determined by the difference in the light falling on the two photocells. If, therefore, a current is fed into a coil of this movement the output current from the photocell unit will bear a direct linear relationship to the current and will therefore simulate the ideal process regulating unit. This small regulating unit simulator is shown diagrammatically in the top left-hand corner of Fig. 11. It will be seen that if the output from the controller is fed into terminals G and H, then the position of the regulating unit will be indicated on the indicator and simulated by the movement of the shutter in front of the photocells. The current output from these photocells, which is simulating the liquid flow of a plant, passes round the circuit to modify the charge on capacitors C_1. These capacitors then act as the capacity of the vessel of the plant; their voltage will represent the level of liquid in the vessel. This level is then detected and transmitted to the controller by joining capacitor C_1 between the grid and cathode of valve V_1. The anode current of this valve then simulates the level of the liquid in the plant, and is indicated on indicator M_1 and passes through the standard electronic repeater unit. This standard repeater unit is interposed so that connexions may be made to the input of the controller in the standard method. These connexions will then complete the process loop.

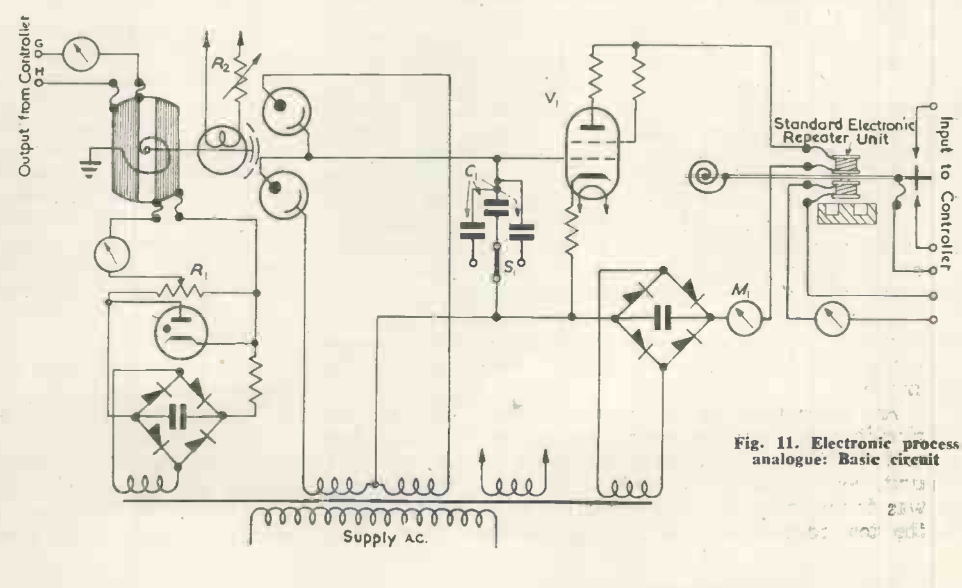


Fig. 11. Electronic process analogue: Basic circuit

The only other simulation still required is that of the loading on the plant. This would be most correct if it were arranged as a shunting resistor across the capacitors simulating the vessel because the resistance would leak away electrons similar to the liquid flow from a vessel. However, since the current output from the photocell bridge is very small (0-5μA) this resistor to shunt the capacitors would have to be extremely high, and not very practical. It was therefore decided to wind a second coil on the regulating unit simulator, and inject into this second coil a current which would represent the load on the plant. This current is obtained from the stabilized D.C. source and potentiometer R_1. Since the current passing through this second coil is arranged to be in opposition to the first coil, then the action will be to decrease the current flowing from the photocell bridge into the capacitor and thereby modify the charge of capacitor C_1. In fact, if this "load current" is greater than the current from the controller, the photocell bridge current will reverse and the voltage across the capacitor will start to fall instead of rise, thus simulating a falling level in the vessel.

The only other adjustment necessary on the simulator to assist testing of a controller is that which alters the effective size of the vessel. This is done in two ways. There is a coarse adjustment (S_1) which changes the size of the capacitor C_1, then there is a fine adjustment (R_2) which alters the flow of current from the photocell bridge by varying the intensity of the illumination from the electric bulb.

It will therefore be seen that sufficiently adequate simulation of a plant can be arranged so that adequate tests of the efficient operation of a controller may be made. This arrangement as it stands, of course, only represents a plant with a single capacity, but that should be sufficient to ensure that the faulty controller trays have been satisfactorily repaired.

Flame-Proof and Intrinsic Safety

One difficulty met in the introduction of electronically controlled equipment to process plants is the possible risk of explosion if there is a chance of an inflammable gas or vapour getting into the atmosphere surrounding the plant.

In fact, this is not an insuperable difficulty and can be met by compliance with certain regulations. In the past, since most of the problems arose through the installation of heavy machinery, such as motors, the solution could only be to flameproof the motors themselves. However, with electronic equipment, a second solution is possible. This is by complying with the intrinsically safe regulations. This is made possible in the case of electronic equipment because of the comparatively low amount of energy stored in the circuits connected to this equipment.

Because it is felt that the exact meaning of flame-proofing and intrinsic safety, is not sufficiently well known, the British Standard definitions of these terms are given below.

Flame-proof Enclosure

In accordance with British Standard 229:1946, a flame-proof enclosure for electrical apparatus, "is one that will withstand, without injury, any explosion of the prescribed inflammable gas that may occur within it under practical conditions of operation within the rating of the apparatus, (and recognized overloads, if any, associated therewith), and will prevent the transmission of flame such as will ignite the prescribed inflammable gas which may be present in the surrounding atmosphere".

Intrinsic Safety

In accordance with British Standard 1259:1945, the words intrinsically safe mean:

"(a) Applied to a circuit, denotes that any sparking that may occur therein in normal working and with the prescribed components is incapable of causing an explosion of the prescribed inflammable gas or vapour.

(b) Applied to apparatus, denotes that it is so constructed that when connected and used in the prescribed conditions any sparking that may occur in normal working, either in the apparatus or in the circuit associated therewith, is incapable of causing an explosion of the prescribed inflammable gas or vapour".

Construction of Equipment

A typical example of a flame-proof enclosure is that shown in Fig. 12. It will be seen that the two controller trays slide into a robust casting, the hinged door of which is closed by six bolts.

It will be noted that the hinged door and the main casting on which the door closes, have very deep flanges. By regulation this depth of flange, for equipments whose volume is greater than 100 cubic inches, must be at least one inch and must be flat to within 0·008in. The reason for this is to provide a cooling path for the flame created by any explosion taking place inside the main casting. In other words, an explosion inside the main casting must not create a larger explosion in the atmosphere surrounding a casting. Similarly any potentiometer spindles or through connecting terminals must have this inch path and 0·016in. clearances as a maximum. There are, of course, no practical difficulties in doing this, as these allowances are well outside the normal machining tolerances. It is therefore comparatively simple to arrange operating knobs outside a flame-proof enclosure which can move mechanically potentiometers inside the enclosure. Separate flame-proof terminal boxes must always be provided on the equipment to terminate the power supply connexions to the unit. In other words, one is not permitted to bring power supply connexions straight to the inside of a flame-proof enclosure.

At the same time as this enclosure was designed, the circuits coming from the measuring unit to the controller, and the circuit going from the controller to the regulating unit, were arranged to be intrinsically safe. No difficulty was found in doing this. It was merely necessary to realize the testing conditions and arrange to meet them. The testing conditions are that there must not be enough energy in the intrinsically safe circuit to ignite a gas when there are two coincident faults on the equipment. One of these faults is made on the external intrinsically safe leads and the other fault is created inside the flame-proof enclosure.

In the case of the electronic repeater circuit which forms the measuring unit loop it was assumed that the worst fault internally inside the flame-proof box would be an inter-electrode short-circuit in the valve. Therefore allowing for this, arrangements were made to limit the energy available in the outside circuit, even though it may be either short-circuited or open-circuited. This meant in effect that sufficient resistance had to be placed in the anode circuit so that when a valve was short-circuited, the amount of energy which could be fed by the H.T. supply into the external circuits, was restricted. In practice, the H.T. supply voltage was of the order of 160 volts, and it was only found necessary to put in anode and screen resistors on the pentode of a value of 3 600 ohms each. This limited the external short-circuit current to 80mA, which proved to be low enough, even allowing for several recorder movements in the external circuit. The authorities are prepared to issue an intrinsically safe certificate to cover a maximum number of inductive units such as recorder and indicator

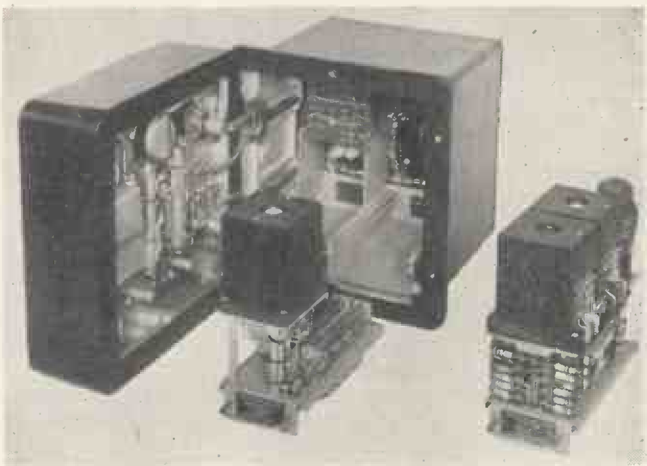


Fig. 12. Controller flameproof case with front opened and trays removed

movements in the circuit. This then gives to the user freedom to choose any number of recorders or indicators up to the maximum on the certificate and still keep within the regulation.

The result of this work means that if the atmosphere can become hazardous then no change need be made to any of the external cabling systems, presumably of the telephone type, nor to the measuring units or regulating units. All that would be necessary would be to enclose the two trays of the controller in its standard flame-proof housing. In other words, the only point at which the problem arises, is in the actual control room itself. Fortunately, the modern control room is now tending to be air conditioned for the benefit of the operating staff, and since this would eliminate the risk of hazardous atmospheres, then the need for flame-proof equipment in this room will disappear.

Performance

It is of interest that the equipments described in this article have been in operational use for some time. Individual controllers have been operating for periods up to three years in various industrial installations. The first large installation of these equipments was, as mentioned earlier in the article, on the SO_2 extraction plant at Llandarcy. In this plant all control was done by these electronic controllers. There are 24 in number, and they have now been giving very satisfactory service for a period of over 18 months. The plant is in fact running at a throughput higher than that for which it was designed. Although operating conditions are far from ideal for electrical equipment, i.e. fairly high concentrations of SO_2 in the atmosphere, etc., the electronic equipments are requiring very little maintenance indeed, and are now accepted as normal equipments by the maintenance staffs. It is interesting to note that because both the heating of the filaments of the electronic valves and their anode dissipation has been arranged to be smaller than that specified by the manufacturers the life of these electronic valves has been much greater than that normally specified. During the whole of these 18 months of continuous running, only one electronic valve has been replaced.

Acknowledgment

The author wishes to thank the Directors of Evershed & Vignoles Ltd., for permission to publish this article.

A New Digital Computor

The "401" electronic digital computor was exhibited at the Physical Society Exhibition last month. It is the first digital computor to be entirely conceived and built by a design team in a commercial firm, and the first "electronic brain" to be built on a full sub-unit principal, aiming at high reliability, low cost, quick production and flexibility of design. Technical papers describing the machine are being prepared.

"401" is a high-speed general purpose electronic digital computor, designed and built by Elliott Brothers (London) Ltd., under contract from the National Research Development Corporation. The machine and the rights in it are owned by the Corporation. It follows the lines of other computors in having a "store", an "arithmetic unit", a "control unit", an input device to take in the instructions and numbers

The complete computor (with the cabinet doors removed)

required to initiate a calculation and an output mechanism to record the results. "401" differs from other machines in the emphasis placed on the reduction of initial and maintenance costs by standardization and thorough design of a few basic circuits built in the form of plug-in packages.

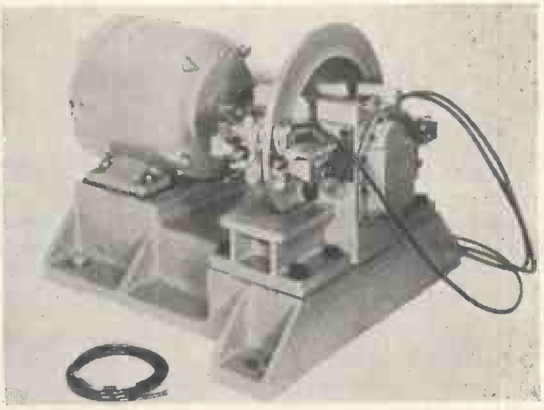
The installation comprises three units, a main cabinet 13ft by 2ft by 7ft 6in. overall, a test trolley and an operating trolley each 2ft 6in. by 2ft 9in. by 4ft in size. The main cabinet is in seven sections. Four of these house the operational part of the computor, the other three containing the power rectifier and stabilizers fuses and protective circuits, meters and air circulating fan.

The "arithmetic" and "control" functions of the machine are placed together in three sections (the logical sections) and are entirely in the form of plug-in packages. Common supplies are wired in standard form to all chassis. Signal wiring between packages in a section is by the shortest route. Connexions between sections are made "straight over" between directly opposing pins on paxolin boards.

The end section of the machine contains the store, an oxide-coated disk, 9in. in diameter, rotating at 4 500 R.P.M. The whole of the computor operates in serial binary mode at 3μsec digit time and digits are recorded and read on annular tracks on the store disk at a spacing (round the tracks) of 160 to the inch, corresponding to the 3μsec digit time. Recording and reading is by the same head. Timing waves for the computor circuits are derived from a "clock" track on the store disk. There are 8 recording reading heads in the machine exhibited, but a new store is being made with 23 heads. Each track stores 128 numbers of 32 binary digits each (about 10 decimal digits) so that the 8-track model stores 1 024 such numbers or instructions. The 23-track model will store nearly 3 000 "words".

The operating trolley carries a specially designed photo-

One of the chassis with three packages removed.



The magnetic dial store.

electric reader for the 5-hole teleprinter tape input, and a solenoid-operated electric typewriter for printing out results. The trolley also carries all the controls necessary for starting the machine from complete shut-down and for operating it.

The test trolley carries out monitor facilities for fault diagnosis. There are test sockets on the front of the plug-in packages so that in case of fault, using the display trolley, diagnosis should usually be possible without going behind the machine. Facilities for feeding in numbers and instructions set manually on switches are also provided on the display trolley.

Except when using the display trolley all pulse circuits are in the main cabinet and connexions with the outside (power input and connexions to the control trolley) are filtered against interference.

The plan to make "401" was agreed in September, 1952, so that only 7 months elapsed between the plan and the operation of the machine.

Voltage Stabilization

(Part 2)

By F. A. Benson*, M.Eng., Ph.D., A.M.I.E.E., M.I.R.E.

Thermionic Valve Stabilizers

The simple series-parallel valve-stabilizing circuit is now well known. A general discussion of the design of such circuits has recently been given by the author[41]. The limitations of the additional correcting devices[1,2] for the circuits are discussed and some information is given concerning the choice of rectifier unit and series valve. Amplifier design, heater-voltage variations of the valves, ageing effects of valves and performance for high-frequency components of load current are also dealt with briefly.

Although good stabilization, adequate for many purposes, can generally be obtained by using a single D.C. amplifier valve in these circuits, special methods have been suggested for improving the amplifier gain. For example, Seely[42], and also Elmore and Sands[43], have described a variety of 2-stage circuits. A 2-stage arrangement has also been published by Solomon[44]. Sulzer[45] has recently given a further circuit in which he increases the voltage-amplifier gain through regeneration to a very high value. In fact the gain he obtains can be made effectively infinite with resulting perfect regulation.

The common degenerative stabilizer has been extended by Dewan[46] to keep the 200kV accelerating voltage for a positive-ion accelerator constant (it is necessary to hold it constant to 0·1 per cent). The series valve handles variations of several thousand volts. It is controlled by the usual amplifier which in turn receives an error signal which is the difference between the voltage across a small part of a 250MΩ bleeder resistor and a reference voltage consisting of a high-stability glow-discharge tube.

Taeger[47] has given mathematical analyses for two conventional low-current circuits, (1) a simple parallel-valve stabilizer and (2) a series-parallel arrangement with a glow-discharge tube as a reference. Two examples of (1) are given for the ranges 218/382V and 130/470V at load currents of about 3mA, and one example of (2) for a voltage range of 175/300V and a load current of 60mA.

It might be pointed out that standard cells are now being used fairly extensively as reference elements in thermionic-valve stabilizers. It is interesting to find that a number of circuits using standard cells have been given in a book[48] published a few years ago.

Tagliaferri and Terra[49] have produced a stabilizer using triode-connected 807 valves. The rectified and smoothed output voltage is compared with a glow-discharge tube stabilized voltage and fed through a single-stage amplifier to bias the control grids of the 807's. It is stated that at a load of 1kW the output voltage is held to within 1 volt of 156 for input voltages with 156 ± 7V with a time-constant less than 0·2sec.

