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Commentary

THE Atomic Age burst upon the world with devastating effect when the first atomic bomb was dropped on Hiroshima in August 1945 and killed no less than 78 000 of its inhabitants. Ever since, mankind has been sorely perplexed by the ever-increasing power of mass destruction that nuclear fission has placed in our hands. "Bigger and better" bombs have been tested from time to time during these uneasy years of peace and the latest bomb exploded at Bikini on March 1st of last year was, it was reported, equivalent in one blast to 10 000 000 tons of TNT and five hundred times the power of the first bomb on Hiroshima. Such a bomb, it is calculated, would cause total destruction by blast over an area of 50 square miles, severe damage over 200 square miles, "moderate destruction" over 600 square miles and destruction by fire over 800 square miles !

With even more devastating bombs on the way to development it is excusable if the peaceful uses of atomic energy have been overshadowed by its more sinister applications.

But the Atomic Age is now upon us and if the statesmen of the world can succeed in reducing the present world tension there begins to dawn a new era in which the peaceful uses offer unlimited possibilities for the benefit of mankind at large.

The Atomic Age had its beginning in 1942 when the governments of the United States, the United Kingdom and Canada adopted an informal *modus operandi* for the development and manufacture of the atomic bomb. This plan, later formalized by the Quebec Agreement of 1943, arranged for the pooling of all knowledge and resources and for the manufacture in America of the atomic bomb itself. In the years that followed many attempts were made to put the development of atomic energy under international control under the supervision of the United Nations, and it is worth recalling that in May 1946 the British Atomic Scientists Association submitted to the United Nations Atomic Energy Commission a six-point proposal on these lines. In December 1953 President Eisenhower in an address to the General Assembly of the United Nations put forward a plan to put atomic energy to work on an international basis, for peaceful purposes. In essence this plan called for a world stockpile of fissionable material to which each country having atomic resources would contribute, the stockpile and its use to be under the control of the United Nations, who would encourage world-wide investigation into effective peaceful uses of atomic energy.

Drawing its inspiration from President Eisenhower's address, a small but highly important travelling exhibition made its debut last month at the South Bank, London. It was the "Atoms for Peace" Exhibition sponsored jointly by the United States Information Service and the United Kingdom Atomic Energy Authority.

After a short stay in London the Exhibition, which is housed in five large mobile trailers, left for a tour of Britain which will last some five months, during which time it will visit the principal cities of this country and will seek to explain in simple language "the endless possibilities for improving world standards through international co-operation in the peaceful use of atomic energy ". With the help of films, models and visual aids the layman, for whom the Exhibition is primarily intended, will be able to judge the practical form the peaceful applications are taking.

It shows, for example, the rapid developments that have taken place in the application of radio-active isotopes to medicine, industry and agriculture with some of the quite startling results which have been achieved.

The "Atoms for Peace" Exhibition is, however, only part of a wider plan for the development of the peaceful uses of atomic energy, for there is being held in August, the United Nations Atoms for Peace Conference at Geneva, having as its aim "to encourage a co-operative approach by scientists on the problem of making the atom a constructive thing for man's future, and to help the nations which are less informed on atomic work, better to understand and appreciate the potentialities of atomic energy in terms of their own future developments."

Of the 52 nations which have already promised to attend the Geneva Conference, 23 governments, the United Nations and three of the United Nations specialized agencies have submitted a total of over 900 abstracts of scientific papers to be presented, the major contributions coming from the United States and the United Kingdom.

Apart from the scientific contributions, the United Kingdom is staging two exhibitions. One of these is purely scientific in character and is principally intended for members of the delegations attending the Conference. Sponsored by the United Kingdom Atomic Energy Authority, it will be mainly concerned with nuclear reactors for research and for the generation of power, and with the associated specialized instrumentation which has been developed in this country.

The second exhibition, of more general character, will provide a survey of the peaceful applications of atomic energy in Britain. Among the subjects it will introduce, will be the world's first full-scale atomic power station now being erected at Calder Hall as part of this country's ten-year power station programme.

A SPEEDMETER . . .
for use at high Traffic Flows

By I. B. Laker* and P. D. Whiting*, B.Sc.

This article describes an instrument capable of measuring the speed of vehicles passing along a road at speeds between 15 and 70 mile/h under conditions where the flow of traffic is high. It is operated by detector tubes on the road and uses a milliampère-second meter operating on a known current to measure time intervals. It includes an arrangement of switches and relays which enable it to be used to measure at will the speed of vehicles passing over the detector tubes in either direction.

AN instrument for measuring the speeds of vehicles at high traffic flows has been developed at the Road Research Laboratory. The time taken by a vehicle to pass between two detectors a known distance apart is measured with a milliampère-second meter operating on a known current. Speeds in miles per hour are found by dividing a constant by the meter-reading, the constant being calculated from the current and the distance apart of the detectors.

The layout and circuit of the instrument are so designed that speeds can be measured in one direction without interference with the speedmeter from the opposing stream of traffic.

The speedmeter described in this article was designed to measure speeds of individual vehicles where high traffic flow was expected. The requirements of the instrument were that:

(1) It should record and reset in less than the minimum time interval between vehicles.

(2) It should measure speeds of traffic in either direction at will without interference from opposing traffic.

(3) It should be easy to read.

(4) It should be easily portable and operate from an accumulator.

Principle of Operation

The speed of a vehicle is determined by measuring the time taken to pass between two detectors on the carriageway a known distance apart. The instrument used to measure this time is a milliampère-second meter which is basically an electromagnetically damped milliammeter with no pointer return spring. When a vehicle passes over the first detector a known current is switched through the meter until passage of the vehicle over the second detector switches off the current. The meter indicates the total quantity of electricity that passed through it in this time. Knowing the current switched through the instrument, the time interval to pass between the detectors can be determined. The circuit is so designed that by incorporating two extra detectors, interference from opposing traffic is prevented.

General Description

The apparatus has three main parts, the detectors, the switching unit and the meter unit. The power supply is a 12V, 65Ah accumulator, which is sufficient to record over 10 000 vehicles.

DETECTORS

The detectors may be of any pattern that closes an electrical contact for longer than 3msec. So far the instrument has been used with pneumatic tube and diaphragm detectors (Fig. 1). The passage of a car wheel sends an air pulse down the tube which moves the diaphragm and closes an electrical contact. The four detectors are laid down in pairs. A vehicle travelling in the direction 1234 is timed between detectors 1 and 3, while detectors 4 and 2 prevent interference from opposing traffic. Similarly when timing a vehicle travelling in the direction 4321 the operative detectors are 4 and 2, while detectors 1 and 3 prevent interference from opposing traffic.

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Switching Unit

The pulses from the detectors are passed to the switching unit which contains the electromagnetic relays necessary to switch current through the meter unit and to prevent pulses caused by opposing traffic from affecting the meter. Two manually operated push-button switches on flexible leads are connected to the switching unit; these are used to make the apparatus sensitive to vehicles in either direction as desired. A rotary switch is incorporated for use in testing by simulating the action of a vehicle passing over the detectors.

Meter Unit

The meter unit houses the milliampère-second meter, a milliammeter and a coarse and fine rheostat control to set the desired current. The milliampère-second meter, which has an 8in dial to facilitate reading, is calibrated in 50 divisions from 0 to 5 milliampère-seconds.

Field Procedure

Fig. 2 shows how the instrument is set out for use inside a vehicle. Two operators sit in the rear seats; one operates and reads the instrument, while the other notes the readings.

A vehicle whose speed is required is selected and the appropriate push-button switch closed according to the direction. When the meter has recorded, the milliampère-seconds are read and noted by the second observer; the pointer is automatically returned to zero by releasing the push-button. Once a vehicle has recorded, the speed of a second vehicle cannot be recorded until the push-button switch has been released and closed again. The meter reading is converted into speed by dividing the recorded figure into a constant calculated from the tube spacing used and the current in the meter circuit.

The resetting time of the milliampère-second meter is a maximum of a fifth of a second from full-scale deflexion, so that the rate of recording depends upon the skill of the observers rather than upon the performance of the instrument. It has been found possible in practice to obtain timings of vehicles passing at a rate of one every two seconds.

Circuit

The circuit diagram is shown in Fig. 3 with all the relays de-energized. Four high-speed Siemens type relays A, B, C and D are used, needing a pulse length of 2 to 4msec to operate them; F and G are G.P.O. type 3000 relays needing a pulse of 30 to 40msec, while relay E is the same G.P.O. type with a heavy metal slug giving it a long release time of the order of 200msec. S_1 and S_2 are hand-operated press button switches and S_3 is the rotary test switch.

Measurement in Direction 1234

Switch S_1 is closed, which operates relays E and F with their contacts and also lights an indicator bulb. As the wheel of the vehicle strikes detector 1 an electrical pulse flows through diaphragm contact 1, contact F_4 (which is in the energized position) and contact A_1, so that relay C is energized. This is locked by its own contact C_1 and current flows through the milliampère-second meter via contacts F_1, C_1, D_1, F_2 and F_3; C_1 also removes the shunt across relay D, thus preparing for its subsequent operation.

When the wheel of the vehicle causes diaphragm contact 3 to close, a pulse passes through contacts F_5 and B_1 and energizes relay D. This is locked by contact D_1 and the meter circuit is broken. After the reading on the meter has been noted switch S_1 is opened which releases all the relays except E; since relay E has a release delay of about 200msec, contact E_1 remains closed, allowing a reverse current to pass through contacts E_1, G_3, F_3, through the meter and back through contacts F_2 and G_2, thus resetting the needle of the meter to zero. When relay E finally releases contact E_1 opens and reduces the reverse current to about 1mA; this is to ensure that the pointer is held back at the zero stop.

Fig. 1. Layout of detectors

Measurement in Direction 4321

Switch S_2 is closed, which operates relays E and G with their contacts and lights a second indicator bulb. The action is similar to that described in the last paragraph. Passage of the vehicle over detector 4 energizes relay C via contacts G_4 (energized position) and A_1, causing a flow of current through the meter. When the vehicle crosses detector 2, relay D is energized via G_5 and B_1, thus breaking the circuit to the meter.

Interference from Opposing Traffic

Since the operation is symmetrical we need only consider the case in which vehicles in direction 1234 are being timed. Switch S_1 being closed, relays F and E are operated as before. Contacts of detector 4 will be the first to be operated by the passage of an opposing

Fig. 2. The instrument mounted in a vehicle

vehicle's wheel, causing a pulse through contact G_4 energizing B relay which momentarily makes contact B_1. The next pulse will be received through diaphragm contact 3, contact F_5 and contact B_1, but contact B_1 stays made sufficiently long for the pulse to pass back through B_1 to relay B and not relay D, thus isolating the pulse received from diaphragm contact 3 from the meter unit. Diaphragm contact 2 will be the next operated; the pulse will travel through G_5 energizing relay A which momentarily makes contact A_1. Finally diaphragm contact 1 is made and sends a pulse through contact F_4 to A_1, but contact A_1 stays made sufficiently long for the pulse to pass back through A_1 to relay A and not to operate relay C, thus isolating the pulse received from diaphragm contact 1 from the meter unit.

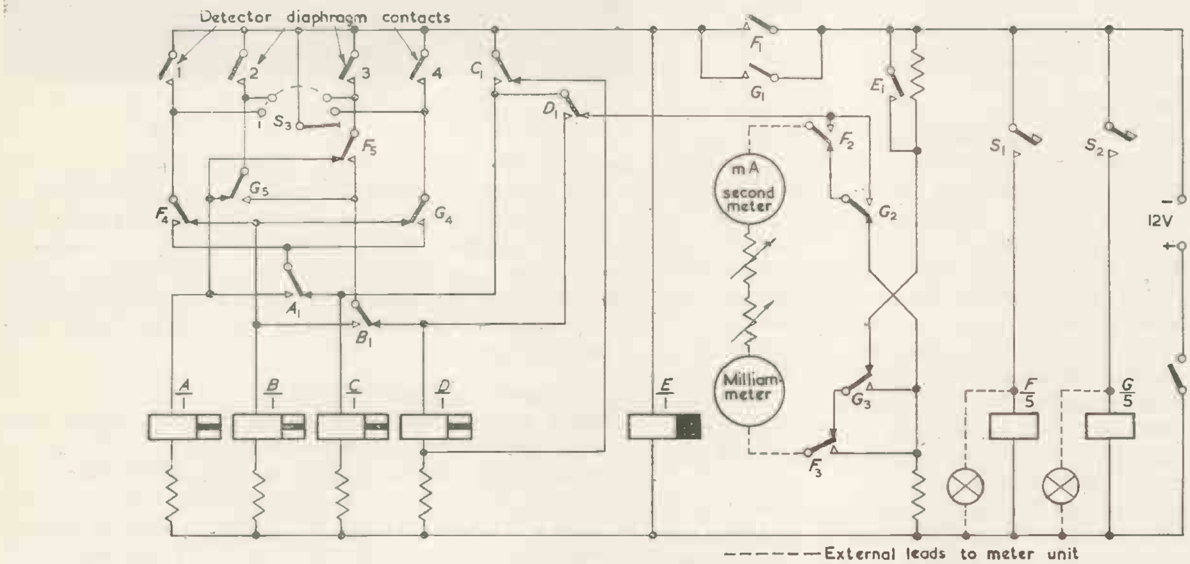

Fig. 3. The speedmeter circuit

It is, however, possible for interference to occur if two opposing vehicles strike either pair of detectors simultaneously, but this occurrence is rare. The detector tubes must all be the same length to ensure that the passage of the air pulse to each diaphragm contact takes precisely the same time.

Calibration of the Milliampère-second Meter

The milliampère-second meter was calibrated against an instrument which measures short time intervals to an accuracy 1 in 20 000. The latter consists of a Dekatron scaling unit or high speed electronic counter used in conjunction with an oscillator controlled by a 100kc/s quartz crystal. Time intervals of varying length were obtained by rotating test switch S_3. The time is slightly underestimated by the milliampère-second meter and in practice can be allowed for by making a 2 per cent correction. The particular milliampère-second meter used in this instrument is recommended for use between 25 and 50mA and calibration charts have been made to cover this range.

Spacing of Detectors

The accuracy to which the meter can be read is constant throughout the scale and so the accuracy of an estimate of speed is poorer at high speeds than at low speeds. The selection of the detector spacing must be a compromise on the basis of the lowest speed to be recorded and the accuracy at high speed. The variables to be considered are:

v—speed in mile/h
x—milliampère-second meter reading
L—detector spacing in feet
A—current in milliampères
V_o—lowest speed to be measured
X_o—highest meter reading in milliampère-seconds
Δx—maximum error in reading x
Δv—corresponding error in v due to error in reading x

We can derive the relationships:

$$v = 15/22 \,.\, LA \,.\, 1/x \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$\Delta v = 22/15 \,.\, v^2/LA \,.\, \Delta x = v^2/V_oX_o \,.\, \Delta x \text{ (approx.)}$$

For this particular instrument X_o is 5 milliampère-seconds and in practice the scale can be read to the nearest half division or 0·05 milliampère-second, hence $\Delta x = 0{\cdot}025$. Thus:

$$\Delta v = v^2/200V_o$$

Values of Δv for different values of V_o are as follows:

V_o (Min. speed in mile/h)	Δv (Max. errors in estimate of speed)	Error in mile/h at 30 mile/h	Error in mile/h at 60 mile/h
5	$v^2/1\,000$	0·9	3·6
10	$v^2/2\,000$	0.45	1·8
15	$v^2/3\,000$	0·3	1·2
20	$v^2/4\,000$	0·22	0·9

For investigations on rural roads the minimum speed was taken as 15 mile/h giving a maximum error of 1·2 mile/h at 60 mile/h. Substituting $V_o = 15$ mile/h and $X_o =$ 5 milliampere-seconds in equation (1) we get:

$$LA = 110$$

The recommended range of current for this milliampère-second meter is 25 to 50mA, hence L should be between 2·2ft and 4·4ft. Since the percentage error in laying the detectors will be less at the wider spacing, 4·4ft is preferable.

Acknowledgments

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Automatic Square Rooting

By E. H. Lenaerts*

A method is described by which the facility for automatic square rooting can be incorporated in a computer of the LEO type[1,2,3]. It is found that this can be provided with a minimum of extra circuits, the register and other facilities needed, being already required for other computing processes. By this method the time taken to evaluate the square root of a 40 digit number is reduced to 6·4msec as compared with 80msec using programmed square root.

SO few contemporary calculating machines appear to have been built with the facility of automatic square root, that one tends to assume that such a facility can only be achieved by excessively complicating an already complicated machine. This idea tends to be corroborated by the tortuous sequences introduced into programmes to evaluate square roots.

Although LEO is fundamentally an accounting machine, and therefore not likely to use such a facility to any extent, sufficient mathematical work has been done on LEO I to justify considering the possibility of incorporating in LEO II a means of evaluating square roots automatically.

It has been found that far from requiring a lot of complicated circuits, it is possible to provide this facility by means of simple additions to existing circuits such as are already available for carrying out multiplication and division.

These arrangements are based on the method by which one learned to obtain square roots at school, which starts with the digits of the number being marked off in pairs starting from the decimal point. By dealing with each pair in turn a digit of the result is obtained. (Example I illustrates this method).

```
            √ 2 5 7 6 9
               1   6   0·  5   2
         1 /02'57'69·00'00
               1
    2 6 / 1 5 7
          1 5 6
  3 2 0     / 1 6 9
              0 0 0
 3 2 0 5     / 1 6 9 0 0
               1 6 0 2 5
3 2 1 0 2          / 8 7 5 0 0
                     6 4 2 0 4
                     2 3 2 9 6
```

The first result digit obtained is one which when squared can be subtracted from the most significant pair of digits of the number to give a partial remainder. For each pair of digits after the first, the partial result is doubled and a new result digit is obtained such that when multiplied by the doubled partial result plus the new result digit, it will subtract from the partial remainder and give a positive remainder.

If the number $N = a_n 10^{2n} + a_{n-1} 10^{2(n-1)}$ etc., and R_n, R_{n-1}, R_{n-2}, etc., are the successive partial remainders, then the result digits d_n, d_{n-1} etc. obtained are such that:

$$R_n = N - d_n^2 10^{2n}$$

$$R_{n-1} = R_n - (2d_n 10 + d_{n-1})d_{n-1} 10^{2(n-1)}$$

$$= N - (d_n 10^n + d_{n-1} 10^{n-1})^2$$

$$R_{n-2} = N - (d_n 10^n + d_{n-1} 10^{n-1} + d_{n-2} 10^{n-2})^2$$

Thus when R is sufficiently small, N is equal to the squared result.

This method works well in the binary code because it is essentially a binary process, and no alteration to the partial result is required other than to add the new digits to it.

At each step the factor to be deducted is found by taking the partial result so far obtained, and adding 01 or 00 to it in the next least significant positions, according to whether or not it "will go" and multiplying the result by the digits so added. (Example 2 gives an illustration of the system used in extracting the square root of a binary fraction.)

```
          √ ·00'1 0'0 0'0 0'0 0'1 0'1 1'1 0'1 0'1 1
              0   1   0   1   1   0   1   0   1   1
        1 / ·00'1 0'0 0'0 0'0 0'1 0'1 1'1 0'1 0'1 1
               1
      1 0 0   / 0 1 0 0
                  0 0 0
    1 0 0 1   / 0 1 0 0 0 0
                    1 0 0 1
  1 0 1 0 1     / 0 0 1 1 1 0 0
                      1 0 1 0 1
 1 0 1 1 0 0        / 0 0 1 1 1 1 0
                          0 0 0 0 0
 1 0 1 1 0 0 1            / 1 1 1 1 0 1 1
                            1 0 1 1 0 0 1
 1 0 1 1 0 1 0 0            / 1 0 0 0 1 0 1 0
                              0 0 0 0 0 0 0 0
 1 0 1 1 0 1 0 0 1            / 1 0 0 0 1 0 1 0 1 0
                                  1 0 1 1 0 1 0 0 1
 1 0 1 1 0 1 0 1 0 1              / 1 1 0 0 0 0 0 1 1 1
                                    1 0 1 1 0 1 0 1 0 1
                                    0 0 0 0 1 1 0 0 1 0
```

When the requirements of this procedure are translated into the circuits of a serial computer such as LEO it is found that four facilities are required, namely:

(a) *An Accumulator* in which is held, first the number to be squared-rooted, and later the partial remainders, and in which it is possible for a partial remainder to be shifted one place to the left after each step.

Associated with the accumulator register is an arithmetic circuit which permits numbers applied to it to be added to or subtracted from its prior contents.

It is usual for the accumulator of a digital computer

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EXAMPLE 3

STAGE	SUB-STAGE	OPERATION	ACC. SIGN	ACCUMULATOR	ESC. PULSES (E)	RESULT (R)
1	A	Subtract $R + E/2$		00100000001011101011 01000000000	1000000000	0000000000
	B	Add back	(−)	1.11100000001011101011 01000000000		
			(+)	00100000001011101011		
	C	Shift		01000000010111010110	0100000000	
2	A	Subtract $R + E/2$		00100000000		
			(+)	00100000010111010110		
	B	Stack result				0100000000
	C	Shift		01000000101110101100	0010000000	
3	A	Subtract $R + E/2$		01010000000		
	B	Add back	(−)	1.11110000101110101100 01010000000		
			(+)	01000000101110101100		
	C	Shift		10000001011101011000	0001000000	
4	A	Subtract $R + E/2$		01001000000		
			(+)	00111001011101011000		
	B	Stack result				0101000000
	C	Shift		01110010111010110000	0000100000	
5	A	Subtract $R + E/2$		01010100000		
			(+)	00011110111010110000		
	B	Stack result				0101100000
	C	Shift		00111101110101100000	0000010000	
6	A	Subtract $R + E/2$		01011010000		
	B	Add back	(−)	1.11100011110101100000 01011010000		
				00111101110101100000		
	C	Shift		01111011101011000000	0000001000	
7	A	Subtract $R + E/2$		01011001000		
			(+)	00100010101011000000		
	B	Stack result				0101101000
	C	Shift		01000101010110000000	0000000100	
8	A	Subtract $R + E/2$		01011010100		
	B	Add back	(−)	1.11101010110110000000 01011010100		
			(+)	01000101010110000000		
	C	Shift		10001010101100000000	0000000010	
9	A	Subtract $R + E/2$		01011010010		
			(+)	00110000011100000000		
	B	Stack result				0101101010
	C	Shift		01100000111000000000	0000000001	
10	A	Subtract $R + E/2$		01011010101		
			(+)	00000110010000000000		
	B	Stack result				0101101011

to be capable of holding a double-length number such as may result from multiplying two normal-length numbers together. Conversely a double-length number held in the accumulator may, by the method described, be square-rooted or divided to give a result which is a normal length number. This register is the same as would be used in such multiplication and division processes.

(b) *A Result Register* in which the digits of the result are accumulated. Once again this register is already needed for holding the result of a division process or one of the factors during multiplication.

(c) *An "Escalator Register"* providing the trial digit which starts in the most significant position and is progressively stepped down one position at each stage of the sequence. This register is used in a similar way during multiplication and division.

(d) *A Sign Indicator* which according to the sign of the accumulator will provide voltages which can control the opening and closing of gates. This again is needed for purposes other than square rooting.

The sequence proceeds in the following stages:

(1) The escalator digit is subtracted from the number in the accumulator. In applying the escalator digit to the accumulator it is arranged that its phase is such that it appears to be shifted one place to the right, that is, divided by 2.

(2) If, as a result of (1), the accumulator remains positive then the same escalator digit is stacked as a result digit in the result register.

(3) If as a result of (1), the accumulator becomes negative, then the same escalator digit is added to the accumulator thus restoring it to its original state. In this case no digit is stacked in the result register.

(4) The partial remainder in the accumulator is shifted one place to the left.

(5) The escalator digit is stepped one place to the right.

(6) The partial result in the result register is mixed with the escalator digit, (as before phased as if its significance were divided by 2), and the resulting pattern is subtracted from the contents of the accumulator.

(7) If, as a result, the accumulator becomes negative, then the pattern is added back again. On the other hand, if the accumulator remains positive, then the escalator digit is stacked as a result digit in the result register.

(8) The process continues as in (4), (5), (6) and (7), until the escalator digit has been shifted to the least significant position of the escalator register.

It is convenient to arrange that numbers to be square rooted are scaled so that the most significant "1" is at least one position removed from the binary point. This is assumed to be immediately to the left of the most significant digit position. This is done so that at no time is a "1" shifted to the left of the binary point, a position which is regarded as indicating a negative number when occupied by a "1" digit.

Computer Sequence

The computer sequence may be considered as consisting of a number of stages—one for each binary digit permissible in the result. Each stage consists of three sub-stages, A, B, and C.

A is the action stage in which a pattern is subtracted from the accumulator;

B is the result stage in which, according to the sign of the accumulator, either a result digit is stacked or the pattern is added back to the accumulator;

C is in preparation for the next stage, the contents of the accumulator and the escalator digit being shifted. In fact, stages B and C take place at the same time, so that the time taken to complete the whole operation in LEO where a word consists of 40 digits is 6·4msec.

This compares very favourably with the time for programmed square root which is 330msec on LEO I and 80msec on LEO II for a 40 digit number. In the automatic process no extra time is needed if the number to be square rooted is a double length number resulting from previous arithmetical operations in the accumulator. Programmed square root in this case could only be done by using double-length arithmetic which would take considerably longer.

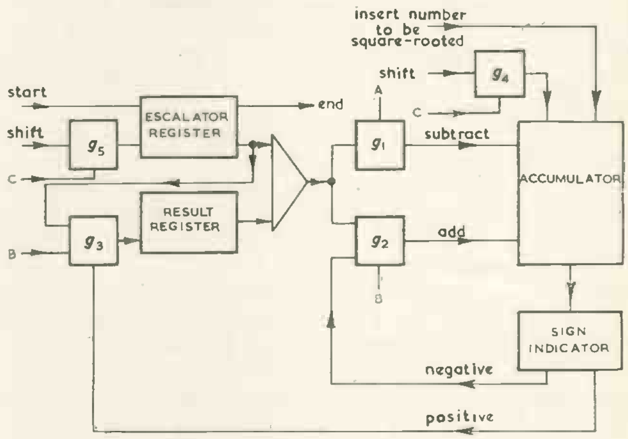

Fig. 1. Simplified diagram of computer elements involved

Fig. 1 is a highly simplified diagram of the inter-connexions of computer elements involved. This shows how during stage A, the escalator digit mixed with the contents of the result register is gated into the accumulator (g_1) via a subtracting mechanism. The sign indicator is used in sub-stage B to decide whether the escalator digit should be stacked as a result digit (g_3) or whether the pattern subtracted should be added back (g_2) to restore the accumulator to its previous condition. In sub-stage C the accumulator contents are shifted one place to the left (g_4) and the escalator digit one place to the right (g_5) in preparation for the next stage of the sequence.

The end of the sequence is reached and indicated by the arrival of the escalator digit in the least significant position of its register. (Example 3 gives the contents of the registers of the calculator at each stage of the sequence. A word length of 10 digits has been used to simplify the example).

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Ceramic to Metal Sealing

Its Development and Use in the American Radio Valve Industry

By D. E. P. Jenkins*, B.Sc.

This is a review of the American literature published to date on Ceramic to Metal Sealing including reports on the symposium held on this work in 1953. Some of the advantages and disadvantages of ceramics in valves are mentioned; the established sealing processes and investigations into the seal mechanism are described. Photographs show typical American valves using ceramics and ceramic to metal seals.

ALLIED technical teams visiting Germany after the war found that the Telefunken Laboratories, Berlin, had during the war developed a process for making vacuum tight valve envelopes, using ceramic materials instead of glass. The technique had not been perfected and the ceramic, a steatite body which was manufactured at the laboratories, was of poor quality, but it was significant that the German technicians felt justified in producing ceramic valves of this type, when the process was in such an early stage of development.

The allied technicians quickly realized the possible advantages of using a valve envelope of ceramic material, and consequently the American services placed contracts with various research bodies, for development work on ceramic to metal seals and their application to the manufacture of ceramic enveloped valves. The results of these investigations have been fully described in the literature, and ceramic valves have been manufactured ranging from miniature triodes to large tetrodes and klystrons. Some of the effort has been directed towards the use of ceramic techniques and materials in the production of reliable valves, and many designs have been tried using this new approach. Two main techniques were evolved and are now in use, but research and development work still continues, and during a symposium held in April 1953 various workers described the results of their investigations into the development of simpler techniques and more suitable ceramic materials. A later publication describes the use of a third method for ceramic valve assembly.

The Use of Ceramics in Valve Envelopes

In order to decide whether the use of a ceramic material as an envelope in a radio valve is justified one has to bear in mind the advantages and disadvantages to be expected from the properties of the material itself and the difficulties involved in making a ceramic envelope.

The following are some of the possible advantages:

(1) The limiting factors on the outgassing temperature are the softening point of the braze and the expansion match of the ceramic and its sealing metal. In any case, one would expect to be able to outgas at about 700°C to 750°C. This is better than with a glass valve, and in some assemblies it might be possible to do without a "getter".

(2) Due to the high temperature seal, a ceramic valve is able to operate at higher temperatures and therefore dissipate more power than a glass valve of similar dimensions.

(3) Closer tolerance in envelope manufacture would be obtained since ceramics can be ground to accurate dimensions.

(4) At high frequencies certain ceramics have lower loss factors than the best glasses, and for a given power there is less dielectric heating in the ceramic material. This means that up to the safe maximum operating temperature the ceramic can pass more high frequency power than glass.

On the other hand, the following disadvantages can be mentioned:

(1) A good thermal expansion match between the ceramic and sealing metal is difficult to achieve in the limited range of materials suitable for ceramic valve manufacture.

(2) Of many possible types of ceramic-to-metal seals, only one, the compression seal, is suitable for use in valve envelopes. Butt seals and other seals, where the ceramic is in tension tend to be rather weak and are not generally used.

