ELECTRONIC ENGINEERING

VOL. 32 No. 383

JANUARY 1960

Commentary

IT will be recalled that within the last year the Advisory Council on Scientific Policy was asked to consider a proposal put forward by a group of Fellows of the Royal Society led by Professor Massey that the United Kingdom "should embark upon a programme of scientific experiments in the upper atmosphere, and in extra-terrestrial space, by means of a series of earth satellites launched by vehicles developed from British military rockets adapted to that purpose."

At that time, the successes achieved by the Americans and the Russians in this particular field were attracting world wide attention and it was the opinion of many that because no comparable efforts were being made in this country we were falling behind in this space race and losing prestige in the eyes of the world.

The programme put forward by Professor Massey and his colleagues listed a number of possible scientific applications of artificial earth satellites but the Advisory Council while giving support to the proposals came to the conclusion that a period of at least five years would be required before the British military rockets could be suitably modified for the purpose and that the whole project would be a very costly undertaking.

They recommended, however, that the design and construction of instruments to be carried in a series of earth satellites be put in hand without delay and in the meantime, while design studies for the modification of British rockets were being considered, they suggested that the American Government be approached to see if we could "thumb a lift" on an American rocket for our instruments—a suggestion to which the Americans readily agreed.

This somewhat limited British space programme, which contained no proposals to put a man into outer space, came as a disappointment to those who were clamouring for a more vigorous participation.

But it is well to recognize that a more ambitious space programme than putting a few satellites into orbit round the earth is fantastically expensive and would make demands on our financial and scientific manpower resources which are quite beyond our means, and the Advisory Council on Scientific Policy has therefore very wisely restated its views in its annual report* which has just been published.

They pay tribute deservedly to America and Russia for the pioneer work which has been done in those countries but they go on to say that "We in this country cannot hope to provide all the resources necessary to develop space exploration independently on an equal footing with these two great nations" and "because the cost of venturing into space with lunar, planetary or solar probes would be too great for our resources and because we do not think that the scientific and technological return to be expected is likely to be commensurate with that cost, we have not recommended any British participation in these activities at the present time, nor in the attempt to launch human beings into space."

There is no denying the glamour of space research and space exploration and the world wide interest which is aroused, but it must not be assumed that it is the only branch of modern day science with a high prestige value.

The Council expresses this point of view most succinctly when it states that it "has repeatedly emphasized the importance of adequate expenditure on research and development in fields of endeavour which are vitally important for the welfare of our people and for the strengthening of our economic position, as well as for the improvement of the living standards in the less well-developed countries, particularly in Commonwealth countries and colonial territories."

To leave these needs unsatisfied in order to shoulder the crippling cost of a large programme of space exploration on a purely national basis would be, in the Council's view, the grossest folly.

It would indeed be the grossest folly to embark on such a project.

It should be remembered that very worthwhile results in upper atmosphere research have already been made by this country with a comparatively modest expenditure and it is certain that we can continue to make our contribution.

If we believe, to quote again from the Report that "scientific prestige is obtained through research which is important scientifically and is well planned and executed, and does not depend on the size or spectacular nature of the project" then we can derive considerable comfort in turning to the National Research Development Corporation's Annual Report† which, too, has just made its appearance.

Here there is ample evidence of research covering a very wide range, important scientifically, being well planned and executed and, which, when brought to a successful conclusion, will enhance our prestige and more important, contribute in no small way to the well-being of the world at large.

Of greater popular appeal is the invention of the "Hovercraft" which the Corporation is developing and to which reference is made to the construction of the manned prototype which successfully crossed the English Channel in July.

Another project of potential importance is the development of a group of new antibiotics, the cephalosporins, including cephalosporin C which is resistant to destruction by the enzyme penicillinase which inactivates penicillin.

Reference is also made to the development of automatic chromatographic equipment, a television compression system, an improved technique for rolling mills, the mechanized processing of leather, a ditch cleaning machine, pitch stabilization of ships and a pharmacological screening project.

All small beer compared with space research, but no apology is called for.

* Annual Report of the Advisory Council on Scientific Policy 1958-59. Cmnd. 893. Her Majesty's Stationery Office.

† Report and Statement of Accounts for the year 1 July 1958 to 30 June 1959. Nat. Res. Dev. Corpn. Her Majesty's Stationery Office.

AUTOMATIC CHARACTER RECOGNITION

By D. A. Young*, M.A.

Following an introductory survey of some of the principal automatic character recognition systems that are currently in either the production or research stage, the fundamental semantic features and limits of character patterns are discussed. It is demonstrated that by an analysis of these limiting features, it is possible to formulate definitions of character patterns that are particularly amenable to translation in terms of discriminatory logic. In a later article, it is hoped to give details of some logical circuits, specially suited to this form of analysis, as applied to the design of a versatile character recognition system.

(Voir page 61 pour le résumé en français: Zusammenfassung in deutscher Sprache Seite 65)

BEFORE commencing this article, a note on the title may not be out of place. The phrase "automatic character recognition," although widely accepted, is objected to, in certain quarters, as implying the identification of one out of a given set of standard symbols, and the phrase "automatic pattern recognition" is preferred. This argument assumes a most arbitrary connotation of the word 'character,' which, outside the vocabulary of psychology, is usually held to connote any semiotic pattern whatsoever. 'Pattern,' on the other hand, means much more than just 'character pattern,' and generically connotes an arrangement or inter-orientation, with no necessary semantic value.

Early work on automatic character recognition involved very little research into the fundamental features of character patterns. The main object was to provide some equipment that would respond correctly to one or more characters (frequently the ten decimal numerics), each being of one standard shape. An obvious way to do this was to place each character in front of a sensory mechanism or scanning device, and to compare the number and relative positions of black and white responses so obtained with a set of master patterns. Much research work was undertaken over several years, in order to design equipment capable of fast and accurate character recognition using this comparison of sensed characters with their respective 'masters.' Highly developed forms of this technique were incorporated in the design of the Solartron 'ERA' and of the optical and magnetic versions of the E.M.I. 'FRED,' each of which will shortly be available as production models.

The Solartron machine has been a working device since early in 1957, when the first prototype was built. A specially designed installation will be brought into use by a multiple store in February 1960 (see Fig. 1) for the reading of branch cash register tally rolls, and this will be the first delivery of a production model of this machine. Several other multiple stores are planning to install ERA machines for a similar purpose and an insurance company is having a portable machine manufactured for printing information concerning weekly industrial insurance payments.

The ERA employs a spot-scanning system with a raster of 28 lines by 16 columns, designed to more than cover the dimensions of each character to be read. Filter circuits clean up the scan-data before being stored as 'black' or 'white' signals, and this data is then compared with 'master' sets to determine the character read. The machine can read twelve capital alpha-characters (A, B, C, D, H, L, P, S, T, U, X, Z), in addition to the decimal integers, and three fractions, $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$. A certain number of alternative alpha-characters can be used in place of some of the twelve mentioned, but the final combination of characters must be such as will not confuse the machine's discrimination logic, which cannot at present distinguish, uniquely and with certainty, all the other fourteen alpha-characters. If it is required to read a different kind, or size, of type-face from the specification prescribed, this can only be achieved if the recognition logic is altered. In the event of excessive mutilation of characters, smudging, or poor quality print, an automatic checking procedure is initiated, resulting in a visible indication on the typewritten output of the reader for every character that is unrecognizable.

* *The National Cash Register Company Ltd.*

Extensive paper-feed inter-locking devices are installed, ensuring the minimum likelihood of breakdown due to mechanical errors, and comprehensive monitoring facilities enable visual displays to be switched on from any part of the reading process. The reading speed is at present 300 characters per second, but greater speeds are being planned.

As to future developments of this equipment, considerable work has been, and is, going on, towards producing a more versatile system. Detailed studies have been made of document handling, and equipment will soon become available for feeding individual documents, of certain

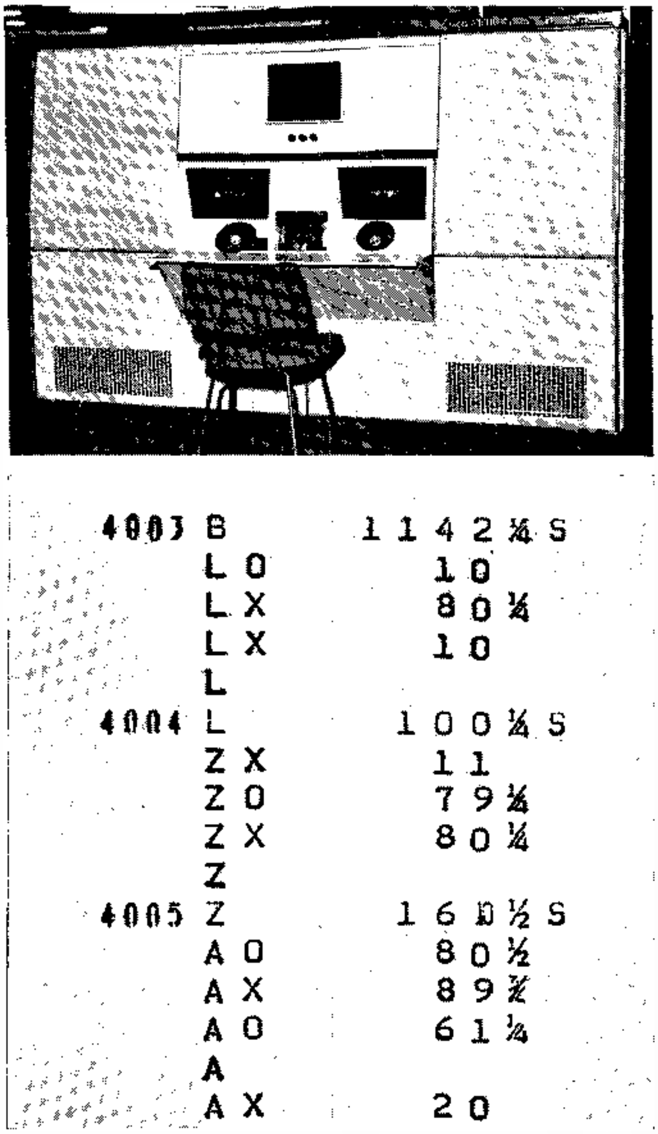


Fig. 1. The 'ERA' designed for reading cash register tally rolls and, below, a section of a typical tally roll

selected sizes, at high speed. Handwritten mark recognition is being developed, and a pilot model for this purpose is expected to be in operation by the end of this year. Designs for handwritten numeral-reading equipment are also being studied, and it is hoped to produce a prototype machine, by 1961. In this connexion, a development contract is at present under negotiation.

FRED is essentially a numeric character reading device, designed to read a special form of type-face by either optical or magnetic means. This transistorized equipment

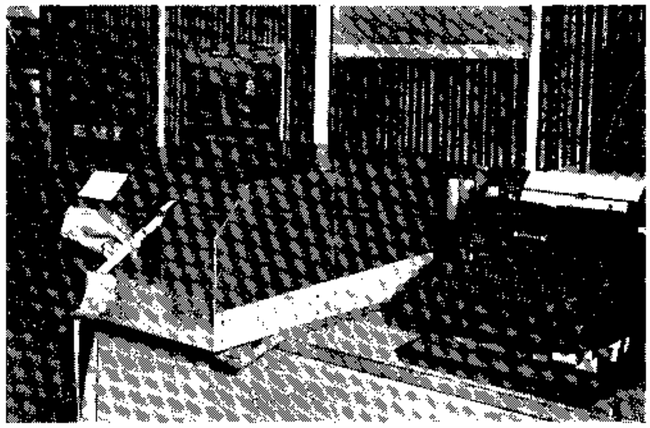


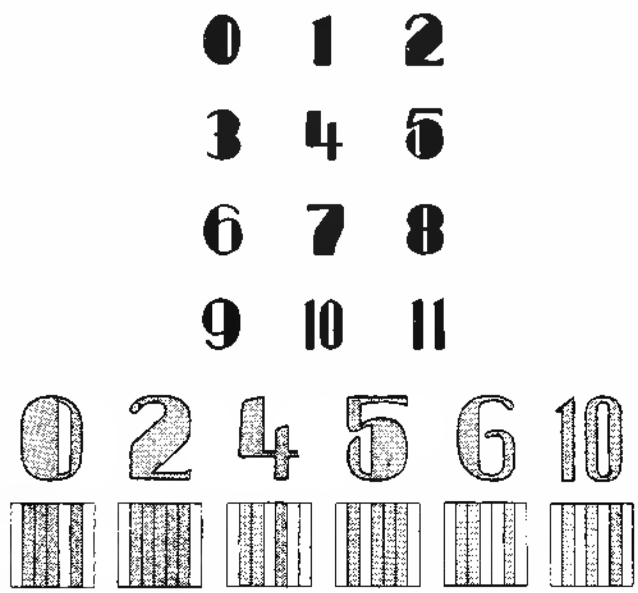
Fig. 2. Tape being fed into 'FRED'

(see Fig. 2) is particularly suited to the high-speed reading of printed numerals orientated in a particular part of documents of fixed dimensions (e.g. cheque serial numbers). Each numeric character must conform to certain specific limitations of size and shape, and consists essentially of the central five elements of seven vertical columns (see Fig. 3). The first four of these five columns, reading from left to right, form the keys to the discrimination logic, being either mostly black or mostly white, allowing for a maximum of $2^4 = 16$ different characters (i.e. the decimal numerics, and six extra selected characters or symbols). The fifth colum is always mostly black, and serves as a 'start' signal for the reading machine.

In both the magnetic and optical systems, each character is identified by scanning each of the five columns, through a slit corresponding to the size of the columns. Characters printed in the 'magnetic', or, more accurately, the 'magnetizable' ink, are scanned by a magnetic head containing a slit which corresponds to the scanning slit in the optical system. All characters are read while moving past the sensing head, and are not required to be sensed at rest.

The reading speed of both these equipments is about 10 000 numeric characters per second, but even higher

Fig. 3. The 'typeface' used by 'FRED' and the method by which it is read



speeds, of up to 100 000 characters per second, could be achieved, if the working speed of the document-handling mechanism could be sufficiently increased. Alpha-recognition has not been, and is unlikely to be, accomplished for more than a few characters, in this particular machine, but work on the design of a more versatile machine than FRED is already under way.