A stabilized supply whose voltage can be adjusted from a few hundred volts down to zero is sometimes required. The conventional series-valve stabilizing circuit will not function with an output voltage below about 100V because too small an anode voltage is then available for the D.C. voltage amplifier valve. Houle[50] has described two circuits which meet the above requirement. The first circuit is a simple one, using an auxiliary negative supply, giving an output voltage adjustable between zero and 300V. The second circuit is a more complicated one, for the same voltage range, using a carrier-type four-terminal D.C. control amplifier. The value of a regulated D.C. supply whose output voltage is adjustable to zero has been stressed by May and Skalnik[51]. They have described a supply unit giving 0 to 250V.

Two conventional thermionic-valve stabilizers have been described by Wintle[52,53] and Cahoon[54]. Wintle's unit gives 300V output. It uses two 12E1 valves in parallel as the series element and a CV138 valve as the amplifier. The reference voltage is obtained from a glow-discharge tube type CV287. Cahoon's stabilizer provides an output voltage between 110 and 125V. It employs 6AS7 valves in parallel as the series element, a 12AX7 valve as the amplifier and a VR75 glow-discharge tube for a reference.

Templeton[55] has produced a power-supply unit giving a current of 1mA at a stabilized voltage of 3kV. The output voltage is steady to within ± 1 part in 10^4 over periods of 30 minutes.

Some circuits of conventional supplies for operating klystron oscillators have been presented by Harrison[56].

The majority of the thermionic-valve circuits which have been described from time to time have provided compensation for both variations in supply voltage and load resistance. Baruch[57] has proposed the use of a regulator which provides a low output impedance, but which is not primarily intended to operate as a regulator for changes in input voltage. Baruch gives the theory of his circuit and shows how a zero-impedance supply can be obtained by operating the amplifier valve in the region of negative anode resistance.

Stabilizers Employing Grid-Controlled Rectifiers

Since writing *Voltage Stabilizers*[1] the author has found reference to a 350V, 2·5A stabilizer circuit[58] which should prove to be of great value to many electrical engineers and physicists. Regulation is effected by altering the striking point of grid-controlled mercury rectifiers type BT35 and the principle is well known. A voltage proportional to the output is taken from a potentiometer chain and a novel method of translating this into phase shift for controlling the thyratrons is used. A stabilovolt is used as the reference voltage. A circuit diagram with full details for construction is given in the report. Standard components are used throughout. The circuit has a nominal output of 350V D.C. A variation of 6V is obtained between the minimum limit (200V A.C. input and 2A D.C. load) and maximum limit (250V A.C. input and zero D.C. load).

Voltage Stabilization of Van de Graaff Generators

An interesting article by Taieb[59] has recently given a discussion of the different methods in use for stabilizing voltages of several million volts. He also gives a description of the voltage-regulation system proposed for a 5MV electrostatic generator which is now under construction for the French Atomic Energy Commission.

Voltage Stabilization in Television Transmitters

Nind and Leyton[60] have recently described the vision transmitter for the Sutton Coldfield Television Station in which they devote a section to special features of the power-supply equipment including stabilization.

The low-voltage D.C. stabilizers are of well-known types but there are some interesting features about the high-voltage ones. It is pointed out that, whereas for low-power applications the stabilizing valves are used either,

* *The University of Sheffield.*

or both, in series or shunt with the load, the shunt arrangement is preferred for large-power equipment. This can be explained by considering a short-circuit of the output voltage. For a series valve all the voltage from the rectifier will appear across the valve and also the bias will be reduced to zero by the control circuit. This will generally mean that the anode dissipation or the peak current of the valve will be exceeded before the protective gear operates. The shunt stabilizer, however, is not so affected and since it needs a rectifier of high regulation no restriction in this respect is placed on rectifier design.

The circuit used by Nind and Leyton is shown in Fig. 12. In the usual electronic stabilizer of this type a sample of the output voltage is obtained from a resistor chain, compared with a reference voltage and then amplified. This method involves a loss which is high when the output voltage is about 2·5kV and the reference voltage is only 80V. The loss is avoided by replacing the bottom element of the resistor chain by a valve taking constant anode

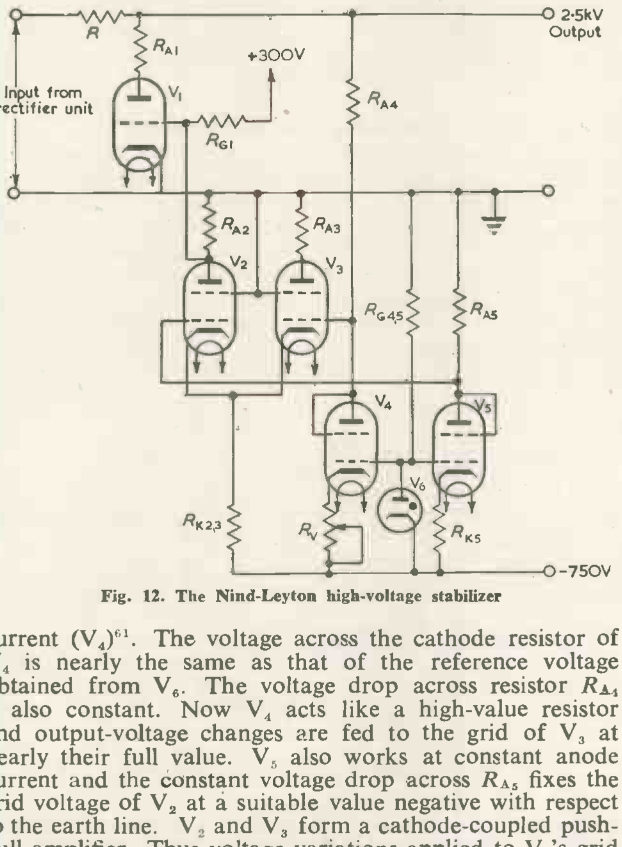


Fig. 12. The Nind-Leyton high-voltage stabilizer

current (V_4)[61]. The voltage across the cathode resistor of V_4 is nearly the same as that of the reference voltage obtained from V_6. The voltage drop across resistor R_{A4} is also constant. Now V_4 acts like a high-value resistor and output-voltage changes are fed to the grid of V_3 at nearly their full value. V_5 also works at constant anode current and the constant voltage drop across R_{A5} fixes the grid voltage of V_2 at a suitable value negative with respect to the earth line. V_2 and V_3 form a cathode-coupled push-pull amplifier. Thus voltage variations applied to V_3's grid appear magnified and in the same phase at the anode of V_2 and are then applied to the grid of the shunt valve V_1. In this way, if the output voltage tends to rise, V_1 takes more current producing a compensating voltage drop in series resistor R (which includes the resistance of the supply).

Nind and Leyton state that the effective output impedance of such a stabilizer using a single ACM3 valve as V_1 is about 10 ohms.

Some brief mention has also been made by Nind and Leyton of A.C. stabilization in television transmitters. It is advisable to work the filaments of transmitting valves (particularly hot-cathode mercury-vapour rectifiers) at constant voltage for long life and satisfactory operation. D.C. electronic stabilizers are also less expensive if they have to cater for small changes only in the supply voltage. Thus, in the Sutton Coldfield vision transmitter a stabilizing equipment is fitted which consists of moving-coil regulators and control apparatus.

Diode-controlled Regulators

The author[1] has previously mentioned briefly some diode-controlled regulators for both A.C. and D.C. operation which were developed by Helterline[62,63]. The diode is placed in one arm of a bridge circuit, the other arms of which are composed of resistors. The filament voltage of the diode controls its anode resistance. In America there are now several such regulators commercially available in units as large as 15kVA[64]. The manufacturers claim accuracies of 0·1 to 0·5 per cent for them. They are finding wide application for providing low values of stabilized voltage at high currents.

The Mazda diode type 29C1 has been produced for use in such regulators. The characteristics of these diodes have been studied by Attree[65], Seaman and the author[66] and stabilizers using them have been constructed by Seaman[67] and Richards[68].

Attree[65] has plotted the relation between anode current and anode voltage for several values of filament voltage for a number of diodes. He finds that the emission current i_A and the filament voltage V_f are connected by the equation $i_A = KV_f^{\beta}$ where K and β are constants. Attree states that with 50V on the anode and with $V_f = 4{\cdot}0$V β is 8·5. Thus, according to him a 1 per cent change in filament voltage alters the anode current by 8·5 per cent. The diode warm-up is complete in 5 minutes and the emission current is not affected by variations in ambient temperature. It is also found that the diode characteristics can be altered by as much as 0·2 per cent by a sharp tap on the glass envelope although the initial conditions can usually be reproduced by switching off the filament for a short time.

Seaman and the author[66] have determined the characteristics of several diodes and have published static curves and life-test figures. The characteristics of the valves were found to be of a similar nature but there are large variations in anode current at a given filament voltage. It has been found that the value of β in the expression $i_A = KV_f^{\beta}$ is almost independent of anode voltage in the range 30 to 100V but it depends on the filament voltage. Values of β between 8·4 and 9·8 were obtained.

During life the anode current decreases with time although small variations of a random nature occur. A drop in anode current of 10 per cent in the first 250 hours and 25 per cent in the first 1 500 hours occurred at a filament voltage of 4·0V compared with 10 per cent in 500 hours and 25 per cent in 2 100 hours for a filament voltage of 3·5V.

Richards[68] has designed a stabilizer to provide up to 150W of A.C. power at low voltage (12V or less) with the R.M.S. voltage stable to ± 0·1 per cent. A 29C1 diode is used as the reference element and a saturable choke as the control element. The output waveform of the system is poor. The output voltage is virtually independent of supply frequency over the normal range of mains variation. After a warming-up period of about an hour, during which a slow drift of 1 or 2 per cent occurs, the long-term stability is limited by the diode to ±2 or 3 per cent over 5 000 hours. Richards gives sufficient data to enable the design of similar systems of different performance to be made easily.

The stabilizer developed by Seaman[67] is similar in principle to the Helterline circuits[62,63] and work is still continuing on it.

A stabilizer has been described by Attree[69] which uses a 1T4 miniature valve as the control element and which will deliver up to 10W A.C. or 7W D.C. A 10 per cent change in mains voltage or a 50 per cent change in load current vary the output voltage by only 0·1 per cent. A constant-current output can be obtained from the unit by means of a simple circuit change. The stabilizer uses a 2kc/s multivibrator controlled by a series modulator, it is almost independent of ambient-temperature changes, has a short warm-up time and has good long-term stability. The 1T4 valve is run under reduced filament current conditions. The properties of miniature valves types DL66 and 1T4 used in this way have been given in a separate article by Attree[70]. The filament consumption is 12mW in the 1T4 compared with 3·2W for the Mazda 29C1 used in Richards[68] stabilizer. Attree concludes that the performance of the 1T4 valve run under suitable operating conditions as a saturated diode compares quite favourably with that of special diodes having pure tungsten filaments.

Bridge-Stabilizing Circuits

Several types of bridge-stabilizing circuit have been described previously[1]. In these circuits any number of the bridge arms, from one to four, may consist of resistors with non-linear volt-ampère characteristics. Attree[71] has recently described a tungsten-lamp bridge having a lamp in one arm only. The lamp used is a 6·3V, 0·04A torch bulb underun because it has been pointed out by Turner[72] and Patchett[73] that if a tungsten-filament lamp is run at about one half its nominal voltage excellent long-term stability is obtained and the effect of ambient temperature variations is small.

Cunningham[74] has commented on Attree's stabilizer and mentions that there are two points overlooked by Attree and other previous workers. Attree draws attention to the fact that a sinusoidal current in the lamp leads to a non-sinusoidal voltage across it. Cunningham points out that in addition to a sinusoidal component of voltage there are also cosinusoidal components at both the frequency of the current and three times this frequency. If the frequency is sufficiently low, or the current sufficiently high, these cosinusoidal components are no longer of equal amplitude as is often and incorrectly stated.

The second point which Cunningham raises has to do with the statement which Attree makes implying that the resistance of a lamp is dependent only on the R.M.S. value of the current. If by resistance is meant the ratio of the amplitude of the fundamental sinusoidal voltage to that of the sinusoidal current the statement is not quite correct. There is a fluctuation of temperature in the lamp occuring at twice the fundamental frequency. When combined with the sinusoidal current this fluctuation leads to a small additional sinusoidal component of voltage. The additional voltage produces a small increase in the apparent resistance of the lamp. Cunningham[75] has also published a paper discussing incandescent lamp bulbs in voltage-stabilizing circuits.

Transductor Voltage Regulators

It is felt that a brief mention should be made here of voltage regulators incorporating transductors. Hedström[76] has described such regulators which have been designed to give an output voltage which is constant to within ±1·5 per cent of the normal value with line-voltage fluctuations within +10 and −15 per cent of the nominal value, with load variations between 0·2 full load and full load and power-factor changes from 0·8 to 1. These regulators have been produced with ratings from 200VA to 6kVA.

The Hedström type of regulator has also been described briefly by Feinberg[77] in a review of transductor principles and applications. Incidentally this review contains an extensive bibliography on transductors. A further review dealing with the basic principles of transductors has also been given by Feinberg[78].

An interesting paper on the design of saturable chokes for the control and regulation of alternating currents at power frequencies has been given by Double[79].

Other stabilizers employing transductors have been described by Wolff[80, 81] and Smith[82] and mention has been made of this type of stabilizer by Maddock[83]. With Wolff's equipment regulation is effected at 160/400V to within ½ per cent for load currents from 0 to 500mA and with constant line-voltage or for line-voltage changes of ±10 per cent and load currents from 0 to 300mA. It is stressed that the stabilizer is virtually indestructible and its life is almost indefinite.

Smith's stabilizer supplies 0·6A at 6·3V for valve heaters. It has a stabilization ratio of 100 to 1 when the supply voltage varies from 10 per cent below normal to 5 per cent above normal. For the same output current (i.e., 0·6A) when the load resistance is varied from a short-circuit to 33 ohms so that the output voltage rises from zero to about 20V the drop in current is 2 per cent. The same stabilizer may be used for different output currents by suitable adjustments but the best performance is obtained for output currents from 0·4 to 0·6A. The reference source for the stabilizer consists of a 650V D.C. supply stabilized with a series valve controlled by two stages of valve amplification, the ultimate reference being a high-stability glow-discharge tube. The stabilized output of 300V is fed through a resistor to the reference winding of the transductor. Smith gives some figures for the effects of temperature and sudden changes in supply voltage on stability. Some information is also presented on the long-term stability of the equipment.

A Low-Power Alternating Voltage Stabilizer

Martin and Maddock[84] have designed a stabilizer giving an output of about 15V with a current drain up to 2mA. It is thought it will find its main use as a reference voltage because its efficiency is low and the output voltage varies with changes in load. The action depends on the change of resistance in a semi-conducting material which is voltage sensitive. These materials respond instantly to voltage changes so that when used with alternating voltage a cyclic variation in resistance would occur and heavy distortion would result. Thus, in this case, a large direct voltage is

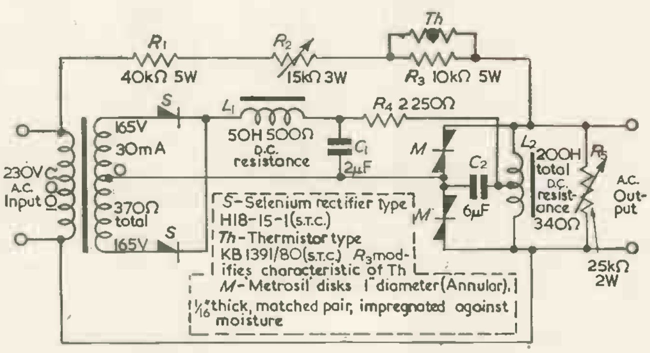


Fig. 13. Low-power alternating voltage stabilizer

superimposed on the alternating one so that the incremental resistance is nearly constant over the cycle and its value is controlled by means of the direct voltage.

The circuit arrangement of the stabilizer is shown in Fig. 13. The semi-conducting elements are Metrosil disks and the resistance they give to the A.C. circuit depends on the D.C. flowing through them. The D.C. is also a function of the input supply voltage from which it is obtained. The input and output voltage relationship can by suitable choice of circuit values be made of the form shown in Fig. 14 which shows two turning points. Variation of circuit values separates the turning points further or brings them closer together. In this way a small change of output voltage ΔV_o corresponds to a large change of input voltage ΔV_i (Fig. 14). The thermistor is fitted to compensate for the temperature-sensitivity of the Metrosil disks. The direct voltage is made about ten times the A.C. one so that for this case of 15V A.C. (7·5V from each disk) a direct voltage of 75V is required. In Fig. 13 there is a direct connexion between input and output terminals. To isolate these it is necessary to use a double-wound transformer with a centre-tapped primary instead of choke L_2.

With this circuit, changes of alternating voltage of 230 ± 17 per cent produce changes of only ± 0·1 per cent in output voltage.

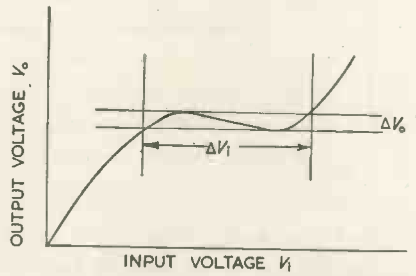


Fig. 14. Possible input-output voltage curve for the low-power alternating voltage stabilizer

Stabilized Heater Supplies

There are now many electronic applications which require the heater voltages of valves to be kept constant. Elmore and Sands[43] have given a complete circuit diagram with component values of one stabilizer which supplies up to 15A at 6·3V and which copes with line-voltage variations from 105 to 125V.