(3) Generally speaking, ceramics with expansions of the order of 7 to 10 $\times$ 10^{-6} have poor thermal shock properties. Certain ceramics with low expansions have good thermal shock properties, but these are difficult to match.

(4) The grinding of ceramic surfaces sometimes causes cracks to appear during subsequent processes.

(5) The ceramic material is opaque, which means that electrode assemblies cannot be visually examined after sealing.

(6) The ceramic to metal seal must be mechanically strong, and leak-tight over the range of operating temperatures, therefore the bond to the ceramic must be good and the braze must be of high quality. The metals used in bonding to the ceramic are usually active or refractory, and this immediately imposes a limitation, namely, that the seal making temperature, which is in the 1 000°C to 1 400°C range, must be done in a protective atmosphere. The high temperature furnaces must therefore be of the vacuum, inert gas, or hydrogen gas type.

The general feeling among valve engineers seems to be that the use of ceramic materials in valve envelopes, and as power output windows for high frequency devices, is justified by the advantages gained over glass in the temperature and frequency ranges in which the modern valve may be required to operate.

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General Background

A study of the literature shows that the problem of making a ceramic to metal seal, brazed with a high temperature solder and capable of withstanding a subsequent high temperature bake, has been investigated along three separate lines; (a) by applying a strongly adhering layer of metal to the ceramic and then brazing the metal member to this; (b) by using an alloy of an active metal which bonds directly to the ceramic and brazes to the metal member in one operation, and (c) by making a "graded seal" from ceramic to metal using graded mixtures of ceramic and metal powders.

The techniques involved in the first approach are described in two patents specifications. The first, by Schirmer[1] in 1936, where he described a method in which a layer of metallic oxide was painted on to the ceramic material. This was fired in air and then in a reducing atmosphere, giving a final surface layer of metal which was firmly bonded to the ceramic by the unreduced base layer of oxide. The other, by Pulfrich[2] in 1937, where a layer of molybdenum, tungsten or rhenium metal powder was painted on to the ceramic surface and then sintered in a reducing atmosphere. This gave a strong bond between the metal and the ceramic. There is no evidence of Schirmer's method being used on a large scale in America, but experimental valves have been made in this country using an oxide sealing method. These were shown at the 36th Physical Society Exhibition[30]. Pulfrich's method was used in a modified form, at the Telefunken Laboratories, Berlin[14], for the production of ceramic envelope valves. Iron was added to the molybdenum powder to improve bonding. Nolte and Sprunk[15] later, in America, made a further modification to this process by adding manganese powder to the molybdenum powder before sintering; ; this has become known as the "molybdenum-manganese" sealing method and is now one of the processes in regular use for valve production by American valve manufacturers.

The second approach to the problem was described in 1947 by Bondley[17], where a layer of titanium hydride powder was painted on the ceramic surface, the body assembled with a ring of silver in position and then heated to 1 000°C in vacuum or pure dry hydrogen. This technique of using titanium hydride has also been established as a process for ceramic valve manufacture.

The method for making graded ceramic to metal seals is described by Knecht[37,38], but this method does not seem to have progressed beyond the experimental stage. Of these methods, therefore, two have become well established in the valve industry for the production of ceramic valves.

The Processes

(a) THE MOLYBDENUM MANGANESE PROCESS

(1) The pre-cleaned ceramic is painted (or sprayed) to a thickness of 0·001in to 0·002in, with a mixture of finely divided molybdenum and manganese powder held in a suitable binder.

(2) This coating is air dryed and then sintered in wet hydrogen for half an hour at a temperature within 50°C of the softening point of the ceramic being used. This treatment causes the powder mixture to bond firmly to the ceramic, and become conductive.

(3) The bonded metal layer is now electroplated with copper and nickel to improve wetting during the brazing operation.

(4) The electroplated layers are sintered for half an hour in wet hydrogen.

(5) The body is now assembled with the brazing metal in position, and the braze completed in the normal way in hydrogen.

There are many other combinations of metal powders which can be used for this work, where the sealing techniques are very similar to those described above. Table 1 tabulates these combinations and at least one American valve manufacturer uses[28] the 10 per cent iron, 90 per cent tungsten combination.

(b) THE ACTIVE METAL HYDRIDE PROCESS

The pre-cleaned ceramic is painted with a layer of titanium hydride powder in a suitable binder; this is allowed to dry and the metal parts and the alloying metal located in position. The fully assembled body is then heated to 1 000°C in vacuum (at least 10^{-4}mm Hg), or very dry hydrogen. The alloying metal must not have a melting point above 1 000°C. The hydride dissociates into hydrogen and active metal, and the latter alloys with the metal already located in position (e.g. pure silver). This alloy bonds to the ceramic and brazes to the metal member of the envelope in one operation.

Recent Trends in Processes and Material

Many ceramic and metal combinations have been reported to give vacuum tight seals; some of these are tabulated in Table 2. Alsimag 243 ceramic has been used a great deal for this work on account of its low dielectric

TABLE 1
Powder Mixtures for Ceramic Seals

METAL POWDERS ALONE	MIXTURES CONTAINING MANGANESE	MIXTURES CONTAINING IRON
Mo, W, Rh[10, 11, 4, 6]	10% Mn with :—	30% Fe with 70% Mo[3]
Fe, Ni, Ag, Cu. [6]	Fe, Mo, W, Ni[6]	4% Fe with 96% Mo[14, 16]
—	20% Mn with 80% Mo[15]	10% Fe with 90% W[28]

TABLE 2
Ceramic Metal Combinations

CERAMIC MATERIAL		METAL
TYPE	NAME	
Forsterite	Alsimag 243	50% nickel iron [22, 37, 16] 46% nickel iron [22, 37, 16] 51% nickel iron [28] 16% chrome iron [15, 17]
Steatite	Alsimag 196 Telefunken Labs.	Kovar [22] 42% nickel iron [14] 46% nickel iron [14]
Zircon	Z17A Z14	Molybednum[37] Molybdenum[37] Kovar[37]
Alumina	Alumina Al 200 Alsimag 491 Alumina 2548	Copper : Nickel [37] Kovar[37] 44% nickel iron[15] 44% nickel iron[15]

loss properties at high frequencies, but alumina ceramics are now being used increasingly. Their loss properties are in general not as good as the forsterites, but they have better resistance to thermal shock since their thermal expansion is lower and tensile and compressive strengths higher. It is of interest to note that copper and nickel have been sealed directly to the aluminas. The Eimac valve 2C39B (Fig. 1) is made using high conductivity copper sealing directly to the ceramic for anode and grid shells. Typical expansion curves are given in Figs. 2 and 3 for Alsimag 243 and Alumina materials together with their sealing metals. The room temperature loss factor at 10 000Mc/s of Alsimag 243 is 0·0011[22] and Corning glass 7070 is 0·008[22], while that of Coors A1200 Alumina is 0·0158[50], and Alumina No. 2 548, 0·0039[37].

Dolittle[23] has investigated the various known processes for ceramic to metal sealing, and an extract from his conclusions reads as follows[22]:

For small assemblies not required to insulate high voltages at high frequencies, the molybdenum metallizing process is to be preferred. Quantity production set-ups are feasible for fairly rapid production.

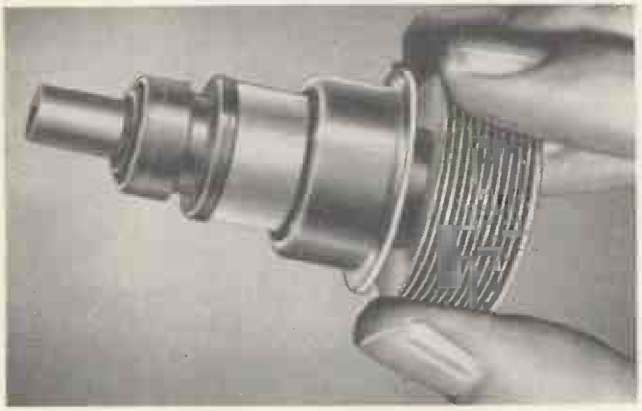


Fig. 1. Eimac 2C39B. Planar triode.
Output power 15W at 2 500Mc/s.

The vacuum hydride process is preferable for large assemblies.

(a) The brazing cycle is faster, consisting of fewer operations.

(b) Parts are more thoroughly outgassed.

(c) Controlled atmospheres are eliminated.

(d) High chrome alloy metal parts máy be used.

However, a later report[24] indicates that the molybdenum-manganese process is preferred by the radio valve manufacturers, although the hydride process is still used.

Process Investigation

(a) MOLYBDENUM MANGANESE PROCESS

The mechanism of the bond which exists between the ceramic and the layer of refractory metal has been discussed in the literature. One hypothesis is that the action is a diffusion of metals into the ceramic and possibly the bond is created by a peculiar arrangement of crystals at the interface. Another is that solid reaction takes place because of loosening of the atomic bonds by thermal agitation permitting mutual diffusion of the different atoms into adjacent parts of the structure[28]. Kingery[46] and Pincus[41,37] have dealt with the problem more fully. Pincus deals at length with the molybdenum-manganese process and he proposes[41] an interpretation of the mechanism of adherence in the case of an alumina and a forsterite ceramic. The importance is shown of the formation of manganese oxide in hydrogen which contains more than about 0·001 per cent by volume of moisture. This slag interacts with the alumina to form manganese aluminate spinel, and at 1 400°C sintering occurs with the molybdenum particles. In the case of the forsterite ceramic the sintering occurs at 1 350°C. Pincus' second paper[37] discusses the formation of oxides and it is shown that the

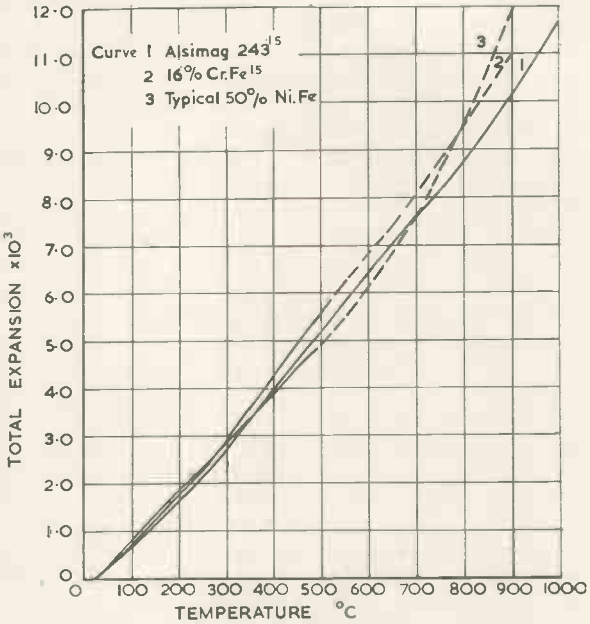


Fig. 2. Temperature-expansion curves for forsterite ceramic and sealing metals

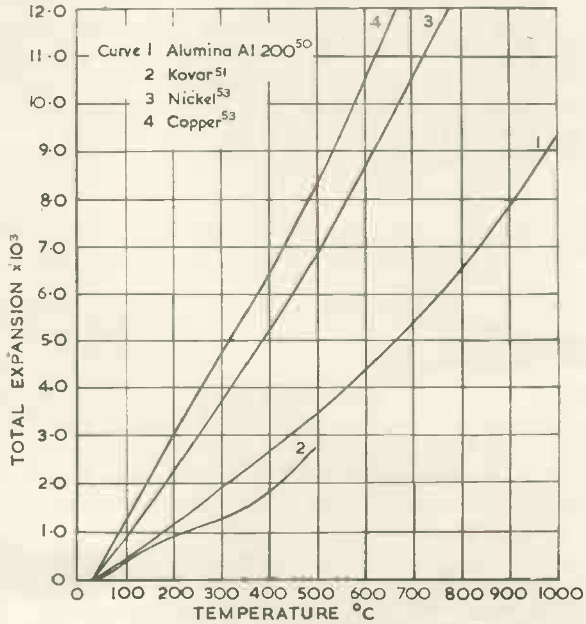


Fig. 3. Temperature-expansion curves for typical alumina ceramic and sealing metals

controlled formation of the oxide cf the adherence promoting metal still is a pre-requisite for successful seal making. For good adherence of molybdenum to alumina, oxygen must be present at the ceramic-molybdenum interface so that the metal oxide can be formed, and the temperatures must be high enough to cause appreciable dissociation of some oxide constituent of the ceramic. Controlled experiments with a mixture of molybdenum and molybdenum trioxide powders gave penetration into the alumina at lower temperatures.

(b) Active Metal Technique

An early report by M.I.T.[21] shows that in addition to titanium hydride the hydrides of zirconium, tantalum and

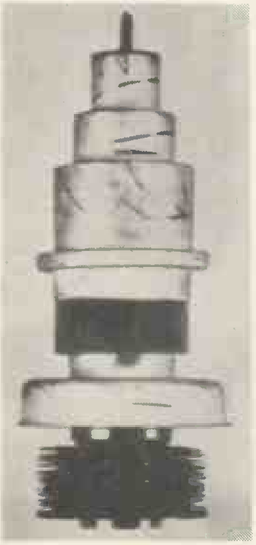


Fig. 4. Machlett type ML281. Planar power tetrode.
Output power 50W at 2 500Mc/s.

Fig. 5. RCA type 6181 v.h.f. power tetrode.
Output power 1 200W at 900Mc/s.

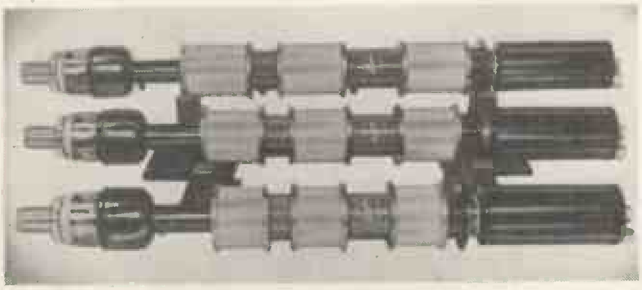


Fig. 6. Eimac klystrons 3K50000LA, F. & K.
12kW peak output. Timing range covered by the three tubes, 370-890Mc/s.

columbium also gave good results, and zirconium hydride is reported to give better wetting and bonding than titanium hydride. Further investigations led to the use of previously prepared active metal alloys, placed in contact with the ceramic and metal members. These alloys when heated to flow point, wetted and bonded to both the ceramic and metal. For example, an alloy containing 15 per cent zirconium and 85 per cent silver by weight, wets and bonds to the ceramic in much the same way as in the

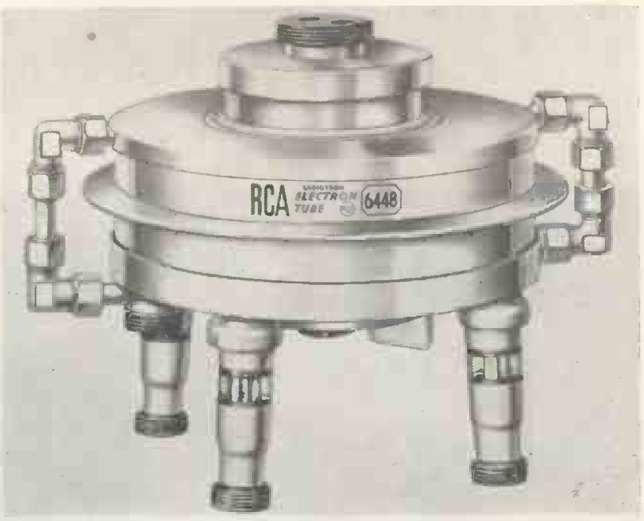
Fig. 7. Machlett type EG-25. X-ray tube.
42kV with wide angle Ceryllium window.

hydride method. This is confirmed by later investigators[37], who state that an alloy of 10 per cent zirconium and 90 per cent silver gives good wetting and bonding in vacuum on aluminas and zircons. Titanium cored B.T. solder (9 per cent titanium) also gives good results with alumina. These investigators have found that the active alloy technique is satisfactory only if carried out in vacuum. From the mass production point of view, processing in hydrogen is more desirable. A recent article[52] from the same company describes a small ceramic valve made using a titanium cored copper-silver entectic solder at 900°C. From the appearance of the valve it would seem that the sealing is done under vacuum.

Typical Ceramic Valves

Fig. 1 and Figs. 4-8 are included to show some of the ceramic valves which have been manufactured. Little comment is needed, except to say that this is not intended to be a full list of ceramic valves available at present in the American market. The Machlett valve types ML-281 and EG-25 for example, are not in current production, and are not available as catalogued items. Fig. 9 is a sketch

Fig. 8. RCA type 6448 v.h.f. beam power tetrode.
Output 12kW at 900Mc/s.



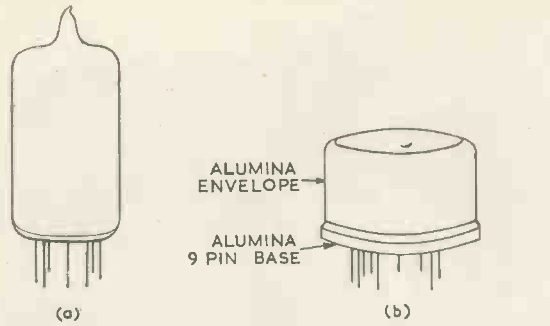


Fig. 9. Diagrammatic representation of:— (a) Conventional 7 pin glass miniature valve. (b) Sylvania ceramic envelope 9 pin reliable valve

showing the external appearance of the new Sylvania ceramic reliable valve. It is compared in size with a standard 7-pin miniature valve. The new valve is unique in that it has a 9-pin ceramic base and the envelope is a closed ended alumina tube. The final seal is therefore a single step ceramic to ceramic seal.

Acknowledgments

Acknowledgment is due to the following valve manufacturers for permission to reproduce photographs and details of the ceramic valves.

Eitel McCullough Inc. for Fig. 1 and Fig. 6.
Machlett Laboratories, Inc. for Fig. 4 and Fig. 7.
Radio Corporation of America for Fig. 5 and Fig. 8.

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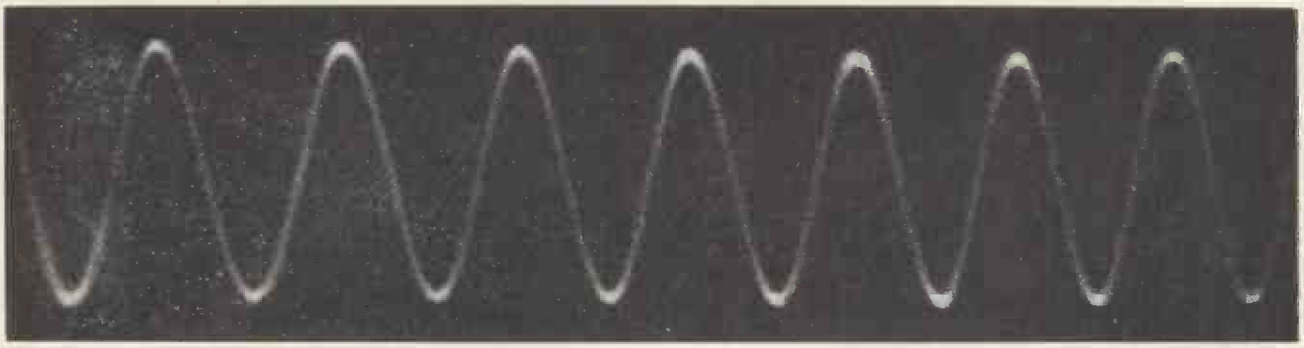
Note.—References marked thus *, refer to work carried out under contracts from the U.S. Government, and these reports are not readily available in this country.

A NEW HIGH SPEED RECORDING TUBE

The illustration below is a reproduction of an untouched photograph taken by Mr. R. A. Fothergill of A.W.R.E. using a 20th Century cathode-ray tube type S6AB working at 20kV total accelerating potential. The sine wave is 500Mc/s with an amplitude of 2cm on the face of the tube. The horizontal sweep speed is approximately 650cm/µsec.



A Decade Frequency Divider

By R. B. Mobsby *

A frequency divider developed for use with quartz crystal clocks is described. Dividers for this purpose should ideally remain in synchronism over periods of several years, with a minimum of scatter between output pulses. A well established counter circuit in which feedback reduces the division ratio of a series of binary pairs is employed.

ALL methods of accurate frequency measurement depend ultimately upon comparisons between the sub-standard of frequency and the fundamental standard of time—and therefore of frequency—the period of rotation of the earth. The comparison is best made by deriving 1c/s from the radio frequency of the sub-standard and referring the pulses so obtained to time signals radiated under the control of astronomical authorities. The frequency standard and divider chain then function as a clock, the divergence from nominal of the frequency standard being apparent as a gain or loss in the clock's rate.

This sub-division to 1c/s presented a number of problems, the main difficulty being to obtain reliable synchronized operation at this frequency with a low order of scatter between output pulses. Details had been published[1,2,3], however, of a form of decade divider which, when reconstructed with modifications at the Greenwich Royal Observatory, was found to provide a solution.

The Royal Observatory version was eventually adopted, with minor modifications, to replace the existing divider chain used with the group of oscillators, maintained at its Tatsfield Receiving Station, which form the BBC's Standard of Frequency. Its success has led to the development of additional circuits which widen its applications. One of these enables a number of impulse type clocks, used for normal time-keeping purposes, to be driven from the frequency standard and so provide a reliable and extremely accurate time service.

The divider consists basically of a chain of Eccles-Jordan trigger, or binary, pairs[4] whose overall division ratio has been reduced by means of feedback. Various forms of this circuit have become well known in recent years by their use in counting devices. In this application the divider fulfils the necessary requirements of (a) being equally responsive to either a periodic or a random rate of triggering, and (b) having ten stable states within the circuit from which an indication of count can be made. It is, however, particularly useful as a frequency divider for the following reasons: the circuit is inherently reliable, each binary pair having only two modes of operation; there is no low frequency limit of operation; supply voltages are not critical; it is quiescent if the input frequency is removed; a large output pulse is produced and all decade units in any divider chain can be identical.

The Binary Pair

The basis of the divider is, as stated earlier, the Eccles-Jordan binary pair, a form of which is shown in Fig. 1.

The circuit is symmetrical, having nominally equal load resistors R_a and cross-connexion networks C, R and R_g, the values of R and R_g being so chosen that one valve has a grid-cathode potential near zero when the other is cut off. The anode loads are connected to a common resistor R_b, which simulates a relatively high supply impedance and avoids short-circuiting the input pulses. On applying h.t. slight asymmetry will cause one valve, say V_2, to take more current than V_1 and the circuit eventually reaches a condition of equilibrium where V_2 is fully conductive and V_1 is cut-off.

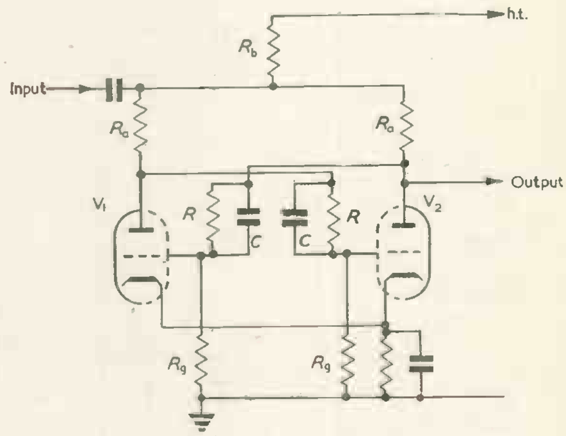


Fig. 1. The basic circuit

If a negative pulse is now injected at the input, the anode potential of V_1 is suddenly reduced and a transient negative voltage is passed to the grid of V_2 via the coupling network R and C. This causes a reduction of anode current in V_2 resulting in the grid potential of V_1 moving in a positive direction. The anode potential of V_1 thus falls still further until eventually the second equilibrium condition—V_1 conducting V_2 cut-off—is reached. The change-over action is extremely rapid, being limited only by stray reactance. A further negative input pulse will cause a second reversal and provide a negative going transient at the output, thus effectively dividing the input pulse frequency by 2.

The circuit is mainly sensitive to negative input pulses and Blume[3] states that it discriminates against equivalent positive pulses in the ratio of 3:1, while the function of the cross-connexion capacitors C has been described by Phelps[5].

Division by any Positive Integer

To convert a chain of binary pairs to any division ratio less than 2^n (where n is the number of pairs) it is necessary to provide feedback loops between selected stages in such a way that anomalous reversals are caused. These reversals have the same effect as additional input pulses, causing the circuit to act as if it had received 16

*The British Broadcasting Corporation.

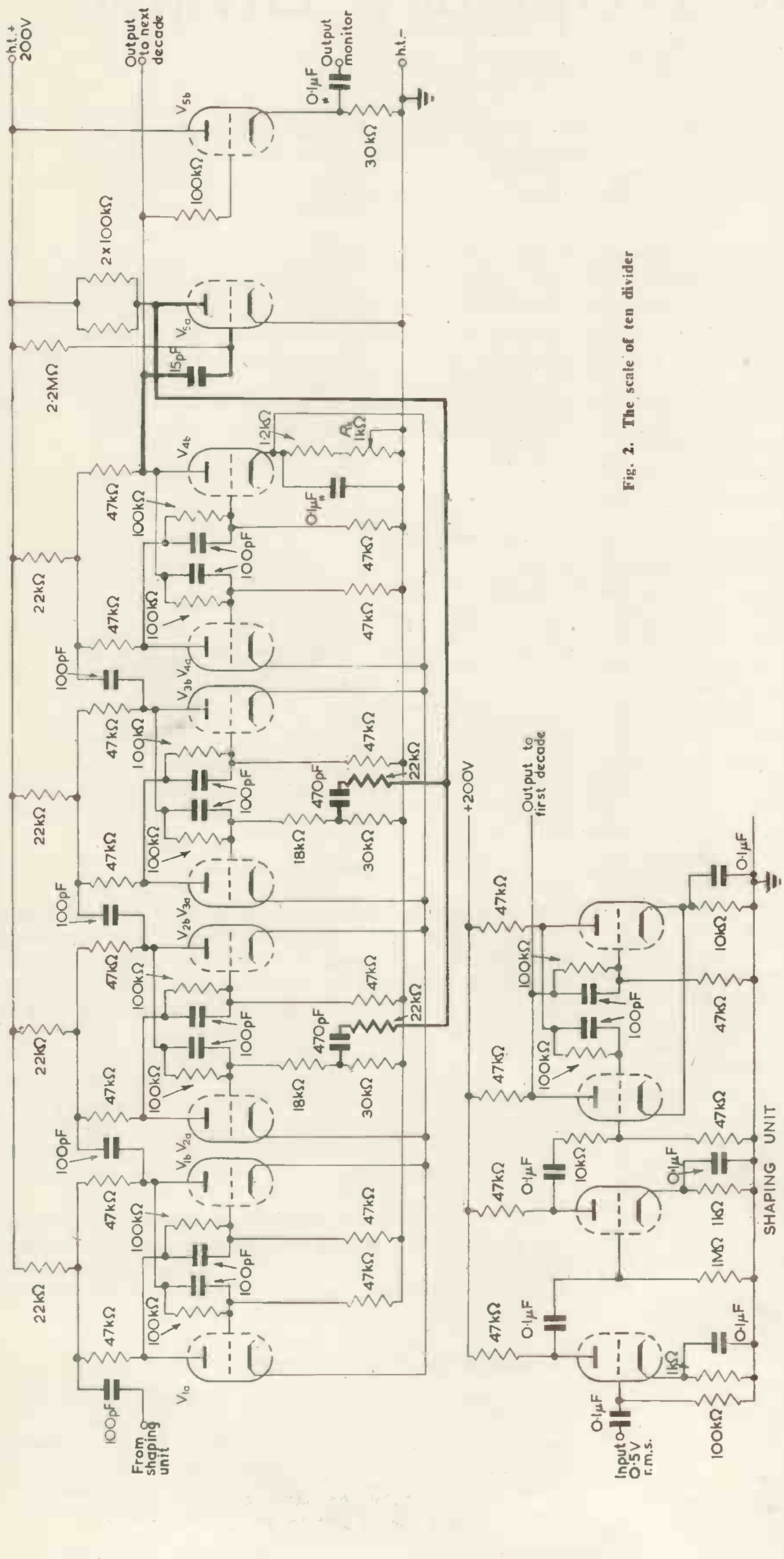


Fig. 2. The scale of ten divider

input pulses instead of 10 in the case of a conversion to scale of 10. Since a unique state, i.e., a different combination of conducting or non-conducting valves, exists for each input pulse applied to a chain of binary pairs, the effect of the feedback is to reduce the number of states and so to reduce the division ratio.

The feedback loops may be applied between stages along the chain but from practical considerations are best taken from the final stage.

The number of stages within the feedback loops may be determined quite simply. Firstly, if x is the required division ratio and n the number of stages, then the expression $C = 2^n - x$ determines C, the number of states that are required to be missed within the circuit in changing from a division ratio of 2^n to x. It is then necessary to find the smallest set of binary numbers, 2^a, 2^b, 2^c, etc., which, when summed, are equal to C. The number of stages within each loop is then equal to n-a, n-b, etc.

Suppose, for example, the desired division ratio is 89. If the divider is to have a fixed division ratio we may select the lowest value of 2^n above 89, which is 128 or 2^7. Thus 7 stages are required. The number of states to be missed are $128 - 89 = 39$. By inspection we now find the smallest set of binary numbers which, when summed, are equal to 39. They are:—

$2^5 = 32$ leaving $39 - 32 = 7$
$2^2 = 4$ „ $7 - 4 = 3$
$2^1 = 2$ „ $3 - 2 = 1$
$2^0 = 1$ „ 0

Thus, four feedback loops are required, embracing $7-5=2$, $7-2=5$, $7-1=6$ and $7-0=7$ stages.