Both the Solartron ERA and the E.M.I. FRED are, however, restricted to a comparatively narrow range of work, by virtue of their inherent principle of comparing sensed characters with masters or their constituent codes. But without making equipment which is prohibitively expensive, no truly versatile reading machines can be built along these lines, if only because of the storage space and parallel logic that would be required for the necessary fast comparisons with a large number of master-patterns.

It is sometimes contended that the introduction of automatic data-processing systems will gradually do away with the need for automatic reading devices. A considerable quantity of written and typed material will, it is true, be gradually eliminated, both in the course of changing from manual to automatic systems, and as a direct result of improvements in overall systems of decision and control, consequent upon the application of operations research techniques. But the continued growth in demand for more and more commercial and scientific data, and for increased communications, both in industry and in government departments, will far outweigh the reductions in written material. The need for automatic translation of written and typed information will, in fact, increase, rather than decrease, with every new installation of automatic data-processing equipment.

A truly versatile character recognition system has extensive fields of application, in industry, commerce, and government departments. Research and development in some of these applications has been under way for some time. Automatic typewriters, that either 'listen' to a dictating voice, or read handwritten letters and manuscripts, are already in the development stage. Completely automatic sorting of handwritten and typed mail is a recognized possibility, and both the British G.P.O., and the United States Post Office, are carrying out extensive research toward the design of suitable equipment. Many other applications exist, however, on which little or no work is being undertaken. For instance, it would be possible, with a suitable reading device, to copy printed and handwritten documents, automatically, on to punched cards, paper tape, or magnetic tape, for use in an electronic filing system, or for direct insertion into a digital computer system. In this latter connexion, the automatic high-speed punching and checking of handwritten computer programmes would make for considerable savings in time and money, so frequently wasted under the slower and more error-bound manually-operated methods.

During the last few years a growing interest and activity has developed in the design of versatile character-recognition systems. Discussions, and papers read, at the 'Symposium on the Mechanization of Thought Processes,' held at the National Physical Laboratory in November 1958, and at an I.E.E. Specialist Discussion Meeting in February 1959, brought to light the activities of several research groups of whose work little had been known hitherto.

A Manchester University project[1], under Dr. R. L. Grimsdale, incorporates a design in which characters are recognized by assessing the number, size, shape and orientation of their constituent parts, with the assistance of a computer. Comparison with master character-patterns is substituted by comparison with master segments of character-patterns. The semantic equivalence of different sets and orientations of segments, within any one pattern, makes the equipment capable, in principle, of reading quite a large variety of type-faces. Nevertheless, there is too much storage of, and comparison with, master segments, to allow the equipment to be sufficiently fast, compact, and versatile, at a price commensurate with industrial applications, even with the help of a special purpose computer. (The original speed of one character per minute obtained using the Manchester Mark I Computer, can be increased to one character per 3 seconds using a Ferranti Mercury Computer. It is expected, however, that, with improved scanning and the use of a special-purpose computer, this speed can be further increased to about 100 characters per second). Considerable attention has been paid to the problems involved in recognizing ill-formed characters, and an interesting feature of the design is that, where any dis-

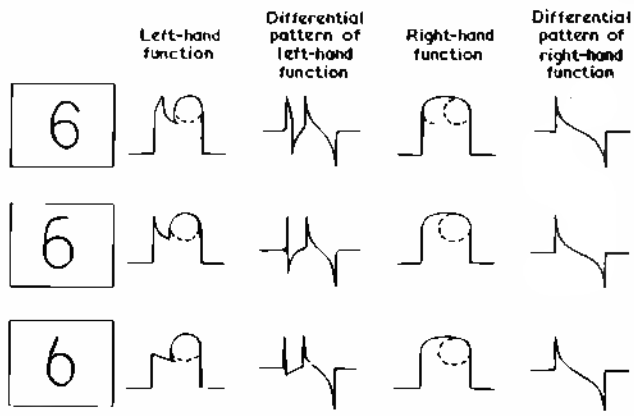


Fig. 4. Three examples of scanning the figure '6'
(*Sprick and Ganzhorn*)

criminatory dubiety is encountered, a probability code is printed out after each character of the several which are considered possible.

Dr. W. K. Taylor[2], of University College, London, in a sideline to his work on neutral analogues, has developed a system of pattern recognition which differs from current trends in being principally analogue in nature. The prototype model, shown at the National Physical Laboratory last year, was too small and semantically unstable to be of practical use. But Dr. Taylor claims that his system can be applied, with suitable modifications, to a wide range of reading processes, including the discrimination of a variety of different sizes and shapes of type-faces, and, in principle, of some handwriting as well. The prototype was attractively compact and inexpensive, but it is difficult to see how the overall size and cost would not be very much increased by any considerable extensions to the scope of the machine. It would appear that an inordinate amount of logic would be required to analyse the summations of all possible semantically equivalent combinations of sensory data, derived from a sensory matrix sufficiently large to permit of the necessary discriminations.

The work of Sprick and Ganzhorn[3], in Germany, is perhaps the most advanced of all the research projects that were discussed at the I.E.E. Convention. They have recognized that the principal semantic feature of a character pattern consists of the combination of points at which the relative rate of change of direction of the pattern line is significantly altered. A system has been devised for identifying any printed or handwritten numeric character, within the set of decimal integers, by analysing the shapes of the left- and right-hand contours of each character, which contain their principle semantic features.

The figures are scanned in two directions, one by simulation only, and the analogous functions of the side contours so obtained are then differentiated. The diagram in Fig. 4 illustrates the left- and right-hand functions obtained from scanning three samples of the figure '6'. By means of a differentiating circuit, corresponding differential pulse patterns are obtained, as shown. When the function suddenly rises, a high positive pulse is obtained; when it suddenly drops, a high negative pulse appears; and when it remains horizontal, the pulse pattern is identical with the x axis.

Characteristic sequences of positive and negative pulses are obtained from each semantic class of numeral pattern. regardless of location, size, or of any semantically tolerable variation in shape or tilt. Variations in the horizontal width of characters, for instance, will only influence the amplitude of the differential pulse pattern, and measures of amplitude are not, therefore, used as recognition criteria. Time-displaced patterns, similarly, will cause vertically displaced differential patterns, and therefore no time coincidences of pulses are used as criteria in comparisons with master patterns. The six principal types of pattern variation are listed in Table 1, along with their effects on the differentiating patterns, and the compensation allowed for them in the recognition logic.

The prototype machine scans with a flying-spot tube, and the video pulses from a photo-multiplier are amplified and then clipped by opposite sawtooth voltages in two parallel clipping circuits. After smoothing, analogue functions are obtained for both sides of the scanned character, and the functions are then differentiated and passed to a criteria detecting circuit. Further logical circuits co-ordinate the criteria with the numeral pattern data by comparing these patterns with reference patterns. In an experiment in which only seven criteria combinations were used, a wide variety of numeral shapes was successfully recognized (see Fig. 5).

TABLE 1.

FIELD OF CHARACTER VARATION	RESULTANT VARIATION IN DIFFERENTIAL PATTERN	COMPENSATION FOR THESE VARATIONS
(1) Horizontal location of character	Nil	The differential quotient is independent of any vertical displacement of a pattern
(2) Vertical location of character	Horizontal time-shift of scan-data pattern	No time coincidence is used as recognition criterion
(3) Height of character	Change of amplitude of scan-data	No amplitude comparisons are used as recognition criterion
(4) Width of character	Alteration of horizontal (time) intervals between successive scan-data	As for (2)
(5) Inclination of character	Small changes of amplitude and horizontal intervals of scan-data	As for (2) and (3)
(6) Distortion within vertical length of character	Non-Linear distortions to horizontal pattern	As for (2)

Although the main part of their work has been concerned with the discrimination and recognition of only the numeric characters, earlier papers[4] suggest that alphabetic character recognition is well within the scope of the study. There is, indeed, no apparent reason why the semantic features of alpha-character patterns cannot be uncovered by a similar horizontal scanning technique to the one used

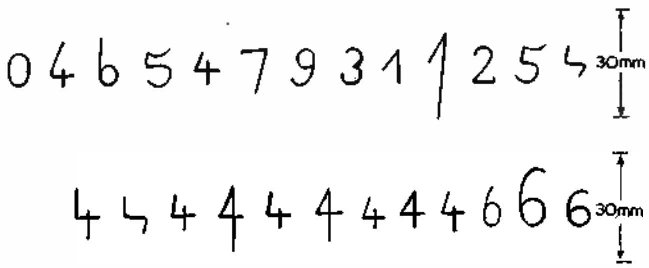


Fig. 5. Examples of figures recognized by scanning
(Sprick and Ganzhorn)

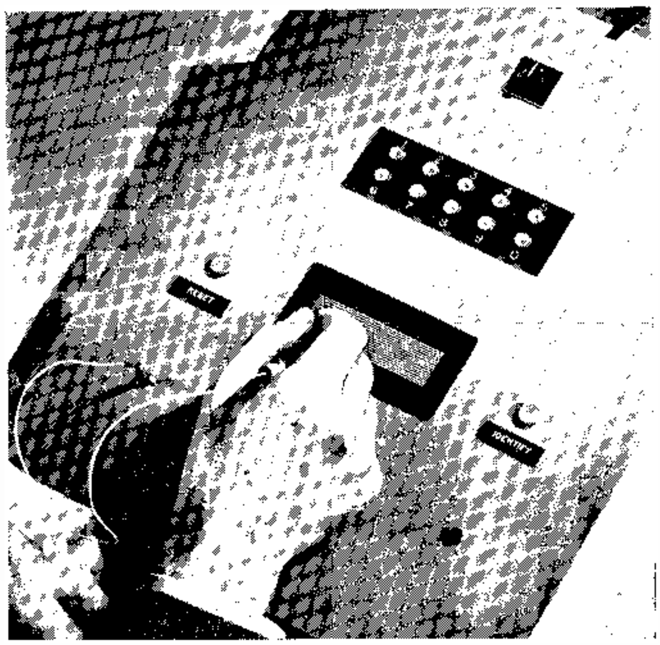


Fig. 6. The Bell Telephone Laboratories 'handwriting reader'

for numerals. Considerable difficulties have, however, been caused by poor quality print, smudges and specks, and these are particularly important problems to solve when using a fast contour-following technique. The general principles of this character recognition system are founded on some careful fundamental research into character shapes, and it may well form the basis of one of the first versatile character recognition machines.

A recent development by Bell Telephone Laboratories (Fig. 6), although not a character recognition machine, is interesting in that it identifies any of ten handwritten words, corresponding to the decimal integers. It does not identify individual characters, but recognizes each complete numeral word by sensing the spatial and temporal patterns of contacts made between a stylus, held by the writer, and a special writing surface. This surface consists of fifteen narrow horizontal metal bars, interspaced with insulating strips. The central horizontal one-third of this surface is outlined by two brass bars among the other thirteen bars that are made of copper. It is essential that the main middle portions of character shapes be written within this central one-third of the writing space, and that normal upper and lower extensions to character shapes as, for example, in

t and g

respectively, and dots above "i's," be carefully written, above or below this central area.

With handwriting specially suited to the purposes of this device, the identification of only four pattern features would be sufficient for the recognition of the ten numeral words. Two further features are incorporated, however, to allow for some of the extensive variations in people's handwriting. From these six pattern features,

zero

for example, is recognized by its lower left extension, and

seven

by more than a limit of nine crossings of a central bar of the writing surface. Using only six pattern features, it was possible for the machine to recognize more than 97 per cent of 1 000 words, written by twenty different persons.

It is claimed, for this equipment, that some of its principles may be extendable, in conjunction with certain others, to the design of a more generalized reading device. While, however, the basic principle of elementary Gestalt pattern perception may function adequately with a small vocabulary of ten words, it seems most unlikely that it could be satisfactorily applied to more than a fraction of, say, a small Basic English vocabulary. In any event, the inability of this equipment to recognize words after they have been written, and without actually following the writing of them, is a disadvantage that makes it unsuitable for many e.d.p. systems.

A certain amount of work is being done in the United Kingdom, as in Germany and the U.S.A., of a rather more fundamental and advanced nature than most of the projects so far discussed. Special attention is being paid by several workers to the reading of handwritten characters, and, in this connexion, a number of studies are being made of pattern discrimination, both in animals and human beings. Much valuable information is coming to light, from a variety of research sources, which, when pieced together, gives an increasingly clearer picture of the principles involved in the human and animal processes of pattern discrimination and recognition. For instance, it is now well established that the human eye, when, as far as its owner is aware, it is looking steadily at (or 'fixating') a particular part of an object, is in fact making rapid omnidirectional movements, of three different kinds and of different average frequencies, which, in effect, 'scan' the part of the object fixated. In a different field of research, the behaviour of the octopus, when confronted with various shapes that it has been taught to recognize, has revealed abilities to discriminate better between some of the shapes than between others. Analyses of the details of these and other experiments, along with the discussions and conclusions reached by the workers concerned, constitute a most valuable source of information in this field.

Despite the large quantity of research work that is being undertaken, however, most of it is concentrated around problems of sensing, filtering, and high-speed sorting of scan data, and too little attention is being paid to the fundamental semantic features of character patterns. It is the aim of this article to offer an introduction to this particular aspect of automatic character recognition, and to show that, by an analysis of the semantic features and limits of character patterns, definitions of characters can be formulated that are particularly amenable to translation in terms of discriminatory logic. In a later article, it is hoped to give details of some logical circuits particularly suited to this form of analysis, as applied to the design of a versatile character recognition system.

The Semantic Features of Character Patterns

One of the first steps in the design of automatic character recognition equipment is to determine what minimum sets of data would be needed to discriminate, with reasonable certainty, between one character and another. The complexity of this depends on, among other things, the number, shape and size of the different characters that are required to be read.

Normal typescript, for instance, usually consists of a number of discrete characters, the shapes of which, within any one semantic group (e.g. of different 'E's or different '2's), are restricted to a few capital and small-character variations. For example, a capital 'A' is always of the same general shape, even although small differences, such as asymmetries, as in

A

or horizontal extensions to extremities, as in

A

may occur. Small typed 'a's, on the other hand, have two common shapes,

a and ɑ

Differences also occur between the shapes of semantically equivalent characters of different languages, e.g. as between the English and the Continental

7 and 7

but these again are confined to a comparatively small number of variations. Handwritten capitals and script, on the other hand, have very many more variations; but, since their characters have equivalents in typescript, the principles of pattern formation must be essentially the same. Similarly in longhand, which is the most variable form of writing in nearly every language, a comparatively small number of pattern principles exists each of which has equivalents in the pattern principle of other kinds of handwriting and typescript. Eccentric handwritten or typescript characters, such as in

H and A

are of infinite variety, but must still conform to a small limited number of pattern principles.