In this circuit the R.M.S. value of the heater voltage is stabilized. Operation depends on the change in resistance of a tungsten-filament lamp when the current through it is changed. A number of special type lamps in series are placed in opposite arms of a Wheatstone bridge which is fed directly by the 6·3V supply voltage being stabilized. Low-temperature-coefficient resistors are fitted in the other two bridge arms and chosen so that the bridge balances in the range 6/6·3V. When the input voltage is higher than the voltage for balance the bridge output voltage will have one phase but if the input voltage is lower than the voltage for balance the output voltage will have the opposite phase. The bridge output voltage is amplified and is then used to add to, or subtract from, the supply voltage to the primary of the heater-supply transformer.

Woodville[85] has suggested an improved heater-chain arrangement for A.C.-D.C. television receivers. He proposes that two parallel chains be used, a critical one, containing the heaters of time-base valve, vision detector and cathode-ray tube and fed via a barretter and a second chain, grouping all the remaining valves, fed via a thermistor.

Brown[86] has described a unit which provides a D.C. heater supply of 20W suitable for use with an ion source. The stability of the emission current is ±0·4 per cent for a mains supply voltage change of ± 10 per cent. Two 12E1 valves act as a multivibrator which has a frequency of oscillation of about 1kc/s. A pulse transformer connected between the anode of the 12E1's supplies substantially square pulses of current to a bridge rectifier which feeds the heater. The voltage supplied to the heater is dependent on the current in the 12E1 valves during their conduction periods and a suitable control circuit is given by Brown.

An interesting article has been written by Vance and Shumard[87] describing a regulator for supplying the 6V filaments of some 4 000 valves in a computor. In this case an error signal acts through a chopper, amplifier and limiters to control (by phase control) the firing time of thyratrons in the primary windings of three-phase transformers. The voltage reference used is obtained from a specially stabilized 300V supply that is itself referenced against a glow-discharge tube.

The demands of a thermionic ion emitter with regard to heating power stability have been stated by Reutersward[88]. He has also given characteristics and details of a stabilized A.C. supply by means of which ion currents constant to some tenths of 1 per cent are obtained. He uses a novel circuit which delivers 15W. A block diagram of the equipment is shown in Fig. 15. It consists of a power amplifier with negative feedback and fed by an oscillator. The oscillator is controlled by the rectified output voltage from the amplifier after comparison with the reference voltage

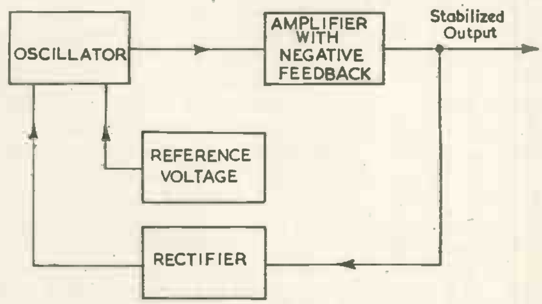


Fig. 15. Stabilized heater supply

from a high-stability glow-discharge tube type 85A1.

Another unit for supplying heater currents at voltages from 2·5 to 6V constant to within ±0·1 per cent has been described by Helmes[89]. In this case variation of output voltage produces a deflexion in a mirror galvanometer which controls the illumination of a photocell. The photocell governs the anode current of a valve which feeds the primary of the output transformer.

The reader should note that other schemes for obtaining stabilized heater supplies have been mentioned in other sections of this article.

Some Miscellaneous Circuits

Collinge and Marsham[90] have described a stabilizer which gives a continuously variable alternating voltage that is independent of mains frequency variations and is free from waveform distortion. The output voltage is held constant to within ±0·5V by electronic control of a 2kVA Variac. An output voltage in the range of the Variac can be obtained. The output voltage from the Variac is rectified and compared with a glow-discharge tube stabilized direct voltage. An error signal thus produced is amplified and operates a servo system consisting of a reversible motor generator which is geared to the Variac shaft. A similar stabilizer has been produced by Long[91] and a small modification of this has been suggested by Thomas[92].

Improved stabilization has been obtained from a glow-discharge tube by Armitage[93] who has employed a barretter in place of the normal series resistor. Similar arrangements have been investigated by Smith[94] and Kessler[95]. It is probably now well known that Gilvary and Rutland[96] have shown how improvements in the performance of a voltage stabilizer of the glow discharge tube type can be obtained by connecting the tube across the output of a current-stabilized power supply.

The advantages of cold-cathode valves over filament ones for low-power applications have been stated by Goulding[97] in a very interesting article. Goulding proceeds to describe an arrangement in which a cold-cathode gas triode behaves as a D.C. amplifier. This type of amplifier is shown to possess certain desirable characteristics when used as a voltage stabilizer in low-current circuits. From the description of the amplifier given it is evident that a cold-cathode triode may be used as a parallel-valve stabilizer. By virtue of the fact that the valve passes no current until the grid voltage reaches a certain value the amplifier can be regarded as supplying its own reference voltage. Goulding gives some examples of stabilizing circuits and compares them with two-electrode stabilizers.

Wight[98] has dealt with the problem of maintaining constant the intensity of a light source. An extra lamp is used in series with the lamps whose intensities are to remain constant. A D.C. supply feeds the lamps and the extra lamp acts as an automatic control. This particular lamp illuminates a photocell which provides an input to a D.C. amplifier. The output current from the amplifier froms part of the lamp current. Increase in lamp intensity decreases the amplifier output current and this tends to maintain constant intensity. The amplifier is of conventional form and coupling is by means of batteries. Wight gives curves showing the stability obtainable over a period of several hours and the effect of mains voltage variations.

Vance and Shumard[99] have given details of supplies producing 0·001 per cent regulation which are required for the anode and grid voltages of about 4 000 valves in a certain computor. The anode supplies give +300 and −300V at 20A and the grid supplies give +75 and −75V at 6A and −500V at 3A. The full regulation of the +300V supply is obtained in two stages. In the first, called the pre-regulator stage, a moderate degree of regulation is obtained by using grid control on thyratron rectifiers. The output voltage of the pre-regulator stage is fed to the second stage stabilization, called a super-regulator, which is a servo-stabilized D.C. amplifier. These power supplies are interesting because of the high degree to which some of them are stabilized and their particularly high current ratings.

A continuously variable D.C. output voltage from 0 to 300V with stabilization to within 0·1V has been obtained by Houle[100]. He employs an oscillator which feeds a small signal to an A.C. amplifier. In series with the amplifier input is a germanium diode connected so that the D.C. control signal varies the diode bias current. The amplifier output is rectified.

Jennings[101] has published an article covering the more popular types of stabilizers and control units and has described a recently-developed control unit for use with electro-mechanical type regulators. He also gives a good deal of information on magnetic amplifiers.

Mention should be made of a method described by Mulverry[102] for measuring very small changes in the ratio of V to I^2 in the electron microscope, where V is the electron accelerating voltage and I the lens exciting current. Since it is comparatively easy to measure and stabilize the lens current independently the method can be applied to measure the stability of the high-voltage supply, the slow variations of which are quite difficult to measure directly. Mulverry states that variations in accelerating voltage of 1 part in 50 000 have been readily measured.

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Frequency-Radius and Acceleration

By A. E. Maine*

THE chart relates the three quantities, frequency, radius and acceleration, involving only a single operation of a straight-edge laid between the required points on the scales.

Example 1

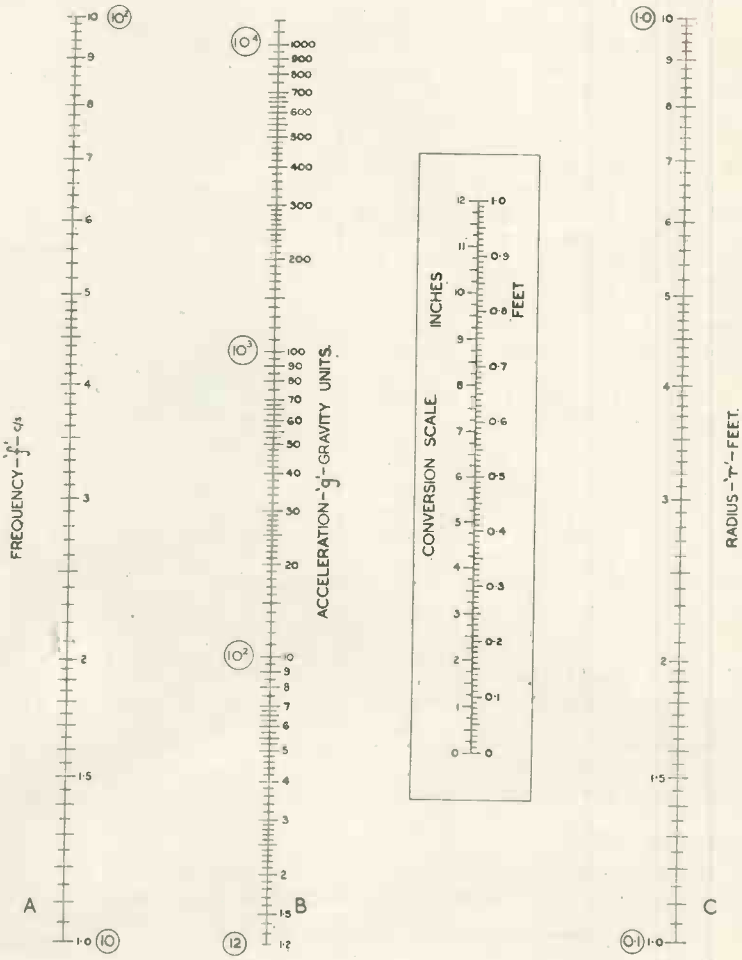
A large centrifuge with an arm of 10ft diameter rotates at 264 R.P.M. At what radius must a test specimen be positioned in order for it to experience a force equivalent to 100g?

Converting the speed to cycles per second, 4·4 is set off along scale "A". A rule is placed between this point and 100g on scale "B". The required radius is read off from scale "C" and is 4·21ft.

Example 2

The conductors laying along the length of a motor armature 10½in. diameter rotate with the armature at 2 400 R.P.M. What is the force acting to throw them off the armature?

Converting the speed to cycles per second, and the radius to a fraction of a foot using the conversion scale, the values 40 and 0·4375 are set off on scales "A" and "C" respectively using the scale calibrations indicated by the circled numbers. A rule joining these points yields the answer at the intersection with the central scale, i.e., 855g.



* De Havilland Aircraft Ltd.

The Use of Nickel in Valves

By K. Jackson*, B.Sc., A.I.M. and R. O. Jenkins*, A.R.C.S., D.I.C., F.Inst.P., Ph.D.

THE manufacture and operation of thermionic valves impose special requirements upon the materials used in their construction. The various metal components have widely differing functions, each requiring individual metallurgical consideration. With few exceptions, nickel or a nickel alloy is found to satisfy these needs; indeed, for certain purposes there are no satisfactory alternatives[1,2].

General Requirements for Metals used in Valve Construction

It is obvious that any metal used in valve construction should allow fabrication of the components by mass production methods. This implies that the metal should in general be ductile and capable of being formed by the usual processes of metal working. Scarcely less important is the property of spot-welding readily to itself and other metals used in manufacture, since this permits the rapid assembly of components without the introduction of other and perhaps deleterious metals. Nickel fulfils the above requirements admirably, since it is readily cold worked and can be spot-welded both to itself and to molybdenum and tungsten. These properties are shared by many alloys containing nickel as a base.

Nickel offers considerable resistance to corrosion under normal atmospheric conditions. The problems of storage of large numbers of components are therefore much reduced, compared with iron or steel parts for example. Similarly the heat treatment of nickel is simplified because of the ready reducibility of nickel oxide in hydrogen, even in the presence of water vapour.

Many components in valves are heated to high temperatures during manufacture or in service. This is particularly true for the cathode which may run at temperatures in excess of 1 800°C for the "bright emitter" types. The only satisfactory metals which can be employed are the refractory group and the use of tungsten is universal. For the alkaline earth coated cathode, the usual operating temperature lies between 700°C and 800°C and the cathode structure must be capable of withstanding this temperature indefinitely without dimensional change or sagging. In addition the cathode may be heated to 1 100°C for a short period during manufacture and must be able to withstand this treatment. Although the demands upon other components are not so stringent, it is necessary that they should not distort or sag during the sealing-in operation, nor during the high temperature out-gassing of the electrodes, employed to remove the traces of gas which would otherwise interfere with valve operation.

The melting point of pure nickel is 1 453°C and the boiling point is 2 700°C. The strength of nickel is adequate to meet the normal requirements for valve parts running at 800°C under low loads, and short periods will withstand the higher activation temperature. At temperatures above 1 000°C the vapour pressure is sufficiently high to cause deposition of nickel films on cold structures, but this usually becomes serious only where the temperature is maintained for a considerable length of time.

Gases in Nickel

The presence of gases in metals is an important problem since metal parts, at elevated temperatures or under electron bombardment, may liberate gas which interferes with normal operation. A study of the gases liberated from nickel[3] shows that the results vary considerably with the methods of production and fabrication used. Traces of grease or oxide at the surface may greatly increase the effective gas content. When care is taken to avoid surface contamination, the gas obtained from the body of the nickel is found to be mainly hydrogen and carbon monoxide, with smaller amounts of carbon dioxide (see Table 1). Carbon monoxide and dioxide do not originate as molecules, but are formed by diffusion to the surface and subsequent reaction between oxygen and carbon atoms present in solution in the nickel. The removal of carbon monoxide from nickel is a slow process, requiring temperatures of about 1 000°C for completion. It is therefore preferable to limit the formation of carbon monoxide by using nickel with low oxygen and carbon contents.

Hydrogen diffuses particularly rapidly through nickel, even at temperatures as low as 500°C. It is therefore possible to "de-gas" nickel in hydrogen at high temperature, subsequently using a low temperature treatment in high vacuum to remove hydrogen during processing of the valve.

TABLE 1
Gases from Commercial Nickel
(99·14 per cent purity, degreased 1mm wire)

	cc/100gm
Hydrogen	0·43
Carbon dioxide	1·81
Carbon monoxide	0·22

Indirectly Heated Cathodes

This type of oxide-coated cathode incorporates a heater, electrically insulated from the cathode proper. Such cathodes are usually operated from A.C. power supplies where relatively high thermal mass is advantageous and power consumption not of major importance. The cathode structure can therefore be located under low stress by insulating supports such as punched mica disks. The nickel shell acts as a conducting support to the oxide coating. Very pure nickel is not generally suitable as the cathode material, since the initial development of thermionic emission depends largely on small amounts of "activating agents" present in the nickel. At high temperature, these agents chemically reduce a small amount of barium oxide, thus providing free barium necessary to activate the barium-strontium oxide emitting surface. It is known that this interaction between activator and coating does in fact take place, since a compound is often formed between coating and metal.

Typical elements used as activators are: magnesium (forming a magnesia interface), silicon (barium orthosilicate), titanium (the titanate), and aluminium (the aluminate). Magnesium is the most commonly used of these, in amounts of 0·05-0·15 per cent. It has the highest rate of activation of those listed and the magnesia interface does not appreciably alter the thermal emissivity of the cathode, so that its temperature for a given power input is similar to pure nickel. Silicon, a somewhat slower activator, forms a relatively thick interface which tends to become an insulator when no anode current is drawn.

* Research Laboratories of the General Electric Co., Ltd.

Silicon-nickel is not therefore used where the valve operates for considerable periods in the stand-by condition, e.g. in computors, since the interface resistance may increase sufficiently to interfere with operation. In mercury vapour filled valves, however, the silicate interface may be advantageous since it appears to protect the underlying nickel from mercury attack while the valve is in storage. The properties of interface compounds and their relation to valve performance have been recently reviewed[4].

Wherever the nickel for cathode manufacture contains an element used as an activator, the composition limits must be carefully specified. Too low a concentration would slow the activation process, while excess may lead to the formation of excess barium, heavy interface formation and, for magnesium, the evaporation of magnesium films on the surrounding electrodes. For this reason it is often desirable to limit the magnesium content to 0·1 per cent. Work is continuing on the various activators, and the use of about 0·1 per cent aluminium has recently been advocated[5].

While the presence of small amounts of activating agent is important for satisfactory emission, certain other impurities, principally chlorine and sulphur, are deleterious and may even poison emission completely. Chlorine is unlikely to be a contaminant of nickel, except by corrosion due to atmospheric contamination, and chlorine-containing degreasing agents which have become acidic. Sulphur is a common impurity in metals and, since a sulphur content of 0·02 per cent in nickel is sufficient to reduce emission below a workable value, a maximum sulphur content of 0·005 per cent is specified for use in cathodes. The presence of magnesium and manganese may offer some protection and the attacked layer may be superficial, so that the mechanical properties of the nickel are unimpaired. Nevertheless, the considerable effect of sulphur on thermionic emission is usually specific enough for the cause to be recognized. When present at the internal surface of the cathode, the sulphur may have another damaging effect by reducing the insulating properties of the alumina between heater and cathode. This results in heater/cathode leakage, the insulation often being reduced by a factor of 100.