Division by 10

A diagram of the scale of 10 divider is shown in Fig. 2 with the feedback path drawn in heavy line, while Fig. 3 shows the state of the circuit for each input pulse. The assumption has been made here that the 'original state,' that is the state of the circuit prior to the first input pulse, is V_{1b}, V_{2a}, V_{3a} and V_{4b} conducting.

For the first 9 input pulses the circuit behaves as an unmodified binary chain, a reversal occurring on the succeeding pair each time a right-hand triode conducts. After the 9th pulse, however, all the right-hand triodes are cut-off, consequently the 10th causes each of these to conduct. This results in the first negative transient at the output and a positive pulse on the feedback line (after phase reversal in V_{5a}). Since the valves to which feedback is applied, V_{2a} and V_{3a}, are cut-off at this time, the positive pulse on their grids causes them to conduct and all stages revert to their 'original state' before the arrival of the 11th input pulse.

The output is taken from the anode of V_{4b} to the succeeding decade unit while an output for monitoring purposes, isolated from the divider proper, is provided by V_{5b}.

V_{5a} removes unwanted negative pulses and increases the amplitude of the positive pulses on the feedback line. It is not, however, essential and the feedback line may be connected directly to the anode of V_{4a}. It will be seen from Fig. 3 that, with this arrangement, a negative pulse will occur on the feedback line upon the arrival of the second input pulse, but its polarity is such that it does not cause a reversal. The feedback might equally well be obtained from the anode of V_{4b}, in which case it would be applied to V_{2b} and V_{3b}.

When supplied with pulses of the correct shape and

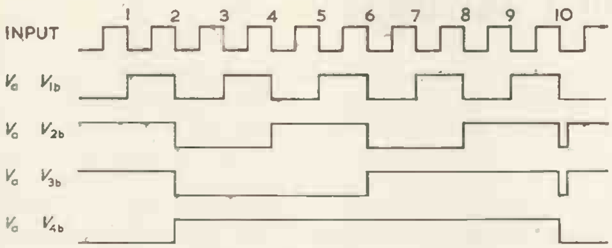


Fig. 3. Circuit waveforms

amplitude the divider operates satisfactorily at any input frequency up to 110kc/s, remaining in lock over a range of 130 to 300V h.t. and 5 to 7V l.t. after the non-critical setting of the bias resistor R_k has been established. The output pulses have a mark-to-space ratio of 4:1 and an amplitude of approximately 70V peak-to-peak, when the h.t. voltage is about 200V. The scatter between output pulses is known to be less than 10μsec and is probably less than 1μsec.

Although the divider will operate over a wide h.t. range, it is important that sudden fluctuations be avoided and that large noise components are not present.

The component layout finally adopted, after experiments to determine the effect of various configurations, consists of a long tag board running the length of the chassis on which all components, with the exception of those in the feedback leg, are mounted (see Fig. 4). This arrangement, although not ideal, lends itself to easy maintenance.

The output from one decade unit is suitable for direct connexion to the next, but some form of wave-shaper is usually required at the input to the chain. A suitable circuit, comprising an *RC* coupled amplifier and 'squarer' is included in Fig. 2. This will operate the first divider satisfactorily over the range 20c/s to 100kc/s with a sine-wave input of about 0·5V.

Type 12AU7 valves have been used throughout the shaper and divider and, in the present design, stabilized, close tolerance components have been used to ensure maximum reliability. A chain of five dividers of this type has operated continuously for 12 months without losing synchronism.

Although no attempt has been made to extend the upper frequency limit in the present design, it is considered that it could be increased to 1Mc/s by reducing the anode loads and inserting small peaking inductors in series with them. In addition greater care would have to be taken in the layout of components, and the coupling time-constants would need to be reduced in value.

Effect of Original State

The circuit condition prior to the first input pulse can have an important effect in some applications. Referring again to Fig. 3, an output pulse is delivered after the 10th input pulse with the original state assumed. If, however, that state had been all right-hand triodes conducting, and the feedback connexions had remained as shown in Fig. 2, then the first output pulse would not have been delivered until 16 input pulses had been applied. Thereafter it would progress in normal fashion, providing an output

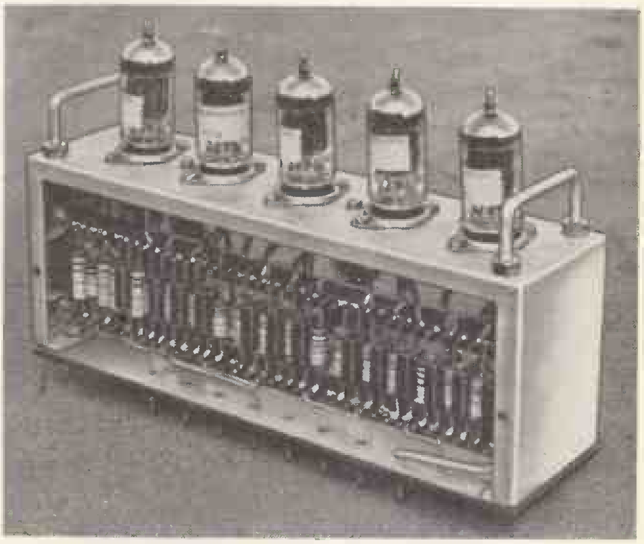


Fig. 4. A complete divider unit

pulse for every 10 input pulses. A maximum delay of 6 input pulses per decade stage can thus be produced, the amount of delay depending upon the original state.

For frequency division this fact is not, in general, of importance, but in counter applications it is. For normal counter operation, in which some form of indication translates the circuit conditions for each input pulse[2], the original state shown in Fig. 3 is required if the feedback circuit is connected as shown in Fig. 2. The counter is 'reset' to that state before counting commences, usually either by increasing the resistance of the grid return path of those valves which are required to be conducting, or reducing it on those required to be cut-off.

A variation of original state is equivalent to a change of scaling factor over the period of the first output cycle. Suppose, for example, that a scale of 10 counter is set, prior to counting, to the circuit conditions corresponding to the 3rd input pulse. It would then deliver an output pulse after 7 input pulses had been applied. If means are provided for the selection of any particular original state then a counter can act as a controlling device, signalling the arrival of a particular input pulse[6]. This facility has obvious applications in industry.

Variable Division Ratio

If a divider of variable division ratio is required it would probably be necessary to provide a feedback injection stage for each binary pair. The valve used for this purpose might be arranged to become conductive by means of a simple switch in its cathode circuit, thus providing d.c. switching of feedback paths.

It is normally desirable to have some arrangement providing a known time delay of the feedback pulse but, in the case of division ratios equal to or less than 2^{n-1}, it is a necessity. In this event, feedback is required to reverse the state of the stage initiating the feedback, hence additional delay is required. The alternative is to include in the switching arrangements means to by-pass a sufficient number of stages and so reduce 2^n.

Acknowledgments

Acknowledgments are due to the Astronomer Royal for permission to publish some of the information given, and to G. B. Wellgate and H. G. Gill of the Royal Observatory who developed the scale of ten divider described. Also to H. V. Griffiths and L. V. Parkinson for their assistance in the preparation of this article, and to the Chief Engineer of the BBC for permission to publish it.

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A Man-Carrying Centrifuge

A MAN-CARRYING Centrifuge has recently been installed at the R.A.F. Institute of Aviation Medicine, Farnborough. It is an apparatus capable of simulating the centrifugal acceleration encountered by pilots when they change direction at high speed.

It is the most modern in Europe, costing some £350 000, and has a three-fold purpose—research, clinical investigation and training.

Combat manœuvres such as high-speed turns or the pull-out from a dive produce a tendency for the pilot's blood to "pool" in the lower parts of the body at the expense of the supply to the brain. The pilot experiences an apparent increase in weight. Fatigue, impairment of muscular functions, loss of vision ("black-out") and loss of consciousness may result. "Black-out" was first encountered to any noticeable extent by pilots training for the 1929 Schneider Trophy race when they rounded the turns on the course.

During the war some research was done in service aircraft, but the scope of investigation was necessarily limited, and it was found impossible to install in the aircraft the delicate apparatus required to measure brain and heart functions. It became apparent that inquiry into the whole field of centrifugal acceleration called for the use of special ground equipment operating under controlled laboratory conditions—a centrifuge which could test the effects of prolonged *g* and enable the physiologists to determine how men should be equipped and clothed, details of cockpit design, and various other matters concerning the aircraft of the future.

Tentative designs were worked out during the war, but it was not until 1947 that the main features were finalized. The centrifuge at Farnborough offers tremendous scope for the conduct of much new basic research and for the development of equipment designed to increase the safety,

A general view of the centrifuge

comfort and efficiency of aircrew. It does not mark the culmination of aviation medicine. Rather is it a notable milestone in the furthering of knowledge which is essential for the advancement of flying generally.

General Description

The man-carrying centrifuge consists of a 60-foot rotating arm, pivoted in the centre, at each end of which is a car weighing 1 150lb. These cars can attain a speed of more than 115 m.p.h., and at this speed the centrifugal force on the cars is equivalent to 30*g*. Their apparent weight is therefore increased 30 times.

The arm is also capable of rotating two much heavier cars, each weighing $1\frac{1}{2}$ tons, at 66 m.p.h., the acceleration then being equivalent to 10*g*. For normal purposes where men are being carried, the centrifuge is restricted to a maximum of 10*g*, but where prone or supine pilot positions are to be investigated this can be increased to 12 to 15*g*.

The maximum figure of 30*g* is regarded as high enough to provide all necessary information of practical value within the foreseeable future.

A vertical direct current electric motor driving the arm is sunk below floor level and can bring the cars up to the maximum speed of 54·4rev/min in 9 seconds. It develops 2 200 horse-power while doing this.

Control can be either automatic or manual. With automatic control each run of the centrifuge is governed by one of a number of interchangeable cams, each of which is designed to give a different maximum *g* with a different rate of acceleration from rest. The cam revolves until the required *g* is attained, remains stationary for a predetermined time—usually a few seconds—then the direction of rotation of the cam is reversed to decelerate the centrifuge and bring it to rest. The cam may be operated at four speeds, enabling the required *g* to be reached in 9, 12, 18 or 30 seconds. The cars can be attached to the arms at 10, 15, 20, 25 and 30 feet radii as required.

Method of Operation

The normal operating team consists of controller, observer, recorder and, of course, the subject in the car. The rate of acceleration or deceleration can be controlled manually by the subject—if he feels that the *g* is getting beyond endurance—or by the controller, using a standard "joystick".

Controller, recorder, observers and subjects, are all provided with means of stopping the arm in case of illness or emergency, and in addition, the controller has an emergency push-button, which cuts off the electricity supply entirely, and brings the arm to rest by the application of the mechanical brakes.

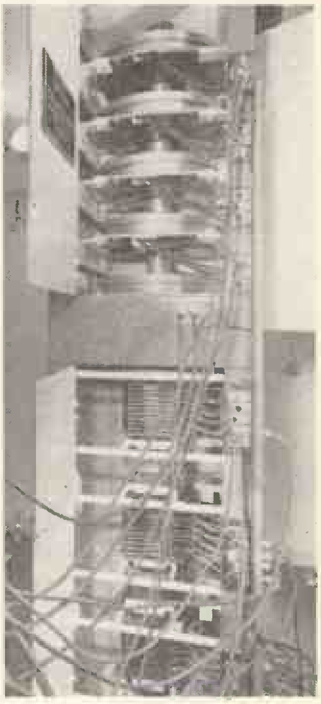
The subject is always in communication by microphone and loudskeaker with the observer, who sits near the centre of the arm and thus revolves with him and can keep him under continual observation. The observer in turn is in two-way communication with the controller and the recorder—the former in the control room having an overall view of the whole arm, and the latter in a laboratory on the roof of the building.

The reactions of the subject—pulse and respiration rates, blood pressure and heart and brain functions — are recorded electrically from electrodes attached to his body, the wires being run from the car, along the arm, up through a hollow shaft in the centre of the arm which extends to a slip-ring column in the roof near the recording room. Reactions are indicated either as curves photographed in a camera-recorder, or as graphs drawn by a pen-recorder. The pen-recorder is so sensitive that the minute currents generated by the subject's brain or by moving his eyes can be measured.

This extreme sensitivity makes recording a very difficult operation, as small outside electrical influences can easily spoil the records. For example, stretching a piece of elastic, or combing the hair near the subject, can cause the recording-pen to move right off the paper chart.

For this reason all the conducting wires have to be screened. Many of the rooms in the building above have been completely screened by covering the walls, floor and ceiling with copper mesh, and the doors covered with sheet copper. The screening is believed to be the most effective of any centrifuge in the world.

Apart from physiological research the centrifuge offers great possibilities in the testing of aircraft and guided missile equipment and components. In this role it will be possible to submit to test articles weighing 1 100lb up to the maximum of 30*g*—i.e., they will in effect weigh 31 000lb when under test. Another alternative is to fit larger compartments at the end of each arm. Each compartment has a wooden floor and end and side walls of duralumin covered with sponge rubber, and they can be rotated up to 10*g*. The subject may be observed closely and filmed while performing simple operations such as standing up, lying down or putting on parachute harness. It will be possible to study the effects of *g* on a pilot attempting to leave an escape hatch when an aircraft is out of control, and the maximum amount of *g* at which a pilot can operate an ejection seat.



The slip-ring column

The man-carrying centrifuge was installed under contract with the Air Ministry. The design requirements were specified by the Chief Mechanical and Electrical Engineer Air Ministry Works Directorate to meet the functional requirements of the Institute of Aviation Medicine and his division supervised the construction, installation and tests.

The contract for the centrifuge was placed with M. B. Wild & Co. Ltd., of Birmingham, who acted as main contractors, all the electrical plant and control gear being supplied by The General Electric Co. Ltd. M.L. Aviation Ltd. were responsible for the design and construction of the centrifuge cars.

The electro-encephalograph was supplied by Messrs Edison Swan Electric Co. Ltd., Camera-Recorder by Messrs. Films and Equipments Ltd., and the amplifying equipment for the recording apparatus by Messrs. Southern Instruments Ltd.

Power Considerations in Induction Heating

By D. Warburton Brown, A.M.I.Mech.E.

The increasing use of the induction heating process makes it interesting to examine the method of assessing the power requirements for different applications. Although figures obtained from theoretical considerations are reasonably accurate, the power of the equipment used is dictated by the heaters which are commercially available.

WITH the increasing use of induction heating in the engineering industry for various processes such as soldering, brazing, hardening and annealing it is of some interest to examine the question of the power requirements for different applications.

Induction heaters are available commercially with a wide range of power outputs and it is useful for the potential user to have some means of assessing the size of equipment which will be necessary for any specific operation. This will, of course, have a definite bearing not only on the initial capital outlay, but also on the running costs and hence the ultimate price of the operation.

Until comparatively recently there were no defined methods of computing the power rating of induction heaters and this led to a good deal of confusion and made it difficult for the potential user to gauge exactly what power would be available at the output terminals of the equipment which could be translated into useful work. The situation is now improved, however, as the whole question of power rating of induction heaters of the valve oscillator type is covered by British Standard Specification 1799:52.

The above specification sets out the method which must be adopted by manufacturers of specifying the power available at the output terminals, but it must be appreciated that other factors must be considered when assessing the power necessary to carry out a given heating operation. Various losses will occur between the output terminals and the workpiece and it is proposed to examine these losses in somewhat greater detail.

Power Losses

In order to appreciate the losses which occur it is first necessary to have a clear picture of the normal arrangement used in induction heating. The general aspects of the subject have been described so frequently that it is not proposed to deal with them in any great detail in the present article. It is sufficient to state that the usual induction heating set-up comprises the following:

(1) A suitable form of high frequency generator.
(2) An inductor or workcoil.
(3) The workpiece.
(4) A mounting fixture to hold the work.

High frequency generators are of three main types, namely, rotary generators, spark gap generators, and valve oscillators. Each type have their own sphere of operation and the rotary and valve oscillator types are the most widely used in industry. The main difference lies in the frequency of operation. Rotary generators in general operate between 2kc/s and 10kc/s. Spark gap heaters cover the range between 20 and 400kc/s, and valve oscillators normally operate in the 350-550kc/s range, although equipments are available for megacycle frequency operation.

Induction heaters are available commercially with power output ratings from 1 to several hundreds of kilowatts.

The normal arrangement for induction heating is for the work coil or inductor to be connected to the output terminals of the generator and the workpiece to be located inside or adjacent to the workcoil. Heat is generated in the work by virtue of the fact that the workcoil—which is usually a coil of copper tube—is surrounded by lines of flux when a current is flowing in the coil. These lines of flux induce currents in the work-piece. The induced currents circulate in the work and are resisted by the inherent electrical resistance of the work and the energy which is dissipated manifests itself in the form of heat.

The process depends therefore on the transfer of electrical energy from the generator to the work and, as previously pointed out there will be certain losses which must be taken into account. These losses may be summarized as follows:

(1) Coil losses and lead losses.
(2) Radiation losses.
(3) Convection losses.
(4) Conduction losses.

} Thermal losses.

The sum of these losses must be added to the power which is theoretically necessary to carry out the heating operation, and it is proposed, after having considered the theoretical power assessment, to deal with each of the above losses in greater detail.

Theoretical Power Requirements

It is not possible to consider the question of induction heating without also considering heat and its behaviour. Heat is a form of energy and it can be measured. It must also be remembered that energy of one form can be transformed into energy of another form, and in the case of induction heating, the transformation does not occur until the workpiece is placed inside the workcoil. The output of high frequency induction heaters is generally given in terms of electrical units, namely kilowatts.

The relationship between the quantity of heat necessary to raise the temperature of a body, and time is as follows:

$$Q = \frac{me(\theta_1 - \theta_2)}{t}$$

where Q = quantity of heat
e = specific heat
m = mass of material (lb)
θ_1 = final temperature (°C)
θ_2 = initial temperature (°C)
t = time (min)

This equation assumes no heat losses, but does in fact enable the theoretical electrical power for a given application to be calculated, because 56·8 B.t.u. are equivalent to 1kW. In order to calculate the theoretical power requirements the above formula can be modified as follows:

$$P = 0{\cdot}0316 \frac{mc(\theta_1 - \theta_2)}{t} \quad \ldots\ldots\ldots\ldots (1)$$

In the majority of induction heating problems the value of θ_2 is so small in relation to the final temperature of the work that it can be neglected.

Coil Losses

Because the material which is used to connect the generator to the coil has inherent resistance to high frequency currents electrical losses will occur in these conductors and also in the coil itself. In the majority of cases the coil and feeding lines will be made from copper, and if the specific resistance of copper is taken as $1{\cdot}72\mu\Omega/\text{cm}^3$, the following expression can be used to determine the extent of the losses which occur in the coil and feeding lines.

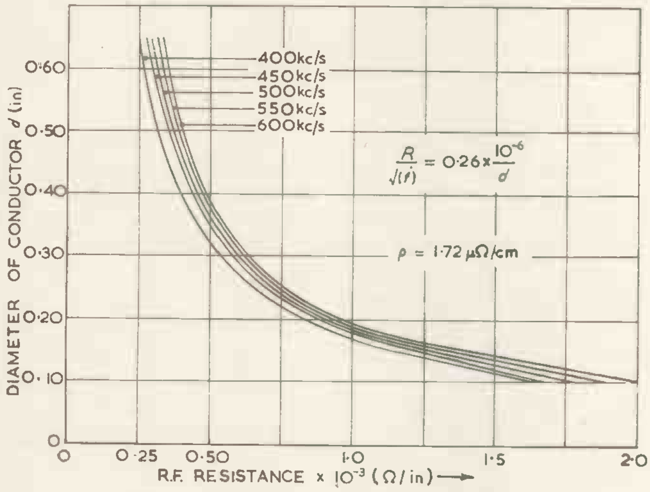


Fig. 1. R.F. resistance of copper conductors

$$R/\sqrt{f} = 0{\cdot}26 \times 10^{-6}/d \quad \ldots\ldots\ldots\ldots (2)$$

where R = r.f. resistance in ohms/in

f = frequency in c/s

d = diameter of conductor (in)

The total line and coil resistance will therefore be the value obtained from equation (2) multiplied by the total length of the lines and conductor used for the workcoil. The coil loss will then be found from:

$$P_1 = I^2 R_c \quad \ldots\ldots\ldots\ldots (3)$$

Values for the radio frequency resistance of copper conductors of various diameters and at different frequencies associated with valve oscillator type induction heaters calculated from equation (2) are plotted in Fig. 1. The values read from these curves must be multiplied by the overall length of the lines and coil conductor.

For example, with a generator operating at 450kc/s and using a coil wound from ¼in diameter tubing and having a length of 20in, the total r.f. resistance will be:

$$0{\cdot}00053\Omega/\text{in} \times 20\text{in} = 0{\cdot}0106\Omega$$

When dealing with solenoid coils the resistance can be obtained from the developed length of the coil and connectors or alternatively Fig. 2 can be used which gives the resistance in terms of the ratio between the coil diameter and its axial length.

If the total length of conductor is taken at 20in as in the previous example, this would be equivalent to a 4-turn coil 1in in diameter and having an axial length of 1in with connectors 3in long. The D/l ratio will be 1·0 and from Fig. 2 the resistance will be equal to 0·0106Ω which is the same as the results obtained from the other curves.

The resistance value multiplied by the square of the current flowing in the coil will give the power loss in the coil.

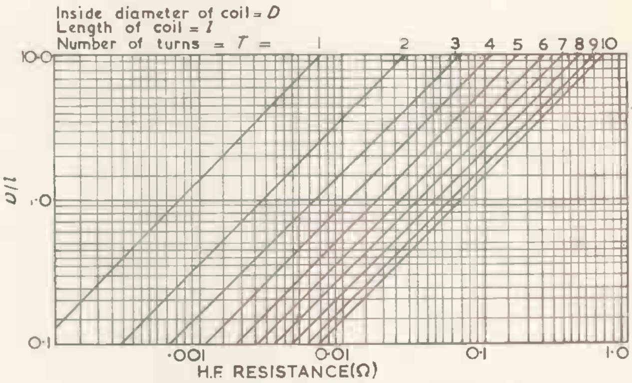


Fig. 2. H.F. resistance of copper inductors at 490kc/s

TABLE 1
Typical Values of Emissivity Factors

MATERIAL	POLISHED	ROUGH	OXIDIZED
Aluminium	0·04	0·055	0·11/0·19
Brass	0·03	0·06/0·20	0·60
Copper	0·02	—	0·57
Steel	0·13/0·40	—	0·80/0·95
Nickel	0·05	—	0·40
Silver	0·035	—	—

Radiation Losses

Part of the thermal losses which occur are due to the radiation of heat to the surrounding atmosphere and it will be apparent that as the temperature increases so do the radiation losses. These losses will also depend upon the area of the radiating surface and also upon the nature of the surface being heated. In terms of electrical energy radiation losses can be assessed from the expression:

$$P_r = 37e[(\theta_1/1\,000)^4 - (\theta_2/1\,000)^4] \quad \ldots\ldots (4)$$

where P_r = radiation loss in watts per in²

e = emissivity factor.

θ_1 = final temperature (°K).

θ_2 = initial temperature (°K).

The value of the emissivity factor is dependent upon the type of material being heated and upon the condition of the surface. Typical values are given in Table 1 and the curves shown in Fig. 3 enable the radiation losses to be assessed for various materials.

In some cases the value of these losses may be of a substantial order and to reduce the loss of energy due to this factor, it is sometimes necessary to enclose the work and the inductor in some form of lagged material.

Convection Losses

A certain amount of heat can be lost by convection, and although generally this is only of a small order it can, when dealing with large components at high temperatures,

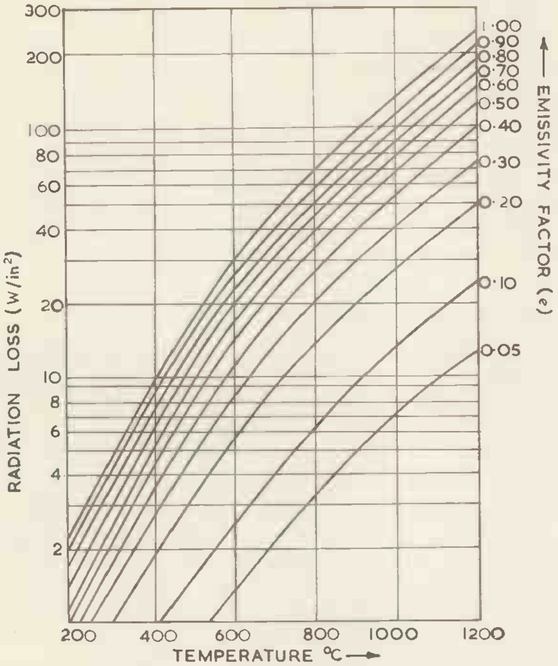


Fig. 3. Radiation loss curves for different emissivity factors

attain some significance. The energy lost is due to the minute air currents caused by the expanding gases surrounding the heated object carrying heat away from the surface.

Convection losses in terms of electrical energy can be calculated from the expression:

$$P_c = 4{\cdot}66 \times 10^4 \ (\theta_1 - \theta_2)^{1{\cdot}33} \quad \ldots\ldots\ldots \ (5)$$

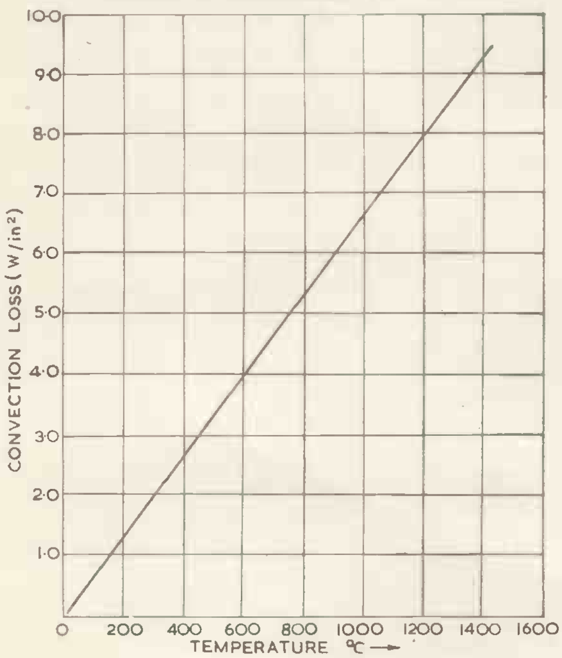
where P_c = convection loss (W/in²)

θ_1 = final temperature (°F)

θ_2 = initial temperature (°F).

A curve of convection losses is given in Fig. 4.

Fig. 4. Convection loss curve



Conduction Losses

The majority of industrial applications of high frequency induction heating take advantage of the localized heating made possible by the process—an exception being found in the melting of metal. It follows, therefore, that there will be a mass of cold metal lying adjacent to the heated area of the component or assembly.

Since heat always flows from a hot body into a cold one there will be a transfer of heat into the cold mass of metal, so that as energy is being supplied to the work it is being drawn away from the area which it is desired to heat.

Generally speaking it is necessary to estimate the power lost in this manner, but in certain simple cases it can be calculated from:

$$P_{cm} = 1{\cdot}78 \, . \, (\theta_1 - \theta_2) \ \sqrt{(kc\rho/t)} \quad \ldots\ldots\ldots \ (16)$$

where P_{cm} = conduction losses (watts/in²)

θ_1 = final temperature (°F)

θ_2 = initial temperature (°F)

k = coefficient of conductivity

c = specific heat of material

ρ = density of material

t = time (min).

The effect of conduction so far as induction heating is concerned is most marked in surface hardening problems, since despite all theoretical considerations of frequency and skin effect, the conduction of heat effectively limits the minimum depth of case which can be obtained.

Total Power Requirements

In order to illustrate the application of the above equations, the following example has been worked out.

Consider a bar of steel 1in diameter by 1in long which has to be raised to a temperature of 1 000°C in one minute. Assume an atmospheric temperature of 20°C and a polished surface.

(a) Surface Area of Work

The total surface area will consist of the area of the two end disks plus the developed area of the cylinder, thus:

$$\text{Area of 2 end disks} = 2 \times \pi d^2/4 = \frac{2\pi \times 1}{4} = 1{\cdot}56\text{in}^2$$

$$\text{Area of developed surface} = \pi d \, . \, l = \pi \times 1 = 3{\cdot}14\text{in}^2$$

$$\text{Total area} = (1{\cdot}56 + 3{\cdot}14) = 4{\cdot}70\text{in}^2.$$

(b) Mass of Work

$$\text{Mass} = \pi d^2/4 \, . \, l \times 0{\cdot}28$$
$$= 0{\cdot}78 \times 1 \times 0{\cdot}28$$
$$= 0{\cdot}22\text{lb}.$$

(c) Theoretical Power Requirements

(Note: Specific heat of steel = 0·11.)

$$P = \frac{0{\cdot}0316 \, me \, (\theta_1 - \theta_2)}{t}$$

$$= \frac{0{\cdot}0316 \times 0{\cdot}22 \times 0{\cdot}11 \times (1\,000 - 20)}{1}$$

$$= 0{\cdot}710\text{kW}.$$

(d) Radiation Losses

(Note: Emissivity factor for polished steel = 0·10 = e.)

$$\theta_2 = 20°\text{C} = 293°\text{K}$$
$$\theta_1 = 1\,000°\text{C} = 1\,273°\text{K}$$

$$P_r = 37 \times e\,[(\theta_1/1\,000)^4 - (\theta_2/1\,000)^4]$$
$$= 37 \times 0{\cdot}10\,[(1\,273/1\,000)^4 - (293/1\,000)^4]$$
$$= 9{\cdot}3\text{W/in}^2$$

Total radiation loss = 9·3 × 4·70
= 43·7W
= 0·0437kW.