Thus it may be seen that the core of the problem of character discrimination lies in an analysis of the common features of different character-patterns and type-faces of the same semantic order (i.e. that enable them to be used according to the same rules). These sets of common features will be referred to as the *semantic patterns* of characters.

There is a natural tendency, when studying character patterns, to concentrate most of one's attention on the actual appearance of characters. But one may look at them for a very long time, and, as likely as not, be almost overwhelmed by the infinite variety of possible shapes that have the same semantic content. It is frequently helpful, therefore, if one reflects carefully on the way one forms or writes these characters, and tries to determine exactly what differences in these patterns one would guide one's hand to write. If one does this, several important semantic features of character patterns soon become apparent:—

(a) The relative changes of direction of character lines.

(b) The relative lengths of character segments.

(c) The frames of reference of individual characters.

(d) The constituent shapes of normal characters.

(e) The orientations of characters.

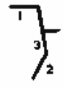
(f) The proportional proximities and continuities of lines.

(g) General legibility.

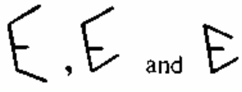
(a) Every character, with the occasional exception of modern small 'L's and small 'I's, and some handwritten and printed numeric 'I's, incorporates at least one significant change of direction in its constituent line track. The direction in which these changes are permissibly written, depends upon the relative direction of the other constituent line segments of each character. Given one line segment, orientated within the limits of a normal character, the rest of the character can be built up on it, subject to limitations as to the sign of the Δx and Δy element of the changes in direction relative to the axes set by the direction of the original line segment, and the relative lengths of the limbs (see paragraph (b)). Thus

could be developed into

for an 'E', but not into

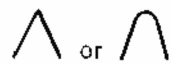


in which 1 and 2 are x-negative with respect to 3, and should be x-positive. But the segments 1 and 2 *could* be in almost any direction *x-positive* to 3,



for example, are all just readable as 'E's. A limit is reached as the Δx-element, with respect to 3, approaches zero, with Δy negative or positive. Abrupt changes of direction of character lines, as in crossed lines, are usually essential semantic features of the character, although they can be only partial or apparent, as for instance in

An 'A' would not, however, be recognizable if it were completely without a horizontal bar, e.g.



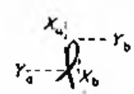
In longhand, the rates of change of direction of constituent lines of characters are almost more important than in typescript, because there is no fixed frame of reference (see paragraph (c)), and because longhand writing consists essentially of one continuous succession of alterations in the rates of change of direction of lines. The longhand word

for example, involves more than a dozen figure alterations of this kind, as indicated:—

Without these alterations in the rates of change of direction of lines, the semantic patterns of characters would not exist. This matter will be studied in more detail further on, when an attempt will be made to define the semantic pattern of a character.

(b) The importance of the relative lengths of constituent lines, or segments of characters, is easily demonstrated. If, for instance, the length of the uppermost horizontal limb of a capital 'E' is 4 x-units, and the length of the centre horizontal limb is 2 x-units, it is almost impossible to recognize the character if the length of the lowermost horizontal limb is 1 x-unit, as in

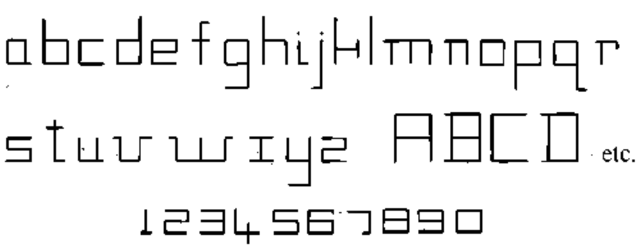
In fact it is then an 'F'. In handwriting, similarly, the x and y lengths of predominantly x- or y-directed segments must be within certain normal proportions relative to each other. In



for instance, the value of $(Y_b - Y_a)$ must be proportionately greater than the value of $(X_b - X_a)$, otherwise the 'L' may become a badly shaped longhand 'O', or a small 'E'. (It can, of course, become an 'E' anyway, due to the height of the character in relation to the height of its adjacent characters; this is referred to in paragraph (h)).

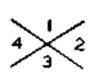
(c) In typescript, the frame of reference remains the same for each character of any one type-face. In handwriting, however, the frame of reference is set and re-set, successively, by each part or segment of a character as it is written, and is usually not the same for any two samples of the same character of any one person's handwriting. Thus, while it would be comparatively simple to arrange for a minimum system to discriminate between several semantically different characters of one or more given typeface, it would be impossible to use the same system to discriminate between the corresponding handwritten characters (unless, of course, they were very carefully drawn).

(d) Although alphabetic and numeric characters could be legibly written as constituted either by curves only, or by straight lines only, both curves *and* lines are normally essential parts of character shapes. An example of an eccentric, completely 'square', alphabetic and numeric system is given below.



In this system the 'K' is almost unrecognizable without its obliques, and the elements of the pairs 2 and z, 5 and s, 9 and g, 8 and capital B have to be distinguished by some device, such as using double thick lines for the bottom horizontal elements of the numerals. Oblique or uniformly sloping lines can, however, take the place of curves, without eccentricity, and in fact it is simpler, with some character recognition systems, for curves to be translated first into series of successive obliques.

(e) The orientation of characters is, as a rule, extremely flexible. Some characters have stricter limitations than others, however. An 'A', for instance, can be recognized as an 'A', whether on its side or upside-down. A modern 'U' with no tail, however, has four values, according to its orientation within the approximate limits of a flattened 'X';



In sector 1 it is a 'U'; in sector 2 it is a 'C'; in sector 3 it is an 'n', and in sector 4 it is the logical symbol of implication. As a rule, however, handwriting and typescript can be very tilted up to a point approaching the horizontal, and still remain legible.

(f) The proportional proximity of points, lines, and ends of lines can be a very significant semantic feature. For instance,

C and O

have the same distance between the ends of their constituent curves. But, since the relation of the size of the gap to the height of the first character is different from the relation of the size of the same gap to the height of the second character, the first is clearly a 'C' and the second could be an 'O'. Similar significant disproportions in the proximities of lines and end of lines occur between '13' and 'B', and between 'H' and 'A', e.g.,

13 and B ; H and A

The importance of proportional proximity of points, particularly in connexion with scan-data analysis, is very clearly demonstrated by some patterns used in an experiment of Wertheimer's referred to by Woodworth[5].

In Fig. 7(a) the hexagon shape is clear, but in Fig. 7(b) it is obscured, due to the equivalent proximities of other similar spots. In Fig. 7(c) an outer and inner hexagon becomes apparent due to the difference in the proximities of spots in the outer and inner shapes. In Fig. 7(d) and Fig. 7(e) one notices, introspectively, a tendency to group the spot-shapes according to shape and proximity. In Fig. 7(f) one recognizes a tendency to group spots of the same continuity.

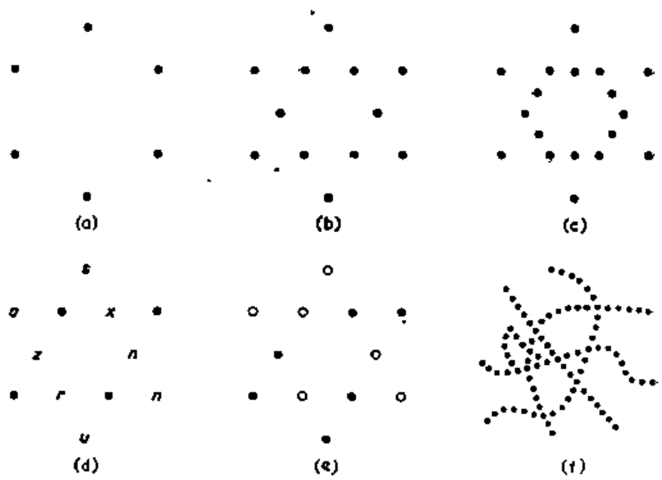


Fig. 7. The importance of the proportional proximity of points

(g) Other factors of character legibility are due to such things as adjacent characters, word or sentence context, line thickness, ink-continuity within character lines, and comparative brightnesses of character and background.

Some character patterns are recognizable completely dissociated from any adjacent characters or any word or sentence context. There is a considerable amount of experimental data available on this matter, some of which is referred to by Woodworth[5]. Frequently a misprinted character, within a meaningful word, passes undetected, if it is at the middle or the end of a word, but is usually noticed at the beginning of a word. In nonsense words (handwritten or typescript) letters at either end are better read than those at the middle. Wagner, for example, obtained the following results with these three nonsense words (selected from a large number used), read by an observer in an exposure time of 100msec.

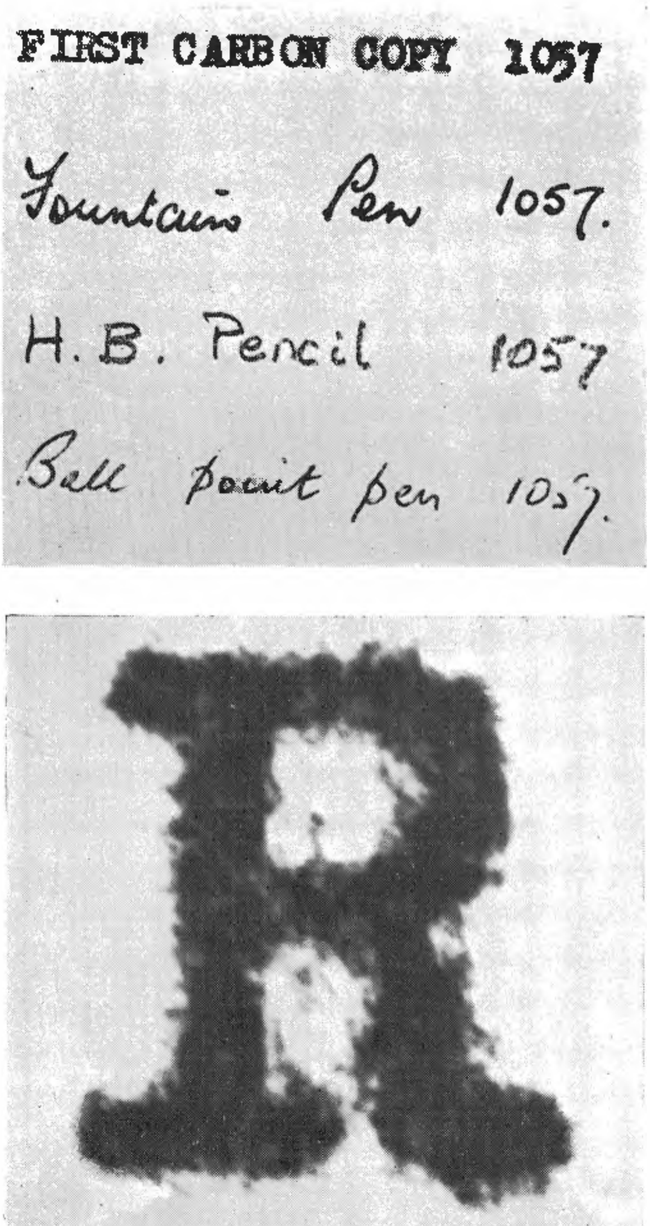
Letters Exposed	*Letters Read*
Lnzdwrrtschnfts	Lzdtschfts
Frghnwlyrhpnjam	Fhnwyjm
Varwczhukzcwpot	Vawhuzkpot

In shorter nonsense words, written in capital letters, all the characters were nearly always read accurately, suggesting that the general shape of words has some definite part in the human character recognition process. Since the whole nonsense word is of approximately uniform external shape, it means that every character would have to have been individually recognized.

Adjacent groups of characters are also important features of legibility, particularly where the groups are familiar to the reader. In some instances, familiar groups of characters can assume greater importance than the overall shape and details of the words in which they occur. An experiment was conducted by Wilkins in which some sets of pseudo-words were exposed to an observer, each for a period of 50 to 100msec. In every instance the observer transposed the last syllable(s) of the lower word of the pair observed, so as to become the last syllable(s) of the upper word; and the last syllable(s) of the upper word were transposed to become the last syllable(s) of the lower word, thus:

Words Exposed	*Words Read*
Talder	
Powcum	Talcum Powder
Davfield	
Copperid	David Copperfield
Psychment	
Departology	Psychology Department
Woodson	
Wilrow	Woodrow Wilson

Fig. 8. Slightly enlarged typewriting and handwriting and (below) greatly enlarged typewritten character



Line thickness, line homogeneity (Fig. 8), blurring and smudging of characters, and comparative background brightnesses, while affecting the discrimination of semantic patterns, do not, in themselves, constitute any essential semantic features. In so far as they affect the presentation and sensing of patterns, special techniques are required to minimize their influence. (Since any worthwhile discussion of these techniques would constitute an article in itself, no attempt is made to survey them in this present article.)

Semantic Definitions of Character Patterns

Having discussed some of the essential semantic features and limits of character shapes, it will now be possible to form *semantic pattern definitions* for each semantic class of character. In order to do this, it is essential to consider all the semantic features and limits in connexion with each semantic class of character. This can, perhaps, be most easily achieved by systematically deforming each character in all possible combinations of ways. The deformed characters can then be checked for their intended semantic content by ensuring that at least a few persons, chosen at random, can recognize them, either isolated or in comparison with adjacent recognizable characters. Since it is impossible within the scope of this article to do more than introduce this technique of systematic deformation, the necessarily brief discussion will be con-

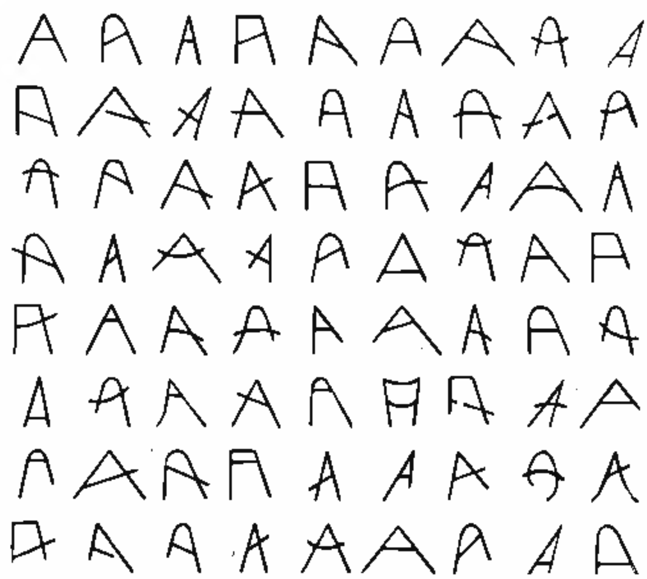


Fig. 9. Variations of a recognizable letter 'A' using a uniformly thick line and no 'frills'

fined to an application of this technique to one character of one class of writing, namely to the normal typescript capital, and the handwritten block-capital 'A'.