Sulphur contamination may be caused by the incomplete removal of sulphonated drawing oils before annealing, but is more often caused by leakage of sulphur-containing gases from gas-fired annealing furnaces into the chamber containing the charge. The use of an inner tube separated from the furnace proper does not ensure freedom from contamination since this tube may itself be attacked and serve as a source of sulphur. The best safeguard is the use of electric furnace heating with a cracked ammonia or hydrogen atmosphere to protect the charge. Where gas heating is necessary, every care is required to remove surface attacked metal during manufacture and to check equipment regularly for leakage.

Nickel prepared for indirectly heated cathodes is generally called "0" nickel in this country, and the equivalent "220" nickel is used in the U.S.A. (see Tables 2 and 3). Owing to its high general purity, electrolytic nickel is usually used as a basis for manufacture. The small amount of cobalt that is always present has little effect on cathode performance. Iron is usually present, but is not known to produce any effect in quantities below 0·2 per cent.

Until recently little attention was given to the physical nature of the cathode surface, although this is an important factor in determining the adhesion between nickel and the coating. While the chemical cleanliness of the surface is of utmost importance, a smooth highly polished surface produced for example by electropolishing is equally unsatisfactory since there is no "keying" between coating and metal. Coating adhesion problems are usually solved by varying coating techniques. A more satisfactory solution is the development of techniques for manufacturing nickel tubing or sheet with a clean and slightly roughened surface. There is evidence that at least one American manufacturer is attempting this.

TABLE

Composition Limits for "0" Nickel and "220" Nickel

	"0" NICKEL	"220" NICKEL
Nickel cobalt	99·5 MIN.	—
Copper	0·1 MAX.	0·2 MAX.
Iron	0·2 MAX.	0·2 MAX.
Manganese ..	0·15 MAX.	0·2 MAX.
Carbon	0·04 MAX.	0·08 MAX.
Silicon	0·01–0·10	0·05-0·07
Sulphur	0·005 MAX.	0·008 MAX.
Magnesium ..	0·07–0·15 MAX.	0·01–0·10

TABLE 3

Physical Properties of "0" Nickel

Melting point	1435–1445°C
Density	8·9gm/cc
Specific heat	0·13cals/gm
Coefficient of expansion ..	13×10^{-6}
Electrical resistivity	9·5 microhm cm
Electrical resistivity temperature coefficient	0·004–0·005/°C
Tensile strength	50 000–80 000lb/sq. in.
Yield point (0·2 per cent offset)	10 000–30 000lb/sq. in.

Directly Heated Cathodes

In this type of oxide-coated cathode, the current passing through the cathode raises it to the operating temperature. It is used where insulation between the heater and cathode is unnecessary, as in many rectifier valves, or where the heating current is drawn from storage or dry cells. In the latter, the power supplied to the heater must be kept to a minimum and this is achieved in the directly heated cathode by using a thin wire or ribbon to give a low thermal mass and high resistivity. Cathode rigidity is maintained by spring tension which must be adequate to avoid microphony, and the operating temperature must be high enough to give the necessary emission. The alloy used must operate for a considerable period without breakage occurring, in addition to fulfilling emission requirements similar to the indirectly heated cathode.

For the 1·4V 50mA valves designed to run from a dry cell, the cathode is a wire 23mm long, 0·023mm diameter, 0·1mgm weight and of 0·5gm tension. The directly heated cathode thus has to meet conditions similar to the creep and rupture tests used when examining metals for high temperature service. Normal test pieces, however, contain many grains per cross-section, while in the cathode filament the grain size can be of the same order as the diameter. The wire thus effectively becomes a series of single crystals placed end to end[6]. Creep and failure for such a system may be unrelated to results obtained on larger polycrystalline specimens, although stress and temperature still strongly affect the time taken until failure by breakage of the wire, i.e. "mechanical life" as distinct from "emission life".

The effect of surface conditions on wires of small diameter can be very marked, and the nature of the core-coating interface can alter the time to failure appreciably. Because of the relative amount of surface area and the number of grains per cross-section, the mechanical life of the filament is dependent upon cross-sectional area, increasing markedly with increasing diameter for given stress and temperature conditions.

Pure tungsten and alloys based on nickel have been used as core materials for directly heated cathodes. Tungsten has the advantage of remarkable strength at high temperatures which removes any difficulties due to filament breakage. The emission is not usually so satisfactory as with nickel alloys, however, and the low resistivity and high thermal conductivity introduce design problems owing to system length or the much smaller wire diameter required.

For valves with a rating above 50mA, alloys which are essentially nickel with an added activating agent can be used. The percentage of activator is usually higher than is used in indirectly heated cathodes, since the ratio of coating to core weight is higher. Typical alloys used for 100mA cathodes are nickel, 0·4 per cent aluminium and nickel, 0·25 per cent magnesium. For higher ratings, "0" nickel is used except for mercury vapour rectifiers where nickel-silicon or nickel-cobalt-silicon is preferred. The life performance and hot resistivity of these alloys are, however, inadequate for use in the lower rating valves which need smaller diameter wire. In certain directly heated valves with high wattage filaments, design considerations call for short filamentary cathodes. Filament length is kept to a minimum by using high resistance alloys, a nickel alloy containing 20-40 per cent cobalt being suitable.

The range of alloys for use in small battery-operated valves is seriously limited by the need for producing and maintaining satisfactory thermionic emission. Elements such as chromium and molybdenum, which have a pronounced strengthening effect on nickel, are unsuitable additions because of the formation of undesirable interface compounds. Only small quantities of titanium, silicon magnesium, aluminium or zirconium may be added, since larger amounts will either over-activate the coating or form a heavy interface layer. The metals which can be alloyed with nickel in substantial amounts are limited to tungsten and cobalt, both of which have an extensive solid solution range in nickel. Carefully controlled smaller quantities of activators can then be added to improve emission or increase life.

Alloy N93 used in directly heated filament cores has the composition nickel, 2 per cent tungsten, 1 per cent aluminium, 0·2 per cent carbon, and is prepared by melting nickel in air and de-oxidizing it with carbon to leave the preferred amount of carbon present. The remaining constituents are then added and the melt cast[7]. The alloy shows good working properties and can be rolled, swaged and drawn to 0·001in. wire required for 50mA rating valves. Life tests of the alloy in valves show good performance when the coating is applied as a sludge and sintered on to the wire at high temperature. If coatings are applied by cataphoresis, not involving high temperature treatment, results are not so satisfactory. The core-coating interface formed with drag coating may have a beneficial effect.

Alloy N100 is a development of N93 in which 0·2 per cent magnesium is added to the latter's composition. This causes considerable improvement in the mechanical life performance of the filament and an increased rate of activation.

The quantity of metal required for the manufacture of alloys for filament wires is small, most of the manufacturing cost going into the drawing of the alloy to fine sizes. Processes giving close control of the alloy composition or beneficial properties to the finished wire are therefore used. Decisive advantages are offered by powder metallurgy techniques, on which most research and production at the G.E.C. Research Laboratories have been based.

The further development of alloys for directly heated filaments rests largely on a better understanding of the mechanism of failure and of the effects of the coating-core interface and finely dispersed oxides on the mechanical life. Although the nickel-aluminium-tungsten-magnesium alloy has given satisfactory service for the 0·023mm filament size, present trends in battery valves call for smaller wire diameter to meet the low filament ratings. There is no guarantee that this alloy is capable of meeting these requirements, nor does the material appear capable of giving a satisfactory life at temperatures above 800°C with the spring tensions necessary to avoid microphony.

Anodes

In most valves, the choice of material for the anode is not so critical as for the cathode. The metal should be able to withstand temperatures of 800°C without sagging, should possess a low gas content and should be readily degassed during pumping. In the higher rating valves, the considerable heat generated at the anode must be dissipated by radiation, so that the outer surface should be blackened to improve radiating efficiency. Nickel fulfils these requirements admirably, except for the last provision and the anode temperature must be reduced by a special coating to produce the matt black surface required. This coating is usually of carbon, which has a radiating efficiency of 80 per cent black body compared with 20 per cent for bright nickel.

The purity of nickel required for anode use is generally not so high as for the cathode, although any volatile impurities present may reach and poison the cathode. Contamination by sulphur, introduced during annealing treatment in gas-fired furnaces or by sulphonated lubricants, may also cause difficulties.

The quantity of nickel used in anode construction is high compared with that used in cathode manufacture, and the nickel shortage has prompted attempts to find alternative materials. One of the most promising is aluminium-coated iron, prepared by rolling together aluminium and pure iron sheet with suitably cleaned and roughened surfaces. A sufficiently great reduction in thickness causes the metals to cold-weld and the resulting bimetal sheet withstands forming and bending without separation. The material cannot, however, be fully annealed before shaping because of embrittlement due to the formation of an aluminium-iron compound. This alloying is a considerable advantage at a later stage since, on heating the anode during outgassing, formation of this compound roughens and darkens the outer surface of the anode, producing a good radiating surface. On grounds of cost and convenience, this material may replace nickel as the major anode material, provided supplies become available in quantity. As a further improvement, successful attempts have been made to prepare iron, clad on one side with aluminium and on the other with nickel. In operation, the cathode faces a nickel surface, while the aluminium forms the radiating outer surface. By this means, the slight poisoning of the cathode due to gas released from the aluminium-iron anode surface may be reduced.

Support and Grid Wires

Large quantities of nickel and manganese-nickel wire are used as lead and support wires where considerable strength is not required. The principle advantages here, apart from purity and freedom from contamination, are the reasonable conductivity and good spot-welding characteristics.

The wire used in winding the grid assemblies in receiving valves is almost always molybdenum or a nickel alloy. Molybdenum has considerable advantages in high strength, and also very good resistance to dimensional changes during heat-treatment and subsequent assembly and manufacture. Its disadvantages are the high cost, brittle patches and ease of oxidation. The last-named necessitates considerable precautions during sealing to avoid molybdenum oxide formation which damages cathode emission. Where possible, the use of 5 per cent manganese nickel is preferred since this alloy has a reasonable tensile strength with low grid emission. Its main disadvantage is that the stress relief temperature is lower than that of molybdenum. There is a danger that, at the "lighting" stage of valve manufacture, the grid may reach a temperature sufficient to cause relief of residual stress resulting in distortion of the winding wire and alteration in the conductance of the valve. The side rods of the grid are usually of pure nickel or manganese-nickel unless the grid temperature is sufficiently high to give trouble by grid emission, when copper or chrome-copper is preferred because of its higher thermal conductivity which enables the heat to be conducted away to radiators and to the foot tube.

Conclusion

The manufacture of valves demands closer control of metal purity and alloy composition than is usual for other applications. It is hoped that this article has explained some of the metallurgical problems in valve construction and how they are being met. The subject is of importance both to those engaged in making the valves and to those seeking to provide the metals required, and work in this field calls for close co-operation between the valve engineer and the metallurgist.

The nickel alloys used in valve components are summarized in Table 4.

TABLE 4
Nickel Alloys Used in Valve Components

APPLICATION	ALLOY	NOMINAL COMPOSITION
INDIRECTLY HEATED CATHODES	"0" Nickel (INCO "220" (U.S.A.))	Ni and Co. 99·5 per cent minimum and controlled Mg
DIRECTLY HEATED CATHODES		
Battery-operated valves	0·25 per cent Magnesium nickel	As given
Do. Do.	0·4 per cent Aluminium nickel	As given
50mA rating range	N93	2 per cent W, 0·2 per cent C, 1 per cent Al, balance Ni.
Do. Do.	N100	2 per cent W, 1 per cent Al, 0·2 per cent Mg, 0·2 per cent C, balance Ni
MERCURY RECTIFIER	Cobanic	40 per cent Co, 0·20 per cent C, 0·2 per cent Si, balance Ni.
ANODES AND SUPPORT WIRES	"A" nickel "G.F.A." nickel	Ni and Co., 99·0 per cent minimum
GRIDS		
Winding wires and side rods	5 per cent manganese nickel	4·5–5·5 per cent Mn, balance Ni.
VALVE SPRINGS	Nimonic	15·21 per cent Co, 18–21 per cent Cr., 5 per cent maximum Fe, balance Ni.

Acknowledgments

The authors wish to thank Henry Wiggin and Co., Ltd., and the Mond Nickel Co., Ltd., for their interest throughout the preparation of this article.

The authors also desire to tender their acknowledgments to the M.-O. Valve Co., Ltd., on whose behalf some of the work described in this publication was carried out.

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THE DECCAPLOT

The Decca Radar Plotter, the "Deccaplot", may be used with any Decca type 12 radar display. It is designed to allow direct plotting on the face of the radar display and thus ensures extreme rapidity and accuracy in forecasting movements of other vessels. It allows direct measurements of distances and times, it provides a quick and positive method of distinguishing fixed marks such as buoys and light vessels and enables ones own course and speed to be precisely determined when passing a fixed point such as a headland which may be obscured to the eye by darkness or fog. The principle of the Decca Radar Plotter is simple and foolproof, there are no adjustments to make and it does not obscure the normal radar picture in any way.

If the navigator plots directly on the normal radar screen, a serious parallax error is caused by the screen being some distance above the actual radar picture. Such a method of plotting would obviously be impractical and the Decca Radar Plotter has been developed so that plots made over the P.P.I. display will always coincide with their radar echoes no matter from where they are observed.

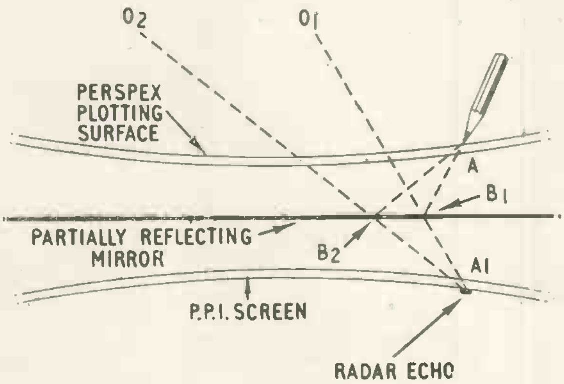


Fig. 1. The principle of the Deccaplot

Fig. 1 shows the method of construction and illustrates how a reflexion of any mark made on the Perspex plotting surface will always coincide with its corresponding radar echo on the screen below. A partially reflecting mirror is placed between the P.P.I. screen and the Perspex plotting surface. This plotting surface is curved to match exactly the opposite curvature of the P.P.I. screen. If a pencil is placed at A and the eye of the observer is at 0_1, light rays originating at A will strike the partially reflecting mirror at B_1. To the observer, this will appear to have originated at A_1, (an extension of the line 0_1-B_1) and since both the plotting surface and the P.P.I. are equidistant from the mirror, the point A will appear to be on the face of the P.P.I. at A_1, which is directly below A. It will also be seen that if the observer moves his position to 0_2, the point A will not change its apparent position at A_1 position.

The plotting screen is edge-illuminated so that a wax-pencil mark will show up clearly on the radar picture. These marks are easily removed by wiping with a cloth. When the plotter lighting is switched off, the marks cannot be seen and the P.P.I. picture will be observed normally. The complete unit fits directly on the front of the Decca 12-inch display and can be simply removed when not required. It is constructed in cast light alloy and finished to match the display unit.

A completely water- and weather-proof sea-going radar equipment has also been introduced recently by the Decca Company. This has the great advantage that it can be installed on an open bridge in full view of the man at the wheel—an important point when navigating in crowded waters in poor visibility.

The 37th Physical Society Exhibition

A review of some of the more interesting exhibits shown at the Physical Society's Exhibition, held at Imperial College, South Kensington, from April 13th to 17th.

Allied Electronics

60Mc/s Amplifier

THIS unit is submitted as an example of miniature technique as supplied to a stagger-tuned amplifier.

The overall dimensions of the instrument are 11in. by $2\frac{3}{4}$in. by $1\frac{3}{4}$in. For a mid-band frequency of 60Mc/s the voltage gain and bandwidth are 1 000 and 15Mc/s respectively.

(Exhibited by courtesy of the Ministry of Supply.)

Peak to Peak Millivolter

This instrument is designed to meet a demand for a source of low frequency A.C. for calibration of amplifiers and oscilloscopes, and includes a screened and balanced transformer, a calibrated attenuator and a metering circuit. The voltage available at the output terminals is continuously variable from 100 microvolts to 100 volts and may be read directly on the scale of the instrument; the arrangement of the multiplier dial is such that only powers of ten are involved. The instrument may be connected directly to the A.C. mains as a source of 50c/s, or may be used with an audio-frequency oscillator. Applications have been found in many fields from biology to fuel research.

Allied Electronics, Ltd.,
28 Upper Richmond Road,
London, S.W.15.

Baird and Tatlock

Self Balancing Photoelectric Absorptiometer and Electronic Potentiometer

(*Illustrated below*)

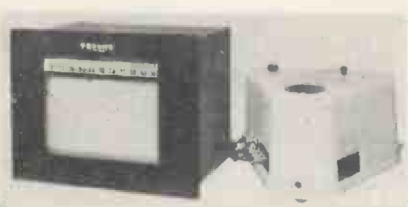
THE continuous flow self-balancing absorptiometer is an instrument for detecting and giving continuous indication of small changes in colour density of a liquor flowing, for example, in a chemical process. The instrument is intended for use in conjunction with a potentiometer employing an electronic continuous balance measuring system.