(e) Convection Losses

$$P_c = 4{\cdot}66 \times 10^{-4}(\theta_1 - \theta_2)^{1{\cdot}33}$$
$$= 4{\cdot}66 \times 10^{-4}\,(1\,825 - 65)^{1{\cdot}33}$$
$$= 4{\cdot}66 \times 10^{-4}\,(1\,760)^{1{\cdot}33}$$
$$= 10{\cdot}30\text{W/in}^2$$

∴ Total convection loss = 10·3 × surface area
= 10·3 × 4·7
= 48·4W = 0·048kW which is negligible.

(f) Conduction Losses

(Note: For steel. $k = 0{\cdot}11$, $e = 0{\cdot}11$, $\rho = 7{\cdot}8$.)

$$P_{cn} = 1{\cdot}78\,(\theta_1 - \theta_2)\,\sqrt{k c \rho / t}$$
$$= 1{\cdot}78\,(1\,825 - 65)\sqrt{\frac{0{\cdot}11 \times 0{\cdot}11 \times 7{\cdot}8}{1}}$$
$$= 3\,140\,\sqrt{0{\cdot}094}$$
$$= 960\text{W/in}^2$$

∴ Total conduction loss
= 960 × surface area
= 960 × 4·7
= 4 500W = 4·5kW

(g) Coil Losses

For the example assume that a 4-turn coil 1·25in diameter wound from 3/16in tube and having an axial length of 1·00in is used. Then from Fig. 2 the r.f. resistance will be 0·025Ω.

If a coil current of 250A is assumed then the coil loss will be:

$$P = I^2R.$$
$$= (250)^2 \times 0{\cdot}025$$
$$= 1{\cdot}5625\text{W}$$
$$= 1{\cdot}56\text{kW}.$$

(h) Total Power Requirements

The total power required will, therefore, be the sum of the theoretical power and all incidental losses which will be in the example 7kW, this being greatly in excess of the theoretical figure. The results obtained from the above calculations correspond very closely to the results obtained in practice, it being interesting to note that the major loss is due to conduction.

kVA to kW Ratio

The fact that an induction heater has a known output in terms of kilowatts does not give a complete picture of the performance of the equipment. Unless it is possible to couple the available power from the generator into the load—that is unless it is possible to draw the full output from the equipment—poor performance is inevitable. The kVA output of the equipment is of considerable importance in this respect and the ratio between the output in kVA and the rated output in kilowatts will have a profound influence upon the performance and versatility of the equipment. In general, for good all round performance with a wide variety of workcoils and workpieces, the kVA to kilowatt ratio should be approximately 60 for operating frequencies between 400 and 600kc/s per second, thus for any generator:

$$\text{kVA/kW} \geqslant 60$$

If the ratio is smaller it becomes increasingly difficult to draw full power from the generator and consequently the heating performance will be poor and the equipment will be inflexible and critical regarding the design of the workcoil.

For normal induction heaters designed for commercial use the output voltage will be approximately as follows:

(a) Generators for use with low impedance workcoils 50/300V
(b) Generators for use with medium impedance 150/600V
(c) Generators for use with high impedance 1 000/3 000V

and the aim of the designer of the equipment will be to keep the kVA output at the highest possible value. There is a limit to this, of course, but the ratio of 60 should be regarded as being essential for general purpose, commercial type heaters. It is evident, therefore, that the current flowing in the workcoil should be as high as possible. The effect of low current will be to restrict the density of the flux surrounding the coil and hence, since the heating effect in the work is a function of the number of lines of force cutting the surface, the coupling between the work and coil becomes critical and in generators with a low kVA/kW ratio it is generally necessary to employ very tight coupling in order to draw the full power from the generator. This has, of course, serious practical disadvantages from the point of view of jigging and flashover.

When the ratio is high, however, the density of flux is increased and the coupling is not nearly so critical with resultant increase in flexiblity and ease of handling. It should be pointed out that, in order to obtain a high ratio, the cost of the equipment will rise and there has been a tendency for manufacturers to economize on production costs at the expense of performance. In America this is particularly true and many of the American equipments are made with low kVA/kW ratios, it being deemed more economical from a production standpoint to use higher power outputs. This practice is of questionable value, however, since in order to obtain greater outputs more expensive oscillator valves have to be employed, the generator is seldom delivering the maximum power and running and depreciation costs are high.

With high impedance generators it is usual practice to utilize output or matching transformers which have the effect of stepping down the voltage in the workcoil and increasing the current.

It is important from the user's point of view to realize that the rated output of induction heaters is of little significance unless the full output of the generator can be coupled into the work using a fairly wide range of workcoils. The importance of this aspect of induction heating will be realized from the prominence it receives from the British Standard Specification relating to the rating of valve type induction heaters.

Conclusion

It is hoped that the remarks given in this article will enable a better picture to be obtained so far as the power requirements for induction heating applications are concerned. As previously pointed out, the use of high frequency heating equipment involves a transfer of energy and all energy losses must be taken into consideration when estimating power requirements.

Regulated D.C. Power Supplies at Low Voltages

By R. K. Hayward*, B.Sc., A.M.I.E.E., J. C. Jennings*, B.Sc., A.M.I.E.E., and R. C. Barker*.

The limitations of cold cathode stabilizer tubes are discussed. Reference tubes used with cathode-followers are shown to give improved regulation and greater current output for low d.c. voltages. The application of this in a valve stabilized power unit for 50 to 100V is described. For supplies of less than 50V a low impedance circuit without stabilization is recommended.

D.C. power supplies for general use in laboratories and for electronic control gear are not usually required to have a high degree of stabilization, although something better is necessary than that obtained by direct rectification of the a.c. supply followed by smoothing. An increasing variety of electronic devices for amplification and switching are coming into use having operating voltages lower than those hitherto needed for thermionic valves. For instance, voltages of 150V or less are used with cold cathode tubes and voltages of 50V or less with transistors, and with rectifiers used as switches. The purpose of this article is to discuss methods of providing such supplies having regulation of a few per cent or better, with due regard to electrical efficiency and cost.

Cold Cathode Tubes

In the range 60 to 150V cold cathode stabilizers have been used for many years (Fig. 1), but these circuits have several limitations.

(1) Tube-to-tube variations of stabilizing potential are generally ± 3 to 6 per cent, quite apart from load variations.

(2) The stabilized voltage has to be that of one of the available tubes or the sum or difference of two or more tubes (Fig. 1).

(3) Step voltages of up to 0·5V occur as the tube current is increased or reduced, these usually being associated with the change in position of the glow on the cathode.

(4) Tube life is short when the load is small, as in this condition a large tube current is drawn. In general the life of the tube is inversely proportional to the cube of the current.

(5) The current in the load has a maximum value of approximately half that of the rating of the tube. Because an allowance must be made for sufficient potential to strike the tube when first switching on, the load current cannot be more than about two-thirds of the stabilizer tube rating, and if the d.c. supply to the tube is obtained by rectification of the a.c. supply there must be further allowance for change of supply voltage. This reduces the figure to a half.

These difficulties can be overcome by the use of voltage reference tubes such as the 85A2 or QS83/3 in association with a cathode-follower valve as shown in Fig. 2.

In this circuit, two of these series-connected tubes are shunted by a high resistance potentiometer, which is tapped

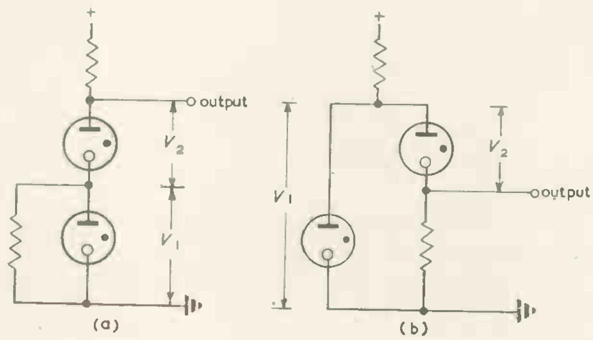


Fig. 1. Conventional cold cathode tube stabilizers
(a) output $= V_1 + V_2$
(b) output $= V_1 - V_2$

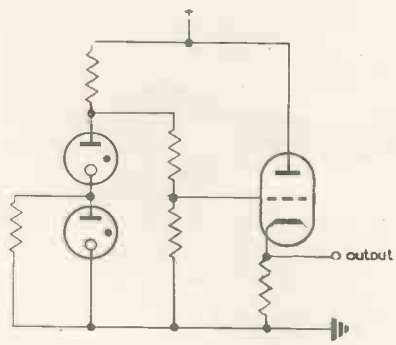


Fig. 2. Cold cathode tube stabilizer with cathode-follower output

to feed the grid of a cathode-follower. The output voltage is determined by the setting of the potentiometer and may have any desired value. The maximum load current depends on the choice of valve and the voltages available for it, and is no longer dependent on the cold cathode tube which is run under optimum conditions to avoid the occurrence of step voltages.

As distinct from cold cathode stabilizer tubes which usually have an oxide coated cathode, voltage reference tubes have a metallic cathode; this results in tube-to-tube variations of less than ± 1·5 per cent at a given current and also leads to a much longer life.

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The regulation depends on the cathode-follower valve and the part of the valve characteristics used, but it is always a falling characteristic. A close estimate of the regulation can be obtained directly from the valve characteristics. For instance, suppose a valve type EF91 is triode-connected with its anode at + 150V, its grid connected to + 50V and its cathode to earth through a load resistor, then approximately 100V is dropped across the valve. From the triode

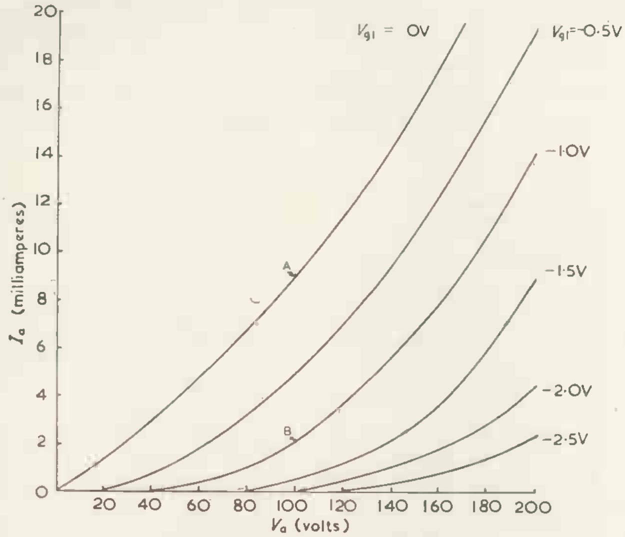

Fig. 3. Aged EF91 triode connected
g_2 strapped to a
g_3 strapped to k

Fig. 4. Cathode-follower, EF91 triode connected. Variation of output potential with load.
(a) 1. Aged valve.
2. Two aged valves in parallel.
(b) New valve.

characteristics of the EF91 shown in Fig. 3 it can be seen that at the maximum current of 8·8mA, (point A) the output potential will be 50V. At a bias of 1V (point B) the current is 2·2mA and the output voltage 50 + 1 = 51V. Fig. 4(a) curve (1) shows the cathode-follower output characteristic constructed from values read off in this way.

It should be borne in mind that the maximum current decreases as the valve deteriorates and a more conservative value than that of the published curves should be used for design purposes. Output characteristics for an aged valve and a new valve are shown in Figs. 4(a) and 4(b) respectively. The maximum current for an aged valve is seen to be 8·8mA and that for a new valve 12·2mA. The EF91 characteristics shown in Fig. 3 are for an aged valve. The internal resistance also changes with age and for the two cases considered above is 130Ω for the new valve and 165Ω for the old valve.

Although the regulation is not particularly good, the internal resistance being between 100Ω and 200Ω, the result is predictable and repeatable with changes of components. Improved regulation and greater current output can be obtained by connecting further cathode-followers in parallel. The output for two parallel valves is shown in Fig. 4(a) curve (2).

One application of this circuit is to provide a low voltage reference source for use in a valve stabilized power unit as described below.

A Valve Stabilized Power Supply Unit

The conventional valve stabilized power supply unit is shown in Fig. 5. The stabilized output voltage is the sum of the voltages across the stabilizer tube V_2, the amplifier valve V_4, and resistor R_3; the latter voltage having a value equal to the maximum grid bias necessary to control V_5 when it is passing low current. Now the minimum voltage across V_2 is 55V using a cold cathode tube of doubtful stability, or 84V when a stable tube is used. The voltage drop across V_4 can be made small if V_4 is a pentode with a high value anode resistor. The maximum grid bias necessary for valve V_5 can be reduced by providing good regula-

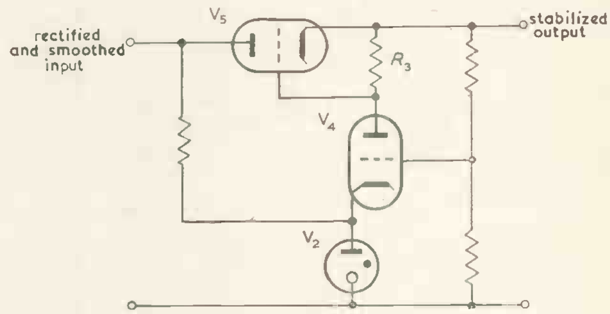

Fig. 5. Conventional series valve stabilizer

tion at the input, by choosing a high gain valve and by taking only a restricted current through it. The last two conditions can be met to some extent by using two or more valves in parallel. However, the total voltage adds up to about 150V and an extensive literature exists on units delivering 150V or greater.

The problem of adapting this circuit to supply voltages of 100V or less consists essentially of lowering the reference voltage on the cathode of V_4. One method of achieving this is to provide an additional rectified, smoothed and stabilized negative voltage supply to which the output potentiometer can be connected while earthing the cathode of V_4.

A more simple and economic solution is to make use of the cathode-follower circuit of Fig. 2. The complete circuit is shown in Fig. 6. This gives an output of 250mA at 50V or 150mA at 100V with regulation better than ±0·5 per cent for supply variations between 225V to 250V. The potential applied to the grid of V_3 is virtually constant because it is derived from the 84V reference tube V_2 which is run at a fixed current, its resistor being connected to the preceding 150V stabilizer tube V_1.

The current through V_3 varies slightly due to the changing load in V_4. This variation is from 1·20 to 1·30mA over the full range of the power unit. However, V_3 cathode potential varies by less than ± 0·1V at 15·5V so that the cathode-follower provides a good reference voltage.

Other features of the circuit are:

(1) A choke input circuit with a low resistance choke to obtain good regulation.

(2) The stabilizer tube V_1 acts not only as a non-linear device to bleed proportionally more current from the d.c. supply at high voltages than at low ones, but also to give a roughly stabilized voltage to feed the reference tube V_2 and the cathode-follower V_3.

(3) Feedback resistors R_1 and R_2 to provide changes of voltage at the grid of V_4 to give some compensation for changes of input voltage and load current, thereby reducing the changes of output voltage necessary to control V_4.

the anode voltage must be increased to a value greater than that of the screen to allow for the voltage drop in the screen regulator circuit. This could consist of a cold cathode stabilizer tube fed through a resistor, but in practice it is extremely difficult to design. This is because the screen takes a very small current when the output current is small and the input voltage is high, and a large current when the output current is large and the input voltage is low. In turn the current through the stabilizer tube is very low at low input voltages and very high indeed at high input voltages.

However, when large output currents of 2A or more are required and these must be supplied by a number of

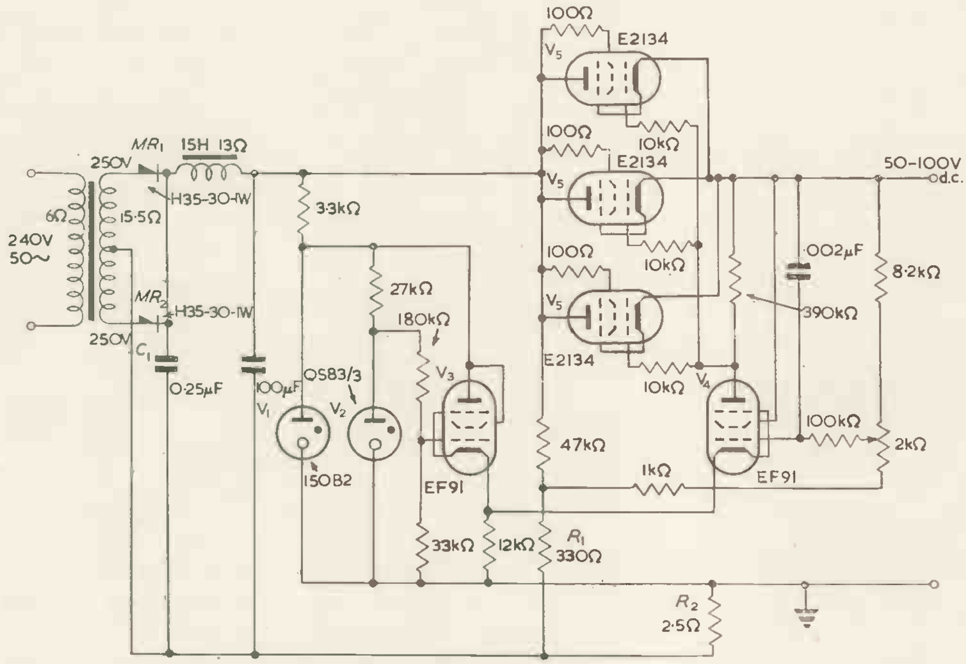

Fig. 6. Stabilized d.c. power supply 50 to 100V.

(4) A low value capacitor C_1 to reduce ringing in the choke. The capacitor C_1 is small enough for the smoothing circuit to work as choke input.

It was mentioned earlier that another factor determining the minimum output voltage was the grid base of the series valve V_5. One way of reducing this is to connect V_5 as a tetrode or pentode instead of a triode, but this involves the provision of a source of potential, preferably stabilized, at some 100V above the cathode potential of the series valve, if full advantage is to be taken of its current carrying capacity. Assuming that such a screen voltage can be applied, then the anode voltage need be only some 40 per cent of the screen voltage without the valve running into excessive screen current at low grid bias. Furthermore, provided that the screen voltage is stable, the anode voltage need not be particularly free from ripple, since the valve is working in the constant current region and fluctuations of h.t. voltage have only a slight effect on current passing and this can be dealt with by V_4.

Unfortunately the requirements for efficiency, i.e. that the screen voltage be high and stable, and the anode voltage low and only partially smoothed cannot be met from the same source of rectified h.t. For a simple power unit such as discussed here, the rectified h.t. and consequently

series stabilizer valves it is convenient and economical to arrange for the anodes to be fed from one supply and the screen grids, control valves and reference tubes from a separate stabilized supply.

Reverting to the case of a single self-contained power supply unit, the grid base is most effectively reduced by connecting a number of series stabilizer valves in parallel. The total output current is then shared between the valves, each of which has a relatively short grid base and a lower anode to cathode voltage drop. The effective g_m is also higher than for a single series valve.

A Supply Unit Having Good Regulation But No Stabilizing Components

The arrangement just described involves the provision of high voltage from which to derive a lower one, and is progressively less efficient as the required output voltage becomes smaller. Germanium junction rectifier diodes can be used in a conventional rectifying and smoothing circuit to give an efficient and well regulated low voltage d.c. supply from a.c. mains. This is shown in Fig. 7 together with its regulation curve.

The germanium junction is a more efficient rectifier than selenium because it has:

(1) A lower forward voltage drop.
(2) Lower dynamic resistance.
(3) A higher permissible reverse voltage, thereby reducing or eliminating the need for series connexion of units.

Typical values are:

	Germanium Junction GJ3D	Selenium 35mm
Voltage drop at 300mA	0·43V	0·93V
Dynamic resistance at 300mA	0·27Ω	1·1Ω
Maximum reverse voltage	200V	18V

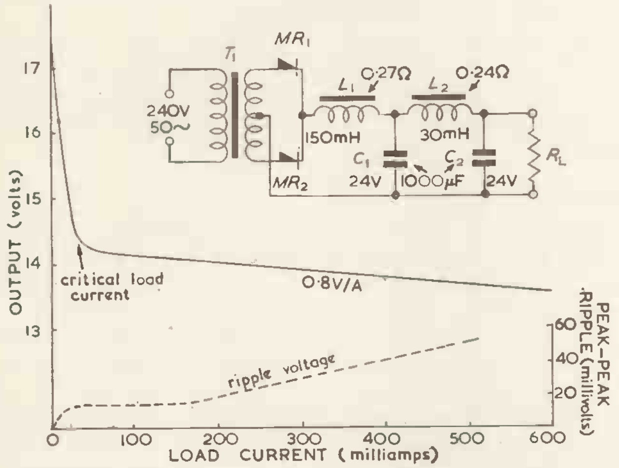

Fig. 7. D.C. power unit using germanium junction rectifiers

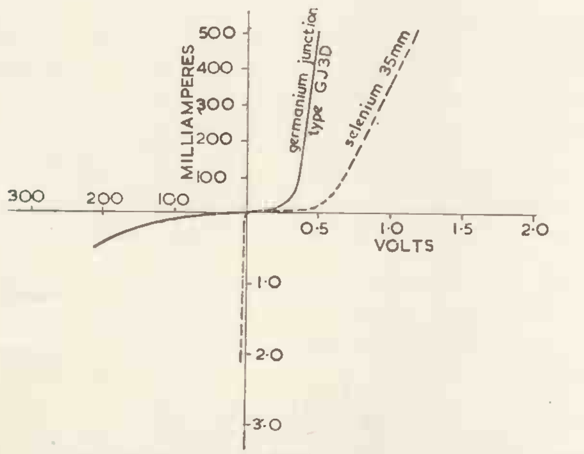

Fig. 8. Static characteristics of germanium junction and selenium rectifiers

The static characteristics are compared in Fig. 8.

The electrical properties of germanium are particularly sensitive to temperature change and normally the working temperature should not exceed 60°C. If the reverse voltage is at or near the maximum, then during the half-cycle when the junction is reverse biased the power dissipated is a large proportion of the total, thus reducing the forward d.c. rating to a minimum. In the circuit here considered, the applied reverse voltage is a small fraction of the permissible maximum, so the d.c. rating can be increased.

Typical values are:

100mA d.c. rating for a peak inverse voltage of 200V

330mA d.c. rating for a peak inverse voltage of less than 40V.

Referring again to Fig. 7, the knee of the regulation curve occurs when the total series resistance including that of the load is reduced sufficiently to ensure continuous flow of current through the input inductance. For a given supply voltage this is at a particular value of output current. When this critical load current is exceeded, further regulation of the filter is due to the resistance in series with the load. The requirements of L_1 are, therefore, firstly a high inductance at low currents so that the knee of the regulation curve is at a low load current, and secondly that it has a low forward resistance to give good regulation for currents greater than the critical current.

It will be seen from Fig. 7 that the inductor and transformer resistances are designed to be approximately equal to that of the rectifier, which is about ¼Ω. The critical current has been taken as 10 per cent of the maximum of 500mA at 14V output. The inductance of 150mH can be obtained using a standard 15/16in by 15/16in core having 15mil radiometal laminations; the air-gap is 1mil, which gives the required inductance at low load, but because of core saturation, results in a ripple voltage which increases with load. The core size is thus reduced by accepting loss of smoothing.

In this particular application the ripple is further reduced to the required value of less than 50mV peak-to-peak by introducing a second filter stage of 30mH and 1 000μF.

To reduce the effect of supply voltage variations the transformer may be of the constant voltage type. This is somewhat extravagant for a single power unit, but often more than one d.c. supply is required and regulated a.c. is necessary for other purposes. In such cases a single 240V constant voltage transformer can feed a number of d.c. units.

Using the same rectifiers to obtain the same maximum current, lower voltages can be obtained with proportional reduction of the input inductance, although efficiency is reduced because the voltage drop across the rectifier is a greater proportion of the output. Conversely, for increased voltages:

(1) Greater inductance is required if the available output is still to be 90 per cent of the total, while maintaining a low d.c. resistance to ensure good regulation. This leads to bigger and more expensive inductors.
(2) The maximum d.c. rating of the rectifiers is reduced. This will be less important when a wider choice of germanium junction diode types is available.

Conclusions

As stabilizers cold cathode tubes are of limited use by themselves, but when used in association with a cathode-follower enable repeatable and predictable results to be obtained at any chosen load or voltage. Valve stabilized supply units give better regulation and can be designed to give large current outputs at voltages as low as 50V. Voltages lower than 50V can best be obtained by using special components in a conventional rectifier and smoothing circuit.

Acknowledgments

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A Linear Capacitance-Change Circuit

By V. H. Attree*, B.Sc.

Capacitance-changes frequency modulate a Franklin oscillator which drives a nonode f.m. discriminator. Sensitivity is 10V/pF and the ouput is accurately linear between −40 and +40V.

In making measurements of pressure or displacement it is often convenient to use a change-of-capacitance transducer with an appropriate electronic circuit. For dynamic measurements the requirements for the detecting circuit are that it should be stable, linear, reasonably sensitive and should have a fast response. In addition to these properties, all of which are necessary for adequate performance, certain other features are desirable from the operating point of view; these include a simple setting procedure and a method of sensitivity control that does not affect the zero point.

There is an extensive literature on capacitance circuits and the references given with this paper[1-25] have been chosen to illustrate the main circuit types. A full review will not be attempted, but it is perhaps helpful to indicate the main properties of each type.

Beat-frequency methods[1-3] are capable of high sensitivity, but are liable to "pulling" between the two oscillators. Amplitude-change methods[4-5] are insensitive and are now seldom used. Bridge-systems[6-15] may be extremely sensitive[11], but need a phase-sensitive detector if ambiguity of reading is to be avoided. Bridges having more than one balancing control[12-13] are often difficult to set up. Single-valve devices[16-19] may have good sensitivity, but are often non-linear; their main use is for capacitance measurement by substitution. Phase modulated circuits[20,21] are sensitive but restricted in range of control. Frequency modulated methods[22,25] are probably best from the point of view of linearity and speed of response, but the discriminator may be difficult to align and the sensitivity is less than in some of the simpler methods. The circuit described in the present article uses frequency modulation, but the difficulties of discriminator alignment are avoided.

The references[1-25] are all concerned with electronic circuits and have relatively little information on capacitance-change transducers. For the sake of completeness a group of references[26-33] dealing with transducer design is included.

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Circuit Description

The circuit diagram of the capacitance detector is shown in Fig. 1. The capacitance transducer is in parallel with the tuned circuit L_1C_1 on the input of the Franklin oscillator consisting of V_1 and V_2. The signal at the anode of V_2 is fed back to the tuned circuit via the capacitor C_3. The oscillator runs at a nominal frequency of 465kc/s which enables a standard intermediate frequency transformer to be used in the discriminator. The amplifying stages V_1 and V_2 have 2·2kΩ anode loads, R_1 and R_6, and are both untuned. The amplitude of the oscillation is determined by limiting action in V_2 so that the signal at the anode and cathode of V_2 is essentially a square wave of constant amplitude. The amplifier gain is about 200 times, which enables the two coupling capacitors C_3 and C_4 to be made very small (about 2pF), thus reducing the effect of valve capacitance changes on the oscillator frequency. The oscillator gives a constant amplitude, even with quite a large, in phase, loss component in the transducer. This is a practical advantage as it is sometimes difficult to maintain adequate insulation in the capacitance transducer.

The oscillator signal at the cathode of V_2 is fed to the amplifier V_3 which has a 465kc/s i.f. transformer in its

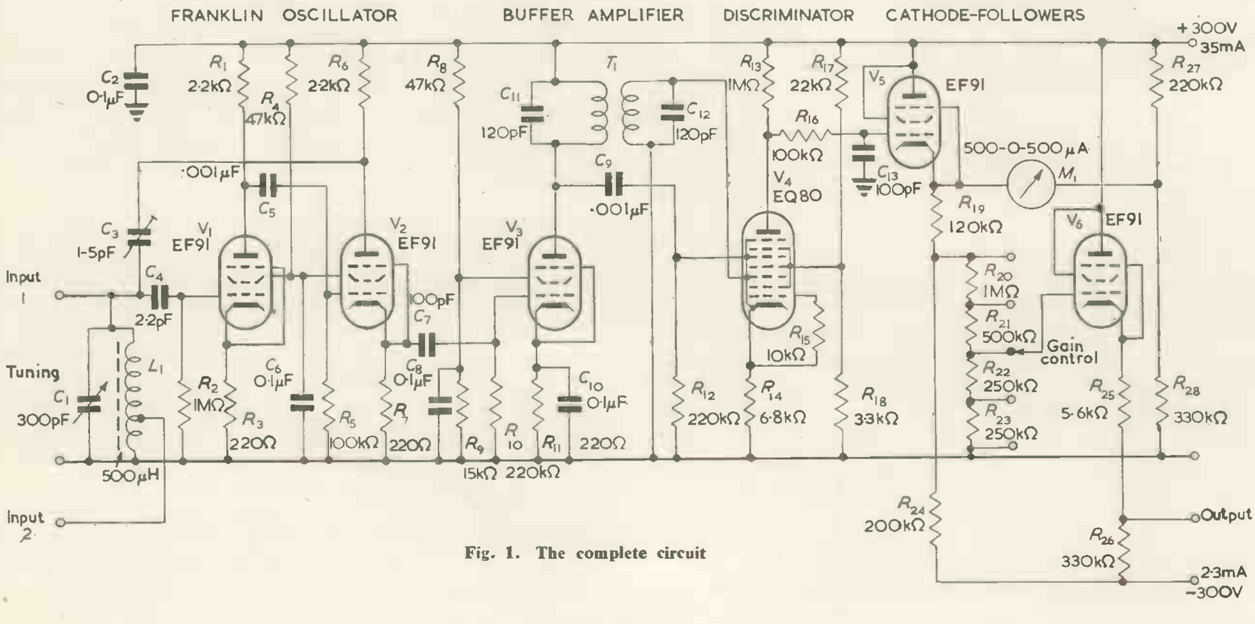

Fig. 1. The complete circuit

anode circuit. The frequency discriminator consists of this transformer and the Mullard EQ80 nonode valve V_4. The nonode was specially developed for use in f.m. demodulator circuits and gives an output at its anode which is a linear function of the phase difference between signals appearing at grid 3 and grid 5. The primary of the i.f. transformer feeds grid 5 and the secondary feeds grid 3. When the frequency of the Franklin oscillator is exactly 465kc/s the transformer is on tune and the two signals are 90° out of phase giving a mean anode current of approximately one-half saturation. Frequency deviations on either side of resonance give anode currents greater or less than this value. A similar type of response can be obtained with an ordinary pentode valve by feeding one signal to the control grid and the other to the suppressor. The advantage of the nonode is that interaction between the driving signals is reduced by the intermediate grids, and that correct action is obtained without precise pre-limiting of the two input signals. In this second respect the nonode is very good indeed and for phase-angles in the range 30 to 150° the response is essentially the same for all signal amplitudes in excess of 8V r.m.s. A full description of the working of the nonode has been given by Jonker and Overbeek[34].