A selection of combinations of shapes and lengths of segments, of various styles of capital 'A', using only a uniformly thick line, and no 'frills", is shown in Fig. 9. It indicates what a very large number of such combinations are, in fact, recognizable as 'A's within the context of character recognition. For instance,

is reasonably recognizable as an 'A' within this context, but would not be if it were outside it. In this particular case the semantic limit is reached when the two legs below the horizontal bar are so small as to be unappreciable by a sensory scan or matrix, or as to be disallowable by recognition logic. Similarly,

approaches the limit of recognizability but, within the context of characters, is still recognizable as an ' A '.

The degree of freedom in orientating the character in relation to the horizontal, without prejudicing its legibility, is, at first sight, surprising. The vertical axis of the ' A ' can be as close as 25° to the horizontal, without making the character unrecognizable. On the other hand, it appears to be essential that either the cross-bar or the line joining the two ends of the main shape of the character, is nearly horizontal, if the character is to remain a sloping ' A ' and not become a ' D ', for instance.

The proportion of the segments below and above the horizontal bar on one side of the ' A ' to the lengths of the same segments on the other side is not very important, and is subject only to broad limits. Similarly, the proportions of the lengths of the upper segments to the lengths of the lower segments is not important, subject to the condition that the overall lengths of the left- and right-hand limbs are approximately the same. If, however, one limb is twice as long as the other, it is important that the upper and lower segments of the shorter limb are of approximately the same length. For example, the asymmetrical ' A ', in Fig. 10(a), approaches the limit of recognizability because, since one limb is considerably longer than the other, the lower segment of the shorter limb is too small in proportion to the upper segment. If the length of the lower segment of the shorter limb is increased by raising the horizontal bar (Fig. 10(b)), or by lengthening the shorter limb (Fig. 10(c)), the legibility of the character will be seen to increase.

Fig. 10. Demonstrating the importance of the proportion of the segments

It is noticeable, however, that the legibility of the asymmetrical ' A ' appears to be greater after it has had its shorter limb lengthened than when the horizontal bar is lifted. Furthermore, if the bar is extended much further than half-way up the shorter limb, as in Fig. 10(d), legibility decreases again; whereas, if the shorter limb be lengthened further still, legibility increases. This is a characteristic to be expected, since, by lengthening the shorter limb (or by shortening the longer limb) the character shape is tending more toward its normal shape; but by displacing the horizontal bar beyond a position between about two-fifths and three-fifths up the length of the shorter limb, the normality of the shape decreases.

The capital ' A,' then, has a kind of ' legibility norm'. In fact, each character from each class of writing has such a norm, and any definition of basic character shape must include the principles of this norm and, at the same time, allow for a margin of reasonable deformation. This definition is termed the semantic pattern of a character.

From this discussion of some of the principles of shape of a capital ' A ', and from a careful study of the various shapes and of their relative limits of legibility, it is possible to draw up a set of such principles which covers any reasonably legible occurrence of this character. For example, a block-capital ' A ' might be defined as consisting of:

> A curve whose single concave aspect faces more y-negative than in any other direction, whose lower extremities are clearly separate, containing a line (or bar) whose mean orientation is not more than 45° to the horizontal; such that both extremities of the curve extend beyond both ends of the bar, or of the bar produced; such that either the bar or a straight line joining the extremities of the curve is orientated at an angle not greater than 45° to the horizontal; and such that neither main limb of the curve is less than three-quarters the y-length of the other.

This is not a completely comprehensive definition, but it covers most of the reasonably legible and reasonably proportioned 'A's that have been illustrated. Nevertheless, the definition is far more comprehensive than is necessary, for it is not anticipated that automatic reading equipment will be required to read such a wide range of ' A ' shapes. The handwritten characters that are to be read will be written reasonably simply and conventionally*. Within this limitation a broad range of character shapes is still possible.

The definition given may, therefore, be reduced to read as follows:

> A curve whose single concave aspect faces more y-negative than in any other direction, whose lower extremities are clearly separate and approximately level, containing an approximately horizontal line such that both lower extremities of the curve extend beyond both ends of the line, or of the line produced.

It will be found that this definition covers almost all reasonably well-formed typescript capital ' A 's and handwritten block-capital ' A 's, and allows for a considerable measure of variety in slope and proportion. The definition provides, in fact, a connotation of the semantic pattern of any standard typed capital ' A ', and of any normal handwritten block-capital ' A '. Similar definitions can be provided for all other characters of any given class of writing or typescript, and they form a basis upon which the logic of a versatile character recognition device may be designed.

Acknowledgments

The author wishes to thank Dr. W. Sprick for providing details of his work in this field, and the National Cash Register Co. Ltd for permission to publish this article. Acknowledgments are also due to the various firms mentioned in the text for supplying information and illustrations.

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** It is important to remember this point. Automatic reading machines are not going to be required to read really badly written characters. Part of the greater accuracy and efficiency of e.d.p. systems lies in the work of the persons among whom it operates. (This is not to say, however, that reading machines have not got to be able to read any badly formed characters).*

The Characteristics and Applications of Corona Stabilizer Tubes

By E. Cohen*, and R. O. Jenkins*, A.R.C.S., D.I.C., Ph.D., F.Inst.P.

The corona discharge used for voltage stabilization takes place in hydrogen between a cathode cylinder and an axial wire anode. Apart from thermal effects which become significant in higher voltage tubes the discharge behaves approximately as a constant voltage in series with a resistance. These two parameters depend on the electrode radii and the gas pressure. The characteristics of tubes with subminiature, B7G and B9A envelopes covering a range of 350V to 7kV are given. The tubes are suitable for operation in circuits supplying currents in the range of 0·02 to 1mA and various applications are outlined.

(Voir page 61 pour le résumé en français: Zusammenfassung in deutscher Sprache Seite 65)

It is only of recent years that the potentialities of the corona type gas discharge for voltage stabilization have been realized. Glow discharge tubes have been used for this purpose for a very long time, and the voltage reference glow tube has become a standard circuit component. In view of the relatively recent development of tubes employing the corona type of discharge, their characteristics and properties are considerably less familiar to circuit engineers. It is the purpose of this article to give details of the properties and performance of some of these tubes so that they can be considered when choosing stabilizing methods.

The Corona Discharge and Some of its Properties

Corona discharges take place between two electrodes in a gas when the electric field adjacent to one electrode is very intense. This results in electrons near that electrode being accelerated sufficiently to ionize the surrounding gas by collision. The electrons released continue the process, thus building up an avalanche of charge. A visible glow may be seen, localized round this electrode in the form of a thin sheath. The conditions for a corona discharge can be realized by making one electrode either in the form of a thin wire or a point, and this electrode may be made either positive or negative with respect to the other. For the purposes of voltage stabilization one electrode is usually a wire carrying a positive potential, along the axis of a cylindrical cathode. When once the electric field is strong enough for ionization by collision to take place, the glow forms adjacent to the wire. The positive ions released, which move much slower than the electrons, escape from the sheath and drift relatively slowly out towards the cathode where they are collected. The form of the discharge is shown diagrammatically in Fig. 1.

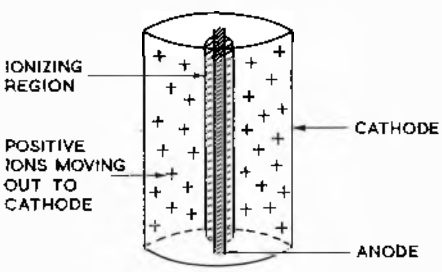
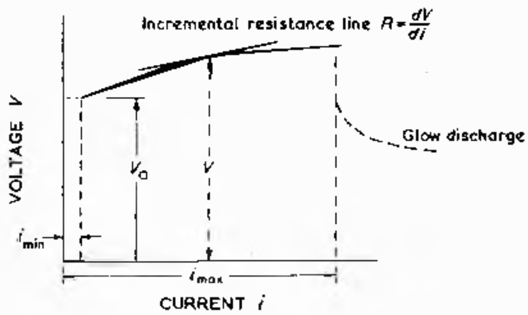


Fig. 1 (left). Diagram of the discharge

Fig. 2 (right). Voltage-current characteristic



This cloud of positive ions forms a space charge which limits the current flowing through the tube. Seen from a circuit point of view, the space charge behaves approximately as a resistance in series with the main voltage drop which occurs in the ionized region near the anode. The resulting current-voltage characteristic is shown in Fig. 2. As the current through the tube is increased, the outside of the ionized sheath moves towards the cathode and the effective impedance of the ion space charge tends to drop, until finally it approaches zero. When this happens the discharge undergoes a sudden change to the glow type. In this discharge the visible glow stretches from one electrode to the other in the form of a localized pencil, while the voltage drop across the tube decreases suddenly. This discontinuous change sets a definite upper limit to the current which can be passed through the tube with the required stable voltage characteristic.

The gas generally employed in the corona stabilizer tube is hydrogen, which is found in practice to be the most suitable. In a given electrode design it has the lowest effective impedance of any gas, and also carries the highest current in the corona discharge mode. It may be seen that the operating voltage of the tube depends mainly on the voltage drop in the ionized sheath. At a given current, the voltage across a tube of particular dimensions is a function of the gas density in this sheath, and to a first order approximation this is proportional to pressure. The voltage for a given electrode system can therefore be varied by altering the gas filling pressure, and Fig. 3 shows a typical curve of the relationship of voltage with pressure. Variations of the gas temperature with current also take place, and while they have a considerable effect on the apparent effective impedance of the tube in the circuit, the effect on actual operating voltage is small compared with that of gas pressure.

This dependence of voltage on gas pressure alone contrasts with the conditions in a glow discharge tube where the voltage also depends very considerably on the activation of the cathode surface. It will be seen that if the voltage of a corona tube is to remain stable during life the gas pressure must remain constant. As hydrogen can be absorbed

* *Research Laboratories of The General Electric Company Limited, Wembley, England.*

by many metals, it is essential that the electrode materials are chosen carefully and given a controlled surface treatment to minimize the 'clean-up' of hydrogen. The tubes are always operated for about 100 hours to stabilize the gas pressure before final measurement. A typical curve of operating voltage against time for a G.E.C. type S.C.1 1kV tube is shown in Fig. 4 showing the stability during the ensuing life of the tube. While the detail characteristics of various types of tube are discussed in the next section it may be said here that if the electrode diameters are small enough to be fitted into B9A bulb it is possible to cover a voltage range of 350V to 7kV without exceeding atmospheric pressure for the gas filling. Such tubes with 60mm long bulbs will pass currents of the order of 1mA in the corona mode, the exact values depending mainly on the gas filling pressure.

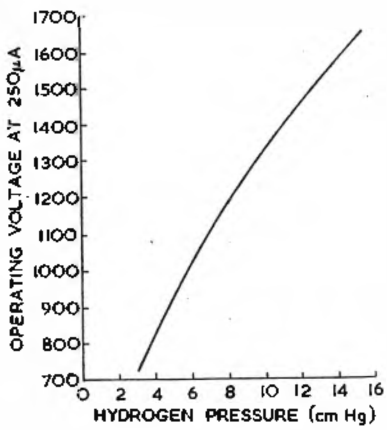


Fig. 3. Typical relationship of voltage with filling pressure

The Tube in its Circuit

Corona stabilizer tubes are used in an exactly similar manner to glow discharge stabilizer tubes except that, as they operate at higher voltages and lower currents, the series and load resistances R_S and R_L respectively are much higher. A typical circuit is shown in Fig. 5(a) and its electrical equivalent in Fig. 5(b). It can easily be shown that the stabilizing ratio dV_1/dV_2 which should have as high a value as possible is given by:

$$dV_1/dV_2 = [1 + (R_S/R_L) + (R_S/R)] \quad \ldots\ldots (1)$$

In general it can be assumed that the user will not want to lose across R_S more than a small fraction of the voltage available, and he will also want to keep the current in the external circuit R_L to a reasonably high proportion of the total current in R_S. This implies that R_S/R_L is considerably less than 1, and neglecting it in equation (1) results in the approximate formula:

$$dV_1/dV_2 = [1 + (R_S/R)] \quad \ldots\ldots\ldots\ldots (2)$$

It may be seen that good stabilization with a particular series load R_S depends on having a low value of R for the tube, while at the same time ensuring that it does not become zero at too low a current, and thus cause a glow discharge to form.

The value of R is likely to be of the order of 100kΩ depending on the voltage of the tube and the method of test. To get a worthwhile stabilization ratio the series resistance R_S is likely therefore to be of the order of 1 to 10mΩ.

The Dependence of Effective Resistance R on the Speed of Fluctuations

While the foregoing theory is quite straightforward, it is not generally realized that with corona stabilizer tubes the speed of the fluctuations of the applied voltage may affect the apparent values of R and therefore the stabilization ratio. This is due to heating in the tube. When the current through the tube is increased suddenly, the temperature of the gas in the discharge sheath rises within a fraction of a second to a higher value, giving a lower gas density locally. This results in a lower voltage than would have been obtained if the gas temperature had remained constant. Subsequently, the extra wattage dissipated in the tube due to the increased current causes the temperature of the electrode system and the gas as a whole to rise over the course of a few minutes. As the temperature rise within the electrode system is greater than outside it this lowers the operating voltage further. These effects become more noticeable with increase of the tube operating voltage. Apart from these temperature effects an increase in the temperature of the bulb as a whole due to its surroundings causes only the relatively small increase in operating voltage of about 0·01 to 0·02 per cent/°C.

For any tube three different fundamental voltage-current curves can be plotted, and appropriate values of R can be derived from their slope (dV/di). The curve giving the highest value of R is observed for fast fluctuations. The tube is operated in the circuit of Fig. 5(a) with a current meter in series with the tube and with 50 or 100c/s ripple on the input voltage. The stabilizing ratio for a particular current is measured directly from the ripple observed with an oscillograph on the input and output. The sheath temperature cannot follow fluctuations of this speed and the value of R obtained from equation (2) depends only on the positive ion space charge. This value of R will apply for ripples of frequencies at least up to tens of kilocycles. If desired, a voltage current curve can be derived by the integration:

$$V = \int_0^i R\,di + V_0$$

In practice, as fluctuations due to hum are small, this voltage-current curve is not of much significance and therefore has been omitted from the characteristics of tubes shown.