As the result of co-operation between Baird and Tatlock (London), Ltd., and Honeywell-Brown, Ltd., of Perivale, Middlesex, the combined apparatus is now available.

Electronic Speed Control Unit for Small Laboratory Motors

With this unit small shunt wound D.C. motors up to about 1/20 H.P. may be operated from 50c/s A.C. mains with a wide range of speed control.

Fairly constant torque from nearly zero up to the rated speed of the motor is obtained by varying the armature current with constant maximum field. The speed range can be further extended to about twice the rated speed with a constant horse-power characteristic by maintaining constant maximum armature current and reducing the field strength. The unit provides for reversing the direction of rotation of motors with brushes set at neutral, and includes a dynamic braking resistor which can be automatically connected when the motor is switched off.



Baird and Tatlock (London), Ltd.,
Chadwell Heath,
Essex.

Cintel

THE exhibit this year is the new "Cintel" flying-spot microscope which has been designed to overcome a number of the disadvantages inherent in conventional microscopical technique and is capable of presenting a picture of high definition and large magnification with low noise level.

Some of the advantages offered by the "Cintel" equipment are outlined below.

(1) The size and intensity of the display are such as to facilitate demonstrations to large audiences. The final picture can be anything up to 20ft by 16ft in size.

(2) The effective contrast of the specimen may be varied simply by a potentiometer control. This obviates the staining of specimens as is necessary in conventional microscopy and improves the contrast of specimens that cannot be stained.

(3) In conventional microscopy a high light intensity can cause damage or distortion to a specimen, especially if live. This danger is obviated with the "Cintel" microscope where although the peak intensity of the flying-spot is high, the average light intensity is low.

(4) By the use of ultra-violet radiation from the scanning tube and an ultra-violet sensitive photoelectric cell, the resolution of the system is as great as that obtained with conventional photographic methods with the added advantage of direct viewing and ease of operation.

(5) The apparatus permits rapid, accurate and automatic counting and sorting of particles and thus replaces the normal slow laborious and inaccurate manual methods.

(6) The use of a flat face cathode-ray monitor tube enables tracings of the specimen image to be easily made.

Cinema-Television, Ltd.,
Lower Sydenham,
London, S.E.26.

Ekco

The Ratemeter Type N522

A PRECISION counting rate meter incorporating an input amplifier, a pulse height discriminator and a variable high voltage supply. It requires only the addition of a Geiger Muller tube or scintillation counter, for which power supply is provided, to form a complete counting equipment.

Ekco Scaler N526

A general purpose scaling unit comprising two high speed electronic decades followed by a re-settable electromechanical register and incorporating pulse height discrimination and paralysis facilities.

The Scaler N529

A five decade scaling unit incorporating a stabilized high voltage supply. The scaling circuits employ Dekatron tubes giving an input resolution time of 250 microseconds.

The Auto-Scaler Type N530

A combined six decade scaling unit and timing unit, and incorporating a stabilized high voltage supply.

The first two decades of the scaling unit employ hard valve scale-of-ten circuits and the remaining decades employ Dekatron tubes. The input resolution time is 5 microseconds.

The timing unit operates from the 50 to 60c/s A.C. supply (as specified), or for greater accuracy an external standard frequency source may be used.

The high voltage supply is variable from 250V to 2 000V in two ranges and is suitable for all current types of G.M. tubes and for Ekco scintillation counters.

High Resistance Meter Type 1190A

This instrument has been designed in conjunction with the British Atomic Energy Research Establishment for the measurement of high values of resistance and insulation.

E. K. Cole, Ltd.,
Southend-on-Sea,
Essex.

Dawe

Type 1206 "Slow Motion" Stroboscope

THIS equipment consists of a high intensity stroboscope together with an oscillator for driving a power amplifier and vibration generator. The stroboscope can be driven either at the same frequency as the oscillator or, alternatively, with a constant frequency difference of ½, 1 or 2 cycles per second irrespective of the oscillator frequency.

Type 1251 Dynamic Balancing Equipment

The new Type 1251 dynamic balancing equipment has been developed to give greater flexibility of application. It consists essentially of the measuring and "sensing" elements of the Type 1250 balancing machine combined into a packaged unit. The user is left to provide his own suspension and drive which are then used in conjunction with the Type 1251 equipment.

Type 1408 Sound Level Indicator

This instrument provides a ready means of measuring sound levels sufficiently accurately for most normal purposes. It is also often possible to use the indicator to make a preliminary survey and to locate the sources of noise, which can then be studied by detailed investigation using a Type 1400 sound level meter. This combination will often save much time, particularly as the indicator can be used even by an unskilled operator.

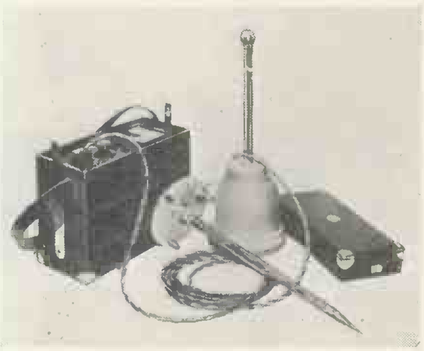
The indicator consists of a microphone, amplifier and meter together with self-contained batteries.

Naturally, some of the refinements of the Type 1400 must be sacrificed in so small an instrument. In this case the range has been somewhat reduced to 40-130db.

Type 1409 Water Leakage Detector

(*Illustrated below*)

The instrument uses a sensitive microphone instead of the inspector's ear to pick up the faint noise of the water leaving the pipe.



The microphone is housed in a bell-shaped casing which has a convenient carrying handle. A separate spike with a flat top is also provided. This is driven into the ground in the vicinity of the suspect pipe and the bell placed on top of it, thus ensuring good conduction of the noise caused by the leak. The spike is comparatively short, so that it should not be inadvertently driven into other mains service pipes or telephone cables. It is only about 1in. thick so that it is sufficient to puncture the road surface, instead of having to dig trial holes.

The signal from the microphone feeds a meter and headphones are provided to give an indication of the intensity of the microphone signals.

The procedure in use is extremely simple since the instrument is battery-operated and is entirely self-contained.

Dawe Instruments, Ltd.,
130 Uxbridge Road,
Hanwell, W.7.

Ediswan
A.C. Stabilized Power Unit

THIS is a new unit giving control of output at 240V, 500VA to better than ±1 per cent for wide variations of input voltage and with no distortion of waveform. Performance is essentially independent of frequency and of load power factor. The unit is designed for 19in. rack mounting.

A two valve amplifier is used to control the A.C. servo motor which drives a Variac. This arrangement is greatly superior to the usual relay actuated motor and gives greater speed of response without overshoot. The voltage sensitive bridge gives a rapid response, is insensitive to ambient temperature, and controls the true R.M.S. value of the output. The output voltage can be varied to meet individual requirements and the unit can be adapted to give outputs of 1 or 2kVA with slightly slower speed of response.

D.C. Stabilized Power Units

The type R1103 is a new unit providing an output of 250-400 volts with a load current up to 200mA.

Either the positive or negative side of the D.C. output may be earthed.

An unstabilized heater supply is also provided. The unit is suitable for bench use or for mounting on a standard 19in. rack.

Another unit is the R1184 which is a highly stable H.T. supply for Ediswan-Mazda Photomultipliers (types 27.M1, 27.M2, 27.M3).

Supplies of 200-1 100 volts can be obtained in nine steps with continuous control between the steps.

The Edison Swan Electric Co., Ltd.,
155 Charing Cross Road,
London, W.C.2.

Electronic Instruments
A Versatile Industrial pH Meter

(*Illustrated above*)

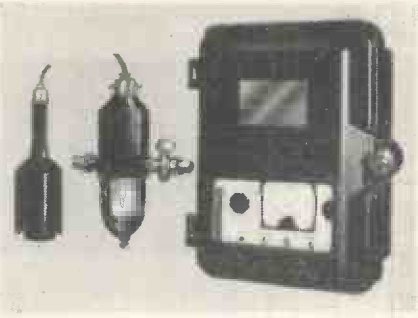
THE Model 28 Industrial *p*H Meter has been developed specifically for factory use and the design of the instrument and the electrode systems is the outcome of many years of practical application in the measurement and control of *p*H in industry.

The Model 28 may be used by itself or it may be linked with standard Recorders and Controllers of the type used in modern factories for the measurement of temperature, pressure and liquid level. This arrangement enables the Plant Engineeer to set up a complete *p*H control installation with the minimum of trouble and often with equipment already to hand.

The Model 28 *p*H Meter will run for several days with a stability of $\pm 0{\cdot}02$ *p*H without routine attention. An important feature is the provision of complete temperature compensation which enables the electrodes to be standardized at one temperature and to operate precisely at all other temperatures without readjustment of the controls. The instrument—which is designed for wall or panel mounting—is hermetically sealed and may therefore be installed in the open or in an atmosphere containing noxious fumes or vapours. Provision is made for pressurizing, and a flameproof case can be supplied for use under exceptionally hazardous conditions.

Other new instruments include a direct-reading Megohmmeter and a Valve Voltmeter.

The Myria Megohmmeter bridges the gap between the Model 47 Milliohmmeter and the Model 29 Megohmmeter. Between them, these three instruments cover the impressive resistance range from



a fraction of a milliohm up to 20 000 000 megohms.

The CT54 Valve Voltmeter is a panclimatic portable test set with interchangeable mains or battery power units.

Electronic Instruments Ltd.,
Red Lion Street,
Richmond, Surrey.

Elliott Printed and Potted Circuits

(*Illustrated below*)

EXAMPLES of Elliottronic printed and potted circuit units were exhibited together with chassis-mounted circuits showing an unusually high degree of miniaturization.

The special features of miniaturization and resistance to extreme conditions, such as shock and humidity, are obtained by using the techniques of hermetic sealing, plastic embedding and printed circuits where they are appropriate.

Examples of printed circuits show the use of ceramic and laminated glass-fibreboard bases. Hermetically sealed printed circuits may be forced air-cooled or water-cooled if necessary.

Elliott/N.R.D.C. Computor 401

This is a high speed automatic electronic digital computor developed and constructed by Elliott Brothers (London) Ltd. for the National Research Development Corporation.

A fuller description of this computor is given on page 201 of this issue.

In designing Computor 401 the principal aim has been to produce a machine of moderate cost, extreme reliability and extreme ease of servicing. To this end the greater part of the electronic circuitry of the machine is in the form of plug-in "packages" of standard form.

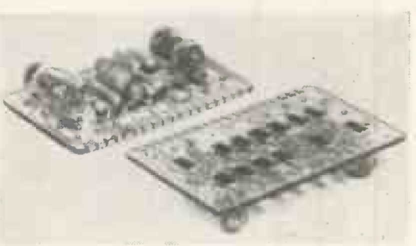
The specification of the computor is as follows:

Digit rate 333 000 per sec.

32 active binary digits to a word.

Two-address code, one order per word, for optimum programming.

Mainstore 1 024 words on a magnetic wheel at 333 000 digits/sec. Average access time $6\frac{1}{2}$ milliseconds. Electronic track selection. Extendable to 3 096



words using relay selection of additional tracks with an average time of 14 milliseconds.

Single word immediate access registers in the form of plug-in magnetic strictive delay line packages. Five such registers for accumulator (two registers), multiplicand, multiplier and instruction, and one general purpose register.

Speed—under optimum programming conditions an order is read from the mainstore and obeyed in 0·2 milliseconds. Multiplication takes 7-10 milliseconds (depending on sign).

Input—5 hole punched tape read photoelectrically at 40 rows/sec.

Output—Electric typewriter at 10 figures/sec.

Number of valves—approximately 500.

Elliott Brothers (London) Ltd.,
Century Works,
Lewisham,
London, S.E.13.

Ferranti

AMONG the new exhibits on display were a high speed oscillograph, a flying-spot scanning cathode-ray tube unit, detachable cathode-ray tube unit and a new type of milled block wave guide component.

Flying-Spot Scanning Cathode-Ray Tube

This cathode-ray tube has been designed to produce a spot, which is virtually a point light source, of controllable brightness.

When a negative image, produced by normal photographic methods is scanned by the light spot of a flying-spot cathode ray tube, the resulting signals can be utilized to reproduce a positive picture on the screen of an ordinary television receiver.

Demountable Cathode-Ray Tube Unit

The equipment has been designed in order to carry out experiments on the characteristics of fluorescent powders and on various modifications of electron gun design. It is readily demountable and is evacuated by means of a silicone diffusion pump backed by a rotary oil pump. Suitable arrangements provide for focus, line and frame scan and the accelerating voltage is supplied by an R.F. unit which is variable over a wide range up to 30kV. The unit is entirely self-contained and the whole apparatus is readily transportable.

Milled Block Waveguide Components

A new type of microwave circuit was exhibited which is made up of mated channels milled in blocks of conductive material. Rectangular channels half the width of the major dimension of the waveguide required are milled in each block and the blocks joined in a suitable manner so that the channels coincide to form complete waveguides and duplexer circuits. Additional guideways to accommodate transmit-receive cells, crystals or probes are milled where required. This technique simplifies manufacture and provides a very robust construction.

High Speed Oscillograph

(Illustrated in next column)

This records the transient voltages which could occur on transmission lines and associated gear such as transformers, switchgear, cables and insulators. The traces can be observed visually and

photographed simultaneously, the size of the negative being 3½in. by 2½in. The oscillograph consists basically of two Ferranti electrostatically deflected tubes operating at 15kV D.C., a common tripping circuit and two independent timebases, the fastest sweep being two microseconds.

Ferranti, Ltd.,
Hollinwood,
Lancs.

G.E.C.

AMONG the several new exhibits on this stand were the following:—

Sine Squared Pulse Generator and Display Unit

This instrument has been developed to provide waveform testing of systems or equipment with low-pass filter characteristics and nominal upper cut-off frequencies of 3, 5 or 10Mc/s.

Pulse widths of 0·34, 0·17, 0·1 and 0·05μsecs at half height are available and the pulse is contained within one half-cycle of an accompanying square wave of the same peak-to-peak amplitude, the frequency of the square wave being switched to 30, 60, 100 or 200kc/s. The signal amplitude is approximately 0·5V peak-to-peak when fed into a 75 ohm load.

The display unit consists of a C.R. tube with a time-base obtained from the integration of the square wave, the return trace giving the initial pulse height.

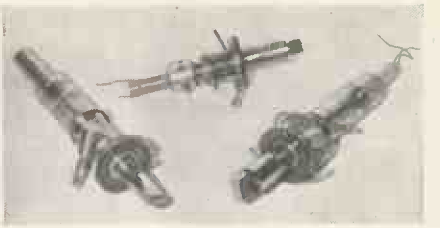
Injection Guns for Electron Synchrotrons

(Illustrated in next column)

It was found in the early stages of synchroton development that increasing the initial energy of the injected electrons increased the X-ray output at a given energy level by a large factor.

The guns illustrated above have been made with this in view.

During operation the cathode and its



structure are pulsed negatively (5μsec pulses at 50 cycles) with respect to the anodes. Some of the resulting electron beam passes tangentially into the stable orbit and is accelerated on to the target.

The electrode systems of guns are adjustable by means of flexible bellows and the direction of the beam is varied in azimuth by potentials applied between the two parts of the anode.

Gun No. 1 (centre) has been used up to 40kV, and gun No. 2 (right) to 75kV.

A third gun (left) is of non-magnetic stainless steel and has a coaxial construction. Beam deflexion in azimuth is achieved mechanically, the degree of deflexion being controlled by micrometer heads.

The General Electric Co., Ltd.,
Kingsway,
London, W.C.2.

Muirhead

Mufax Chart Transmitter and Receiver

THE principal exhibits were the D-658 18in. Mufax chart transmitter and the D-649 18in. Mufax chart recorder, which together provide a complete system for the dissemination of meteorological information in the form of weather charts by radio or landline.

The transmitter employs phototelegraphic techniques, the chart (measuring 18in. by 22in.) being clipped round a drum which is scanned in the form of a spiral by a spot of light and a photomultiplier cell. The Mufax recording principle, which is employed by the recorder, enables a continuous record to be obtained on electrosensitive paper. used in 100ft. rolls.

Magslips

(Illustrated below)

A range of 1½in. Magslip elements has been developed to meet a demand for an element similar to the 2in. and 3in. types which have been used for many years. The reduction in size has been achieved with only a slight loss of accuracy.

Elements are available for operation from a 50V 50c/s or 115V 400c/s A.C. supply; the 50c/s types can be used equally well on 60V 60c/s.

Muirhead and Co., Ltd.,
Beckenham, Kent.

Mullard
An Ultrasonic Reciprocating Drill

IN this instrument a high-Q magnetostriction transducer is used to generate vibrations at about 22kc/s. These vibrations are transmitted via a tapered metal stub to a drilling tip. The amplitudes obtained are large enough to allow rapid drilling and cutting of most brittle materials when a paste of carbide abrasive is fed to the tip. The absence of any rotary motion makes this instrument exceptionally useful for drilling holes of any required shape and for making cuts and depressions in materials that are difficult to machine by more conventional methods.