The voltage across the 1MΩ anode load R_{13} is fed to the grid of the cathode-follower V_5 which drives the centre-zero meter M_1. The filter $R_{16}C_{13}$ removes residual radio-frequency components appearing at the anode of V_4. At the tune frequency of 465kc/s the cathode of V_5 is at 180V and the meter is at centre zero; the values of R_{27} and R_{28} are chosen so that full deflexion on either side of zero corresponds to 180 ± 65V at V_5 cathode. This range of ±65V represents the central linear region in the response at the nonode anode.

The useful operating range at V_5 cathode is at a mean potential of +180V and the potential divider $R_{19}R_{24}$ brings this down to zero potential, thus enabling gain control to be obtained by R_{20-23} without changing the mean d.c. level. The gain-control switch feeds the grid of the cathode-follower V_6. At tune V_6 grid is at earth potential and the final output is also at earth. The potential divider $R_{19}R_{24}$ reduces the useful output range from ±65V at V_5 cathode to ±40V at the output.

The overall response at full gain is shown in Fig. 2. The linear region is from P to Q and the sensitivity is 10V/pF of capacitance change. (N.B. If a commercial i.f. transformer is used it may be necessary to reduce the primary to secondary coupling in order to optain optimum linearity.) The inductance L_1 is 500μH and this tunes to 465kc/s with 235pF. A capacitance change of ±1pF yields a frequency change of very nearly ∓1kc/s so that the frequency variation for full-scale is from −4 to +4kc/s. When the total range of capacitance variation given by the transducer is likely to exceed 8pF the transducer is connected to input 2 (Fig. 1). This second input is tapped half way down the coil L_1 so that the effective value of the capacitance variation is reduced by a factor of four. The linear range of the instrument now becomes −16 to +16pF.

The h.t. supply is stabilized, and therefore drift in the output level due to variations in the h.t. voltage may be neglected. However, the heater voltage is unregulated and a change of ±10 per cent in the mains alters the output by ±0·06pF. The main source of drift is at the EQ80: the effect of mains voltage changes can be reduced by about 10 times by running the EQ80 heater from a saturable transformer. This leaves a residual variation of about 0·005pF for a 10 per cent mains change. The drift measurements were made directly in terms of input capacitance-change by using a micrometer coaxial capacitor in parallel with the input and a null-reading galvanometer on the output.

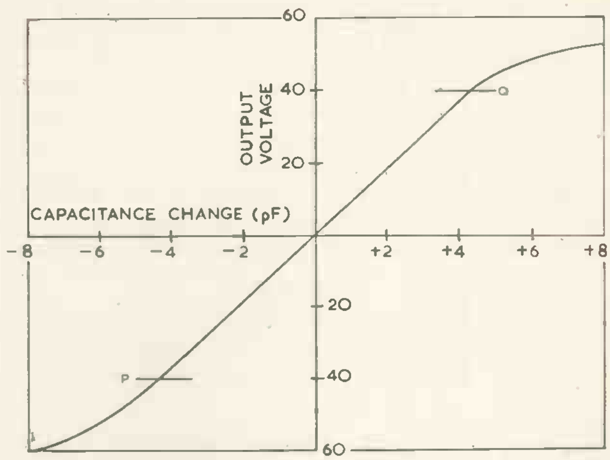

Fig. 2. Lineary of capacitance-change circuit

Frequency Response

The frequency response of a capacitance detector circuit can be measured by modulating the capacitance at the input by electrical or mechanical means. Electrical modulation by a reactance valve is liable to introduce calibration difficulties and a direct mechanical method is preferable. A mechanical method using a single-pole rotating capacitor gives unreasonably high rotational speeds, for instance a modulation at 1kc/s demands a speed of 60 000 rev/min. The difficulty is overcome by using an air-driven gyroscope (from an aircraft bombsight) as a capacitance modulator. The gyroscope rotor has 24 driving slots in its periphery and these are used in conjunction with a capacitance pick-up probe fitted in the housing. A frequency of 1kc/s is now obtained for a rotational speed of only 2 500 rev/min. The stresses in the rotor are proportional to the square of the speed and if high speeds are attempted adequate protection from the consequences of a burst rotor is essential. The overall frequency response of the capacitance detector circuit is from zero up to 2·4kc/s (for 3dB down). With pressure recording this frequency range is normally sufficient to ensure that the overall response is wholly determined by the characteristics of the transducer.

Applications

The circuit has been used for the measurement of pressure, rotational speed and frequency of vibration. The pressure measurements were made with a commercial transducer having a nominal range of 20pF. It was found that hysteresis effects in the transducer are much reduced by choosing a relatively insensitive transducer so that the pressure excursion represented only about a quarter of the nominal capacitance range. The design of diaphragm-type pressure transducers is fully covered in the literature[26-33]. It is perhaps helpful to point out that large lineal displacements, such as the movement of a piston or valve mechanism, can easily be converted to capacitance changes by means of a coaxial capacitor with a moving inner electrode. The end of the moving electrode is always well within the "live" tube so that the end-effects are constant and the transducer calibration is accurately linear. It can be shown that this type of transducer is very insensitive to eccentricity[19] and hence close tolerances are not required in the construction. When measuring rotational speed, or vibrational frequency, only a simple capacitance pick-up is necessary and, assuming the electronic circuit is already available, these measurements can be made much more conveniently than is possible with photo-electric devices.

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Progress with the Transatlantic Telephone Cable

THE loading of Her Majesty's Telegraph Ship, "Monarch" with the first of the Newfoundland shore ends of the Transatlantic Telephone Cable was recently begun at Newington, New Hampshire, U.S.A. The plan of the whole project which is a joint undertaking of the American Telephone and Telegraph Company, the Canadian Overseas Telecommunications Corporation, the Eastern Telephone and Telegraph Company and the G.P.O., calls for the laying this year of the first of the two cables, each about 2 000 nautical miles long, which are to span the Atlantic between Scotland and Newfoundland. "Monarch" has started that operation with loading the 350 nautical miles of cable made by the Simplex Wire and Cable Company.

Early in July she will lay 217 nautical miles of this cable out to sea from Clarenville, Newfoundland, and buoy the seaward end, before returning to the United Kingdom for the next phase of the operation. To control these laying operations and to ensure that the cable is laid accurately on its predetermined course radio stations, including a chain of Decca navigational stations, have been specially built in Newfoundland.

On both sides of the Atlantic the manufacture and construction of the cable is proceeding according to the plan designed to bring the cable into service towards the end of 1956.

Meanwhile at the new plant of Submarine Cables Ltd the rest of the submarine cable required for the project (over 4 000 nautical miles) is being turned out at over 65 nautical miles a week. In mid-July, "Monarch" will start loading 1 130 nautical miles of the cable. This together with 133 nautical miles of the cable made by Simplex will span the deep ocean; after being joined to the buoyed end off Newfoundland it will be laid in one piece to Rockall Bank, about 500 nautical miles off the coast of Scotland. There it will be buoyed and, in September, "Monarch" will lay the cable which will join it to Oban and complete this year's cable laying operations.

The American repeaters (they are 80ft long overall including the cable stubs) which will be joined into this cable at 37 nautical mile intervals before it is loaded on "Monarch," are arriving by air from the U.S.A. in specially designed containers. They are being made by the Western Electric Company at Hillside, New Jersey. X-ray photography will be used to examine the joints, when the repeaters are spliced into the cable, to make sure that no defects exist.

Meanwhile on both sides of the Atlantic the land based installations of the cable system, are well under way; and the links required to connect the end of the Cable system to London, Montreal and New York are being built.

The accommodation for the shore end installations at Oban has been completed. The American cable terminal equipment has arrived and installation is in progress. A similar stage has been reached with the installation at Clarenville, Newfoundland.

Special high quality channels are being provided to extend the cable circuits from Oban to London and as part of this work a new coaxial cable is being provided from Oban to Glasgow. The duct work and the repeater stations, have been completed and the laying of the cable has started.

In London, the International Exchange is being extended and the special switching equipment required to facilitate connexion with inland and continental subscribers is being manufactured.

The section of the cable from Clarenville, Newfoundland, to Nova Scotia (about 360 miles) is of British design, employing a single cable with two-way repeaters. The first part—about 45 miles—which will be laid across Newfoundland, has been delivered there by the manufacturers, Southern United Cables Ltd. The Canadian Comstock Company has started trenching in the cable between Clarenville and Terrenceville in a very difficult rocky terrain interspersed with bogs and lakes. A party of specially trained Post Office engineers are travelling with the construction camp to supervise the laying of the cable, to make the joints, and to insert the repeaters.

The two repeaters to be inserted in the land cable across Newfoundland and the two spares, which are being made by Standard Telephones and Cables, are well advanced. They are due to be shipped in November. The fourteen repeaters for the sea section across the Cabot Strait to Nova Scotia, together with spares are due to be shipped in March, 1956. These are the U.K., twoway type of repeaters.

Phase Measurement in Feedback Amplifiers

By J. F. Young*

The hunting frequency of a feedback amplifier can be changed by inserting in the loop an adjustable phase shift network. Values of gain and phase shift of the original loop at various hunting frequencies can then be calculated rapidly and accurately from the known parameters of the added network.

THE accurate measurement of the loop gain of a feedback amplifier is comparatively easy, but it is difficult to determine loop phase shift if any degree of accuracy or rapidity is required. Ellipse methods of measurement using a cathode-ray tube are inaccurate and inconvenient because of the need to take measurements from the face of the tube. The presence of waveform distortion introduces additional inaccuracies[1]. The difficulty of taking measurements from the face of the tube can be overcome by the addition of an external adjustable phase shift network in one input to the oscilloscope to reduce the ellipse to a straight line[2]. However even with careful observation, the null inaccuracy due to the width of the trace is still rather large, and waveform distortion will make it impossible to obtain a straight line.

For these reasons, if the loop phase shift characteristic is required, it is fairly common practice to calculate it from the gain characteristic, but this takes some time, even with special methods of computation[3]. The experimental method of determination of gain and phase characteristics to be described, can give high accuracy and rapid results.

If a gain control is added to a negative feedback system, and the loop gain is increased from zero until hunting just commences, the loop gain is then unity and the loop phase shift is 180° at the hunting frequency. The addition of an extra phase shift network at some convenient point in the loop, will in general change the frequency of hunt. If the gain control is then readjusted until the system is again only just hunting, the total loop gain will once more be unity and the total loop phase shift will be 180° at the new hunting frequency. The phase shift of the added network can be calculated from the hunting frequency and the component values. The phase shift of the original loop at the new hunting frequency can then be obtained by the subtraction of the phase shift of the added circuit from 180°. In this manner and by variation of the added circuit a phase-frequency characteristic can be obtained for the original loop. At the same time, a gain-frequency characteristic can be obtained, provided the gain control is calibrated, since the original gain setting gave unity gain and any change of setting required to obtain the hunting threshold merely compensates for the attenuation of the added network and for the changed gain of the original loop at the new hunting frequency. A network having either gain or attenuation and either phase advance or phase retardation, can be inserted in the loop, so the method would seem to have wide application for rapid plotting of Nyquist or gain and phase-log frequency diagrams, provided hunting is permissible for testing purposes.

* *Lancashire Dynamo Electronic Products Ltd.*

In practice, simple *RC* circuits can be used to provide the required phase shift. Care must be taken that the additional circuits put no appreciable load on existing circuits, and do not allow stray pick up voltages to be fed into the loop, but since it is permissible to insert the test circuit at any part of the loop, it is usually possible to fulfil these conditions.

Various practical procedures are possible, the one illustrated in Fig. 1 has been found useful where such tests are not required often enough to justify the expense of the construction of a special unit. Fixed capacitors and decade resistors are added to the loop and an audio oscillator and double beam oscilloscope are used for frequency measurement. The voltage at some convenient point in the loop is applied to one set of Y plates on the oscilloscope. The time base is synchronized to this voltage and the audio oscillator output is applied to the other set of Y plates.

The loop gain control is increased carefully until it can be seen on the oscilloscope that the system is just hunting. The audio oscillator frequency is then varied until its trace on the oscilloscope becomes steady. The relationship between the hunting frequency and the audio oscillator frequency can then be seen. By this means it is possible to take readings at an extremely rapid rate. Any other accurate method of frequency measurement can be used. The one described utilizes standard equipment and has the

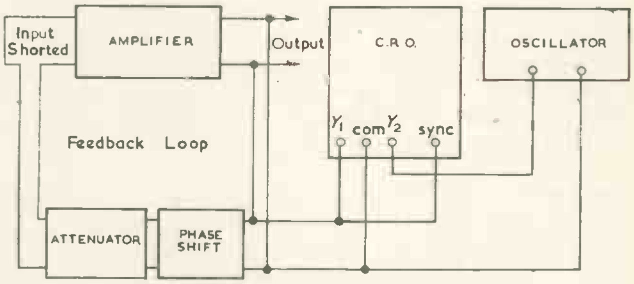

Fig. 1. Arrangement of apparatus

advantage that the audio oscillator need only cover a small range (say one-tenth of the range over which measurements are required). Since there will normally be gain to spare in the system being tested, it should only be necessary to add a simple attenuator to adjust the gain to the threshold of hunting. An abac[4] can be used to simplify the computation of attenuation and phase shift of the added circuit from the experimental data.

The technique described provides means of rapidly obtaining Nyquist or gain and phase-log frequency diagrams with a good accuracy which is independent of oscilloscope trace width, measurements on the tube face or waveform distortion. The limitations are that it must be possible to allow the system to hunt for test purposes and that the accuracy is dependent on accurate frequency measurement, on the precision of the added components, on the correct adjustment of the gain control and on low loading of existing circuits by the added circuits.

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Isocline Diagrams for Transistor Circuits

By Francis Oakes*, M.Inst.E., A.M.Brit.I.R.E.

The method described for the graphical analysis of transistor negative resistance oscillators is based on non-linear mechanics, and does not necessitate approximation of curved transistor characteristics by straight lines. Voltage and current trajectories can be obtained by a simple construction which also indicates the rate of change of the voltages and currents during the course of cyclic or transient phenomena.

MANY transistor oscillator, switching and counting circuits are based on the negative resistance properties exhibited by point contact transistors. These properties can be represented by a voltage-current characteristic at the pair of terminals across which the load or the control circuit is connected. This voltage-current characteristic of the transistor in combination with the parameters of the external circuit determines the behaviour of the system. The transistor characteristic is, of course, dependent on the bias conditions of the transistor and deviates considerably from a straight line or even a group of straight lines. It is therefore desirable to provide design methods which do not rely on assumption of linearity and yet are sufficiently straightforward to be useful in practical application. A basis for non-linear analysis has been provided by A. Lienard[1], and subsequently described by le Corbeiller[2] and W. A. Edson[3].

Following their approach to the general problem of non-linear systems, a practical means of solving transistor circuit problems of this type has been developed and is described in the following paragraphs.

Isoclines

If a non-linear circuit element which exhibits negative resistance characteristics is connected to an external linear circuit containing resistive, capacitive and inductive elements, it can supply energy to produce or sustain steady or transient currents and voltages in the external circuit. These currents and voltages depend both on the circuit constants and on conditions at a given instant of time. Considering the circuit shown in Fig. 1, which is chosen as a basis for this analysis, this means that the voltage and currents in the system subsequent to a given time depend upon the values of R, C, L, on the voltage-current characteristics exhibited by the transistor across the terminals A and B and on the instantaneous currents and voltages in the system at t_0. Since the system contains reactive elements, the currents and voltages will be functions of time. Voltage-current plots can be drawn for the capacitance or the inductance and will then also allow the voltage-current relationships for the other elements to be obtained. In this case, the voltage-current relationship of the capacitance is studied first. Thus, for any point representing a voltage and current pair on the voltage-current plot at the time t_0, there will be neighbouring points representing the voltage and current pairs at the time $t_0 + dt$ or $t_0 - dt$. The movement from the original to the neighbouring point will determine a direction of movement, in other words it will indicate the slope of the tangent to the curve describing the conditions of the capacitance before, at and after t_0 in terms of voltage-and-current pairs.

If curve-elements for $t_0 \pm \Delta t$ are drawn for every point of the voltage-current plane, these elements will join into lines of motion which describe the dynamics of the system. These lines of motion are called isoclines.

It is possible to construct an isocline diagram for one of the elements in the system by means of a simple graphical method. The remainder of the system can then be studied with the aid of the diagram.

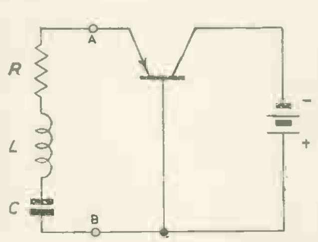


Fig. 1. Typical transistor circuit

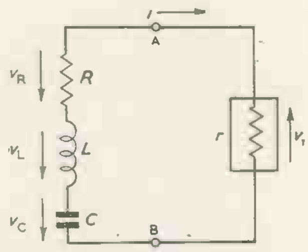


Fig. 2. Equivalent circuit

Construction of Isocline Diagrams

For the derivation of a graphical method of construction of isocline diagrams, the circuit of Fig. 1 is represented in Fig. 2 by its equivalent circuit. R, C and L are the resistance, capacitance and inductance, respectively of the circuit of Fig. 1, while r is the voltage to current ratio of the transistor network seen through its input terminals AB.

The parameter r is resistive but non-linear and can be defined by the equation:

$$r = f(i) \quad \ldots\ldots\ldots\ldots (1)$$

so that:

$$v_r = ri \quad \ldots\ldots\ldots\ldots (2)$$

The input characteristic between the terminals AB of the transistor circuit illustrated in Fig. 1 is of this form, and a typical transistor characteristic is shown in Fig. 3.

Kirchoff's equation can now be written down for the circuit:

$$v_R + v_L + v_C + v_r = 0 \quad \ldots\ldots\ldots\ldots (3)$$

Taking into account that:

$$v_L = L(di/dt) \quad \ldots\ldots\ldots\ldots (4)$$

and:

$$i = C(dv_c/dt) \quad \ldots\ldots\ldots\ldots (5)$$

one obtains a means of expressing dv_c/di as a function of v_c and i, thus eliminating the time derivatives by dividing equation (4) by equation (5).

$$v_L/i = (L/C)\ (di/dv_c) \quad \ldots\ldots\ldots\ldots (6)$$

and eliminating v_L by means of equation (3):

$$\frac{-v_r - v_R - v_C}{i} = (L/C)\ (di/dv_c) \quad \ldots\ldots (7)$$

* *Ferguson Radio Corporation Ltd.*

This transforms into:

$$dv_{C}'/di = \frac{-i\,L/C}{v_{C}' - v_t} \qquad (8)$$

where:

$$v_t = v_r + v_R \text{ and } v_C' = -v_C \qquad (8a)$$

A graph of v_t as function of the current can be obtained simply by adding the transistor voltage-current characteristic v_r to the straight line characteristic of the resistance R, namely $v_R = iR$. Such a combined voltage-current plot is used for the graphical method.

This graphical method relies on approximation by circular arcs. It is therefore necessary to re-arrange the equations so that a graph can be plotted with equal scales in both directions. Dividing both sides of the equation (8) by a scale factor $\sqrt{(L/C)}$ one obtains:

$$\frac{dv_C'}{d(i\sqrt{(L/C)})} = -\frac{i\sqrt{(L/C)}}{v_C' - v_t} \qquad (9)$$

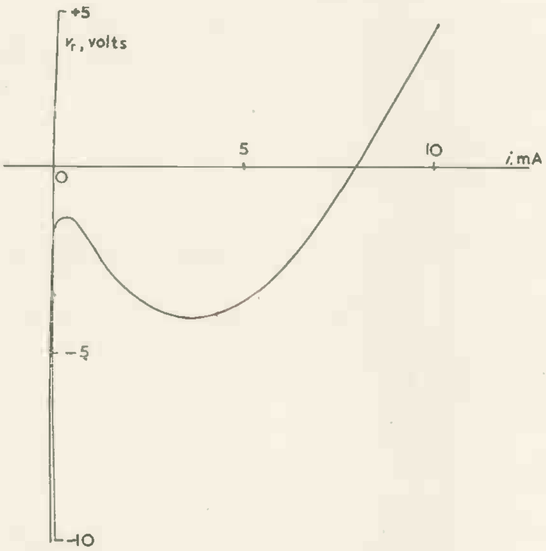


Fig. 3. Typical transistor input characteristic

and since L/C has the dimensions of resistance, one can define a fictitious voltage:

$$u = i\sqrt{(L/C)} \qquad (10)$$

Introducing this into equation (9) one obtains:

$$dv_C'/du = -\frac{u}{v_C' - v_t} \qquad (11)$$

This equation correlates the differential quotient with u, v_c' and v_t, all of which have the dimension of voltage, and therefore can be plotted on the same scale in both coordinate directions.

Fig. 4 shows a graphical method of solving this equation, i.e. for obtaining the slope dv_C'/du of the isocline for any point $P(u, v_C)$ which is defined by a pair of instantaneous values of voltage across and current through the capacitance.

A vertical line is drawn through P to intersect with the curve $v_t = f_1(u)$ in a point V. A horizontal line is then drawn through point V to intersect in a point Q on the v-axis. If a line PT is then drawn through P, perpendicular to QP, this will be a tangent to the isocline through P. A proof of this follows from simple geometry.

Since PT is perpendicular to PQ, the triangles TSP and QVP are similar, and the following proportion holds:

$$SP : ST = VQ : VP$$

i.e.:

$$dv_C' : du = (u) : (v_C' - v_t) \qquad (12)$$

which agrees with equation (11).

The radius for the circle of best approximations at a point on a curve, $y = f(x)$, is given by the formula:

$$a = \frac{[1 + (dy/dx)^2]^{3/2}}{d^2y/dx^2} \qquad (13)$$

For the isocline, this becomes:

$$a = \frac{[1 + (dy/dx)^2]^{3/2}}{d^2v_C'/du^2} = \frac{[(du^2 + dv_C'^2)/(du^2)]^{3/2}}{d^2v_C'/du^2}$$

$$= \frac{(dw^2/du^2)^{3/2}}{d^2v_C'/du^2} \qquad (14)$$

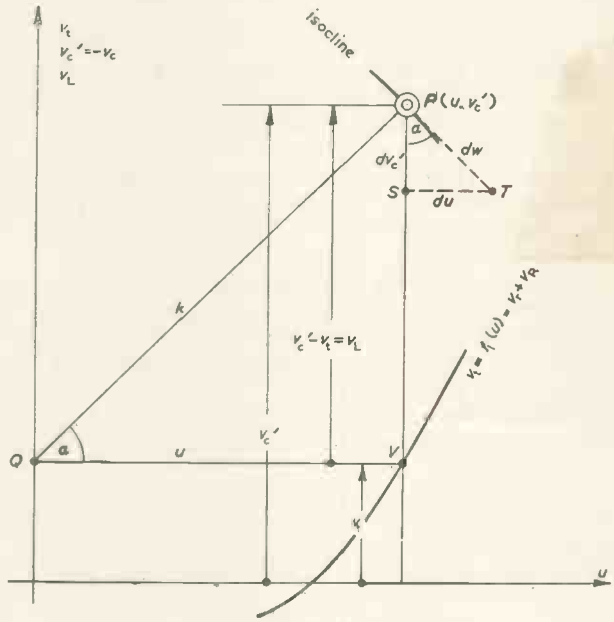


Fig. 4. Derivation of construction

$$\therefore a = \frac{dw^3/du^3}{d^2v_C'/du^2} \qquad (14a)$$

from the geometry of Fig. 4:

$$dw/du = \frac{k}{v_C' - v_t} \qquad (15)$$

thus:

$$a = \frac{k^3/(v_C' - v_t)^3}{d^2v_C'/du^2} \qquad (16)$$

and also from the geometry of Fig. (4):

$$d/du\,(dv_C'/du) = d/du\left(\frac{-u}{v_C' - v_t}\right)$$

from equation (11), therefore:

$$d^2v_C'/du^2 = -\frac{(v_C' - v_t) - u\,d/du\,(v_C' - v_t)}{(v_C' - v_t)^2} \qquad (17)$$

Substituting this into equation (16):

$$a = \frac{-k^3/(v_C - v_t)}{(v_C - v_t) - u\,d/du\,(v_C' - v_t)}$$

$$a = \frac{-k^3}{(v_C' - v_t)^2 - u\,(v_C' - v_t)\,d/du\,(v_C' - v_t)} \qquad (18)$$

Since a function multiplied by its first derivative is equal to the sub-normal, it can be seen from Fig. 4 that:

$$(v_C' - v_t)\, d/du\, (v_C' - v_t) = -u \quad (19)$$

The negative sign in equation (19) is important and follows from the fact that here, $(v_C' - v_t)$ is positive and the slope $d/du\ (v_C - v')$ is negative. Thus:

$$a = \frac{-k^3}{(v_C - v_t) + u^2} \quad (20)$$

and from geometry:

$$(v_C' - v_t)^2 + u^2 = k^2 \quad (21)$$

Introducing this into equation (20):

$$a = -k \quad (22)$$

This means that a short arc of a circle with centre Q through point P will be a good approximation to a short section of isocline through P. It is important to note that this approximation can be made as close as desired simply by restricting the length of the arc used. The negative sign indicates that the curvature (which is the reciprocal of a) is negative, i.e. that with increasing u, there is a decrease in isocline slope.

It is important to observe that the voltage $(v_C' - v_t)$ which appears in Fig. 4 is the value of the voltage across the inductance. This follows directly from equations (8a) and (3).

If the transistor circuit is connected to the load circuit, or under the influence of external disturbances, such as switching voltages, counting pulses, etc., the system will be moved to a point P. From there, the voltage-current trajectory for the capacitor terminals will trace out a path along the isocline. The trajectory will eventually come to rest in a point or it will reach a limiting oscillation round a closed path.

In tracing out the isocline paths it is useful to establish the lines along which the isoclines intersect parallel to the u and v axes. Equation (11) provides a criterion for this.

For intersection parallel to the u (horizontal) axis:

$$dv_C'/du = \frac{u}{v_C' - v_t} = 0 \quad (23)$$

$$\therefore u = 0 \quad (24)$$

This means that the isoclines intersect the v-axis horizontally, i.e. dv_C'/di, the incremental impedance of the capacitance is zero when the current goes through zero.

For intersections parallel to the vertical axis:

$$dv_C'/du = \frac{u}{v_C' - v_t} = \infty \quad (25)$$

$$\therefore v_t = v_C' \quad (26)$$

This means that the isoclines intersect the combined resistance plus transistor curve vertically; in other words, the incremental impedance of the capacitance becomes infinite when the voltage across the capacitor is equal to the negative of the combination $v_t = v_r + v_R$, i.e. when the voltage across the inductance is zero.

A practical example is given below to illustrate this method. Fig. 3 shows a transistor input characteristic exhibiting a negative resistance region. The remainder of the circuit contains an inductance, a capacitance and a resistance of the following values:

$$L = 2\,500\mu\text{H}$$
$$C = 0{\cdot}01\mu\text{F}$$
$$R = 200\Omega$$
$$\sqrt{L/C} = 500\Omega$$

As it stands, Fig. 3 would only be useful for a $\sqrt{(L/C)}$ value of 1 000Ω. This means that the graph has to be re-scaled making 1mA in the i direction equivalent to 0·5V in the v direction.

The re-drawn diagram is shown in Fig. 5. A suitable portion of this plot is enlarged and re-drawn in dotted lines in Fig. 6. The line for the resistance R can be drawn quite easily because the u axis has been calibrated both in volts and their mA equivalents. The combined total resistance characteristic v_t is obtained by adding the two curves. It is shown in heavy black line in Fig. 6.

An arbitrary point P is now chosen as a starting point. The isocline through this point is approximated by the circular arc through P with its centre in Q. Q is found by

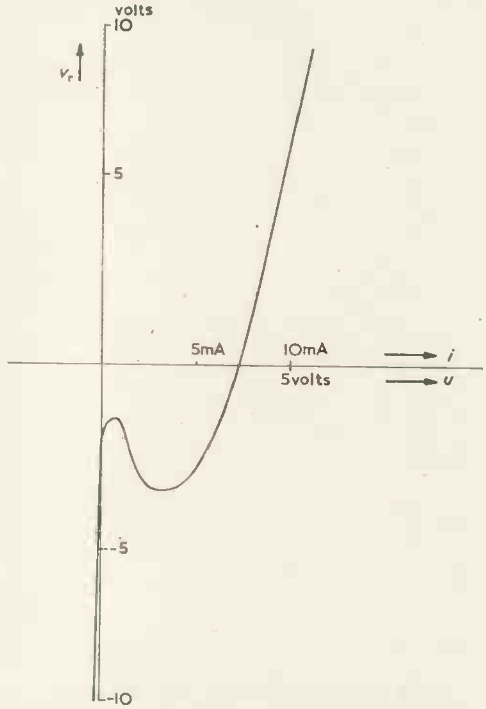


Fig. 5. Re-scaled transistor input characteristic for $\sqrt{L/C} = 500\Omega$

drawing an ordinate through P and a horizontal line through the intersection V with the v_t curve. The horizontal line then intersects the v axis in point Q. If the diagrams are plotted on graph paper, a large number of short isocline-arcs can be drawn quickly without the need of drawing auxiliary lines PV and VQ.