The second voltage current curve is that derived for relatively sudden variations in current through the tube. The tube in Fig. 5(a) is set at a low current and its voltage V_2 measured by d.c. meter or potentiometer with voltage

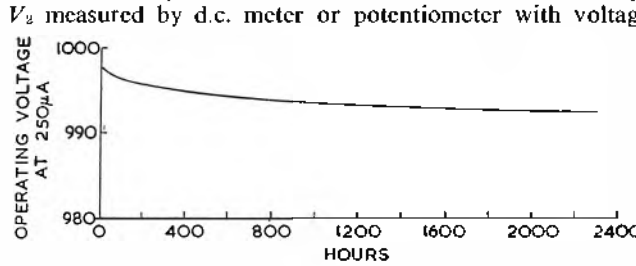
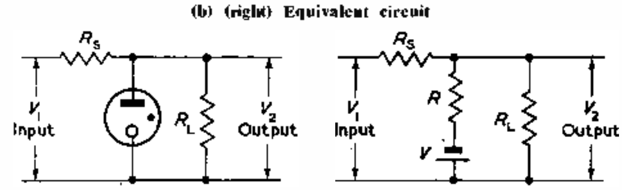


Fig. 4. Variation of voltage during life of SC1/1000 tube

Fig. 5. (a) (left) The tube in its circuit
(b) (right) Equivalent circuit



divider. The current is then quickly increased to a new value and the corresponding voltage across the tube read within a second or two. By repeating this process for other currents, making sure between each observation that the value of V_2 at the low current has returned to its original value, a voltage-current curve can be derived.

The third curve is derived by measuring the voltage after the tube has operated for some minutes at each particular current to allow thermal equilibrium to be reached. The slopes of these two current-voltage curves at any particular current will give different values of R and thus result in somewhat different stabilizing ratios. Some of these curves for various types of tube are shown in the next section. It will be seen that the value of R derived from the a.c. method is somewhat greater than that for fluctuations taking place in a second. The value of R derived from the d.c. curve may be very much lower than the latter and can, in fact, become zero or negative in some of the high voltage tubes.

Performance of Tubes

Voltage Current Curves

The performance of various tubes will now be considered in rather more detail. These tubes include the G.E.C. types S.C.1 (350V to 2kV in a B7G envelope), S.C.2. (2 to 4·5kV

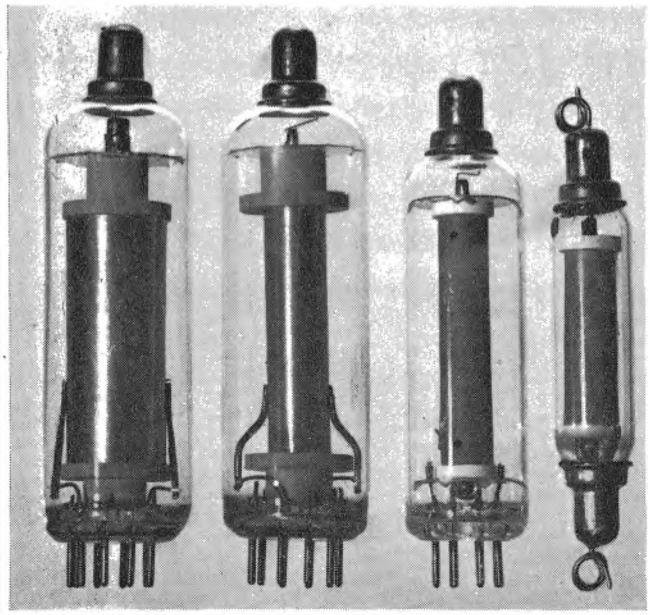


Fig. 6. Various types of corona stabilizer tubes
left to right SC4, SC2, SC1, SC3

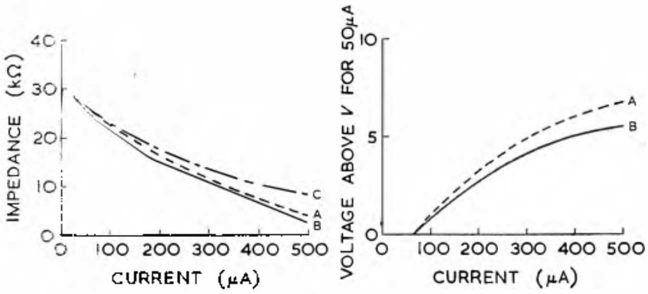


Fig. 7. Characteristics of SC1/400 tube

in B9A envelope), S.C.3 (350V to 2kV in subminiature envelope with flying leads, and S.C.4 (4·5 to 7kV in B9A envelope), all of which are shown in Fig. 6. The characteristic curves for a number of tubes in the voltage range are given. Figs. 7, 8 and 9 show characteristic curves for S.C.1 tubes operating at 400V 1kV and 2kV respectively. These curves give the three values of R plotted against tube current, measured by the three different methods described previously. It will be seen that there is little difference between the three curves for the 400V tube, but considerably greater differences for the 1kV and 2kV tubes. The value of R for the 1kV tube becomes negative for slow changes above a current of 300μA. The two current-voltage curves measured by potentiometer are also shown for each tube, one for the 1kV tube having a voltage maximum at 300μA. On Figs. 7, 8, 9, 11, 12, 13 and 14 curve A indicates fast potentiometric changes, curve B slow potentiometer changes and curve C 100c/s a.c. changes.

Fig. 10 shows the voltage current curves for all the standard voltage S.C.1 tubes plotted from potentiometer readings for fast changes. The low position of the curves for the 350 and 400V tube compared with the 600V tube is caused by the addition of a small amount of an inert gas

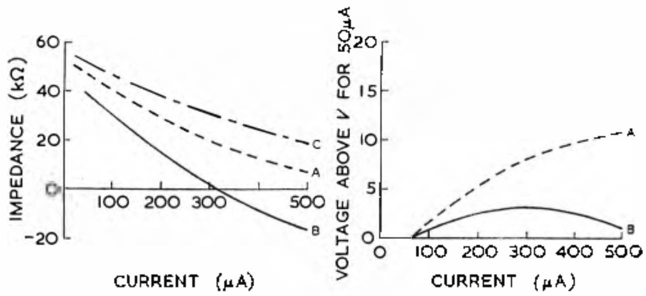


Fig. 8. Characteristics of SC1/1000 tube

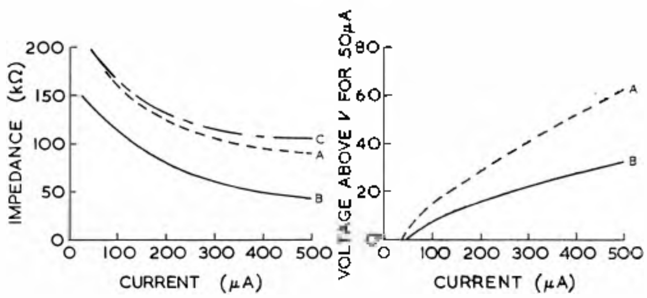


Fig. 9. Characteristics of SC1/2000 tube

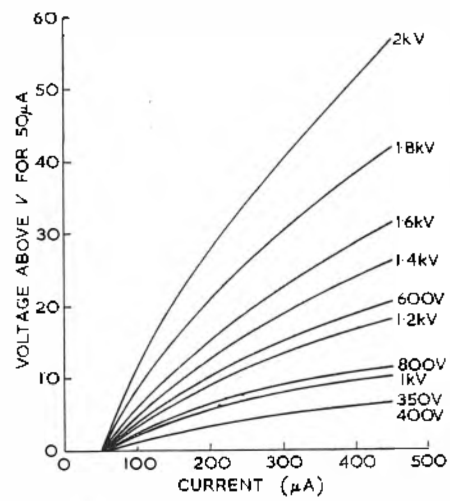


Fig. 10. Voltage-current curves for all SC1 tubes

to the hydrogen filling. This improves the overall performance of these low voltage tubes by enabling the required voltage to be achieved more accurately and also improving the stability with life.

The electrode system of the S.C.3 tubes is similar to that of the S.C.1, but slightly shorter. This results in the S.C.3 tubes having curves very similar to those for the corresponding S.C.1 tubes, but with slightly higher values of R for a given current, and slightly larger changes of voltage with current.

The corresponding curves for the S.C.2 tubes operating at 2·5 and 3·5kV respectively are shown in Figs 11 and 12. It will be seen that the d.c. voltage-current curve for the latter tube has a minimum and the value of R is thus negative at lower currents.

The curves for the S.C.4 tubes operating at 5kV and 7kV respectively are shown in Figs. 13 and 14, the latter d.c. curve showing a negative value for R at high currents. When using these curves the appropriate value of R_s would probably be chosen approximately to give the desired stabilization ratio. This would be calculated using equation (2) and deriving the value of R from the middle of the three curves for the tube with the appropriate voltage. The changes in output voltage and tube current corresponding to any particular change in input voltage or load can then be derived approximately by using the load line technique with the voltage-current curves. In these calculations the current through the tube must be kept within the recommended limits for the tube and it is therefore essential for the circuit designer to have this data.

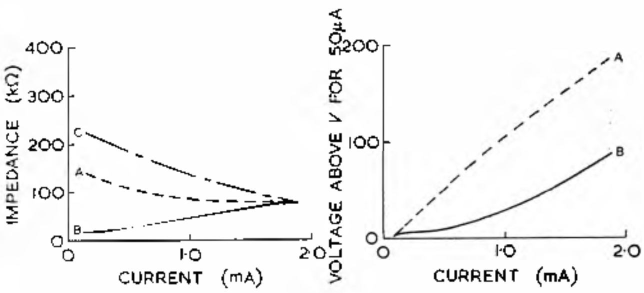


Fig. 11. Characteristics of SC2/2·5kV tube

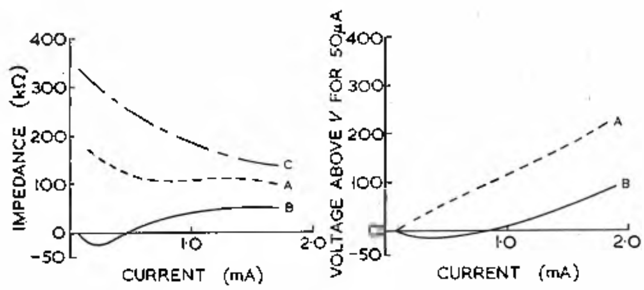


Fig. 12. Characteristics of SC2/3·5kV tube

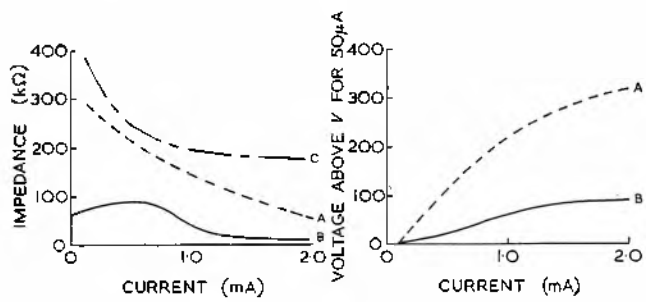


Fig. 13. Characteristics of SC4/5kV tube

Minimum and Maximum Currents

In every tube there is a minimum current below which the discharge becomes intermittent. If the voltage applied across the circuit decreases further, the discharge extinguishes. These currents are very low, ranging from a few microamperes for the lowest voltage tubes up to about 25μA for the highest voltage. This makes the tubes extremely useful for low current high voltage power packs supplying geiger counters, scintillation counters, cathode-ray tubes and similar devices, in which the tubes can be used directly as shunt stabilizers. The minimum current values for various tubes are given in Table 1.

Another feature which makes these tubes useful in supply units with only a small margin of output above what is required is that the excess voltage necessary to strike the discharge is quite small and is unlikely to exceed the voltage drop which would be present in the series resistance R_s in operation. To ensure that there are no appreciable time delays in striking the discharge even when the excess voltage available is only 5 per cent of the tube operating voltage the G.E.C. tubes contain a small quantity of thoria. This is only very slightly radioactive (some orders less than a luminous wrist watch) but it ensures that even after the tube has been kept in the dark for a long time there are sufficient ions present to start the discharge in a fraction of a second.

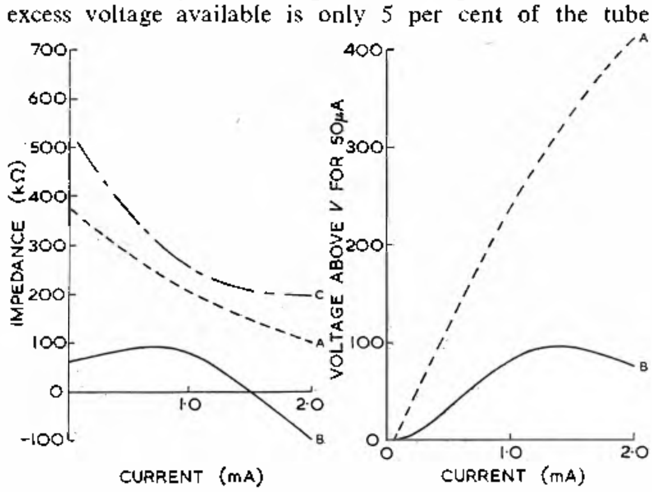


Fig. 14. Characteristics of SC4/7kV tube

The maximum current that tubes should pass is governed by the change to the undesirable glow mode, and there is a peak current for each tube which should never be exceeded. It is found that the rise in temperature when operating higher voltage tubes at currents near the peak value causes the maximum current which can be passed in the corona mode to decrease. At a somewhat lower current there is no serious lowering of the peak value. Two maximum current ratings are therefore given, one for the transient peak current which should never be exceeded, and one for the continuous current which will not seriously lower this peak value. The peak rating is about 50 per cent greater than the continuous rating in the higher voltage tubes. In the case of the S.C.3 tube the maximum steady current rating is kept low as gas clean-up increases with current, and with the small volume of gas available, undesirable voltage drifts during life could occur at higher currents. Typical values for various tubes are shown in Table 2. It should be noted that tubes cannot be operated in parallel to increase the current carrying capacity.