A "Very Wide Band" Dummy Load

A radical departure from previous designs, the very wide band Dummy Load for R.F. power measurements presents a purely resistive input impedance of 75 ohms at frequencies from 100Mc/s upwards. Power measurement is by a calorimetric method.

The device is essentially a coaxial line, terminated in its characteristic impedance. The power is almost entirely dissipated along the inner conductor which consists of a thin gold film on a glass rod. The resistance of the gold film is graded in order to obtain uniform power dissipation.

The maximum power handling capacity is 600 watts. The power measurement accuracy is ±1·5 watts or ±2 per cent, whichever is the greater.

A Reversible Binary Counter

The reversible counter is of the binary type. It employs conventional bistable multivibrator valves and includes gating circuits between each counting stage. The counter may be placed in either the "add" or "subtract" condition by biasing the gates so that pulses for operating the counting stages are selected, either from the first or second anode of the preceding counter stage. The gating circuits are controlled by an electronic "add-subtract" switch which is itself triggered into either condition by input control pulses.

**Mullard, Ltd.,
Century House,
Shaftesbury Avenue,
London, W.C.2.**

Nicolson
Ultrasonic Generator
(Illustrated below)

THIS new equipment has been specially designed for use in laboratories where a source of low power ultrasonic energy is required.

The valve oscillator operates as a shunt-fed Hartley oscillator and can be switched to either 1Mc/s or 5Mc/s. The output at these frequencies is 6 watts and 3½ watts respectively.

The crystal transducer is connected to this generator by a length of flexible coaxial cable and the entry to the crystal holder may be rotated through 360°.

**W. B. Nicholson, Ltd.,
Thornliebank Industrial Estate,
Glasgow.**

Pye
Electronic Projection Microscope

THIS apparatus is designed to enable the picture from a normal light microscope to be distributed to a number of viewing screens. The light from the microscope is reflected into a small camera, containing a photo conductive camera tube. The signal from this camera tube may be distributed to a number of cathode-ray tubes for use as viewing screens. This apparatus may be used with white light illumination, U.V. illumination or with normal phase contrast attachments to a light microscope.

**W. G. Pye and Co., Ltd.,
Newmarket Road,
Cambridge.**

Salford
A.C. Load Analyser

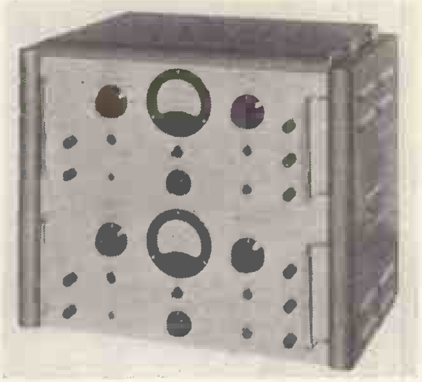
A NEW self-contained A.C. testing set for the measurement of current, voltage, power and power factor in single and polyphase circuits. The test set, which is portable, consists of four 3½in. dial long scale instruments with appropriate current transformers, resistors, chokes and switches, mounted in a teak case with a leather carrying handle.

The instruments fitted are an ammeter, voltmeter, a double element induction wattmeter and a 3 phase unbalanced load P.F. meter placed close together to permit accurate simultaneous readings. The ranges covered by the instrument are 5, 25 and 125 amperes. 150, 300 and 600 volts and from 1 to 100kW.

**Salford Electrical Instruments, Ltd.,
Peel Works,
Salford, Lancs.**

Solartron
Twin Regulated Power Supply, Model SRS. 152
(Illustrated above)

THIS is a new regulated power supply consisting of two identical units each having an output of 0-500 volts in three ranges with a maximum current of 150mA. The output from each unit is isolated from earth, and by means of a multiple switch the outputs can be connected either in parallel or series as required. In the parallel condition, one reference and control circuit is rendered inoperative and the combined outputs provide a supply of 0-500 volts positive or negative at 0-300mA. In the series condition, the combined outputs provide a supply of 0-1kV positive or negative at 0-150mA. Each unit contains an automatic overload cut-out and a meter to monitor the current and voltage output. The stabilization is 0·5 per cent for ±10 per cent variation in the mains supply and regulation in terms of internal impedance is of the order of 3 ohms. The total hum content from each unit is less than 4 millivolts. Both units provide an A.C. output of 6·3 volts at 5 amps unstabilized and provision is made for series or parallel connexion.



Solartron Vari-Pack, Model SRS. 153

This is a new instrument, designed to provide a continuously variable H.T. supply, either positive or negative, from 0-400 volts. The full range of 0-400 volts is obtained in a single sweep of the output control without switching. The maximum current obtainable is 100mA between 0 and 350 volts and 50mA at 400 volts. In addition, a centre tapped L.T. winding on the transformer provides 6·3 volts at 3 amps. The polarity of the output voltage can be changed by adjustment of a simple link type switch.

Harmonic Response Testing Equipment

Designed at the Royal Aircraft Establishment, this equipment is used to obtain the frequency response characteristics (amplitude and phase) of servo mechanisms, passive networks, etc.

**Solartron Laboratory Instruments, Ltd.,
Kingston-on-Thames,
Surrey.**

S.T.C.
Oscillator Equipment 74533A

A PORTABLE mains-operated set to provide frequencies in the range from 10kc/s to 5Mc/s for laboratory and general factory testing. Stable output at all frequencies is obtained by means of an aperiodic bridge network with a thermistor in one arm. The frequency accuracy is within ±1 per cent. There are three output jacks: two of the outputs are each designed to work into a 75 ohm load to deliver levels up to 10db above 1mW simultaneously; the third output is for monitoring and requires a high impedance load, but can deliver a level of 16db above 1mW into 75 ohms with no load on the other two jacks.

The "Humicon" Humidity Detector

This consists of two perforated metal plates some 7in. in diameter, spaced 1in. apart, the space between the plates being filled with ravelled glass silk.

The Humicon behaves as a variable impedance. It is connected to the 230 volt A.C. mains supply through a resistance of 2 megohms.

Changes in impedance of the Humicon caused by variations in relative humidity produce a varying voltage across it. This voltage can be applied to a series of thyratrons which can, in turn, be made to operate outside circuits.

**Standard Telephones and Cables, Ltd.,
Connaught House,
London, W.C.2.**

LETTERS TO THE EDITOR

(We do not hold ourselves responsible for the opinions of our correspondents)

Saturated-Diode Operation

DEAR SIR,—Mr. V. H. Attree's recent article on the temperature-limited diode as a sensitive element in regulators[1] started the writer wondering whether it might not be possible to give at least an approximate theoretical treatment, since he has not seen one as yet. It was, in fact, found possible to fit the diodes' behaviour quite well by a formula derived from very simple considerations.

The following relations, which are known to be at least approximately true, are used:

(a) The resistance R of the filament is proportional to its absolute temperature T, in the working range[2].

(b) The power input W to the filament is equal to the power radiated from it, and accordingly proportional to the fourth power of T.

(c) The plate current i_p of the diode is related to the filament temperature by the equation:

$$i_p = a\,T^2\,e^{-b/T} \qquad (1)$$

a and b being constants. Other symbols to be used are:

i_F is the filament current

V_F is the voltage applied to the filament

From (a), (b), and (c) one has:

$$T^4 \propto W \propto i_F^2 R \propto i_F^2\,T \qquad (2)$$

$\therefore\ T \propto i_F^{2/3}$ and equation (1) becomes

$$i_p = a i_F^{4/3}\,e^{-b/i_F^{2/3}} \qquad (3)$$

If one is interested in V_F, a similar development gives:

$$i_p = a\,V_F^{\,4/5}\,e^{-b/V_F^{2/5}} \qquad (4)$$

Note that constants a and b are different in equations (1), (3), and (4).

It is noteworthy that these relations make

$W \propto i_F^2\ R \propto i_F^{8/3} \quad V_F \propto i_F\ R \propto i_F^{5/3}$

agreeing well with the reference, which has W and V_F proportional to the 2·6 and 1·6 powers respectively of i_F.

To test this development, the data from Fig. 3, reference 1, was fitted to equation (3). They gave:

$a = 2.56\ e^{22.8} \qquad b = 95$

(where i_p is in microamps and i_F in milliamps).

Table 1 compares theoretical values of i_p, calculated by equation (3), with the experimental, from Fig. 3. The agreement is quite good, except at low values, where errors are perhaps to expected.

TABLE 1

i_F(mA)	i_P(μA)	
	EXP	*TH*
7·5	3·15	4·6
8·0	16·5	15·1
8·5	44·5	44·5
9·0	100·0	106·7

Equations (3) and (4) have been tried with the data from tests on other diodes, and have fitted quite well. It is thus felt that these equations may be of use in describing the diode as a sensitive element.

Yours faithfully,

H. L. ARMSTRONG,

National Research Council, Ottawa.

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1. ATTREE, V. H. Saturated Diode Operation of Miniature Valves. *Electronic Engng. 25*, 27 (1953).
2. MOTT, N. F., JONES, H. The Theory of the Properties of Metals and Alloys, p. 267 (Oxford, 1936).

The author replies:

DEAR SIR,—The relations (a), (b) and (c) given by Mr. Armstrong are accurately true for *ideal* tungsten filaments[1,2] and are very nearly true for small-diameter practical filaments run at a high operating temperature. Under these conditions the end-effects are small and hence nearly all of the filament is at the same temperature. However, when the operating temperature is much less than normal, as in the case of miniature-valves used as saturated-diodes, the cooling effect of the filament supports gives rise to a non-uniform temperature distribution along the filament. Thus the resistance per unit length of the regions near the cool ends will be much less than at the centre and, further, most of the thermionic emission will be obtained from the hot central zone. It is difficult, or impossible, to measure the temperature distribution along a small filament and we must therefore either calculate the temperature distribution[1-3] or assume that the whole filament runs at a single temperature. Mr. Armstrong has used the latter method and, as he shows, reasonable agreement is obtained in the particular case of the Mullard DL66 valve. The form of the Richardson equation given by Mr. Armstrong (equation 3) fits the actual characteristics over a somewhat wider range than the simple power-law relation, $i_A = Ki\beta_f$, which I used. However, it must be remembered that oxide-coated filaments do not saturate as well as pure-metal filaments so that the thermionic emission is to some extent dependent on the anode voltage. For this reason it is usually necessary to take account of the anode impedance when calculating the performance of a practical circuit. In general we are concerned with a particular working point and a knowledge of the anode impedance and the exponent β in the simple power-law relation is all that is required.

Yours faithfully,

V. H. ATTREE,

University of Manchester.

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1. FORSYTHE, W. E., WORTHING, A. G. Properties of Tungsten and Tungsten-Filament Lamps. *Astrophys. J. 61*, 146 (1925).
2. JONES, H. A., LANGMUIR, I. The Characteristics of Tungsten Filaments as a Function of Temperature. *Gen. Elec. Rev. 30*, 310 (1927).
3. RIBAUD, G., NIKITINE, S. Temperature Distribution along an Electrically Heated Tungsten Filament in a Vacuum. *Ann. de Phys.* Ser. 10, 7, 5 (1927).

Vibration Measurements

DEAR SIR,—The paper on "Vibration Measurements" in the December issue gives some useful facts, but as the values given in the various formulae are in general neither derived nor related to physical dimensions, it is assumed that they refer to particular items of commercial equipment. It is, therefore, difficult to discuss these values, but one or two general remarks may not be out of place.

The author appears to favour the self-generating pick-up and lists several advantages claimed for this type. To these might be added the ready availability of surplus headphones of the moving-coil or magnetic-diaphragm types which can be easily converted to simple pick-ups.

Only seismic type pick-ups are considered in detail and where the vibration frequencies are low, these tend to be cumbersome owing to the large static deflexion required. In an alternative construction, the mass is pivoted with the control spring in a spiral form, giving a compact unit readily adjustable for horizontal or vertical use. However, it is usually easier to employ a proximity system or, alternatively, an accelerometer pick-up where the vibration frequency is less than about 5c/s. With the latter system the self-generating transducer is at a disadvantage, as three stages of integration would be required to convert the output signal to a displacement indication. However, as accelerometers of the piezo-electric, balanced transformer and other types are available for low-frequency measurements, they are normally used under such conditions.

It is stated that the coil in the exciter described cannot withstand the continuous current rating of 20mA R.M.S. at all frequencies "since no method of limiting increasing electrical impedance with increase of frequency has been incorporated." The writer would be pleased to hear of a means of maintaining the reactance of a moving-coil unit more or less constant over a range of frequency. It is also noted that the insulation of the same coil is adequate for a potential difference of only 52·5V across its terminals at 16kc/s. This is surely very modest insulation for an exciter, which may well be subjected to considerable abuse when used without laboratory conditions.

There appear to be typographical errors in a number of places, including the equation on page 553 and the relationship on page 556, dealing with combined transverse and longitudinal movements of the contact pin in a pick-up. The values given for the amplitudes of the fundamental and second harmonic components are apparently not in accord with the definition of terms listed later.

With regard to terms, the writer is not clear as to the significance of the "maximum peak value of amplitude" compared with the "maximum value of amplitude."

It is confusing to mix the terms "peak" and "amplitude" when it has already been stated that the former is to be applied to non-sinusoidal and the latter to sinusoidal waveforms.

Yours faithfully,
D. S. Gordon,
The University, Glasgow.

The author replies:

Dear Sir,—I must thank Mr. Gordon for having drawn my attention to two mathematical errors in my paper.

The expression on page 553 should be:

$$d\phi/dt = d\phi/dA.dA/dt = d\phi/dA.\frac{d(A_0 \pm x)}{dt}$$
$$= d\phi/dA.dx/dt$$

and that on page 556 should be:

$$y = \delta/50\,\hat{x}\sin\omega t - \hat{x}^2/200\cos\omega t.$$

With regard to Mr. Gordon's other comments:

It is true that the paper deals with specific commercial instruments and this I think is made clear in the introduction. That the paper deals almost exclusively with the seismic type of pick-up is not due to any lack of interest in or awareness of other types of apparatus, but rather is due to the limitation of printing space.

I agree that it is a simple matter to modify standard moving-coil and magnetic diaphragm telephone ear-pieces to make crude vibration pick-ups, but cannot help but believe that the main items for consideration when designing a pick-up are the construction of the spring system and the calibration of the unit.

Proximity pick-ups, balanced inductances and very low frequency accelerometers are, of course, used quite extensively in the detection and measurement of vibration, but it is usual to choose the pick-up to suit the job in hand and it is my experience that no one type of instrument is used to the complete exclusion of any other.

The frequencies at which it has been stated certain maximum current conditions must not be exceeded are, so far as the majority of mechanical investigations go, very high, but (a) as stated in my paper "this limitation of current *may* be a drawback when examining small objects, which often have high natural frequencies, but may in practice be offset by the fact that in such cases smaller excitation forces are required," and (b) it is very unlikely that the operation of such an instrument would be left to the discretion of unskilled persons.

I have been unable to trace the terms "maximum peak value of amplitude" and "maximum value of amplitude" used in such form in any part of my paper, though admittedly the use of the words both "peak" and "amplitude" may give rise to certain ambiguities.

It seems that a typographical error has occurred in Mr. Gordon's letter where he states that "*three* stages of integration would be required to convert the output signal (of an accelerometer) to a displacement indication."

Yours faithfully,
R. Winslade (Miss),
Philips Electrical, Ltd.

Evaporation Chamber and Specimen Holder for Shadow Casting

Dear Sir,—The evaporation, by Williams and Wyckoff[1,2], of metal films at oblique angles on to electron microscope specimens for enhancing the image contrast of the specimen surface relief, has now become an established technique. Shadow casting has also been used for optical microscopy[3] and is of value for exposing the surface detail of transparent plastic replicas taken from surfaces which cannot be examined *in situ*.

The "shadow-casting" of organic film replicas, e.g., collodion, requires large evaporation source-to-replica distances to prevent overheating of the replica by heat radiation from the source and it has been customary to use vacuum evaporation plant fitted with tall glass bell jars for vertical evaporation. This type of plant is unsatisfactory because the bell jar diameter, which must be sufficient to accommodate the lead in electrodes and pump connected to the chamber baseplate, is very much greater than the specimen dimensions, and there is a large amount of unnecessary volume to be exhausted.

A shadow-casting chamber of small volume but with a source to specimen distance of 22cm has been constructed which could be exhausted quickly to the evaporation pressure by a 10l/sec oil diffusion pump and a 30l/min rotary pump.

The chamber, shown in Fig. 1, consists of a horizontal electro-tinned mild steel tube 3 inches diameter by 12 inches length with the vapour source and specimen holder located at each end. Pumping connexion is made to the centre of the chamber via a "T" joint on to which is bolted the diffusion pump isolation valve. Vacuum seals on the chamber and pumping connexions are made with rubber "O" rings retained in re-entrant grooves. The evaporation heater filament is connected between an earthed stud A and insulated electrode B in the end plate C. The electrodes are brass threaded 2 B.A. and the filament heater terminals made of steel. A heater current of up to 30A can be used for evaporations of short duration using tungsten heater wires of 0·5mm diameter. By unscrewing the retaining collar D the filament holder is easily removed from the chamber for either filament renewal or loading of the metal to be vaporized.