It is often useful to cover the voltage-current plane area under consideration with a large number of isocline arcs. This can be done very rapidly in the following manner.

(1) Draw a vertical line across the whole length of the graph area.

(2) Find point Q on the voltage axis by going across horizontally from the intersection point of the curve and the vertical line.

(3) With the compasses centred in point Q, strike a series of short arcs across the vertical line.

(4) Repeat the process for other vertical lines.

This is illustrated in Fig. 6.

A trajectory can then be drawn for any chosen starting point.

Using this method and joining isocline arcs into trajectories, a whole family of curves has been drawn in Fig. 7

for the circuit of Fig. 1. As can be seen from the illustration, there is one stable point into which all trajectories converge. At this point, the voltage $v_C' = -2V$, therefore the voltage across the capacitor is $+2V$ and there is no current flowing through the circuit. The direction of travel along the isocline can be established from the fact that i is the current charging the capacitor. Therefore, the voltage $-v_C' = v_C$ must decrease with time so long as i is positive. Therefore v_C' must decrease with positive i and u.

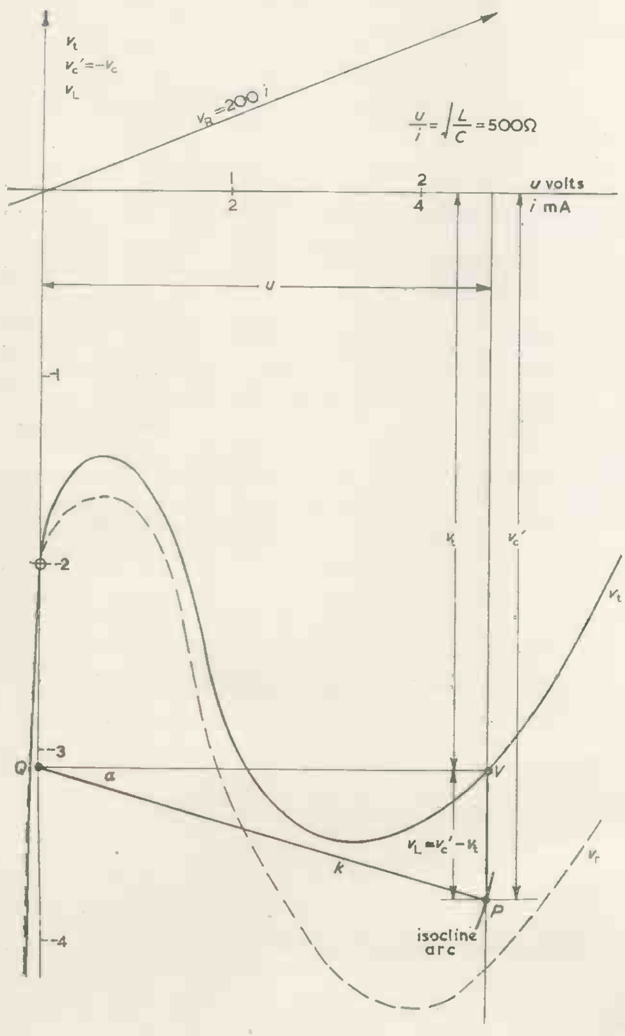
Fig. 8 shows a circuit including the same transistor and external circuit, but including emitter bias to shift the operating point into the negative resistance region. The isocline diagram for this circuit is shown in Fig. 9.

It is apparent from this isocline diagram that all trajectories eventually merge into the cyclic path *X-Y-Z*. In other words, the circuit of Fig. 8 is an oscillator circuit. For such a circuit there are the following classes of trajectories.

(1) *The origin.* This is a point of unstable equilibrium. The circuit noise alone would suffice to produce a disturbance so that the operating point moves outwards.

(2) *An outward moving trajectory.* Such a trajectory follows a path such as the isocline *O.S.P.X-Y-Z-X-Y*, etc.

Fig. 6. Construction of isoclines



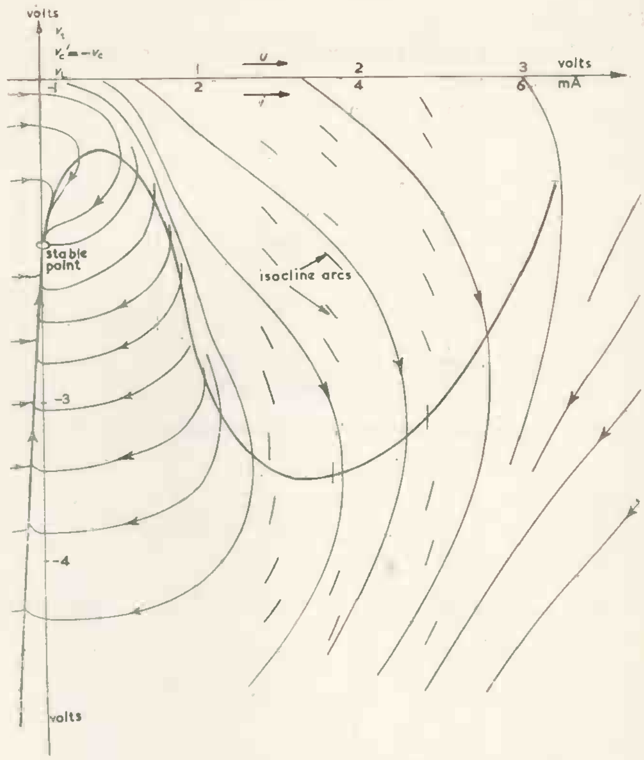


Fig. 7. Isocline diagram of transistor circuit biased to staple point

(3) *An inward moving trajectory.* Such a trajectory follows a path such as the isocline *W-X-Y-Z-X* etc.

(4) *The cyclic path X-Y-Z.*

Following round the oscillatory path it is interesting to observe that in the regions *Y-Z* and *Z-X* the voltage changes across the inductor are of the same order of magnitude as those across the capacitor. The path resembles part of a circle and the movement corresponds to under-damped conditions.

In the region from *X* to *Y*, however, most of the voltage change and voltage drop occur across the capacitance, the voltage drop across the inductance being negligible by comparison. The movement in this region corresponds to overdamped conditions and the path resembles a straight line.

This means that the circuit of Fig. 8 operates partly as a sinusoidal and partly as a relaxation oscillator, over the paths *Y-Z-X* and *X-Y* respectively. Because along the path *X-Y* little voltage is dropped across the inductance, the current change must take place at a comparatively slow rate, i.e. the capacitor charges up at a nearly constant current rate (via the high reverse resistance of the emitter). As soon as the characteristic bends below the slope of 2, corresponding to critical damping, i.e. the incremental damping resistance being equal to $2\sqrt{(L/C)}$, an appreciable voltage drop begins to develop across the inductance (just past point *Y*), i.e. the current changes more rapidly. Since:

$$di/dt = +v_L/L \quad \ldots\ldots\ldots\ldots \quad (27)$$

the horizontal component of the velocity along the trajectory is proportional to v_L, the voltage drop across the inductance. Similarly, since:

$$dv_C/dt = -dv_C'/dt = i/C \quad \ldots\ldots\ldots \quad (28)$$

the vertical component of this velocity is proportional to the current i.

As the graph involves a scale factor, these equations are re-written below.

$$(di/dt)\ \sqrt{(L/C)} = (v_L/L)\ \sqrt{(L/C)}$$
$$du/dt = v_L/\sqrt{(LC)} \quad \ldots \ldots \ldots \ldots (29)$$

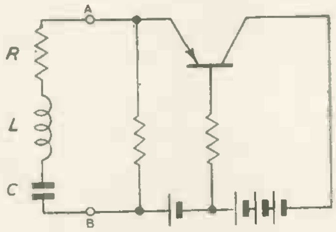


Fig. 8. Transistor circuit with positive emitter bias

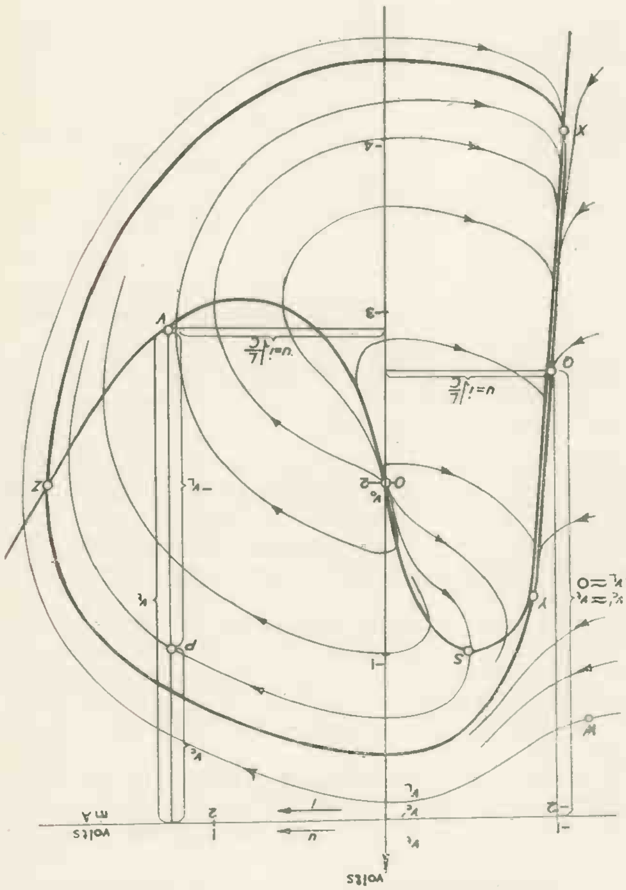


Fig. 9. Isocline diagram of transistor circuit biased for oscillation

and:

$$(dv_C'/dt)\ \sqrt{(L/C)} = -(1/C)\ i\ \sqrt{(L/C)} = -(1/C)\ u$$
$$dv_C'/dt = -(1/C)\ u\ \sqrt{(C/L)}$$
$$dv_C'/dt = -\ u/\sqrt{(LC)} \quad \ldots \ldots \ldots \ldots (30)$$

The velocity is therefore equal to:

$$K = \sqrt{[(dv_C'/dt)^2 + (du/dt)^2]}$$
$$= \sqrt{\left(\frac{u^2 + v_L^2}{LC}\right)}$$
$$K = \frac{1}{\sqrt{(LC)}}\sqrt{(u^2 + v_L^2)} \quad \ldots \ldots \ldots \ldots (31)$$

But it can be seen from Fig. 4 that:

$$\sqrt{(u^2 + v_L^2)} = k \quad \ldots \ldots \ldots \ldots (32)$$

thus, defining $\omega_o = 1/\sqrt{(LC)}$, we obtain:

$$K = \omega_o k \quad \ldots \ldots \ldots \ldots (33)$$

The velocity along the trajectory can therefore be calculated quite easily from the above formula. Since $\omega_o = 1/\sqrt{(LC)}$ is constant, the velocity along the trajectory is proportional to the radius of the arc used in the construction of the isocline.

Following the outward moving trajectory, one thus finds that starting in the direction towards S, v_L is initially small, the speed is small, the charge of the capacitor being determined by the voltage and the high negative slope resistance in this vicinity. As the slope of the v_r curve decreases, the incremental resistance decreases, damping is reduced, and an appreciable voltage v_L builds up across the inductance. As the incremental resistance is reduced, the voltage changes across L and C become equal and opposite as v_L goes through zero, i.e., as the two curves cross point S. By that time k has become considerably larger and remains fairly constant while the trajectory traces a nearly semi-circular path from S to X. This region is characterized by the fact that OP remains approximately constant and it can be seen that:

$$[OP]^2 \simeq u^2 + (v_C' - v_o)^2 \quad \ldots \ldots \ldots \ldots (34)$$

Thus:

$$u \simeq OP\ \cos \omega_o t \quad \ldots \ldots \ldots \ldots (35$$
$$\therefore i \simeq OP\ \sqrt{(C/L)}\ \cos \omega_o t \quad \ldots \ldots \ldots \ldots (36)$$

and:

$$(v_C' - v_o) \simeq OP \sin \omega_o t \quad \ldots \ldots \ldots \ldots (37)$$

indicating approximately harmonic motion. (The accurate behaviour of the system is, of course, given by the graph and can be evaluated with any desired accuracy within the limits of plotting error).

In the vicinity of point X, a drastic change is brought about by the bend towards the steep portion of the v_t curve, and as soon as the trajectory crosses the v_t curve, the voltage v_C across the capacitance rises at a nearly constant rate up the line X-Y (charging at a nearly constant current through the high and practically constant incremental resistance portion X-Y). Here, there is practically constant k again, but while previously the movement was harmonic, it now follows a straight line path. Thus:

$$u \simeq \text{const.} \quad \ldots \ldots \ldots \ldots (38)$$
$$\therefore i \simeq \text{const.} \quad \ldots \ldots \ldots \ldots (39)$$
$$-\ dv_C'/dt \simeq k\omega_o \quad \ldots \ldots \ldots \ldots (40)$$

but since v_L is small, ku and therefore:

$$k\omega_o \simeq u\sqrt{(1/LC)} \simeq i\sqrt{(L/C)}\ \sqrt{(1/LC)} = i/C \ \ldots (41)$$
$$\therefore dv_C'/dt \simeq i/C \quad \ldots \ldots \ldots \ldots (42)$$
$$-v_C' = (1/C)\int i dt = it/C \quad \ldots \ldots \ldots \ldots (43)$$

since:

$$-v_C' = v_C$$
$$v_C \simeq it/C \ \ldots\ i \text{ const.} \quad \ldots \ldots \ldots \ldots (44)$$

An alternative approach is to express v_C in terms of the graph, i.e.:

$$v_C' \simeq v_x + k_o t_x \quad \ldots \ldots \ldots \ldots (45)$$

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where v_x = voltage at point X.

t_x = time after passing through point X_o.

$$v_O' \simeq v_x + i\sqrt{(L/C)}/\sqrt{(LC)}\, t_x$$

$$-v_O = v_O' \simeq v_x + it_x/C \quad \ldots\ldots\ldots\ldots \quad (46)$$

since v_Y and v_X (the voltages at Y and X) and the current i can be read off the graph, the time of movement from X to Y is:

$$t_{XY} = \frac{v_Y - v_X}{i}\, C \quad \ldots\ldots\ldots\ldots \quad (47)$$

i.e. $t_{XY} = R_{XY}C$

where $R_{XY} = \dfrac{v_Y - v_X}{i}$

R_{XY} being the effective "back resistance" over the region X-Y.

After passing point Y, the trajectory continues round the cyclic path YZX.

For example, $\omega_o = 0{\cdot}2$ radians/μsec,
i.e., a frequency $f_{LC} = 30$kc/s,
thus, $t_{LC} = 1/f_{LC} = 33\mu$sec.

The portion Y-X being about three-quarters of the circle, the duration for this path is approximately 25μsec.

The approximate time taken for the path from X to Y can be calculated from equation (47).

$$t_{XY} = \frac{2{\cdot}8}{2 \times 10^{-3}} \times 0{\cdot}01 \times 10^{-6}$$

$$= 1{\cdot}4 \times 10^{-5}$$

$$t_{XY} = 14\mu\text{sec.}$$

The total cycle takes approximately 39μsec round the path XYZ, i.e. longer than the period of resonant oscillation.

Conclusion

This method is useful for the study of negative resistance circuits of the short-circuit stable as well as the open-circuit stable variety. Although only the open-circuit stable circuit has been described in this article, it can be seen quite readily that the short-circuit stable case can be treated in a similar way, by exchanging voltage for current, inductance for capacitance, parallel for series connexion, etc., in other words, by applying the principle of duality. The algebraic as well as the graphical treatment then becomes formally identical for the two cases.

Acknowledgments

The author is indebted to the directors of Ferguson Radio Corporation Ltd for permission to publish this article.

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A Voltage Stabilizer for Photo-multiplier Tubes

By G. N. Davies*, B.Sc.

With the increased use of photo-multiplier tubes for precision measurements in the various fields to which electronics have recently found application, a need arises for a suitably stable source of operating voltage. A basic design is described having a moderate stabilization ratio, together with modifications for achieving greater stability and also for running several tubes from the same supply.

THE normal nine-stage photo-multiplier tube, e.g. the RCA 931A, requires a total supply voltage of about 1 000V in order to achieve the high sensitivity associated with these tubes. This voltage is divided by a resistive chain, so that approximately equal voltages are applied between successive dynodes; normally this is about 100V per stage. In order to ensure that the dynode potential does not alter during operation of the photo-tube, it is essential to have a considerably larger current flowing down the resistive chain than that taken by the tube itself. Hence the total current required from the power supply will be of the order 3 to 5mA per tube.

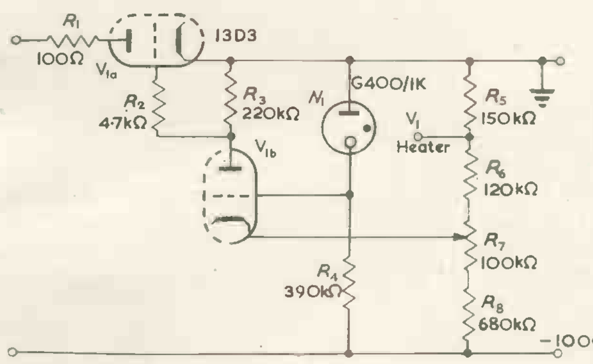
From the data for the 931A photo-multiplier it will be seen that a 10 per cent change of the applied voltage per stage results in as much as 50 per cent change in the sensitivity of the tube. Clearly, then, for any quantitative measurement it is essential to maintain a stable source of voltage for supplying a photo-multiplier tube.

Information in the literature concerning stabilized power supplies to give between 5 and 10mA at 1 000V is surprisingly sparse. Benson[1] has described several circuits for microwave oscillator power supplies, the requirement there being a current of about 6mA at 1 600V. It is possible to adapt these circuits for supplying photo-multiplier tubes with only minor modifications, but the development of new types of valves, in particular the S.T.C. type G400/1K gas-filled regulator, makes it possible to evolve a voltage stabilizer expressly for the requirements on hand.

The circuit shown in Fig. 1 is the logical development of one of the designs referred to above. A type G400/1K tube is used as the reference element and the two halves of a type 13D3 double triode valve are used, one as the control amplifier and the other as the series element in the stabilizer. This use of a single valve is made possible

* *Cottage Laboratories Ltd., formerly with Saunders-Roe Ltd.*

Fig. 1. Basic circuit of 1kV stabilizer



by connecting the valve heater to a point the potential of which lies midway between the two cathode potentials. This potential is obtained in this circuit by a tapping on a resistive chain and ensures that in neither half of the valve is the recommended heater-cathode voltage exceeded.

With this circuit a change of 10 per cent in the input voltage is reduced to a variation of 1 per cent at the output. With an output current of 5mA, a change of input voltage from 1 150 to 1 500V can be accommodated

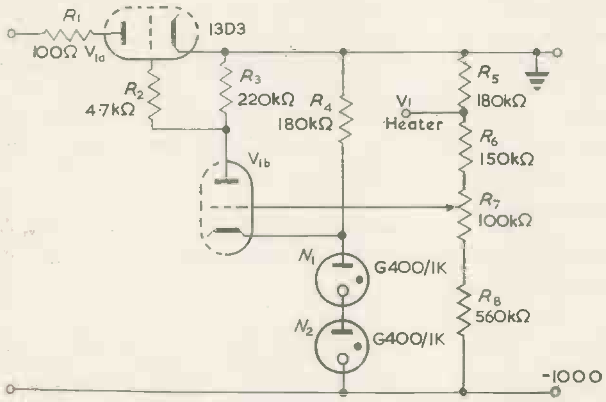


Fig. 2. Stabilizer employing two neon tubes as reference element

without exceeding the rating of any of the components. Any increase in the stabilization ratio of this circuit is not readily achievable due to the large amount of current feedback developed across R_8 in the cathode of the control valve. If, however, the reference potential is obtained with respect to the negative instead of the positive line, it is possible to overcome this disadvantage as shown in Fig. 2. However, in order to keep the anode voltage of the control valve within its maximum rating it is necessary to use two type G400/1K tubes in series as the reference potential.

A rather better modification is given in Fig. 3, where, in addition to dispensing with the unwanted feedback, increased gain is achieved by using a cascode amplifier. Here again the heater of the control valve must be connected to a potential lying midway between the two cathode potentials, a requirement met by making a tapping on the resistor chain. In this circuit a separate heater supply must be used for the series valve, but since the stabilizer is run with the positive of the output earthed this requirement can be easily met. The choice of the

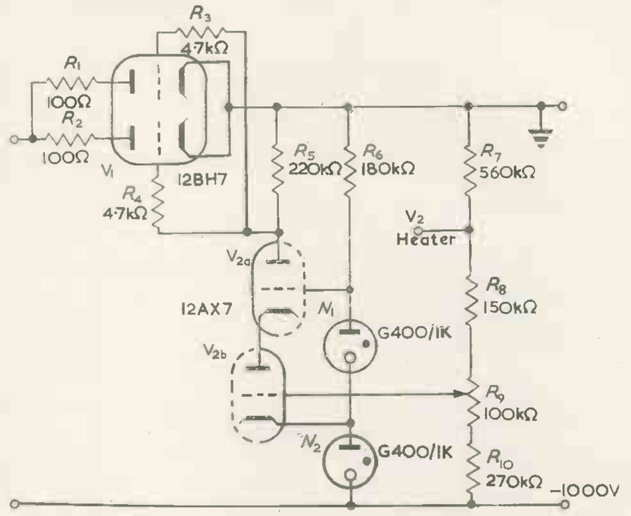


Fig. 3. Improved circuit for 1kV stabilizer, using cascode amplifier

series valve depends on the load to be taken and the maximum variation of input voltage likely to be encountered.

In the design given, which was required to supply two or three photo-multipliers, two halves of a type 12BH7 have been connected in parallel to supply an output current of 10mA. With this circuit the permissible variation in input voltage is between 1 050 and 1 500V. A stabilization ratio of better than 500 is achieved with this circuit, making it ideal for use with photo-multiplier tubes for detecting small changes in luminous intensity.

Acknowledgment

The author wishes to express his thanks to Messrs. Saunders-Roe Ltd. for permission to publish this article.

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A Decade Counter Tube Beam Switch

By G. P. Tonkin*, B.Sc.

A ten-way beam switch for five periods of repetitive frequency modulated wave (such as a telemetry sub-carrier) and five different calibration frequency periods, all in sequence, is described. A decade gas counter tube is used as a commutator before the discriminator to give a very simple and reliable circuit.

THE usual methods of beam switching to produce a so-called "simultaneous" display of several oscillograms depend on gated amplifiers, and the strobe generators to open and close these can be very complex. For example, a four-way switch of conventional type required four double triodes in the waveform generator, with four suppressor-gated pentodes carrying the signals.

The advent of the multi-cathode gas counter tube has made it possible to reduce the number of valves in the generator, especially for the more numerous time subdivisions, but the gated amplifiers must still correspond in number.

However, special cases arise where the counter tube can effect greater economy, and one of these is the histogram display of frequency against time. Here a frequency discriminator must at some stage convert frequency into d.c. level, usually prior to the deflexion amplifiers, and the advantage to be gained is that beam switching may precede the discriminator.

* *The Bristol Aeroplane Co. Ltd.*

The particular histogram under consideration was the result of a time-sharing frequency-modulated telemetry system in which the sub-carriers were of the order of hundreds of kilocycles per second. It was required that lines corresponding to crystal-controlled calibration frequencies should be superimposed on the display, but that not more than half of the intelligence display time should be thereby lost. The sub-carrier repetition frequency was of the order of 100c/s, so that a trigger pulse of this repetition was available.

displayed only ten times per second, and some flicker is observed. This is quite acceptable since the lines are present as a graticule only, and are fixed in position. The tube may be triggered up to 1 000c/s giving waveforms suitable for this service, and, had it been possible to use such a rate, flicker would not have been evident.

From the circuit diagram (Fig. 1), it will be seen that the capacitive cathode returns of the Nomotron are made via the cathode loads of the signal sources, the capacitance being increased accordingly. The tube allows of alternate

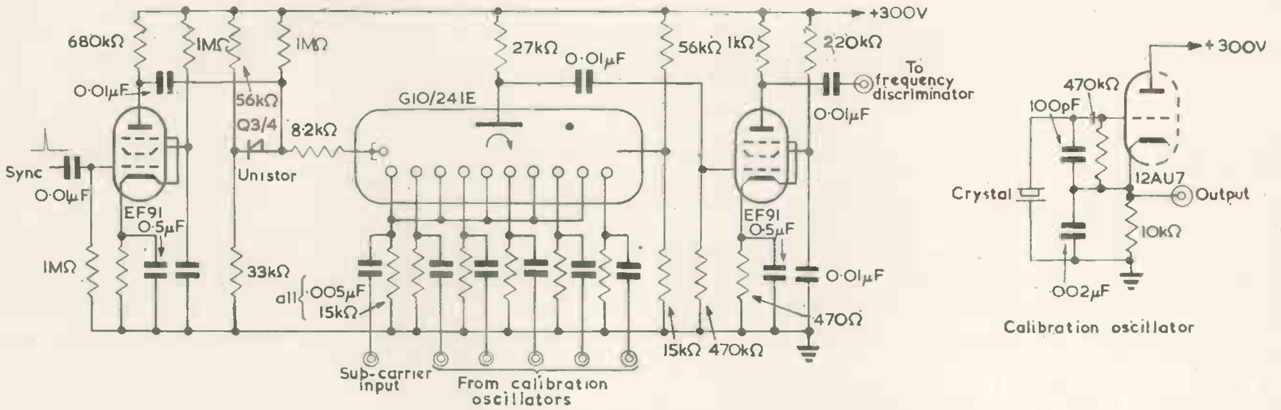

Fig. 1. The beam switch and calibration oscillator circuit

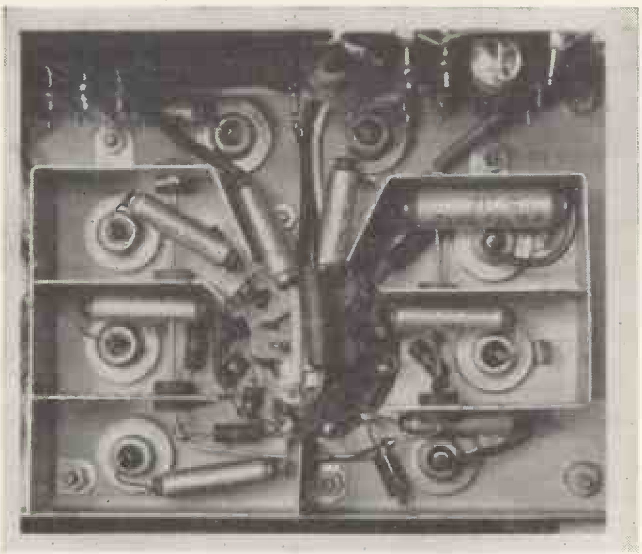

Fig. 2. An under chassis view

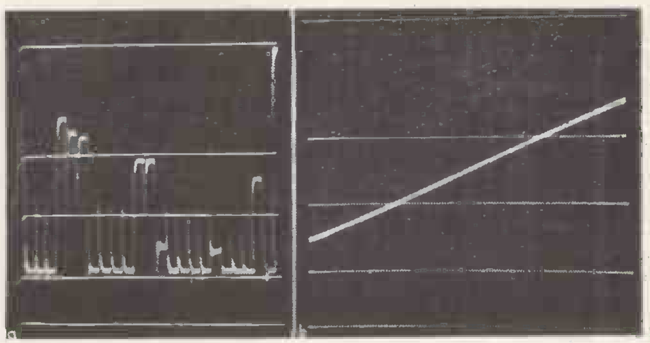

Fig. 3(a) 24 switched channel telemetry signal
(b) Telemetry modulator characteristic for particular voltage input swing

A ten-way switch was decided upon, alternate divisions of time being assigned to intelligence, and the other alternate frames being divided between five calibration frequencies. It was found that if suitable levels of sub-carrier and calibration signals were used, they could be injected into the cathode capacitance lines of a CVX2224 "Nomotron" (S.T.C. G10/241E), the tube becoming a commutator with a discharge "wiper" attached to the anode. From this anode the sequences of intelligence and calibration could be led through a common frequency discriminator and d.c. deflexion amplifiers to the display tube.

In this particular application each calibration line is

cathodes being strapped, and this offered a simple means of injecting the five sub-carrier frames per rotation. Triggering of the counter tube followed standard practice, except that a hard tube was used. To avoid crosstalk, screens between the cathodes at the tube base were necessary (Fig. 2), and it was found from this standpoint and from the standpoint of freedom from interference by the signals in tube triggering, that an amplitude of 10V should not be exceeded in the inputs.

The appearance of the display is shown in the photograph (Fig. 3). The circuit has been found very reliable in operation; and in that only three electronic tubes are associated with it, one of them having no heater, is very economical for what is, in effect, a ten-way beam switch.

Acknowledgments

The author wishes to thank the Bristol Aeroplane Co. Ltd. for permission to publish this article, and also the Ministry of Supply, on whose behalf the work was carried out.

A Radio-frequency Method of "Zone" Location for Paper Chromatography and Electrophoresis

By G. G. Blake*, B.Sc., F.Inst.P., M.I.E.E.

This article presents a new method for locating zones in paper chromatography. The arrangement of the electrode separated by an insulator from the chromatographic strip is a variation of the author's original "Conductimetric tube". A circuit is given also whereby amplification is obtained by use of a transistor.