TABLE 1

Minimum Current for a Stable Discharge

TYPE	NOMINAL VOLTAGE (V)	350	400	600	800	1 000	1 200	1 400	1 600	1 800	2 000
S.C.1	Current (μA)	1	1	4	11	14	16	16	16	16	16
S.C.3	Current (μA)	1	1	3	7	9	11	11	11	11	11

Minimum current for all S.C.2 and S.C.4 tubes is 25μA

TABLE 2
Maximum Current

S.C.1.			S.C.3.			S.C.2.			S.C.4.		
	MAXIMUM CURRENT (μA)			MAXIMUM CURRENT (μA)			MAXIMUM CURRENT (μA)			MAXIMUM CURRENT (μA)	
NOMINAL VOLTAGE	PEAK[1]	CONTINUOUS[2]	NOMINAL VOLTAGE	PEAK[1]	CONTINUOUS[3]	NOMINAL VOLTAGE	PEAK[1]	CONTINUOUS[4]	NOMINAL VOLTAGE	PEAK[1]	CONTINUOUS[4]
350	400	400	350	350	100	2 500	1 750	1 000			
400	500	500	400	400	100				5 000	2 000	1 000
600	600	600	600	450	100						
800	600	600	800	450	100	3 000	1 750	1 000			
1 000	650	650	1 000	500	100						
1 200	700	700	1 200	600	100				6 000	2 000	1 000
1 400	750	750	1 400	650	100	3 500	1 750	1 000			
1 600	800	800	1 600	650	100						
1 800	850	850	1 800	650	100				7 000	2 000	1 000
2 000	900	900	2 000	650	100	4 000	1 750	1 000			

1. *This peak value should never be exceeded as a change of discharge mode may occur.*
2. *The S.C.1 tubes may be operated for prolonged periods at currents approaching their peak values without the peak values becoming lower.*
3. *This maximum recommended continuous current is to ensure an adequate life; operation above this current may result in excessive drift of operating voltage.*
4. *The maximum continuous ratings for S.C.2 and S.C.4 should not be exceeded for any appreciable time as this results in a serious lowering of the peak current value.*

Noise

The noise output from stabilizer tubes is of importance in some applications. While the glow discharge reference tubes generally have quite low white noise outputs, some types with an activated cathode can exhibit instability in the discharge at the cathode which gives low frequency noise. In the case of the corona tubes there are no cathode effects and only the white noise is present. This has a spectrum extending up to a few megacycles. In general the noise is highest near the discharge extinguishing point and then falls rapidly as the current is increased by a factor of about three and thereafter it decreases very slowly with further increase in current.

The white noise outputs for various tubes at a typical operating current of 200μA are given in Table 3. These r.m.s. voltage values were estimated from an oscillograph display of the 'grass' pattern. It may be assumed that the noise voltage near the extinguishing point is about three times the tabulated amounts, and that near the upper current limit is about 2/3 of it.

TABLE 3
Noise

TYPE	NOMINAL VOLTAGE	NOISE OUTPUT (mV r.m.s. measured at 200μA)
	(V)	
S.C.1	350	6
	400	7
	600	12
	800	30
	1 000	41
	(kV)	
	1·2	70
	1·4	84
	1·6	86
	1·8	85
	2·0	76
S.C.2		
	2·5	60
	3·0	60
	3·5	60
	4·0	60
S.C4.		
	5·0	125
	6·0	150
	7·0	165
S.C.3	Noise from the S.C.3 tube at 50μA will be approximately 1·5 times the values for the corresponding S.C.1 tubes given above	

One other effect which sometimes occurs at higher currents in the higher voltage tubes is a coherent output in the frequency range of 1 to 2Mc/s, caused by positive ion oscillation in the discharge.

Conclusions

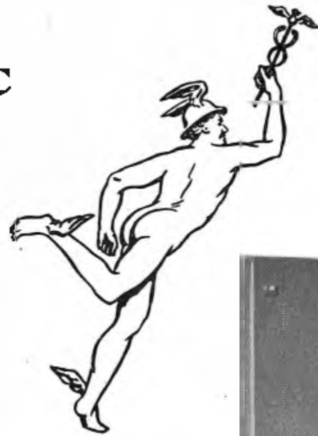
It is hoped that the foregoing description of the properties of corona discharge tubes will help the circuit engineer to realize their potentialities and to design appropriate circuits using them. The tubes are suitable as shunt stabilizers for circuits supplying currents of the order of 0·1 to 1·0mA according to the type of tube.

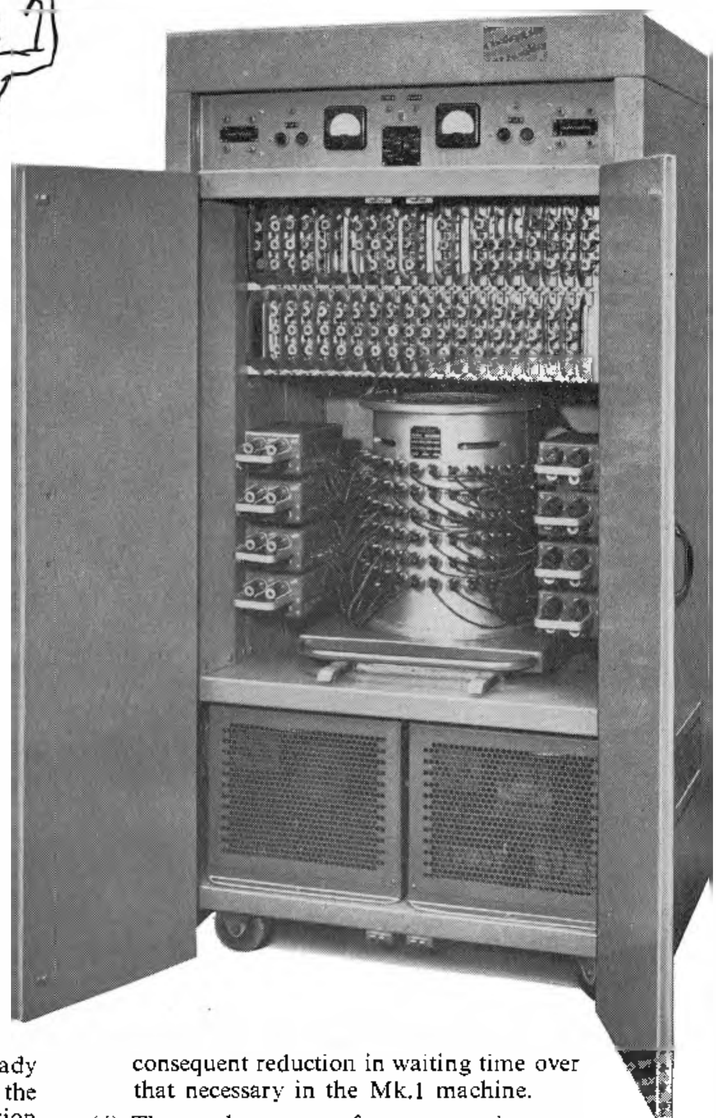
Some typical applications as shunt stabilizers are in power packs for G.M. tubes, photo-multipliers, cathode-ray tubes, or other low current devices. Tubes have also been used for specialized applications such as stabilizing the auxiliary keep-alive discharge in t.r. cells, and protection of capacitors during the initial warming cycle of apparatus. The tubes may also be used as voltage reference tubes over the available voltage range of 350V to 7kV, generally operating with currents of 50 to 200μA according to the tube type.

While tubes can be made to any voltage between the quoted limits for special requirements, a range of tubes with preferred values has been standardized. The preferred values for the G.E.C. types S.C.1 and S.C.3 are 350V, 400V and thereafter every 200V up to 2kV. The preferred 350V to 1·4kV S.C.1 tubes also have Government type numbers CV2456-2462 respectively. The preferred voltages for the S.C.2 are 2·5, 3·0, 3·5 and 4·0kV respectively and for the S.C.4 5, 6, and 7kV. The tolerance on voltage is $\pm 2\frac{1}{2}$ per cent of the nominal value except for the lowest voltage S.C.1 and S.C.3 tubes where it is $\pm$ 20V. It is possible if desired to operate tubes in series and thus to add their voltages and obtain the value required.

In conclusion one of the most important properties of any stabilizer is the stability of voltage during life. From life test data voltage changes for the higher voltage S.C.1 tubes operating at about 300μA are likely to be less than $2\frac{1}{2}$ per cent of their original voltage in 10 000 hours. Drifts are slightly greater for the lower voltage tubes. Reducing the tube current is likely to decrease the voltage changes somewhat. In the case of the S.C.3 tubes, rather similar lives are likely to be obtained, if the recommended continuous current of 100μA is not exceeded for any great length of time. It is anticipated that lives in excess of 10 000 hours will also be obtained on the S.C.2 and S.C.4 tubes.

The Magnetic Drum Store of the 'Mercury' Computer





By K. I. Turner*, B.Sc., and J. E. Thompson*

The universal high speed computer, 'Mercury', has as it main store a number of magnetic drums (up to 8 in all) capable of storing 1½ million bits of information. Each of these is housed along with all necessary circuits in a self-contained cabinet. Electronic track selection on writing and reading allows switching between tracks to be carried out in less than 20μsec. Synchronism between the drum and the computer is achieved by means of an electronic system of speed control.

(Voir page 62 pour le résumé en français: Zusammenfassung in deutscher Sprache Seite 66)

THE high speed digital computer 'Mercury' has already been fully described and some details given of the magnetic drum backing store, together with a description of the transfer mechanism. The present article is concerned with the design of this store and in particular with details of some of the circuits.

The design of the store was influenced by that of the Mk.1 and Mk.1* computers[1,2], but alterations in the system were made in order to fit it to the higher speed of the later Mercury[3]. The more important requirements to be fulfilled were:

(1) Transfers were to take place to and from a core store capable of receiving or delivering one 10 bit word every 60μsec. Drum digit times must be synchronized to the machine in order to carry out direct transfers and servo control of the drum is thus a necessity.

(2) Transfers were to take place 128 words (one page) at a time. It was decided to accommodate two of these pages on each track of the drum and to leave gaps 16 words long for any computations necessary to the control of the transfer. This fixes the number of bits of information per track at 3 456.

(3) An oxide coated drum and relatively high impedance heads were to be used. These allow electronic switching to be used both on reading and writing with a consequent reduction in waiting time over that necessary in the Mk.1 machine.

(4) The total amount of storage to be provided was to be 256 tracks or approximately 885 000 bits. These were to be divided between four drums housed in self-contained cabinets in order to alleviate troubles caused by mechanical failure of the drum.

Each drum unit consists of a free standing cabinet measuring approximately 5ft 6in by 3ft by 2ft 6in and divided horizontally into four different sections.

The bottom portion of the cabinet contains the rectifier units which provide the d.c. supplies used by the circuits of the store.

The drum is housed in the centre of the unit. To either side of it are mounted eight plug-in boxes containing the circuits required for writing to or reading from any one of the 64 working tracks.

The remaining circuits are wired on plug-in packages of the type used in the Pegasus computer[4], mounted in two rows above the drum.

The top section of the cabinet contains the circuits necessary for switching and metering the various power circuits.

* Ferranti Ltd.

The above photograph shows the complete drum unit.

The Magnetic Drum

The drum used, the type 1009, is shown in Fig. 1. A duralumin cylinder 10in in diameter and 9in in length is mounted on a steel shaft. On to the shaft and inside recesses at the ends of this cylinder are pressed two squirrel cage rotors. The ends of the shaft carry angular contact ball bearings of high precision (to Specification APEC 7). This cylinder is diamond turned in its own bearings to obtain an eccentricity of less than 0·0001in t.i.r.

This assembly is mounted vertically between the two end plates of an outer cylinder and the end plates carry the stators associated with the two squirrel cages mounted on the central shaft. The upper of these stators contains a split phase four-pole induction motor winding. This is

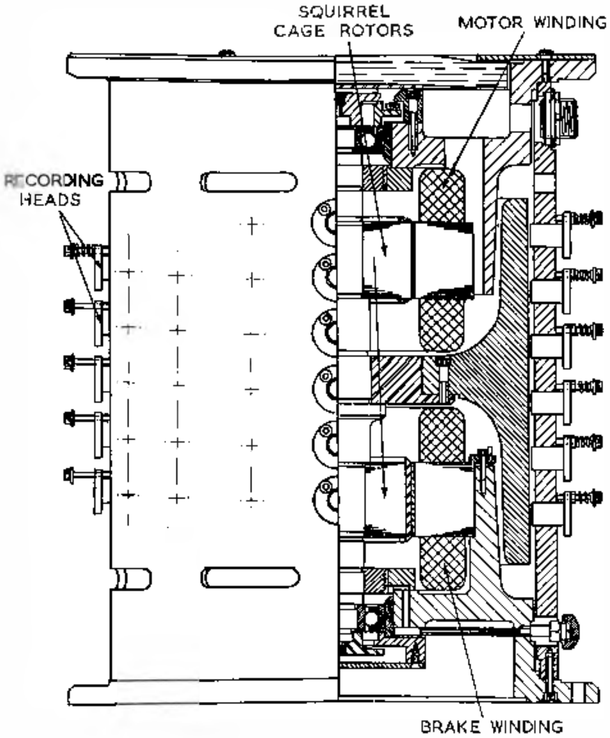


Fig. 1. The 1009 magnetic drum

used to rotate the drum, being driven by a 150c/s supply obtained from a frequency tripler of static type.

The terminal velocity of the drum when driven in this way is approximately 4 000rev/min. In order to reduce this speed to the 3 472rev/min required to run in synchronism with the computer some braking force is required. This is provided by the lower squirrel cage and its stator which contains a single two pole winding. This winding carries a direct current of magnitude determined by the servo-circuits in order to obtain the correct rotational speed.

The actual recording surface is a layer of brown iron oxide of medium coercivity which is applied in mixture with a cold setting epoxy resin by means of an ordinary spray gun.

The Magnetic Recording Heads

The outer cylinder of the drum contains a shallow spiral of holes, which serve to accommodate the cylindrical recording heads. These consist of a stainless steel casing containing the head assembly (Fig. 2).

The magnetic circuit takes the form of two specially formed ferrite cores held in position by beryllium copper springs and separated at the pole tips by an 0·002in thick mica spacer. Each half core supports a small moulded bobbin containing a winding, the ends of which are soldered to pins projecting from the base of the assembly in such a way as to produce a single read/write winding.