The specimen assembly shown has been designed for holding supporting screens used with the Philips electron microscope. The screens are first mounted between two clamping bars E which are then fixed inside the chamber to the metal block F and screwed in position by a knurled nut G. For convenience of setting the vapour incidence angle a protractor scale is fixed externally to one end an ⅛in. diameter shaft which, passing into the chamber via a rotary seal, carries at the other end the specimen assembly.

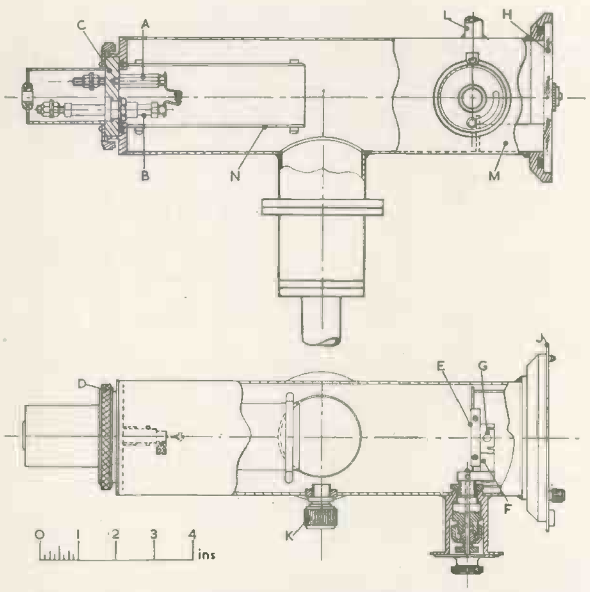

Fig. 1. General arrangement of the shadow casting unit

The glass end plate H serves as a window for observing the evaporation source and is easily removed for access to the specimen holder by releasing the spring clip J. An air release valve K is fitted to the centre of the chamber and a gauge connected at L.

The exhaustion time of the equipment from atmosphere to 0·1 microns of mercury pressure, pressure measurements made with a Philips' ionization gauge, was of the order 10 to 12 mins. To maintain this pumping rate in daily use it was found advantageous to place a desiccant (P_2O_5) in the chamber for absorbing the water vapour liberated from the chamber walls at low pressures. A desiccant tray M, shielded from the vapour source, has therefore been included in the apparatus.

A glass tube N, surrounding the vapour source, is used for preventing the gradual build-up of thick evaporated layers on the chamber walls, which are not only difficult to remove but also absorb moisture when exposed to the atmosphere.

Yours faithfully,
L. Holland,
Research Laboratory,
W. Edwards & Co. (London), Ltd., S.E.26.

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2. Williams, R. C., Wyckoff, R. W. G. Applications of Metallic Shadow-casting to Microscopy. *J. Appl. Phys. 17*, 23 (1946).
3. Scott, D. B., Wyckoff, R. W. G. Metal Shadowing of the Optical Microscopy of Certain Tissues. *Amer. J. Clinical Path. 19*, 63 (1949).

Electro-mechanical Voltage Stabilization

DEAR SIR,—I observe that Mr. P. A. V. Thomas states in his letter in the January 1953 issue of ELECTRONIC ENGINEERING that the M-motor is designed to be operated from a switched D.C. supply.

It may thus be of interest to note that the M-motor, and akin types of motor classed generically as repeater motors, may be operated in conjunction with a magslip system.

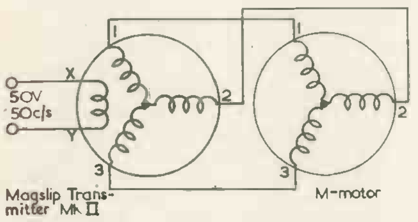

Fig. 1. M-motor connected across the phase leads of a magslip transmitter

The M-motor will, if connected across the phase leads of a magslip transmitter, act as a receiver or indicator following the transmitter rotor in synchronism with, however, a 180° indeterminacy in position due to the rotor receiving its energizing by induction from the stator. Such a motor possesses the advantage that only three leads are required to transmit a positional indication (Fig. 1).

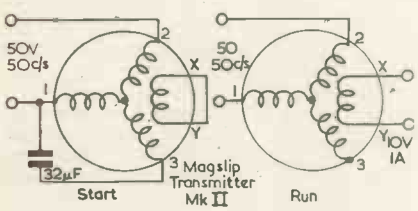

Fig. 2. Use of magslip as synchronous motor

It may also be of note to observe that a magslip may be used as a synchronous motor by applying an A.C. supply across two of the phase leads, shorting the rotor and starting the motor either by hand or with a capacitor connected between the third phase lead and one supply lead. If the rotor short be then removed and suitable D.C. energizing (about 10V 1A) be applied, the motor will pull into step and run synchronously with the A.C. supply (Fig. 2).

Yours faithfully,
D. NAPPIN,
Harrow.

The Author replies:

DEAR SIR,—I am very interested in Mr. D. Nappin's note concerning the use of M-motors in conjunction with magslip transmitters though it seems to me that it has little bearing on the subject of electro-mechanical stabilizers.

However, it is useful to know that M-motors can be successfully driven from magslips as M-transmitters are not so easily obtainable and it also obviates the necessity of providing a 24V D.C. supply.

On the other hand, I cannot see that there is any great advantage in using a magslip transmitter instead of an M-motor as a synchronous motor as not only a low voltage (10V) D.C. supply has to be provided, but also the necessary switching for the rotor winding to change over from start to run conditions.

Yours faithfully,
P. A. V. THOMAS,
Royal Technical College,
Glasgow.

A Differential Transformer Gauge and Amplifier

DEAR SIR,—As we are developing an inductance gauge for measuring strain, it was of interest to read Mr. Dighton's description of a differential gauge in the February issue of ELECTRONIC ENGINEERING. From the strain measurement point of view, Mr. Dighton's gauge might be somewhat heavy, but it is a pity that no calibration was possible for movements smaller than 0·001in. A description has already been given by Schaevitz (Proc. Soc. Exp. Stress Anal., Vol. 4, 1947), of a similar differential transformer gauge and output characteristics were given for movements considerably less than 0·001in.

The strain gauge being developed in this Department depends on a variable air-gap. The magnetic circuit consists of an E core with an armature across the open end of the E. Strain is converted into a change in length of the air-gap between the E core and the armature. A coil is wound on the centre arm of the E and forms one arm of a bridge network, the output of which is amplified and displayed on a meter.

Using this set-up, strains as small as 10^{-7} can be detected, although, at present, readings are only considered reliable down to strains of 10^{-5}. It is hoped to publish further details of the gauge and circuit at a future date.

Yours faithfully,
J. C. SIMMONS,
D. W. VALE,
University College,
London.

The Author replies:

DEAR SIR,—I have been interested to read the description by Messrs. Simmons and Vale of their variable inductance gauge for measuring strain. This type of gauge can be made extremely sensitive and their figures confirm this. The linearity is, however, inferior to the differential transformer type; also one would expect their design to be more sensitive to temperature changes since it is not a balanced system.

We have not used the differential transformer type of gauge for strain measurement but its size is an obvious disadvantage. It is considered, however, that the linear dimensions of the gauge I described could be reduced by a factor of three without loss of sensitivity provided the coils were modified accordingly. The gauge described can be used to detect movements of 10^{-5}in. corresponding to a strain of 10^{-5} in a gauge length of one inch. If one is prepared to abandon the convenience of operation at 50c/s, the sensitivity can be further increased since it is approximately proportional to frequency.

Your correspondents need have no fears on the grounds of linearity. The differential transformer gauge described is linear to 1 per cent over a range of 0·1in. so that, over a range of 10^{-4}in. the linearity should be so good as to defy measurement; there is no non-linearity in the neighbourhood of the zero with this type of gauge.

Yours faithfully,
D. T. R. DIGHTON,
Kodak Limited.

Slotted Line Techniques

DEAR SIR,—On reading through an article by E. G. Hamer in your issue of December, 1951, I was surprised to see that in his summary of the relationships existing between the various quantities involved in transmission line measurements, he quotes the standing wave ratio as being given by

$$\text{S.W.R.} = \frac{|Z|}{|Z_0|} \text{ or } \left|\frac{Z_0}{Z}\right|$$

where Z is the terminating impedance and Z_0 is the characteristic impedance of the line. This formula is quite incorrect.

The reflexion coefficient is correctly quoted as

$$\dot{K} = \frac{Z - Z_0}{Z + Z_0}$$

and if Z is put in the general form $R + jX$,

$$\dot{K} = \frac{R - Z_0 + jX}{R + Z_0 + jX}$$

$$\therefore |K| = k = \sqrt{\left[\frac{(R - Z_0)^2 + X^2}{(R + Z_0)^2 + X^2}\right]}$$

Therefore, on Mr. Hamer's definition of S.W.R. as $\dfrac{1 + k}{1 - k}$,

$$\text{S.W.R.} = \frac{\sqrt{[(R + Z_0)^2 + X^2]} + \sqrt{[(R - Z_0)^2 + X^2]}}{\sqrt{[(R + Z_0)^2 + X^2]} - \sqrt{[(R - Z_0)^2 + X^2]}}$$

which certainly cannot be simplified to $\dfrac{|Z|}{|Z_0|}$ or $\left|\dfrac{Z_0}{Z}\right|$, except in the special case when $X = 0$.

Perhaps a more obvious method of demonstrating the error is to consider a line terminated in a pure reactance whose magnitude is Z_0. All the power is reflected, and the standing wave ratio is infinite, whereas the formula in question would give a standing wave ratio of 1.

Yours faithfully,
T. P. FLANAGAN,
St. Albans,
Herts.

The Author replies:

DEAR SIR,—I am quite in agreement with the point raised by Mr. T. P. Flanagan, the formulae should have read

$$\text{S.W.R.} = \frac{Z_a}{Z_0} \text{ or } \frac{Z_0}{Z_b} \text{ (Scalar Quantity)}$$

where Z_a = Impedance at a voltage maximum

Z_b = Impedance at a voltage minimum.

It was decided to omit this from the final text as it might be confusing, but unfortunately although the qualifying statement was omitted the formula was left in.

Yours faithfully,
E. G. HAMER,
The General Electric Company, Ltd.

Notes from the Industry

The Radio Group of the Institution of Post Office Electrical Engineers is holding its Second Radio and Models Exhibition on May 7, 8 and 9, at Metropole Hall, Northumberland Avenue, London, S.W.1. The exhibition will be on home construction, together with additional exhibits of interest to the radio and model enthusiast. Secretaries of radio clubs and societies are invited to write for further information to the Honorary Group Secretary, 23 Surrey Lane, Battersea, London, S.W.11. Admission is by programme which is obtainable at the door.

British Insulated Callender's Cables, Ltd., announce that they have acquired the cable and wire business of Phillips Electrical Works, Ltd., Canada, and will, through a new Canadian company which they are forming with the name of Phillips Electrical Company (1953), Ltd., carry on this business at the existing Brockville (Ontario) and Montreal factories. The existing personnel engaged in the cable and wire business of the present Phillips company will be retained.

Marconi's Wireless Telegraph Co., Ltd., have dispatched to Caracas, Venezuela, what is believed to be the largest single consignment of television equipment air-freighted from England. Nearly a ton and a half of telecine and studio lighting equipment was transported by a Dutch Airlines Skymaster in time for installation for the opening of the Televisa Station at Caracas, which was itself designed and manufactured by Marconi's.

The BBC announces that Mr. C. Duddington has been appointed Engineer in Charge of the low-power television transmitting station at Glencairn, near Belfast, Northern Ireland.

The Electro-Physiological Technologists' Association will be holding their annual general meeting at Hurstwood Park Hospital, Haywards Heath, Sussex, on Saturday, May 16, commencing at 10.30 a.m. There will be papers and demonstrations of interest to electro-physiologists and others concerned with the recording of sub-audio phenomena. Non-members are welcome to attend and should communicate with Mr. G. Johnson, the honorary secretary of the Association.

The Radio and Electronic Component Manufacturers' Federation at their annual general meeting elected the following vice presidents: Mr. A. F. Bulgin, Mr. E. M. Lee, Major L. H. Peter, Mr. S. Wilding Cole and Mr. Hector V. Slade. Mr. P. D. Canning was elected chairman for the coming year and Mr. W. F. Randall vice-chairman. Since 1948 Mr. Canning has been engaged on special duties connected with trade association activities and overseas liaison for the Plessey Co., Ltd., Ilford, Essex.

The Royal Society have recently elected into the Fellowship, among others, Professor Willis Jackson, Professor of Electrical Engineering, Imperial College of Science and Technology, London, and Mr. A. R. Powell, Research Manager of Johnson, Matthey & Co. Ltd.

The British Sound Recording Association are holding their fifth private exhibition of sound recording, reproducing and audio frequency equipment on Saturday and Sunday, May 16 and 17, at the Waldorf Hotel, Aldwych, London, W.C.2. The exhibition will be open from 10.30 a.m. to 6 p.m. on both days and will be free to members. Admission of non-members will be by catalogue available at the door, price 1s. 6d. or 1s. 8d. by post from the Hon. Secretary, R. W. Lowden, "Wayford", Napoleon Avenue, Farnborough, Hants.

The Ministry of Supply announce that, owing to the continually growing use of radioactive isotopes throughout the world, the Isotope School at Harwell has had to introduce an additional course this year. The series of courses planned for the year did not include one for July, but there has been such a heavy demand for places that an extra course will be held from July 6-31. Applications should be sent to the Isotope School, A.E.R.E., Harwell, Berkshire, not later than June 8, 1953. Students pay a fee of £40 for the course, and accommodation can be arranged at an additional charge of £7 7s. a week.

Mr. T. E. Goldup, M.I.E.E., has been elected chairman of the Radio Communication & Electronic Engineering Association for 1953 in succession to Mr. K. S. Davies. Mr. C. G. White remains vice-chairman.

Pye, Ltd. have secured the contract for supplying equipment for two complete television studios for Institut National Belge de Radiodiffusion, the Belgian television service. The total amounts to some £70,000. This equipment will operate on both 819 and 625 line systems, only a simple switch being necessary for the change over. Test transmissions are due to commence in the autumn.

The Norwegian Industries Development Association is sponsoring an exhibition to be held in Oslo from June 10-20. The exhibition is to cover measuring and control techniques with instruments and apparatus, which are used in industry and research laboratories. A study conference is also being planned, with the aim of supplementing the exhibition.

The Physical Society are holding a Science Meeting on Friday and Saturday, May 15 and 16, at Imperial College, Imperial Institute Road, London, S.W.7. The meeting, arranged by Dr. O. Klemperer of Imperial College, will be on "Recent Research in Electron Optics". Visitors wishing to attend should apply to the offices of the Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7, for further particulars and application forms. Closing date for applications is Thursday, May 7.

The 20th National Radio Show at Earls Court will be opened on September 2 by Field Marshal Lord Montgomery.

The Industrial Spectroscopy Group of the Institute of Physics has formed a panel of members interested in direct reading equipment for spectrochemical analysis. The object of the panel is to organize meetings which would serve the interests of users and potential users of this equipment. Particulars may be obtained from the Secretary, the Institute of Physics, 47 Belgrave Square, London, S.W.1.

The Sixth Canadian International Trade Fair will be held in Toronto from June 1-12. Britain's exhibits at the Fair will cover an extremely wide range of products. To give the world's buyers more information about Britain's products and services in the widest possible varieties of fields, a number of the United Kingdom's leading publishers of business journals are combining in the display of their most widely read technical, trade and specialized publications, among which the publications of Morgan Bros. will be represented.

Ferranti, Ltd. have received an order from Royal Dutch/Shell Group to provide an electronic digital computor for use in their large research establishment in Amsterdam. The machine will be housed in a new laboratory now under construction.

Mr. Alfred Blount who, for the last seven years has been general manager of Vandervell Products, Ltd., has been appointed a member of the executive board of the Plessey Company, Ltd., Ilford, Essex.

The Atomic Energy Research Establishment has now issued the fourth list of some 28 reports produced by members of the staff, which are available for sale. Copies may be purchased from Her Majesty's Stationery Office.

The Radio Industry Council has issued the first two sections of a specification No. RIC/121 "Resistors, Rotary, Variable, Wire-Wound". This specification has been produced by agreement between B.R.E.M.A., R.C.E.E.A. and R.E.C.M.F. For the time being this is meant for use internally within the industry, but it is intended to submit it in due course to B.S.I.

Errata. The trade name of the permanent magnet material produced by Swift Levick and Sons, Ltd., Sheffield, and mentioned in the R.E.C.M.F. Exhibition Preview in the April issue, should read "Columax". Also the first symbol in the magnetic properties given should read "B rem".

We regret that an error occurred in the circuit diagram of "A Gramophone Pick-up Pre-Amplifier" by E. J. Miller on page 498 of the November, 1952, issue. The wiper arm of the lower half of S_1 should be joined to the junction of the 0·01μF and 0·5μF capacitors and the 32kΩ resistor via a 0·03μF capacitor and not direct as shown in the diagram.

BOOK REVIEWS

Proceedings of the National Electronics Conference

835 pp., 625 figs. Royal 8vo. Vol. 8. National Electronics Conference Inc., Chicago 19, Illinois. 1952. Price $5.