THE process of chemical separation by adsorption as first suggested by Tswett[1] in 1906 is now well known and in general use. Substances are separated by passing them in solution through a column of adsorbent, after which the column is washed through with solvent and its contents form into bands or zones as they are adsorbed. One of the more important developments of this technique which is employed by analysts is known as "paper chromatography".

A strip of filter paper is suspended in a closed tube above and dipping into a small quantity of the chemical mixture to be analysed. The latter gradually rises by capillary action until finally it reaches the top of the strip. As it travels the different constituents are adsorbed and separate to form bands or zones, some of which are coloured and some colourless. Repeated washings with the same solvent increases the zone concentrations. Among its many and varied uses this method is employed in the analysis of drugs, foods, dyes and oils. One of the greatest difficulties is to locate colourless zones, especially when a number of them are present on one chromatographic strip.

Such colourless zones often occur when chromatographs are made from mixtures in which metallic ions are present.

R.Rf. Method of Zone Location

This article presents an electrical method for discovering the exact positions of ions along the filter-paper strips employed for chromatography, also for measuring their rates of migration.

The simplicity of the process can be seen from the diagrams. As an example of the procedure, take the case of an aqueous mixture containing ions of several different metals.

Firstly they are separated along the strip in the usual manner by capillary attraction, employing the method suggested by Martin, Consden, and Gordon[2]. While the strip is still damp it is sandwiched between two strips of glass G in the accompanying figures. Two spring clips (not shown) supply an even pressure on the glass and hold it in position. The r.f. field around the electrodes is restricted by a metal shield which is earthed. (See Fig. 1(b)). The leads to the electrodes are also shielded.

After adjusting the meter reading (by means of the zero-shunt, *Z* Fig. 2) so that it registers zero for a portion of the damp strip on which none of the metallic ions are located, the strip is passed slowly across the electrodes

As each congregation of metallic ions crosses the gap the meter deflexion will rise to a sharp maximum, and will then gradually fall back to zero.

To obtain an indication of the magnitude of the meter deflexions obtainable the following rough test was made:

A strip of filter-paper 2·5cm wide was damped with distilled water and two separate bands of KCl each about 4mm wide were painted across it. The concentrations respectively being N/10 and N/400. The paper was then

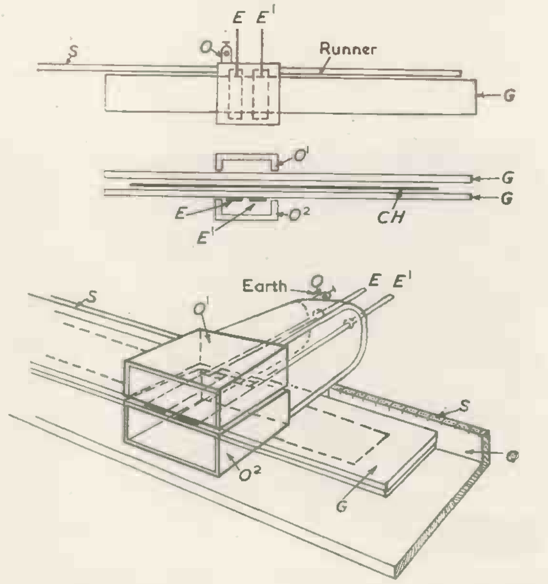

Fig. 1(a). The chromatographic zone locater is seen in position above and below the strips of glass between which the paper chromatograph is sandwiched.

(b) This sketch indicates the general appearance of the zone-locater.

placed between two strips of glass and passed across the gap between the electrodes. Readings were then taken first using the diode circuit Fig. 2 and then with the transistor circuit Fig. 3. The results were as follows:

	Diode Circuit	Transistor Circuit
KCl N/10	51·4μA	N/10 360μA
N/400	7·15μA.	N/400 50μA

Quantitative results were not attempted as the quantities of KCl applied by brush were empirical. The coupling between the oscillator and electrode *E* (about 10μF) was extremely weak and could quite well have been tightened so as to have increased the meter deflexions by four or five times, and still without causing any appreciable rise in the

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temperature of the strip. The two variables in these impedance measurements upon which the meter deflexions depend (the other parameters being treated as constants) are resistance and capacitance. When the resistance is low, as is the case where the metallic ions are present, the capacitance variation may be an almost negligible factor, and the change in dielectric constant may be also insignificant. However when the zone is practically a non-conductor, capacitance and dielectric constant become important factors. It is likely therefore that this method may be applicable to bio-chemistry and the study of enzimes and proteins and to their rate of travel in an electric field. It may possibly find use also in the hands of the haematologist.

If the foregoing scheme is applied to electrophoresis a radio-frequency choke or chokes should be included in the d.c. circuit. It should then be possible for observations to be made while the constant current is in operation.

As the ends of the strip must dip into solution containers

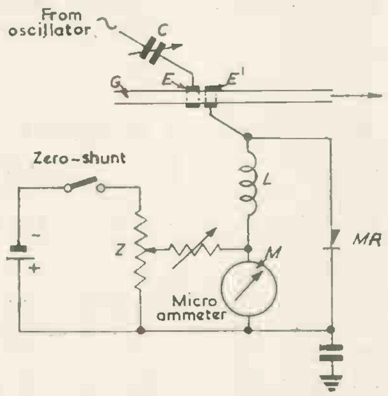

Fig. 2. This is a simple crystal diode circuit by means of which the ionic bands or zones are indicated by microammeter deflexions

it would be better probably to have the electrodes as the moving member.

The work of developing this new technique is proceeding.

Description of Apparatus

The oscillator is not shown in any of the diagrams. A suitable 1Mc/s oscillator was described by the author for use with his r.r.f. method of titration[3]. If this is used it will be necessary to include a small coupling capacitor (of the trimmer type) between the output from that instrument and electrode *E*. This is marked *C* in Figs. 2 and 3.

The radio-frequency impulses pass as displacement currents through the lower strip of glass (which should be as thin as possible), thence across the filter-paper and through the glass again to the second electrode *E'*, and from there through the crystal diode MR to earth. *L* is a radio-frequency choke which while preventing the passage of r.f. through the 0 to 60 microammeter *M* allows the rectified current to pass.

The zero-shunt circuit gives control of the position of the meter needle[4].

The two electrodes *E* and *E'* are strips of metal foil each 1·2cm wide by 3·6cm long, and the gap between them is 1mm. They are attached to an ebonite base with rubber solution. It is necessary that very thin foil be used in order to reduce the capacitance of the gap to a negligible quantity. Fig. 1(b) is a sketch to illustrate the manner in which the mechanical part of the instrument is arranged. The distances between the various zones of ionic intensity are accurately measured against a scale *S* along the top of the wooden guide *Q* as each maximum meter deflexion is found. The rest of the sketch and the diagrams are self explanatory.

The author's Q-metric method as employed for measuring the rate of liquid diffusion in glass tubes with his original diffusiometer and micro-diffusiometer[5] could be used for the present work. However he has found his r.r.f. method easier to operate and would recommend instead that r.r.f. be employed to replace his earlier Q-metric circuit[4, 8].

Transistor Amplification

The author published a circuit recently[9] in which a tran-

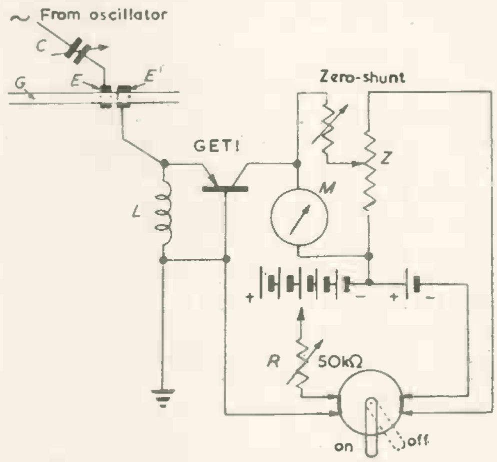

Fig. 3. A transistor circuit which performs the dual function first of rectifying and then of amplifying the current after it has been modified by its passage through a zone

sistor served the dual purpose of rectification and amplification, use is made of this in Fig. 3. A GET1 transistor takes the place of the diode seen in Fig. 2. By the employment of this circuit up to sevenfold amplification is obtained without the necessity of increasing the r.f. current passed through the paper strip. By its use, as demonstrated by the preceding experiment, greatly increased sensitivity is available. However the simple diode circuit in Fig. 2 is sufficiently sensitive for most metallic solutions. The variable resistor *R* (50kΩ) gives a very fine control of the negative voltage applied to the collector of the transistor.

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Notes from North America

Conference on Aeronautical and Navigational Electronics

PLANS for the 1955 East Coast Conference on Aeronautical and Navigational Electronics, to be held 31 October and 1 November, have been announced jointly by the Baltimore Section of the Institute of Radio Engineers and the IRE Professional Group on Aeronautical and Navigational Electronics. The conference will be held at Baltimore's Lord Baltimore Hotel.

The technical portion of the conference will be devoted to the general field of Aeronautical and Navigational Electronics.

National Electronics Conference

THE eleventh annual Conference will be held 3, 4 and 5 October, 1955, at the Hotel Sherman in Chicago.

Mr. O. I. Thompson, Educational Director, DeVry Technical Institute, Chicago, Illinois, has been elected president of the 1955 National Electronics Conference, Inc. Mr. G. E. Anner, Associate Professor, Electrical Engineering Department of the University of Illinois was elected Chairman of the Board of Directors.

The Conference is sponsored by the American Institute of Electrical Engineers, Illinois Institute of Technology, Institute of Radio Engineers, Northwestern University and the University of Illinois with participation by Michigan State College, Purdue University, University of Michigan, University of Wisconsin, Radio-Electronics-Television Manufacturers' Association and the Society of Motion Picture and Television Engineers.

The "Proceedings of the National Electronics Conference"—1954, Vol. 10, is available from the National Electronics Conference, Inc., 84 E. Randolph Street, Chicago 1, Illinois. This book contains all of the technical papers and luncheon addresses presented at the 1954 Conference and a cumulative index by subject and author of all of the technical papers presented during the ten-year life of the National Electronics Conference.

Nuclear Battery

A NUCLEAR battery that converts nuclear energy into electrical energy has been developed by the Patterson-Moos Research Division of the Universal Winding Company.

It is claimed that the battery is capable of performing reliably under temperature conditions ranging from $-60°$F to $+160°$F and has an operating life in excess of 25 years. Three models are available with voltage and current ratings ranging from 1V to 10kV and 5$\mu\mu$A to 2μA. The disintegration of Strontium 90 is used as the energy source, and the company states that the external radiation of the battery is within the Atomic Energy Commission tolerance limits.

One of the models is a multiple voltage source with taps at 1, 10, 100 and 1 000V and a current of 2$\mu\mu$A. Another supplies a voltage of 375V at a current of 50$\mu\mu$A, while the third model is a high voltage source supplying 10kV, its current rating being 500$\mu\mu$A. This model is less than 5 cubic inches in size.

Low Noise Oscilloscope Pre-amplifier

THE VS61A oscilloscope pre-amplifier made by the Volkers and Schaffer Manufacturing Corporation is a sensitive dual input adding or differential amplifier having substantially less than 1μV r.m.s. noise.

Walter K. Volkers and Norman E. Pedersen have shown that transistors, contrary to general experience and opinion, are inherently less noisy than valves, if suitable operating parameters are selected. The resulting, new "hushed transistor amplifier", having less than 1μV r.m.s. noise over a frequency band of 60kc/s, provides the input stages of the VS61A. Additional amplification is provided by valves.

The amplifier has a stage selector switch which provides a choice of either straight valve amplification (maximum gain 10, input impedance 100kΩ, frequency response 2c/s to 250kc/s) or combined transistor and valve amplification (available maximum gains 200 and 1 000, input impedance 1kΩ, frequency response 2c/s to 60kc/s). The maximum noise with straight tube operation is 5μV r.m.s. over the full 250kc/s pass-band and with transistor and valve operation usually much less than 0·5μV r.m.s. over the full 250kc/s pass-band.

Remote Control of Jet Fighters

A NEW, improved system for remote control of jet fighter aircraft, on special "drone" missions, pilotless intercept or nuclear tests, was announced recently by the Air Research and Development Command of USAF and the Sperry Gyroscope Company.

The system provides automatic take-off and landings, with exact control at all times by radio and radar during climb and dives, cruise, orbiting or other aerial manœuvres.

New u.h.f. radio guidance and command sub-systems supply "tighter" precision signals to the drone fighter craft, from USAF jet pilots at the "beeper" ground stations or in an accompanying jet "director" plane.

If all control signals should be cut off while the drone is airborne, if it is below a pre-selected altitude, in 5 seconds electronic controls take over the plane—and it begins a full-power climb of exactly 7 degrees, retracts dive flaps if these were extended, and at 200 mile/h changes to a climbing turn to the left until proper altitude is reached. Then it engages altitude control and continues a left-turn orbit at 265 mile/h, at this constant level and position—until signal is restored to guide the aircraft back for normal landing procedures.

If the plane is above selected altitude, or perhaps even in a critical take-off climb when signal shut-off occurs, the safety control takes over all required measures to produce a station-keeping orbit at proper altitude.

In the new control layout, special care was given to accessibility of sub-systems and components for ease of maintenance, and to design simplicity for manufacturing in production quantities. Size and shape of numerous elements have been reduced, in order to retain the standard Lockheed F-80C cockpit arrangement, especially for all flight safety and emergency controls. A safety pilot is frequently carried, during training or flight test check-outs of the airborne system.

Noteworthy improvements include new anti-skid control in the remote brake sub-system; centre-line tanks with parachute recovery gear for certain recording instruments; and improved provisions in the nose section for a telemetry system of coded signals air-to-ground and air-to-air.

LETTERS TO THE EDITOR

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

Computation of Waveguide Wavelengths from Free-Space and Cut-Off Wavelengths

DEAR SIR,—In the course of microwave measurements it is often desired to calculate waveguide wavelength in terms of free-space wavelength and cut-off wavelength. The value may be worked out directly from the well known equation:

$$1/\lambda_o^2 = 1/\lambda_g^2 + 1/\lambda_c^2$$

where λ_o is the free-space wavelength
λ_g is the guide wavelength
λ_c is the cut-off wavelength

The following procedure, however, enables the calculation to be made quickly and easily on an ordinary slide rule having A, B, C and D scales with a minimum of scale settings and mental effort. The method follows from expressing the above formula in the form

$$\lambda_g = \lambda_c / \sqrt{(\lambda_c^2/\lambda_o^2 - 1)}$$

The procedure is:—

(1) Set cursor over γ_c on D.
(2) Bring λ_c on C under cursor.
(3) Note value on A opposite the "1" or "100" on B and subtract unity.
(4) Set cursor to new number on A.
(5) Bring γ_c on C under cursor.
(6) Read answer on C opposite "1" or "10" on D.

The method can be easily adapted to give λ_o in terms of λ_g and λ_c if required.

Yours faithfully,
T. H. B. BAKER,
The British Thomson-Houston Co. Ltd.
Rugby.

Feedback Amplifiers

DEAR SIR,—With reference to my letter appearing in your May issue, I wish to point out three errors.

In the paragraph following Fig. 4, "$Z_{12} = Z_3(1, + m)$" should read "$Z_{12} = Z_3/(1 + m)$".

Equation (3) should read:

$$\text{“}g = \frac{-m}{Z_1(1/Z_2 + (1+m)/Z_3) + 1}\text{”}$$

In the last paragraph of column one the expression "$m/1 + mZ_3$" should read $mZ_3/1 + m$.

I apologise if these errors are due to my part in correcting the proofs.

Yours faithfully,
C. W. WARD,
Plymouth,
Devon.

A Design Method for Direct-Coupled Flip-Flops

DEAR SIR,—In their interesting article (June, 1955, issue) Mr. Renwick and Mr. Phister use the word "flip-flop" thirty-seven times in referring to the circuit (once, in the title). Indeed it has now become a fairly widespread habit to refer to the bistable trigger circuit as a flip-flop, but it is hardly correct. While one does not want to be pedantic about the matter, it is perhaps worth while pointing out that Mr. O. S. Puckle in his book "Time Bases" does (on. p. 56) give the original usage of the term (i.e. for a monostable circuit which "flips" over when triggered and "flops" back again after a predetermined relaxation time interval, usually given by an *RC* combination) and he distinguishes clearly between this circuit and the Eccles-Jordan d.c. coupled trigger with two stable limiting conditions which, as he says, was developed prior to the flip-flop.

In view of the fact that Fig. 1 of your authors' text shows a bistable trigger circuit, but is captioned "the flip-flop circuit" it seems that a continuation of this habit might be confusing. If we do need a shorthand for the bistable trigger why not use "flip-flip"? It is more accurately descriptive and less misleading.

Yours faithfully,
P. G. M. DAWE,
Institute of Experimental Psychology,
University of Oxford.

The Author's reply:

DEAR SIR,—Mr. Dawe has partly answered his point in the second sentence of his letter in which he says, "it has now become a fairly widespread habit to refer to the bistable trigger circuit as a flip-flop." Although originally the name "flip-flop" was given only to the monostable trigger circuit, for several years now it has been in wide use to denote the bistable, or Eccles-Jordan circuit (see, for example, page 595 of *Radio Engineering* by F. E. Terman, or page 843 of *Electronic Circuits and Tubes* by the Electronic Staff of the Cruft Laboratory).

The term "trigger" is also used as a short description of the circuit but this can easily be confused with the actual impulse triggering the circuit and should be preferably used only with this meaning. It is of interest to note that "gate" and "trigger" have been used as synonymous (see page 349 of *Theory and Applications of Electron Tubes* by H. J. Reich), but that the name "gate" is now only given to a completely different circuit. Finally, the name "flip-flop" is common to several languages with the meaning given by the authors in the article in question.

Yours faithfully,
W. RENWICK,
The University Mathematical Laboratory,
Cambridge.

Cascode Amplifier Degenerative Stabilizer

DEAR SIR,—I am glad that attention has been drawn so clearly to the features of the cascode type of amplifier in its "starved" form by V. H. Attree on page 174 of your issue of ELECTRONIC ENGINEERING for April, 1955, under the title "A Cascode Amplifier Degenerative Stabilizer". It is interesting to note that E.M.I. Engineering Development Ltd. has found the circuit most valuable for voltage stabilization, particularly where high gain without phase change is necessary with a minimum of equipment, and have been using a circuit in this kind of way as long ago as 1951. To the best of my knowledge, Messrs. Hine and Roche were the first to propose the "starved" type of circuit. This circuit forms the subject matter of British Patent No. 719,064, which was applied for on May 8, 1951.

Yours faithfully,
O. S. PUCKLE,
E.M.I. Engineering Development Ltd.,
Hayes, Middlesex.

A Torquemeter for Testing Gas Turbine Components

DEAR SIR,—In the appendix to the article by Messrs. Field and Towns (Part 2, December 1954), the authors draw a misleading conclusion from their analysis of the differential amplifiers.

They deduce conditions (1), (2) and (3) for optimum operation where (2) and (3) are mutually exclusive, but in fact (2) is incorrect and (1) is incomplete.

The antiphase gain of the amplifier is $\frac{\mu R_a}{R_a + r_a}$ and if $R_a \gg r_a$, this becomes μ which is the most constant of the three triode parameters. If on the other hand $r_a \gg R_a$ then the gain tends to $\mu R_a/r_a = g_m R_a$ and g_m is the parameter most likely to vary with ageing.

Similarly, the inphase attenuation is approximately $\alpha = \frac{2\mu R_k}{R_a + r_a}$ $= 2\mu(R_k/R_a)$ if $R_a \gg r_a$, but if $R_a \ll r_a$ $\alpha = 2g_m R_k$ which is likely to be dependent on valve changes and ageing than $2\mu(R_k/R_a)$.

Note however that α is the greater if $R_a \ll r_a$.

The conditions for optimum operation should be stated as:

(1) For maximum relative attenuation, $\mu R_k/R_a$ should be as large as possible.
(2) For constancy of gain (and relative attenuation) $R_a \gg r_a$.
(3) For maximum gain, $R_a \gg r_a$, μ large.

Even more briefly the conditions may be summarized:

$$R_k \gg R_a \gg r_a,\ \mu \gg 1.$$

Note that the gain is asymptotic to μ, the maximum possible value, but the in phase attenuation varies as R_k, other things being equal, which means that any desired value of α may be achieved with a sufficiently large voltage on the negative rail.

Yours faithfully,
A. B. JOHNSON,
Electronics Division,
Saunders-Roe Ltd.

BOOK REVIEWS

Dielectric Materials and Applications

Edited by A. R. von Hippel. 438 pp. 120 figs. Demy 8vo. Chapman & Hall Ltd. 1955. Price 140s.

THIS large volume contains contributions from over twenty American workers and is edited by Professor von Hippel of M.I.T. It is divided into five sections the first, written by von Hippel, being devoted to theory. Both the classical and molecular approaches are discussed as in von Hippel's own book *Dielectrics and Waves,* reviewed in these columns in the June issue. The theoretical section of the present volume is effectively a summary of the other.

The second section covers measurements on dielectrics and magnetic materials over the whole of the present available frequency spectrum. The most useful feature of this is that it collects in a readily accessible form the formulae which are needed in most of the commonly used measuring techniques: further, detailed charts and tables are provided for the methods involving transmission lines or waveguides and these will be of great value to experimenters in this field. In other ways the treatment is a little disappointing: there is very little about experimental technique, nor are the relative merits of different methods clearly discussed.

The third section dealing with applications is perhaps the most interesting and covers a very wide range of topics. The physical properties of the commonly used dielectrics, classified as gas, liquid, plastic and ceramic, are first compared and then the requirements which have to be met by insulators in power, distribution and electronic equipment are discussed. The information is well presented and amply supplemented by copious references to original papers. Also in this section is a discussion of "dielectric materials as devices" containing a theoretical and descriptive treatment of rectifiers, piezoelectric transducers, magnetic and dielectric amplifiers and memory devices. The level is quite advanced but the accounts are sufficiently complete to be useful as introductions to the devices considered.

Section IV is an explanation by American armed service representatives of the needs of the three services and helps to explain why their specifications sometimes appear to be unnecessarily stringent.

The remainder of the book is devoted to the M.I.T. Tables of Dielectric Materials and gives the electrical constants of some 600 materials over a wide range of frequencies and temperatures. This information, not hitherto available to most workers in this country, is a very welcome addition to the electrical engineer's reference library.

Dielectric Materials and Applications is likely to become the standard work on the subject for some considerable time and it is to be hoped that the high price will not prevent its reaching the wide audience it deserves.

JOHN BROWN.

ELECTROPHYSIOLOGICAL TECHNIQUE

By C. J. Dickinson, B.A., B.Sc.
(Magdalen College, Oxford)

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(Postage 6d.)

The author describes the use of electronic methods as applied to research in Neurophysiology. Chapters are devoted to amplifying, recording and stimulating techniques used in physiology and medicine (e.g. electro-cardiography, electro-encephalography, etc.)

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Sonics

By Theodor F. Hueter and Richard H. Bolt. 456 pp. 221 figs. Demy 8vo. John Wiley & Sons Inc., New York. Chapman & Hall Ltd., London. 1955. Price 80s.

SOUND waves and ultrasonics are finding an ever-widening range of application in science and industry. The techniques which have been developed to deal with the multitude of problems which have arisen have hitheto been included in the general field of "ultrasonics," although audible frequencies are often quite as valuable (sometimes decidedly more valuable) than ultrasonic.

The authors of this book have produced a work aimed at unifying the whole field of industrial and physical techniques—analysis, testing and processing—which depend on the use of vibratory energy of any frequency in the audible or ultrasonic ranges. This field really constitutes a new area of technology which the authors have christened "Sonics."

Major emphasis is placed on the techniques and instrumentation necessary to carry out actual tasks in industry, but the more fundamental aspects of the subject are not neglected. The first three chapters of the book deal briefly with the necessary background of acoustics theory and wave propagation, leading on to Chapters IV and V, which cover piezoelectric and magnetostrictive transducers respectively. These chapters include much new material not hitherto published in book form, all of which is well arranged and logically presented. The only criticism that can reasonably be made is that perhaps the account given of magnetostrictive transducers is not sufficiently comprehensive in view of their widespread use. For example, ferrite ceramic transducers are not mentioned. Nor are any details given of cobalt-iron (Permendur) transducers which now find many uses, particularly in high temperature work. Even so, Chapter V contains a great deal of very valuable information of a fundamental nature and will be found extremely useful to designers of magnetostrictive devices.

Applications work is dealt with in the last three chapters VI-VIII, which together account for just half the total reading matter. Chapters VI and VII which cover processing and the other high power applications are particularly valuable and well presented. The aim of the authors has been to detail the physical principles underlying applications work and then to describe the techniques which have been developed to cope with them, finally illustrating the text with few of the more important applications—cleaning, drilling, soldering and particle agglomeration—rather than attempt a review of the literature on the subject. Chapter VII also includes useful details of whistle and siren-type generators for fluid processing. Chapter VIII covers analysis and testing and finally an Appendix dealing with relaxation phenomena is included.

The authors, staff of M.I.T., are obviously drawing from their own experience for much of their material. Indeed, a very noticeable feature of the work is that it does not borrow to any appreciable extent from existing texts on ultrasonics. The book is a new approach to ultrasonic engineering and can be thoroughly recommended to all serious workers in this field. In the opinion of this reviewer it is the best, most instructive, book yet produced dealing with ultrasonic processes. It contains very few errors, is well printed and the material is well presented and arranged.

E. A. NEPPIRAS.

Circuits and Networks

By Glenn Koehler. 349 pp. 70 figs. Demy 8vo. Macmillan & Co. 1955. Price 45s. 6d.

THE author states, in his preface, that "It is not intended that any chapter of this text constitute a complete treatment of its subject matter. However, the material presented should suffice to help the student prepare for most undergraduate professional courses . . . ." This is certainly true, as in eleven chapters, and some 350 pages, the author attempts to cover almost the entire field of passive network analysis, circuit properties, coupled circuits, wave filters, equalizers, transmission lines (both communication and power), transformers (communication and power) and saturable reactors. In consequence of this, the treatment is necessarily brief.

The method of teaching tends to be by rule and rote, as statements are made that this is so and that is so; however, the essential information is there for people who like to acquire their learning in this way. For the more discriminating student the bibliography tends to be inadequate and the definitions and fundamental concepts could have been made with more care. For example, Kirchoff's Law and various other theorems are given in terms of "Phasor e.m.f.s" and "Phasor currents" as if they apply to sinusoidally excited systems only. This reluctance to consider instantaneous values and clear fundamental definitions, such as of r.m.s. value, leads the author into a peculiar difficulty with the Superposition Theorem where he has to warn the reader against adding superimposed currents, of the same frequency, in quadrature.

From these remarks it will be seen that the treatment and introduction of the subject is very different from the traditional teaching methods employed in this country and, as this book is intended to prepare students for more advanced courses, one cannot help feeling that a little more explanation and emphasis of fundamental concepts could have been given with advantage.

W. R. HINTON.

Transistors and Crystal Diodes

By B. R. Bettridge. 72 pp., 47 figs. Demy 8vo. Norman Price (Publishers) Ltd. 1954. Price 5s.

IN this book devices which still appear to be some way off have been dealt with briefly and the majority of circuits given are of immediate interest in that they are built around transistors and diodes that are actually on the market. In addition, the circuits are in nearly every case ones which have been made up and tested by the author so that there is a practical background to them.

Luminescence with Particular Reference to Inorganic Phosphors

British Journal of Applied Physics. 116 pp. Demy 8vo. Supplement No. 4. The Institute of Physics. 1954. Price 25s.

THE papers presented in this supplement, with the discussion on them, comprise the proceedings of a conference held in Cambridge from 7-10 April 1954. The conference was organized by the Committee of the Electronics Group of The Institute of Physics, and was the first major discussion on the subject of luminescence since a conference held in Oxford in 1938; the emphasis was upon solid inorganic phosphors.

Simple Electronic Musical Instruments for the Constructor

By Alan Douglas. 72 pp. 51 figs. Demy 8vo. Norman Price (publishers) Ltd. 1955. Price 5s.

IT has been difficult for the musically-minded amateur to obtain constructional details for the more mechanical parts of simple electronic tone producers, and this small book describes several well-assorted adjuncts to musical enjoyment in the home, in full detail. There is a chapter on the meaning of musical terms, leading to amplifier, power supply and general chassis details. Six different kinds of instrument are described and there are sections on percussion, attack and frequency division. Instructions are given for making a pedalboard and organ bench, and finally there are suggestions for future improvements. All the instruments are inexpensive and use the same power supply, and it is interesting to note that the author recommends the amplifier described by E. J. Miller in the August, 1952, issue of ELECTRONIC ENGINEERING as being ideal for the home. A useful feature is that the names and addresses of component suppliers are given.

RCA Receiving Tube Manual

300 pp. Demy 8vo. Radio Corporation of America. Price $0.60 or 8s. in U.K.

THIS manual has been prepared to assist those who work on or experiment with electron tubes and circuits. It will be found valuable to engineers, service technicians, experimenters, students, radio amateurs, and all others technically interested in electron tubes.

The manual containing technical data on more than 500 RCA receiving tubes and kinescopes, including types for black and white and colour television.

Storage Batteries

By G. W. Vinal. 446 pp. 163 figs. Demy 8vo. 4th Edition. John Wiley & Sons Inc., New York. Chapman & Hall Ltd., London. 1955. Price 80s.

THIS book emphasizes the scientific principles of storage batteries without allowing the treatment to become too highly technical. Physical and chemical properties of the materials employed in making batteries are discussed, and the reader is given a general description of manufacturing processes. The new edition contains many additional features and illustrations.

Staging TV Programs and Commercials

By Robert J. Wade. 216 pp. 40 figs. Demy 8vo. Hastings House Publishers, New York. Chapman & Hall Ltd., London. 1955. Price 48s.

THIS well illustrated book describes how to plan and execute sets, props and production facilities and aims to help in solving the physical production problems of "live" television programming. It is a valuable reference source for all those who are preparing for a career in television.