This assembly is fixed in the outer shell by means of an epoxy resin and the pole tips are then ground, the grinding process being controlled by a continuous inductance measurement.

Parallel with, and close to, the centre line of the head a short length of fine metal tubing is fixed. This is ground off level with the pole tips and is used with standard air gauging equipment to adjust for the correct head to drum distance of 0·0012in.

Timing

The basic drum unit frequency is 200kc/s and a sine wave of this frequency is obtained from a special track

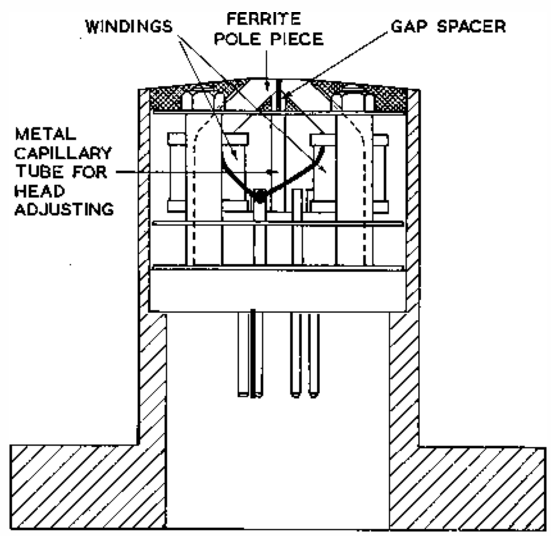


Fig. 2. Magnetic recording head with outer cylinder sectioned to show constructional details

when the drum is running at the correct speed. This sine wave forms an internal timing waveform from which the strobes necessary in forming the write and read waveforms are derived.

Apart from the fact that the easiest way of producing a timing waveform in a drum equipment is by means of a clock track there is a significant improvement in reliability to be obtained by its use. Slight fluctuations in the phasing of the drum relative to the computer, such as occur continually, cause the information track and the strobe used to convert it into digit waveforms to move together. This increases the tolerance without losing reliability of strobing.

The Writing Waveform

The phase modulation system of recording used[2] requires a waveform which consists of a square wave in phase with clock for every '0' and out of phase for a '1'.

The required waveforms are formed by the circuit of Fig. 3, some relevant waveforms of which are shown in Fig. 4.

The incoming digits ((a) Fig. 4) are applied to one grid of a long-tailed pair of triodes, the other grid being held at -5V. A negative going strobe occurring at the middle of the digit period ((b) Fig. 4) is applied to the anode of the crystal diode MR_1, allowing one of the two valves to pass current at the strobe time. According to whether a 0 or a 1 is present at the input, a 15V pulse will be formed at the left- or right-hand anode ((c) and (d) Fig. 4).

The pulses from these two anodes are applied to the two sides of a bistable trigger circuit having a counter connected input. A second strobe ((e) Fig. 4) occurring 2·5μsec after the first is applied to this counter input. There is, therefore, always an edge on the output waveform at this strobe 2 time. There may or may not be an edge at strobe 1 time depending on the state of the trigger circuit at this time.

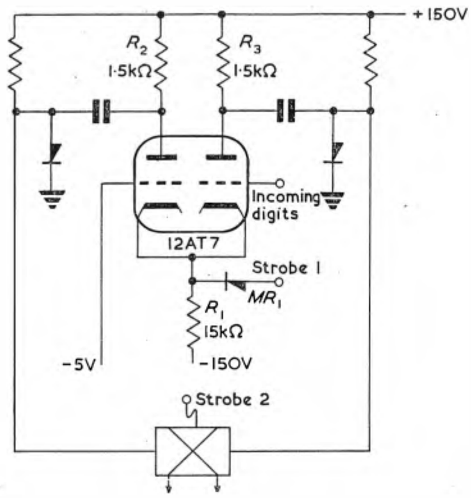


Fig. 3. The write waveform generator

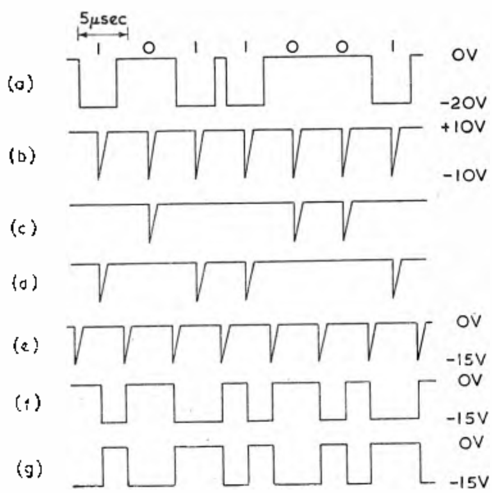


Fig. 4. Write waveform generator waveforms

The two output waveforms of the trigger circuit are cathode-followed and form the write and inverse write waveforms ((f) and (g) Fig. 4).

The Selection Systems

The required information track is selected by means of a matrix consisting of eight rows and eight columns. Each column is given physical reality by taking the form of a box mounted by the side of the drum and containing the selection circuits pertaining to eight heads.

On writing, selection is carried out by applying a positive potential to the centre taps of a number of transformers and switching on the write power amplifier valves connected to one of these activated transformers by the application of suitable waveforms to the grids.

Suppose, as an example, writing is required on head 1 of box 0. Referring to Fig. 5 the following actions are carried out:

(a) A potential of +70V is applied to the centre-tap of transformer 1. This point is joined to the corresponding point in the seven other boxes and so the centre taps of all transformers numbered 1 will be raised to +70V. All other transformer centre-taps will rise to +20V.

(b) The column selection input of the required box is taken to a slightly positive level. All other column selection lines will remain at −20V. If the box required is not isolated by switches the 'column isolation' input will be positive.

(c) Write waveform and inverse write waveform are applied to the cathodes of diodes MR_3 and MR_4 respectively.

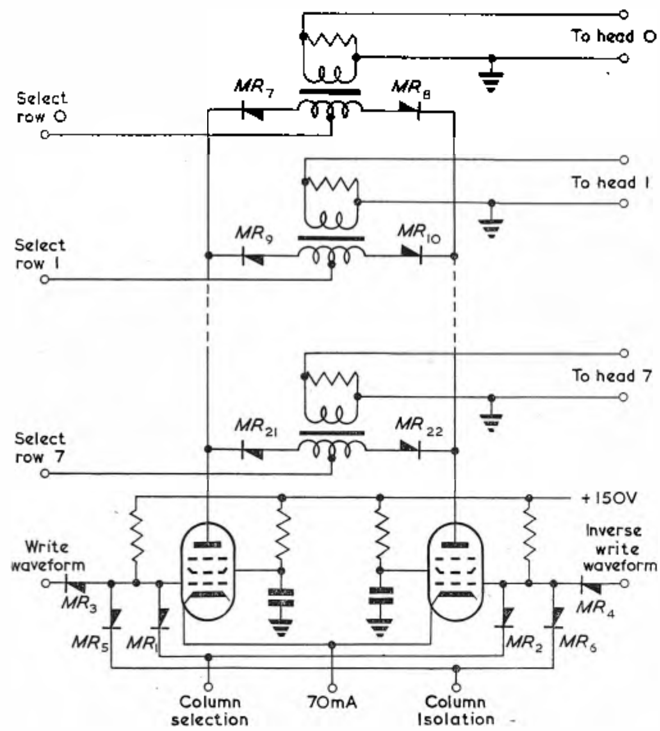


Fig. 5. Column of writing matrix

In the selected box the grids of the two writing valves will rise alternately to earth in sympathy with the two write waveforms. A current of 70mA, defined by one circuit common to all boxes, will thus flow alternately through the valves in the required box. So long as the voltage at the anodes of these valves does not fall below +20V the only diodes biased in the forward or conducting direction are those attached to transformer 1 (MR_9 and MR_{10}). All other diode pairs have reverse bias applied to them isolating their respective transformers from the valve anodes.

The current flowing through the valves thus passes through the half primaries of transformer 1 and causes the correct value of recording current to flow in the secondary which is connected to the required head winding.

On reading, selection of the required head output is carried out in two stages. A low level row selection is performed on the output of the heads, followed by a selection of the required column carried out after amplification. Both selections are made by the same system using a conventional diode AND gate.

The lower half of a matrix box contains the circuits necessary for selecting and amplifying the output of one head out of eight. These circuits are shown in Fig. 6.

In order to select, for example, head 1, the row selection signal applied to point A in gate 1 of each box is raised to +5V. All other row selection signals are held at −5V. Diode MR_2 in all unselected gates passes current and the points B take up a potential of −5V applying a reverse bias to diode MR_1.

In the selected gate diode MR_1 passes current holding the point B at earth potential and so biasing off diode MR_2. Since point B is at earth, diode MR_3 in the selected gates passes current and raises output point C also to earth, cutting off all other diodes MR_3.

Thus in an unselected gate diode MR_2 has a low impedance and MR_1 and MR_3 have high impedances. Consequently any voltage signals appearing at the head driving an unselected gate will be heavily attenuated at point B and this small signal will be further attenuated at point C by virtue of the input impedance of the OR gate formed by all the diodes MR_3. On the other hand the signal from a selected head will suffer little attenuation since, in the particular gate through which it passes, diodes MR_1 and MR_3 are of low impedance and MR_2 is not.

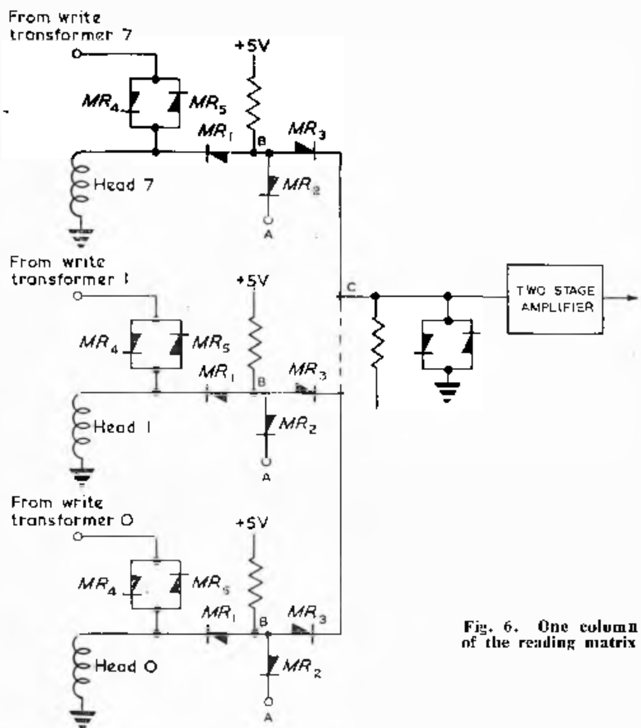


Fig. 6. One column of the reading matrix

If typical values of resistance of 500Ω forward and 500kΩ back are ascribed to the diodes forming the gates, then it can easily be shown that the attenuation of a gate which is 'closed' is of the order of 100dB while that of an open one is negligibly small.

The eight signals from the heads in the required row are amplified by two stages *RC* coupled amplifiers, one per box and the resulting 3V peak-to-peak signals are sent to one of the plug-in packages which carries a further set of eight gates, of the same form as those in the boxes, but able to work with a higher signal level. In the same way as before the output of the required column is selected. This is then amplified and strobed to form a read waveform of similar form to the incoming digit train.

Since a single winding on the head is used for both writing and reading it is necessary to join the two selection systems together at every head position. If this is done directly, the secondary of the writing transformer being joined to the input of the read gate, the transformer and its damping resistor will load the head winding reducing its output voltage to approximately half that available under open-circuit conditions.

To overcome this difficulty the two crystal diodes (MR_4 and MR_5, Fig. 6) have been added between the transformer and the junction of the head winding and the read gate. The properties of a diode pair arranged in this way are such that they present a high impedance in both directions to very small signals but this decreases rapidly to a low impedance as the signal increases. Thus on writing these two diodes present a negligibly small resistance to the writing current and so connect the head to the transformer secondary. When reading, however, the only voltage acting on the diodes is that read by the head, the magnitude of this being about 30mV peak-to-peak. Under these conditions the pair present an impedance of approximately 10kΩ to the signal thus separating the transformer from the read gate and preventing unnecessary loading of the latter.

Phasing

Due to the various delays introduced in forming the required read and write waveforms the outgoing digits are not in phase with those coming from the computer to the drum. A difference in timing of 7·5μsec exists, in fact, between the two. This difference is, however, of little consequence since transfers to and from the drum store all involve a frequency conversion between the 200kc/s of the store and the 1Mc/s bit rate of the main computer. These conversions, necessarily involve delays which are to some extent variable and provide a convenient method of bringing the read-out information into standard computer timing.

Switching Speed

The principal factor limiting the speed with which a track may be selected is the recovery time of the read circuit.

The most serious overloading occurs on writing. When writing on a head a signal of 150V peak-to-peak is present at the input to the associated read gate which is open. The signal transmitted will be limited by the voltages used to operate the gate but a signal sufficient to overload the amplifier will appear at the output.

A second form of overloading occurs when switching between tracks. When changing between read gates a change in the d.c. component of the output waveform will occur, occasioned by the varying resistances of the crystal diodes forming the gates. Voltage changes of the order of 300mV may occur due to this effect, swamping the 30mV read signal normally obtained.

In order to minimize the effect of these occurrences, a further pair of anti-parallel crystal diodes is connected between the input of the amplifier and earth in order to provide a low impedance to large signals but a high impedance to the smaller required information waveform. Further, all time-constants in the amplifier are left as short as possible in order to decrease the recovery time. By these means it has been found possible to carry out track switching or a change from writing to reading in less than 20μsec.

Synchronization

One of the requirements to be met in the design of the store was that the drum should be run in synchronism with the machine. This object is achieved by the use of a servo mechanism developed from that originally used with the Manchester University computer[5]. The accuracy required of this system is such that a drum waveform may be used to strobe an incoming waveform with a positional accuracy of less than 1/10 of a digit. This means that the drum must be at any specified position within $\pm$ 0·5μsec of the correct time. In other words, since one drum revolution occurs in 17·28msec the positional accuracy must be better than $\pm$ 0·01°.

A special track on the drum has recorded on it 288 pulses which are spaced at equal intervals round the drum. When the drum is running at the correct speed these pulses pass the reading head at 60μsec intervals and in order to determine when this is so a timing waveform of 60μsec period (the T waveform) is obtained from the computer. Any difference in timing or phase between these two wave trains produces an error signal at the input to the servo-system and consequently causes a correcting torque to be applied to the drum.