THIS volume gives the texts of the one hundred papers presented at the 8th National Electronic Conference held in Chicago, September 29 to October 1, 1952. The subject matter ranges over the whole field of electronics and the papers are grouped under 22 headings, each embracing the four or five papers presented at a single conference session.

The subject matter and treatment of the papers correspond to what one would expect to find in "Proc. I.R.E." or in "Electronics" and, at the time of writing, six of the conference papers have already been re-published in these journals. Judging from previous years it is unlikely that a great many of the papers will appear elsewhere; however, there is no doubt that this re-publication factor makes it especially important that the proceedings should come out as soon as possible, and the editors are to be congratulated in getting out the volume in just over three months.

The proceedings contain six papers on transistors and four on semi-conductors. These papers cover work in progress at Bell Labs., RCA and G.E. on frequency-characteristics, junction-transistors, trigger-circuits and transistor-amplifier noise. Two papers deal with the proposed N.T.S.C. compatible colour television systems. The first discusses the effect of noise on system performance and the second describes the experimental colour-television receiver developed by Westinghouse. Seven papers are on servo-mechanisms; one of these describes the application of servo-techniques to amplitude-stabilized oscillators; such methods result in an oscillator with better immunity to transient changes than is obtainable with circuits designed on an empirical basis.

In recent years the technique of electromagnetic velometry, initially developed by A. Kolin for blood-flow measurement, has been widely applied, especially to liquids which are "hot" in the radioactive or thermal sense. A recurrent source of difficulty in the A.C. flowmeter is the large and variable zero-flow signal, and a paper of considerably practical value shows how this trouble may be overcome. Two papers deal with printed circuits and several discuss component reliability; both of these subjects are of great importance in guided-missile development. A Naval Ordnance Laboratory paper describes a distributed-constant delay-line with a high characteristic impedance. The electrical performance of this line is much better than that obtained on similar delay-lines currently under development in this country; however, information on the temperature stability is not given.

A list of the contents of this volume, and of each of the previous seven volumes, is included, but unfortunately there is neither a subject index nor an author index. A subject index is very desirable in a book of this type as the grouping of the papers is determined not only by their contents but also by the requirements of the conference timetable. This may lead to papers being overlooked, for example a reader interested in physical measurement may easily miss the paper on a ceramic vibration pick-up which is listed under "Audio" and not under "Industrial Measurements." A multiple-entry subject index, including the contents of previous volumes (a total of some 600 papers), would undoubtedly have added to the value of the book as a reference source.

V. H. ATTREE.

Ultrasonic Physics

By E. G. Richardson. 285 pp., 99 figs. Medium 8vo. Elsevier Publishing Company, New York. Cleaver-Hume Press Ltd., London. 1952. Price 30s.

IT is a pleasant task to review a book which one has so much enjoyed reading; the danger to be guarded against is the possible blunting of the critical faculties by that very enjoyment.

Dr. Richardson's book is quite novel in its subject matter, and, contrary to the modest comment in the first sentence of the preface, needs no justification for its appearance. The accent is largely on the use of ultrasonics as a laboratory tool, but the value of the experiments described will be apparent to any reader with experience of applied ultrasonics.

The outstanding merit of this book is that an attempt is made to relate theory and experiment wherever possible.

A fair proportion of the book consists of descriptions of experiments with which the author has been directly concerned; this is a great asset and adds conviction to the work described.

The least impressive part of the book is Chapter I which deals with "Sources of Ultrasonics."

The circuits shown in figures 6-10 are a little too basic to be useful, and the description provided of their modes of operation is inadequate.

Chapter II is concerned with methods of detecting and measuring ultrasonic radiation and with some of the properties of ultrasonic waves such as cavitation and scattering due to obstacles.

The circuit shown in figure 19 cannot possibly work in the manner described in the text and in figure 21 the polar curves have been wrongly labelled.

The next chapter is devoted to the measurement of propagation constants, namely the velocity and absorption of ultrasonic waves in a transmitting medium. The fixed path and variable path interferometer are introduced for the first time and the use of an ultrasonic wave train as a diffraction grating for light waves is also described in some detail.

Chapters IV, V and VI deal with propagation in gases, liquids and solids in that order and much of the author's own work appears in the first two of these chapters. In the table on page 206 it is surprising to find that the absorption and the velocity of propagation in mercury are not given, especially in view of the considerable use of mercury ultrasonic delay lines in electronic digital computors.

The style of presentation is excellent, despite the use in places of such words as divaricate, pendulation, crispation and animadverted. References to other published work are numerous and well chosen throughout the text, and comprehensive lists are given at the end of each chapter.

In the opinion of the reviewer, this is a really good book on a topical subject and will be welcomed by all workers with an interest in ultrasonic techniques.

L. I. FARREN.

Elements of Radio Engineering

By H. I. F. Peel. 232 pp., 153 figs. Crown 8vo. Cleaver-Hume Press Ltd. 1952. Price 10s. 6d.

THIS book has been written to cover certain examination syllabuses, and sections of others. A common failing of books with this objective is that, concentrating on answering expected forms of question, they fail to give comprehensible coverage of the syllabus. Mr. Peel has not so failed. After careful reading of this book, the student should have a sound appreciation of the subject matter. The reviewer wonders, however, whether the claims on the publisher's jacket may be optimistically misconstrued with regard to scope, but it is hoped that the word "Elements" in the book's title will guard against this.

Maybe some examining bodies will soon be changing the title of this subject from radio to electronics. If so Mr. Peel has well anticipated this trend by opening with a chapter explaining lucidly the action of thermionic valves; following with one each on alternating currents and the triode amplifier; then two very good chapters explain the functions of capacitance and inductance. Further chapters deal with: power supply circuits, including a good simple treatment of smoothing filters; tuning circuits; oscillator circuits, including a concise introduction to aerials; detector circuits; typical complete receiver circuits; radio measurements, and a short chapter on the cathode-ray oscillograph. A series of eight appendices follow, giving mathematical proofs of statements and explanations presented in the main text; an ideal arrangement for early grade students; also some recent examination questions, arranged under chapter headings for which they are appropriate, with answers to numerical parts. The index is rather sparse.

A few criticisms seem important enough not to escape attention here. On page 103 there are four errors of statement in the last two sentences, relative to the high frequency response of an audio transformer; the reviewer would recommend they be omitted from the next printing, as unnecessary at this stage —even the correct statement would be "obscuring the wood", which Mr. Peel cannot be accused of elsewhere. More accurately drawn curves showing the effect of varying Q (Fig. 83) would be an improvement; true they are only intended to give a rough indication, but shapes like this can prove a stumbling-block later in the student's mind. Other figures requiring attention for instructional clarity are numbers 102, 108 and 111, and the text associated with the last named, which gives the impression that a heterodyne beat note has a waveform like the raw output from a full-wave rectifier.

Earlier books covering this subject often seemed to compete for the booby prize for their howlers. This reviewer doubts whether the most caustic of his fellows could seriously find anything more worth "going to town" on than the points mentioned in the previous paragraph. The book must be commended for a coverage of its subjects much better than average.

N. H. Crowhurst

Filter Design Data for Communication Engineers

By J. H. Mole. 252 pp., 126 figs. Demy 8vo. E. & F. N. Spon Ltd. 1952. Price 63s.

THIS is a book which will, as the author claims in his preface, enable engineers to design Zobel filters in "a small fraction of the time otherwise needed". Starting with the desired attenuation characteristic, a design procedure is outlined which terminates in the computation of the element values of the optimum Zobel filter, using coils of a given Q value, and the minimum possible number of elements. In a trial, the reviewer found that Dr. Mole's procedure and data reduced the time taken for the design of a four-section band-pass filter to one-tenth of that required when using a cut-and-try technique and the data presented in a standard textbook.

Dr. Mole assumes the reader to be familiar with classical filter theory, and there is little theoretical discussion. Normal types of symmetrical filters, together with dissymmetrical band-pass filters are treated in a unified manner. The fact that the book is by a single author, and is not a collection of miscellaneous articles, makes it easy to use once the general arrangement has been grasped. In addition to the normal index, there is an index of tables, and one of charts, and a clear and precise introductory chapter to guide the user through the material presented. Each chapter includes examples showing the method of applying the charts and tables to practical filter problems.

There are a few minor, disconnected criticisms, which might be made of the book. Something could usefully have been added on Bode's method of impedance correction, and in one or two passages the author has been too brief, such as in the approach to optimization in Chapter 8. The material on permissible tolerances on element values is new, and very useful, and this chapter also merits expansion. These are, however, arguable points, and were the theoretical discussion to be extended unduly the book would no longer be easy to handle. As it is, the book is of reasonable size and produced in a way that makes it a pleasure to read.

J. T. Allanson

Electrical Measuring Instruments—Part I

By C. V. Drysdale and A. C. Jolly. 2nd Edition. Revised by G. F. Tagg. 279 pp., 361 figs. Royal 8vo. Chapman & Hall Ltd. 1952. Price 75s.

DRYSDALE and Jolly's book on electrical measuring instruments has for long been regarded as the standard work on the subject, but with the passage of years it has inevitably become to some extent out of date and the issue of a second edition will be welcomed by all those who are interested in instruments. The complete modernizing of this great work, 440 pages for Part 1 in the old edition and 600 somewhat smaller pages in the new edition, would be a herculean task which has not been attempted. The new edition follows the pattern of the old, having ten chapters dealing with general electrical principles, mechanical design and construction, conditions of rapid indication, elements of electrical theory and design, properties of electrical materials, permanent magnet moving coil instruments, soft iron instruments, dynamometer ammeters, voltmeters and wattmeters, hotwire instruments and electrostatic instruments. A large part of the text of the first edition is reproduced unaltered except for a few vagaries of printing, such as the reproduction of one figure upside down, showing mercury apparently defying the law of gravity. New sections have been added to cover new developments in insulating and magnetic materials, recent researches on pivots and jewels and recent designs of instruments. The theoretical treatment of mechanical design has been largely rewritten. To make space for new additions a certain amount of the original text has been deleted, but there is still a great deal of material which can now only be considered of historical interest and which might well have been swept away in order to make room for more detailed accounts of recent developments. For example, the space allotted to the high permeability alloys is only one page and does not include any reference to the dynamometer instruments with mumetal cores produced by the Cambridge Instrument Company. There is also no reference to the vacuum enclosed electrostatic instruments produced by the Metropolitan Vickers Electrical Company and electronic instruments are completely excluded. The work on gold-chromium and chromium-nickel-aluminium resistance alloys carried out in the U.S.A. is not mentioned.

M.K.S. enthusiasts will find no encouragement in this book and it is an interesting commentary on the time required to produce a book that the change from international to absolute units, which was announced before the war, and which actually took place on January 1, 1948, is dealt with in an appendix in a book published at the end of 1952.

Notwithstanding these minor points of criticism there is still no other book available which covers the subject so thoroughly as this one and both publishers and reviser should be congratulated on giving this classic a new lease of life.

A. H. M. Arnold

BOOK REVIEWS (Continued)

Photoconductivity in the Elements

By T. S. Moss. 249 pp., 56 figs. Royal 8vo. Butterworths Scientific Publications. 1952. Price 50s.

THE early discovery of the lowering of resistivity of selenium by irradiation with visible light marked the beginning of studies of such photo-conduction in many other solids and compounds. There has been in recent years a considerable practical application of such solids in detectors for visible radiation and for infra red radiation as long as 6-7μ in wavelength. The author of the present volume is well known in photoconductivity research and the text he presents not only surveys the theory and experimental results in the field but adds to these the results of his own studies on a particular group of elements which were not so well known previously.

The first part of the book is concerned with the theory of photoconduction and its related effects. It begins with a concise and readable account of the modern electronic theory of crystalline solids and the use of the theory to interpret the characteristics of photo-conductors. Such characteristics include conductivity, Hall effect, optical absorption and refractive index, spectral sensitivity of photocurrent and the response time of the latter current. Also included are a discussion of the photo-voltaic effect at metal-semiconductor boundaries and at internal boundaries in solids, and a discussion for refractive index in relation to the threshold wavelength for photoconductivity. The final chapter of the first part deals with the photoemissive properties of semi-conductors.

The second part of the text comprises accounts of experimental studies of the particular group of elements including boron, diamond, silicon, germanium, grey tin, phosphorus, arsenic, antimony, sulphur, selenium, tellurium and iodine. Here is provided a survey of all the characteristics of these elements, as known at present, which are related to their photoconductivity. A feature of this section is the attention to experimental methods used in preparation of the samples and in their measurement. The author's direct experience of the difficulties involved provides a most valuable part of the text. His own studies also emphasize the necessity of properly co-ordinated experiments on the same specimen to determine the relation of other effects to photoconductivity. In the past correlation of data from Hall effect and conductivity measurements, etc., has been made difficult because each laboratory so often confined itself to a study of one or two characteristics only, there being no exchange of specimens between the different workers. It is perhaps to the systematic and co-ordinated study of each type of photo- and semi-conductor that we owe the present advances in knowledge of fundamental mechanisms in these solids.

The book forms a valuable and encyclopaedic survey for the research worker in this and allied fields and also provides an introduction to the subject for those with other or wider interests. It contains very complete references and good author and subject indices. The only complaint which will arise from the reader will be the high price level which research monographs of this valuable type have reached.

G. F. J. GARLICK

Radio Engineer's Servicing Manual

General Editor, E. Molloy. 760 pp., 585 figs. Demy 8vo. George Newnes Ltd. 1952. Price 42s.

THIS book is in three sections; the first titled "General", treats concisely such matters as efficient methods of servicing, reading diagrams, maintaining customer goodwill, and various aspects of routine servicing, testing and maintenance for different types of receiver.

The middle section occupying most of the book, gives servicing data from 32 manufacturers on over 300 basic circuits, in nearly 600 different models. Assembling all this information in a reasonably consistent form must be a very considerable task, in view of the wide variety of presentation on individual manufacturer's sheets. In general the presentation has assumed a very consistent appearance. A little over half of the manufacturers show layout drawings of most of their receivers, as well as circuit diagrams, and all except one or two give alignment information and voltage check data. Perhaps a little more standardization of terms could have been achieved. Voltage Checks, Check Points, Valve Analysis, are different headings for the same information; also a few manufacturers list either Audio Output, Undistorted Output or just Output.

It would still be good to see better standardization in the presentation of diagrams. Probably the feature leading to most practical difficulty is the varied presentation of switching using wafer type switches. Valve and trimmer—capacitor and coil—symbols also could do with standardization. These criticisms apply more to general practice than to this book in particular, which presents a wealth of useful information in extremely compact form. Other departures from general uniformity of presentation have been adopted to save space.

The last section gives useful reference material, such as channel allocations in Britain and Europe under the Copenhagen Plan, colour codes, preferred values, etc., and useful formulae with worked examples; two simple errors seem to have crept through here.

The book has a useful general index, and a still more useful index to models for the servicing data, which covers the post-war period from 1945 to the date of printing. It is doubtful whether any two authorities would agree exactly about the material to be included in the first and last sections, but the reviewer agrees almost entirely with the editor's choice as giving the most useful information in its most concise form.

N. H. CROWHURST

Thermionic Vacuum Tubes

By W. H. Aldous and Sir Edward Appleton. 6th Edition. 151 pp., 98 figs. Crown 8vo. Methuen & Co., Ltd. 1952. Price 9s. 6d.

THIS is a completely revised version of the book of the same name by Sir Edward Appleton, first published 21 years ago. The inclusion of almost every valve development during the years brings this work really up to date. After the introduction, an account of modern methods of valve manufacture and a brief theory of thermionic emission are given. As in general, most valves have been developed from the diode and the triode, the comprehensive analyses of the operation of these two valves permits the somewhat less full description of multigrid valves which should be easily understood. The cathode-follower, phase-shift oscillators, noise, and the cavity magnetron are but a few of the diverse subjects described. The bibliography lists 119 references ranging from Richardson's papers on emission to recent writings on travelling wave tubes. Mathematical analyses in the text are adequate, but not formidable. The C.R.T. is not described, as the authors consider that the electronic beam forming action is secondary to the production of light. Why then is the output pentode described? The control of its anode current is surely only secondary in a radio receiver to the production of sound! A chapter on the C.R.T. and a few additional references could only have enhanced the already considerable value of this monograph, which the reviewer has no hesitation in recommending to the newcomer to the radio and electronic field.

H. STIBBE

Worked Examples for Advanced Electrical Students

By D. I. Williams. 160 pp., 117 figs. E. & F. N. Spon Ltd. Demy 8vo. 1952. Price 18s.

THIS volume is of much more value than the title suggests. It is not a list of questions and answers, but a tutorial book with theory developed and led to numerical examples, either in the text or reproduced from given examination papers. It deals only with heavy electrical engineering; the only electronic subject being the mercury arc rectifier. Some errors mar the book; one question asks for R_2 and C_2, but answers are given for R_1 and C_1. Although the text is reasonably correct as to standard terms and symbols, all but one of the diagrams show ω for Ω, a misleading feature due to bad D.O. practice not checked. Similarly ω is often used in mistake for w. These errors tend to detract confidence from such a book, which careful checking would have avoided.

E. H. W. BANNER