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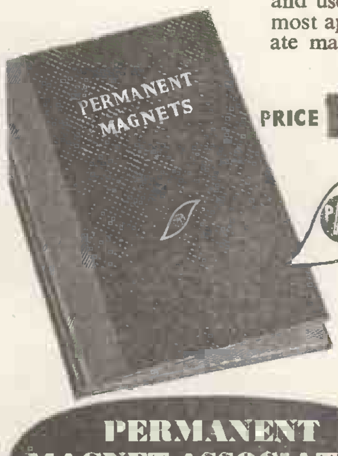

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Short News Items

The Independent Television Authority has confirmed that its London transmitter will start high-power test transmissions during the first half of September and regular service by the London programme companies will begin on 22 September. The Authority's station is being built at Beaulieu Heights, South Norwood Hill, Croydon. It will be the first of the Authority's stations to go on the air and will cover an area extending roughly to Reading, Basingstoke and Wallingford in the west; to Hitchin and Saffron Walden in the north; to Southend, Burnham-on-Crouch and Chatham in the east; and to Horsham and Tunbridge Wells in the south. The number of people living in the area to be covered by the station is estimated to exceed ten million.

The Authority has now received planning permission to build its Band 3 Midland television station on a site some five miles south-east of Lichfield, Staffordshire.

The Lancashire Council have granted planning permission for the I.T.A. to construct its Band 3 television station for Lancashire on Winter Hill, some five miles to the north-west of Bolton.

Goodmans Industries Ltd have recently purchased the Baird radio and television factory in Lancelot Road, Wembley. A development programme is under way to add an additional 15 000sq.ft to the property. This is part of the expansion programme of the company to increase production of vibration generators, amplifiers, oscillators, loudspeakers, transformers, etc.

A new Electronics Department formed at Metropolitan Vickers Electrical Co Ltd, Trafford Park, Manchester, incorporates the present Radio Department, part of Marine and Special Contracts Department and the service electronics section of the Industrial Electronic Control Engineering Department. Mr. E. T. W. Barnes has been appointed superintendent of the Electronics Department.

F.W. Electronics Ltd, contractors to the BBC, GPO, etc, and manufacturers of audio apparatus, have moved their works and registered office to 12a, Prince of Wales Road, Hendon, London, N.W.4.

The English Electric Co Ltd announces the establishment of a special department to deal with atomic power station development. The headquarters of the company's atomic power work is at Whetstone, near Leicester, where the administrative, design, experimental and drawing office staffs are already established. Mr. P. H. W. Wolff has been appointed Chief Engineer of the Atomic Power Department of Whetstone.

Mullard Ltd. have decided to extend the activities of their Hove factory. Accordingly, over 20 000sq.ft of factory space have been taken over in premises at Cromwell Road, near to the existing factory. This new extension is expected to produce over six million valves in the next two years and will open shortly with a small initial staff.

F.M. Demonstration at the Science Museum. In order to explain the benefits of the new system to the listening public, the reasons for its introduction, and the circumstances in which it is of the greatest value, a special demonstration has been arranged at the Science Museum, South Kensington, London, S.W.7, and will remain open for about three months. The Science Museum is open on weekdays from 10 a.m. to 6 p.m. and on Sundays from 2.30 p.m. to 6 p.m., admission free.

Standard Telephones and Cables Ltd have developed and produced a highly successful 100kV oil-immersed rectifier unit with very long life. The development has resulted in the replacement of existing thermionic diodes by "Sentercet" units in a 1 million volt linear accelerator power supply at the Cavendish Laboratory, Cambridge, and a follow-up order for similar units for use with a 2 million volt accelerator. Birmingham University has installed seven 100kV for e.h.t. supplies to a synchrotron injector. A Glasgow University order for ten units has been received, Liverpool University has ordered thirteen, and increasing inquiries indicate the interest aroused by this development.

The United Kingdom Atomic Energy Authority announces that the United Kingdom is to hold two exhibitions on the peaceful uses of atomic energy in Geneva from 8 to 20 August. They will coincide with the International Conference of Scientists, under the auspices of the United Nations, to which 84 countries have been invited.

An International Conference on Electronic Digital Computers and Information Processing will be held at the Institut fur Praktische Mathematik, Technische Hochschule, Darmstadt, Germany, from 25-27 October. This conference is sponsored by Gesellschaft fur Angewandte Mathematik und Mechanik and Nachrichtentechnische Gesellschaft im Verband Deutsche Elektrotechniker. Information may be obtained from Prof. Dr. A. Walther, Institut fur Praktische Mathematik (IPM), Technische Hochschule, Darmstadt, Germany.

The Cambridge Instrument Company, as in previous years, has recognized its long and close association with the University of Cambridge by holding an "At Home" recently for which invitations were issued to the professors, teaching staff, research students and senior men taking science subjects in the university. Some 600 accepted the invitation of the management and visited the works on two days, when all sections of the factory and research departments were open for inspection and a number of interesting demonstrations were in progress. The visitors included the Mayor of Cambridge with civic officials and several Masters of Colleges.

The General Secretary of the Radio Society of Great Britain, Alderman John Clarricoats, is the new Mayor of the Borough of Southgate. He has operated his own amateur radio station—call sign G6CL—since 1926.

International Aeradio Ltd have received an order for three standard air traffic control desks from the Egyptian Air Force. This brings the number of desks in use the world over to more than 100.

Dubilier Condenser Co Ltd announce that Mr. F. W. Hollings has retired from his position as secretary and the board of directors has appointed him a director of the company. Mr. H. S. Clemow has been appointed secretary.

The Royal Society recently held a conversazione at which there were a number of exhibits of scientific interest. Among these were the Cambridge Survey of Radio Stars, exhibited by Mr. M. Ryle, Mr. J. E. Baldwin and Mr. J. R. Shakeshaft, Cavendish Laboratory, Cambridge; a New Flow-Meter and the Telemetering of Ventilation Rate of Human Subjects demonstrated by Mr. H. S. Wolff, National Institute for Medical Research; Animated Diagram Showing in Detail the Chain-Reaction in a Nuclear Reactor, exhibited by Dr. F. A. B. Ward, The Science Museum; The Electrical Contact demonstrated by Dr. M. R. Hopkins, Mr. C. R. Jones and Professor F. Llewellyn Jones, Department of Physics, University College of Swansea.

The British Rayon Research Association, Wythenshawe, Manchester, was visited recently by H.R.H. The Duke of Edinburgh for the opening of their new laboratories.

Pye Canada Ltd, of Ajax, Ontario, have supplied a hand-held underwater television camera, together with associated equipment, for the intended Arctic survey to be made by H.M.C.S. "Labrador". The camera will be used for oceanography, the observation of divers and frogmen working in water at very low temperatures and in other scientific investigations at low temperatures.

Enfield Cables Ltd announce that the South of Scotland Electricity Board have awarded them a contract to the value of approximately £130 000 for the supply and installation of cables between Dalmarnock 132kV grid sub-station and Charlotte Street sub-station, Glasgow.

Colloidal Graphite Ltd announce that, following the recent extension of their plant, their technical manager, Mr. R. W. Burchhardt, has been appointed a director.

The Tenth Annual Exhibition of the Institution of Electronics, as mentioned in the April issue, will be held at the College of Technology, Sackville Street, Manchester, from 14-20 July. Tickets for the exhibition, lectures and film shows may be obtained, free of charge, from the Honorary Exhibition Organizing Secretary, Mr. W. Birtwistle, 78, Shaw Road, Thornham, Rochdale, Lancs. Lecture and film show programmes (price 4½d.. post free) and catalogues (price 2s., post free) are also available on application.

Winston Electronics Ltd, of Hampton Hill, Middlesex, manufacturers of specialized electronic equipment, intercommunications systems, etc., have moved to their new factory premises at Govett Avenue, Shepperton, Middlesex. The telephone number is Walton-on-Thames 2732 and telegraphic address, Control, Shepperton.

Mr. E. Cattanes has joined the Solartron Electronic Group Ltd, Thames Ditton, Surrey, as a senior commercial executive. He will be responsible for developing the European export market for Solartron electronic instruments and will open up the new Paris office later in the year.

The Ministry of Supply announces that Mr. F. E. McGinnety has been promoted to Deputy Chief Scientific Officer and has been appointed Director, Inspectorate of Electrical and Mechanical Equipment.

An Investment Castings Plant has recently been established by West Products (Metals) Ltd at 161 High Street, Hampton Hill, Middlesex. The company is operating under mutual agreement with an American concern and is introducing several U.S. techniques in its processes. Emphasis is placed on the production of waveguides and other electronic components.

The Senate of the University of London has conferred the degree of D.Sc. (Engineering) on Dr. A. Rosen for his work in the field of telecommunication cables. Dr. Rosen, who is Consultant Engineer (Telecommunications) in the Engineering Organization of British Insulated Callender's Cables Ltd, has contributed a number of papers to the Institution of Electrical Engineers and is the author of many articles which have appeared in the technical press on various aspects of telephone cable design and usage.

In the Birthday Honours List a Baronetcy has been conferred on Sir George Nelson, chairman and managing director of the English Electric Company. A Knighthood has been conferred on Mr. Harold Bishop, director of Technical Services of the BBC and immediate past president of the Institution of Electrical Engineers.

Mr. C. Barwell, general publicity manager, of Mullard Ltd, has been elected president of the Incorporated Advertising Managers' Association.

G. A. Stanley Palmer announce that they are supplying transistor-grade germanium, single crystal and polycrystalline, to customers' own specified resistivities, and with life-time of excess minority carriers of 100μsecs, 200μsecs and more.

Airtech Ltd, of Haddenham, Bucks, recently negotiated a contract with the Canadian Department of Defence Production providing for the maintenance, overhaul and repair of all electronic equipment used by the Royal Canadian Air Force in the United Kingdom. The company has been overhauling all the electrical equipment used on R.C.A.F. Sabre aircraft for some years past, and this has now been extended to cover v.h.f., radio compass, i.f.f. and other aircraft electronic equipment.

A.B. Metal Products Ltd, of 17 Stratton Street, London, W.1, announce that the German firm Friedrich Petrick, of Bad Salzdetfurth, near Hanover, have granted them exclusive manufacturing and distributing rights in Great Britain and the British Commonwealth for their piano key action switch. This particular type of switch is popular in Continental radio receivers and its layout makes it suitable for f.m. work.

Nagard Ltd, of 18 Avenue Road, Belmont, Surrey, have changed their telephone number to Vigilant 9161/2.

A. C. Cossor Ltd announce the formation of Cossor Instruments Ltd. The new company will design and develop new instruments to meet the demands of research and industry and is equipped to promote and deal with the application of electronics to industries which heretofore have not used the new science. The Chairman is Lord Burghley, supported on the Board by Mr. J. S. Clark, Mr. H. Chisholm, Mr. H. T. Shepherd, and Mr. L. A. Woodhead (General Manager). The new company is located at Cossor House, Highbury Grove, London N.5.

Philips Electrical Ltd confirm that they have given notice of their intention to resign from the Electric Lamp Manufacturers Association, as from July 1955. This decision results from disagreement on certain matters of policy which could not be reconciled after long negotiations. It does not mean, however, the end of all connexion between Philips and the remaining E.L.M.A. members since some measure of co-operation is likely to continue in the future. It appears unlikely that the price level of Philips lamps will be materially affected.

PUBLICATIONS RECEIVED

THE RADIO AMATEUR'S HANDBOOK now in its 32nd edition has become a leading reference work for many radio amateurs, experimenters, students and engineers. The new handbook features five basic chapters of basic radio theory, three chapters concerned with history and amateur radio operating practices, three of basic experimental data, and fifteen chapters of advanced theory together with practical constructional details. The American Radio Relay League, Inc., West Hartford 7, Connecticut, U.S.A. Price $3 in the United States, $3.50 in U.S. possessions and Canada, $4 elsewhere.

A.M.-F.M. EQUIPMENT by Julius Karl Gorler is a brochure describing the equipment available from Technical Supplies Ltd. Hudson House, 63 Goldhawk Road, London, W.12.

REPORT OF THE INTERNATIONAL TIN RESEARCH COUNCIL FOR 1954 deals with the work of this Institute and the eight overseas branches. Among the main subjects of research at the Institute's laboratories in Greenford, Middlesex, during the year were the newly perfected bearing alloys made of aluminium-tin alloy. Tin Research Institute, Fraser Road, Perivale, Greenford, Middlesex.

RECORD TODAY FOR TOMORROW is the title of a leaflet describing the "Editor" and "Editor Super" tape recorders. Tape Recorders (Electronics) Ltd, 3 Fitzroy Street, London, W.1.

SCHOLARSHIPS AND OTHER AWARDS AVAILABLE TO BRITISH STUDENTS FOR TRAINING IN ELECTRICAL AND ALLIED ENGINEERING is a booklet prepared by the British Electrical and Allied Manufacturers' Association on careers in the electrical industry. It gives details of scholarships open to non-graduates, chiefly those leading to a first degree in electrical engineering; post-graduate scholarships and research awards open to senior students; and scholarships and awards permitting study abroad. The British Electrical and Allied Manufacturers', Association, 36 and 38 Kingsway, London W.C.2.

OPTICAL GLASSWORKING by F. Twyman, an abridged version of the second edition of the author's "Prism and Lens Making", has been written by request as a text-book to meet the needs of those engaged in, or studying, optical glassworking. Hilger Publications, 98 St. Pancras Way, Camden Road, London, N.W.1. Price 24s.

CHEYENNE MOUNTAIN TROPOSPHERIC PROPAGATION EXPERIMENTS is a circular describing the National Bureau of Standards Central Radio Propagation Laboratory's facilities on Cheyenne Mountain, Colorado, and gives some sample results of the research carried out. National Bureau of Standards, U.S. Department of Commerce, Washington 25. D.C., U.S.A. Price 30 cents.

OCCUPATIONAL PSYCHOLOGY, published quarterly in January, April, July and October, is the journal of the National Institute of Industrial Psychology, 14 Welbeck Street, London, W.1. The subscription rate is 30s. a year.

THE 1954 ANNUAL REPORT OF THE INTERNATIONAL NICKEL COMPANY OF CANADA LTD. shows that new records were established for net earnings, and deliveries of nickel to the free world. For the first time in the Company's history, more than 14 000 000 tons of ore were mined. The Mond Nickel Co. Ltd, Publicity Department, Thames House, Millbank, London, S.W.1.

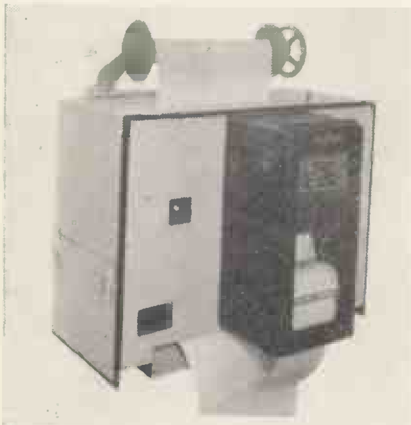
British Instrument Industries Exhibition

A description, compiled from information supplied by the manufacturers, of a small selection of the exhibits which will be on view at the British Instrument Industries Exhibition at Earls Court, London, from 28th June to 9th July, 1955.

Baldwin Transverse Profile Unit

(Illustrated below)

THIS is a self-contained instrument using a radioactive isotope to measure variations in weight per unit area of a



strip of paper or plastic. In practice the strip of material is torn off across the web so that the "transverse profile" (or level) can be measured, the strip being fed through the machine automatically. The output of this instrument is fed to a circular or strip chart recorder.

Baldwin Instrument Co. Ltd,
Brooklands Works,
Dartford,
Kent.

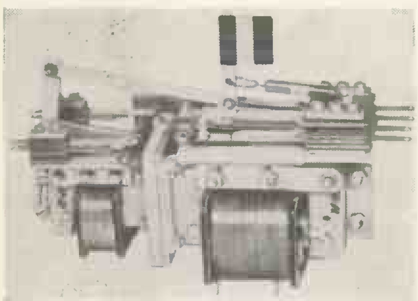
Latching Relay

(Illustrated below)

THE type C.10 latching relay is also known as an "impulse" or "memory" relay as it is operated by a momentary pulse to one coil and holds the new position until a pulse is given to the second coil.

It measures $1\frac{7}{8}$in by $5\frac{3}{4}$in by 4in, consumes (momentarily) only about 4 watts on d.c. or 10VA on a.c. and can have up to eight pairs of contacts rated at 10A 24V and 5A 250V. It can also be fitted with mercury switches of up to 30A.

It has full tropical finish and the latching mechanism is balanced to minimize



false movement by shock or vibration.

Its use can simplify electronic machine tool and mechanical handling control circuits as it can remember which of two limit switches was last actuated by a rotating or reciprocating part, and set the circuit accordingly.

Besson & Robinson Ltd,
East Industrial Estate,
Harlow,
Essex.

B.P.L. D.C. Test Set

(Illustrated below)

THE "Trans Ranger" is a portable multi-range d.c. test set having a resistance of 1MΩ/V. This high impedance is achieved by the use of a built-in d.c. coupled transistor amplifier. An internal standard is provided for setting the amplifier gain and thus the calibra-

tion of the instrument. The lowest voltage range is 0 to 100mV and the highest 0 to 500V. Current and resistance ranges are also provided.

British Physical Laboratories,
Houseboat Works,
Radlett,
Hertfordshire.

Double Beam Wide Band Oscillograph

THE model 1059 oscillograph has two similar amplifiers and a 4in post deflexion acceleration tube operating with a maximum accelerating potential of 3kV. The sensitivity of the amplifiers is variable between 0·2V/cm and 180V/cm over a working bandwidth of 10c/s to 10Mc/s, but an additional pre-amplifier of gain approximately ten times and covering the audio-frequency range is provided so that, if required, the sensitivity of either of the main amplifiers may be increased to 20mV/cm. A signal delay of 150mμsec is provided. The time-base is arranged for triggered operation only although a repetitive sweep is attainable under certain conditions. Sweep time is variable in eleven steps from 50msec/cm up to 0·1μsec/cm and triggering pulses of either sign, whether externally applied or through the Y.1 amplifier, are selectable. The time-base output is available for external uses in the lower sweep ranges. An X amplifier is provided allowing a continuously variable sweep expansion up to five times. It can also be used as an independent amplifier. Both voltage and time calibration systems are incorporated in the oscillograph.

Cossor Instruments Ltd,
Cossor House,
Highbury Grove,
London, N.5.

Counting Instruments Mechanical and Electromagnetic Counters

(Illustrated below)

A WIDE range of mechanical and electromagnetic counters will be on view. Among the latest models are a heavy duty five figure electromagnetic counter with reset (illustrated), and pro-

totypes of small lightweight electromagnetic counters.

These counters are available with a wide range of mounting arrangements.

Counting Instruments Ltd,
5, Elstree Way,
Boreham Wood,
Hertfordshire.

Elcontrol Photo-Electric Equipment

THE Elcontrol standard range includes photo-electric amplifiers with separate viewing heads and a selection of light sources which together cover a wide variety of current industrial applications. Viewing heads and light sources have been improved in design and lend themselves to being fitted in situations where space is an important consideration.

Single and two-way registration controllers are now available for such applications as the synchronizing of cross-cutting with a printed design.

Elcontrol Ltd,
10, Wyndham Place,
London, W.1.

Evans Electroselenium

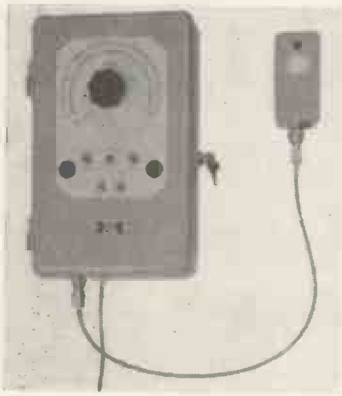
A WIDE range of photocell actuated equipments are being shown by this firm. Included among these is :—

The "Eel" Exposure Controller

(Illustrated below)

This instrument is designed to provide constant conditions of photographic exposure despite any possible illumination variations. It is intended primarily for applications involving photo-copying and provides a means of automatic exposure control.

A hermetically sealed measuring head, containing an emission type photocell, is mounted at the edge of the copy frame and receives the same intensity of illumination as the material being photographed. This head is connected to the main controller unit by a screened flexible cable which may be of any length. The current passed by the photocell, dependent upon illumination conditions, controls a simple electronic circuit. This, after a preset exposure period, operates a relay which may be connected, externally, to operate the camera shutter.



The exposure may be varied by a calibrated dial which carries two scales representing long or short ranges. Exposures may be preselected within a range of 1 : 120 units for any given application, and an iris on the front of the photocell unit permits further adjustment so that the total exposure range obtainable is from approximately 1 second to 20 minutes. The accuracy of reproducibility of exposure at a given dial setting is ±0·5 per cent.

The equipment is fully stabilized against mains voltage and frequency variations.

Evans Electroselenium Ltd,
Potter Street,
Harlow,
Essex.

Ferranti

Magnetic Drums

THE primary use of these is for the storing of very large quantities of data for electronic digital computers, but they also have a variety of other applications when used with digital electronic equipment.

Several different sizes of drum are made. Most drums have been prepared with a nickel surface, particular attention having been paid to perfecting the plating process. Drums are also available with an iron oxide coating bonded with Araldite. All drums are provided with the magnetic heads, and the associated electronic amplifiers can also be supplied. The electronic equipment for controlling the speed of the drum, and also equipment for high-speed electronic switching between the heads can also be supplied.

The largest drum is 12in diameter and 10in high. The normal maximum working capacity is 256 tracks each carrying 3 200 digits, making a total storage capacity of approximately 800 000 binary digits. The maximum access time is 30msec. The second type of drum is also 12in diameter, but carries only 32 tracks, each holding 3 200 digits, giving a total of about 100 000 binary digits.

A third drum recently introduced is of 10in diameter and 7in long. This will carry up to 64 tracks with 3 200 digits on each, giving a total capacity of about 200 000 binary digits. The maximum access time is 16msec. Particular attention has been given to the development of the reading and writing heads for this drum, resulting in a considerably increased signal level with consequent improvement of reliability. Attention has also been given to simplifying all matters of maintenance of the drum and its complete assembly.

Ferranti Ltd,
Hollinwood,
Lancashire.

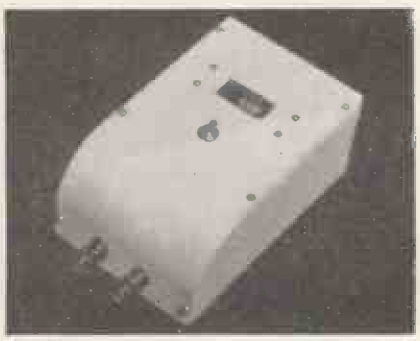
Labgear

Electronic Relay

(Illustrated below)

THIS electronic relay is a device for switching apparatus demanding heavy operating current where it is neither desirable nor permissible for the controlling medium to carry such current. Typical conditions exist where inflammable liquids may ignite or where contacts oxidize and become unreliable.

A single triode valve is employed in a circuit of special design carrying a heavy duty relay in its anode circuit. The open circuit potential across the input terminals is 6V, and the current, depending upon the operating medium, may be of the order of only 30μA. With this small operating current the relay will control one kilowatt. It is provided with double-pole changeover load control contacts giving make or break facilities at the rear terminal block.



The unit is capable of a variety of mounting positions and is complete with self-contained power supply for operation on a.c. mains.

Labgear (Cambridge) Ltd,
Willow Place,
Cambridge.

Marconi Instruments

IN addition to a range of communications measuring equipment, two industrial instruments are being exhibited.

Moisture Meter

(Illustrated below)

The moisture meter (TF 933A) is for the rapid and accurate measurement of the moisture content of a wide range of materials, particularly those of organic origin such as grain, seeds, flour, tobacco, paper, etc. A compression test cell is used which eliminates packing errors and minimizes the effect of uneven moisture distribution. The range extends from near saturation to below air dry values, and the basic accuracy is 0·5 per cent m.c.

pH Meter

The pH meter (TF 889) is a direct reading instrument complete with protected glass electrode assembly. It is highly suitable for routine checks in both works and laboratory. Battery operated, it covers the range 1 to 11pH with a discrimination of 0·05pH and incorporates manual temperature compensation over the range 10° to 50°C. The instrument may also be used with standard laboratory types of electrode.

Marconi Instruments Ltd,
St. Albans,
Hertfordshire.

Mervyn Instruments

High Gain Amplifier

(Illustrated top next column)

THE latest form of the Mervyn spectrometer amplifier has an overall gain exceeding 120dB and its input is suitable for both photo-voltaic and photo-conductive cells. It is thus of interest to all who are concerned with the measurement of radiations from the ultra-violet to the infra-red using these types of detectors.

The complete unit consists of an 800c/s tuned amplifier, a correlation detector, an output stage and a circuit providing the reference signal for the detector. Suitable power supplies are also built into the unit. A monitoring meter is displayed on the front panel, together with the main output termination.

The instrument is available complete with chopper unit and reference signal generator and has been designed to incorporate the maximum flexibility for a wide number of uses. The output is sufficient to drive a standard milliammeter type of recorder.

Mervyn Instruments,
Copse Road,
St. John's, Woking,
Surrey.

Mullard
Laboratory Oscilloscope
(Illustrated below)

THE oscilloscope type L140 is a general purpose laboratory instrument, intended particularly for the measurement of pulse waveforms.

Calibrated and uncalibrated controls for both X and Y shifts enable accurate measurements of time and of signal voltage to be made by null methods.

A new circuit has been developed to ensure time-base linearity, especially at the start of trace sweep; this allows accurate observation of the leading edges of pulses. An optional signal delay is also incorporated so that the full wavefront of a random pulse may be displayed.

The time-base can be triggered externally, or internally by the displayed waveform. Direct coupling allows sweep initiation when the trigger amplifier input voltage reaches a predetermined d.c. level.

A sweep expansion control expands the trace horizontally about the tube centre: when used in conjunction with either of the X shift controls it allows minute examination of any part of the trace. Trace length remains constant on all time-base ranges.

To prevent the trace wandering when measurements are made or when shift is applied, direct coupling is employed from the time-base and Y amplifier to the tube plates.

The Y amplifier response extends from d.c. to 6Mc/s, except when switched for high sensitivity. A rapid rate of rise is maintained for all voltage inputs.

A cathode-follower input probe, having a high input impedance, is provided. A d.c. backing-off voltage, provided at the grid of the cathode-follower, permits small amplitude changes of large pulses to be measured accurately.

Direct access to the tube plates is possible; connexions are made at the back of the oscilloscope.

Stabilized supplies of both h.t. and e.h.t. are provided.

The oscilloscope and power unit are contained in two similar portable cases; this makes for good accessibility and ventilation.

Multiple Pulse Generator
(Illustrated below)

The multiple pulse generator type L141 is a versatile laboratory instrument for tests and measurements on pulse circuits.

It provides several combinations of pulses of either polarity, having accurately controllable amplitude, duration, p.r.f. and separation; square waves are also available.

Typical applications include the investigation of paralysis and resolution times in nucleonic, computing and radar apparatus.

The generator provides two main pulses (A and B respectively) of either polarity, separated by a variable delay, and having variable p.r.f., duration and amplitude. Either or both of these pulses may be obtained from the main output socket.

A pulse of fixed duration and amplitude, suitable for triggering an oscilloscope, is available at a separate output socket; it precedes the A pulse by a fixed interval.

A highly stable p.r.f. generator is incorporated and may be synchronized by an external triggering pulse.

An additional (C) pulse is available at another output socket. It is of either polarity, and of fixed amplitude and duration; the leading edge may be switched to coincide with that of either the A or B pulses.

Square waves of continuously controllable amplitude and frequency are also provided.

The amplitude of both A and B pulses is continuously variable over a wide range and can be set very accurately. Pulse duration, pulse separation and p.r.f. can be set to fair accuracy over a wide range. Pulse separation and p.r.f. are continuously variable; pulse duration is variable in discrete steps. The output pulses retain flat tops and short rise times, even when of short duration, except at the highest output voltages.

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

Pye
D.C. Microammeter

THIS new instrument reading directly in microamps is presented in the "Scalamp" style and makes full use of this familiar taut suspension reflecting movement plus its own built-in optical system and scale. Two models are available, the first having a range of 0·1μA to 15mA and the second a range of 0·01μA to 1mA. Full-scale deflexions of the two instruments on the most sensitive ranges are respectively 15μA and 1μA. The voltage drops at full scale on all ranges are 2·5mV and 20mV respectively. The six-position switch gives 5 degrees of sensitivity with critical damping plus a shorted position. The 14cm translucent scale is traversed by a light spot with a fine hair line enabling measurements to be taken easily and without a fear of parallax. A slow motion drive is fitted to the set-zero head giving rapid and easy zeroing of the instrument. Levelling is not critical and the instrument may be used on benches in laboratory and workshop. An automatic shorting foot is fitted to prevent damage to the instrument during transport. The spot lamp bulb is easily interchangeable, while an in-built transformer allows the instrument to be used on 200 to 250V a.c. mains or from an external 4V battery.

W. G. Pye & Co. Ltd,
Granta Works,
Newmarket Road,
Cambridge.

Solartron
Non-destructive Testing Equipment

THIS is a new equipment (BA.564) based on an application of the Solartron phase-sensitive voltmeter VP.250 to eddy current testing of metals in a balanced bridge system. The equipment will give automatic indication of flaws in material passing through a detector head and may be used to warn operators or to control associated machinery.

Check Weigher

This device is intended for use where items have to be weighed quickly and accurately on a continuous but controllable basis. The check weigher will weigh items of up to 10lb with a constant accuracy of 0·1 per cent at rates up to 120 items per minute, no linkages or springs being employed. A contact output is used for warning purposes, also a separate time integrated output is available for control of dispensing machinery.

The Solartron Electronic Group Ltd,
Solartron Works,
Thames Ditton,
Surrey.