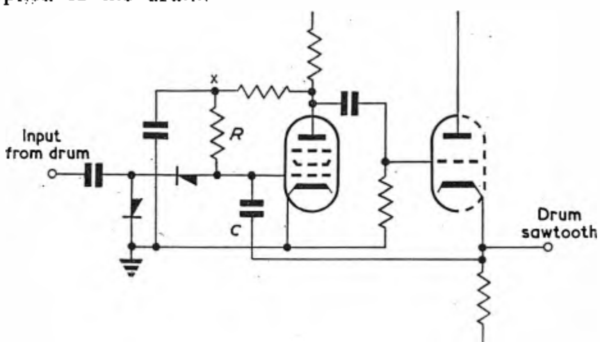


Fig. 7. The drum sawtooth generator

The pulses read from the drum are amplified and used to generate a sawtooth of frequency dependent on drum speed in the circuit of Fig. 7.

The circuit used is a 'driven' Miller integrator receiving a constant amplitude input derived from the drum. This input causes the anode of V_1 to rise by a certain amount and then to run back linearly due to Miller action of the combination of R and C. A feedback connexion ensures that for more frequent inputs the point x takes up a higher potential and so the run down becomes faster. By this mechanism a 'drum sawtooth' of useful size is obtained over the wide frequency range encountered while the drum is running up to the correct speed.

The drum sawtooth is applied to two diode clamp circuits (Fig. 8) which are opened alternately by the edges of T waveform, to provide two sampled versions of the drum sawtooth known as 'slip sawtooth' and 'd.c. level'.

T waveform is connected to the grid of one of a pair of triodes in such a way that each of them passes current for alternate 30μsec periods. The two transformers have low primary inductances, such that a voltage pulse approximately 1μsec wide is produced on switching. This pulse opens the diodes of the clamp circuits connected to the secondary and so produces at the output a voltage equal to that of the input at the time of sampling[6]. The drum sawtooth is connected to the input and so the circuits produce outputs dependent on the level of drum sawtooth at the edges of T waveform. When the drum is running at the correct speed and in phase with the computer the negative going edge of T will occur at the same time as the flyback of the drum sawtooth and the output of both discriminators will be an earth level. When however the drum is not rotating at the correct speed the lower of the two discriminators will produce a sawtooth at the difference frequency of T waveform and drum sawtooth and of a sense dependent on which is the higher frequency of the two. This waveform is known as the slip sawtooth (Fig. 9).

These slip sawtooth waveforms would also be produced by the upper discriminator but are not found in practice since the output of this circuit is integrated to form the waveform used to control the phase of the drum timing relative to the computer.

The final circuit consists of a differentiating and limiting amplifier of the form shown in Fig. 10. The output produced by a slip sawtooth input will be of the forms shown

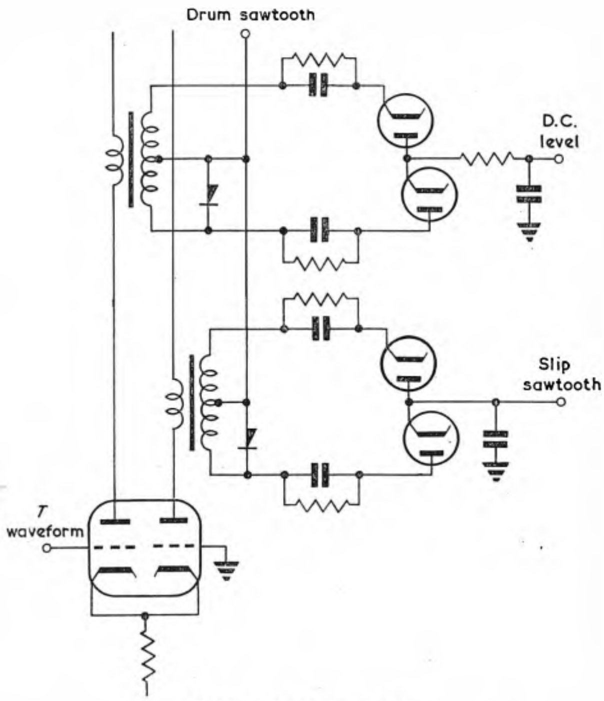


Fig. 8. The discriminators

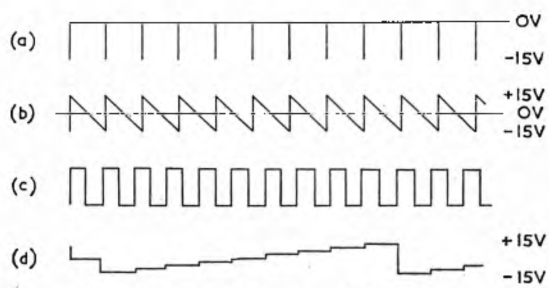


Fig. 9. Method of formation of slip sawtooth

in Fig. 11 for the two cases where the drum is running slow and fast respectively. From this figure it is apparent that the mean level of the output is negative when the drum is running slowly and positive when running fast. This output is connected by an integrating network to the grid of the valve controlling the brake current and so the brakes are held off or applied according to the speed of the drum.

The shaper circuit with the slip sawtooth input alone will bring the drum speed very close to that required but cannot achieve the required speed and phase accurately. This is so, since at the correct speed (and at any phase) the output of the lower discriminator becomes a d.c. level. Phase control is obtained by the use of the d.c. level signal obtained from the upper discriminator. This is amplified and inverted and used to provide the grid bias voltage of the shaper circuit. By this means the mean brake current is controlled at that required for the drum to run at the correct speed. It should be noted that both inputs are

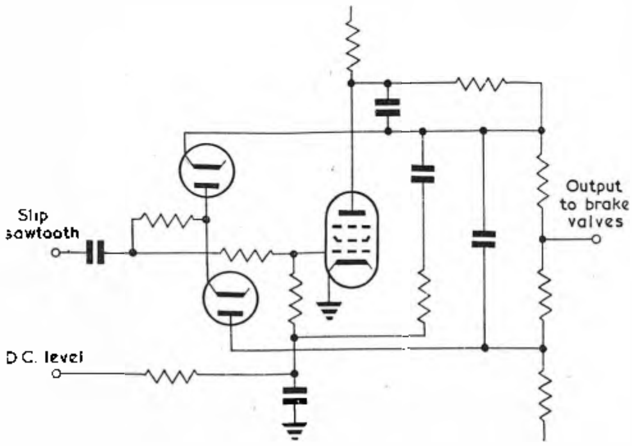


Fig. 10. The shaping circuit

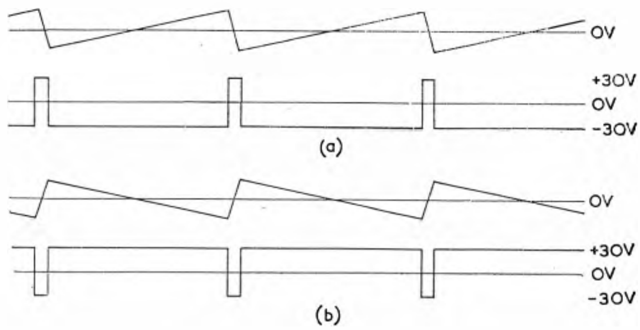


Fig. 11. Shaper inputs and outputs
(a) Drum slow
(b) Drum fast

necessary for the drum to run at this speed. The d.c. level defines the absolute phase but any attempt to move from this condition will cause a change in level at the output of the lower discriminator. This will cause an output pulse to be emitted by the shaper which will return the system to its original state.

A further input to the shaper not shown in the circuit diagram ensures that the output remains negative at all speeds below approximately 2 600rev/min. This obviates all possibility of the circuits attempting to hold the drum speed at some submultiple of the correct speed with consequent over-heating of the motor.

The average brake current required to hold a normal drum at the correct speed is approximately 35mA. This current is obtained from a special power supply in order to isolate the brakes from the rest of the circuits and in particular to prevent oscillations due to feed back between the brakes and synchronizing track amplifier.

A special circuit is provided which checks that the drum is running in sychronism and that no faults have arisen in the servo. In the event of loss of sync or a valve heater failure a signal is sent to the computer and all transfers inhibited.

Acknowledgments

The authors wish to acknowledge their indebtedness to Mr. G. R. Brooks and Mr. F. Cooper, who were responsible for the design of the drum and heads respectively, and to Mr. E. C. P. Portman of the Magnetic Drum Laboratory. They also wish to thank Mr. B. W. Pollard and Mr. G. G. Scarrott for their help and encouragement and Ferranti Ltd for permission to publish the article.

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A Crystal-Pulling Furnace

A crystal-pulling furnace has recently been demonstrated by Nash and Thompson Ltd of Chessington, Surrey, who are manufacturing this equipment under licence from the Services Electronic Research Laboratory, Baldock, the original designers.

The method for growing single crystals from a melt, in which a seed crystal is placed in contact with the melt and then slowly withdrawn through a vertical negative temperature gradient, was described originally by Czochralski and subsequently modified by Marshall and Wickham*.

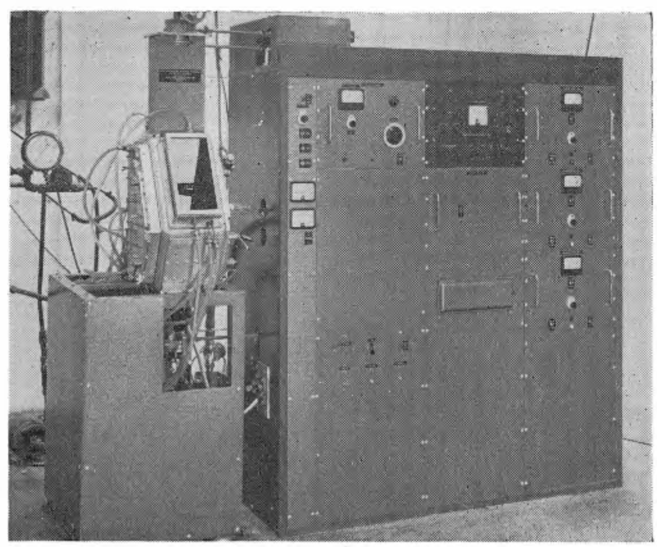
The furnace is intended mainly for high vacuum growing to reduce the difficulty of obtaining an inert gas free from harmful impurities, and the chamber is evacuated to about 5×10^{-6}mb.

Resistance heating is employed to heat the crucible and the temperature is maintained to within ± 1 per cent up to the region of 1 450°. The furnace is water cooled to reduce the working temperature on the inside faces to the region of 100°C. Two rectractable quartz doping cups are fitted to the inside of the door and are manipulated externally.

The independent rotation of the crucible and the molybdenum seed chuck and the vertical movement of the stainless steel pulling rod are achieved by Velodynes suitably geared down.

A 70g charge of silicon required approximately 5·5kW to melt over a period of some 20min and a crystal of 2cm diameter was pulled in about 45min.

The crystal-pulling furnace (left) with its associated electronic equipment for the control of temperature and rate of feed



* Marshall, K. H. J. C., Wickham, R. An Improved Czochralski Crystal-Pulling Furnace. *J. Sci. Instrum. 35*, 121 (1958).

A Transistorized Current Stabilizer for an Electromagnet

By J. C. S. Richards*, B.Sc., Ph.D.

Power transistors can be used to control large currents, but their rated maximum voltage is lower than desirable. By using an auxiliary electromechanical control system on the input to a stabilizer, this voltage limitation can be overcome. A typical unit, giving up to 4A at 200V, is described. Under normal conditions the current is stable to ±2 parts in 10^5 over an hour, and ±2 parts in 10^4 over ten hours.

(Voir page 62 pour le résumé en français: Zusammenfassung in deutscher Sprache Seite 66)

THE design of a degenerative feedback stabilizer for use with a moderately large electromagnet is made difficult by the lack of a suitable control element which will handle large currents (1 to 20A, say) with a fast response time. Thermionic vacuum valves are essentially high voltage, low current devices. Transistors available in Britain at the time of this project will pass currents up to 1·5A, but are rather limited in their maximum voltage rating (about 15V) and maximum power dissipation (5 to 10W, depending on cooling arrangements). Although large currents can be handled by connecting a number of transistors in parallel, in a simple stabilizer the voltage across the load cannot with safety be much greater than 30 or 50V, and not even as great as this if the output is to be readily variable over a wide range.

This limitation can be overcome by employing a dual control system, in which the input supply to the transistor stabilizer is automatically adjusted so that the voltage (and power) rating of the control transistor is never exceeded. Sufficient backlash is incorporated in the input control system so that it is actuated only when a major disturbance occurs; under normal conditions the performance is entirely that of the transistor stabilizer and is almost wholly independent of the input control system.

To illustrate the technique, a stabilizer designed for use with a Newport Instruments Type 'A' electromagnet (4A at 200V maximum) in nuclear magnetic resonance experiments will be described. The design may readily be modified to suit other requirements. With the rapid advance in semiconductor technology, the details of this design will quickly become obsolete. Such details, therefore, are discussed only in so far as they illustrate general principles, or are not immediately obvious.

Basic Circuit

The basic circuit of the stabilizer is shown in Fig. 1. The magnet supply is derived from the a.c. mains via a variable voltage transformer ('Variac') T_1, and isolating transformer T_2, a bridge rectifier MR_1 and a choke-capacitor smoothing system L_1 and C_1. Connected in series with the magnet L_2 and R_1 are the reference resistors R_2 and the control transistor X_1: the latter consists of five Mullard Type 0C16 transistors connected in parallel. A small (2Ω) resistor in each emitter lead ensures that the current divides approximately equally between transistors.

The operation of the transistor stabilizer is straightforward. Part of the potential drop across R_2, which is proportional to the magnet current, is compared with a fraction of the reference potential V_1, in a transistorized differential amplifier. The output of the amplifier is fed to the base of the control transistors X_1, which alter the current through the magnet in such a way as to tend to keep the potential across R_2 constant.

Three relays are connected in parallel with X_1. Two of these are used to control the reversible induction motor M_1 which drives the Variac T_1 via gearing, giving a final speed of 1rev/min. If the potential across transistors X_1 falls below about 3V, one of the relays, normally closed, opens and causes the motor M_1 to run until the potential across X_1 is about 8V, when the relay closes and the motor

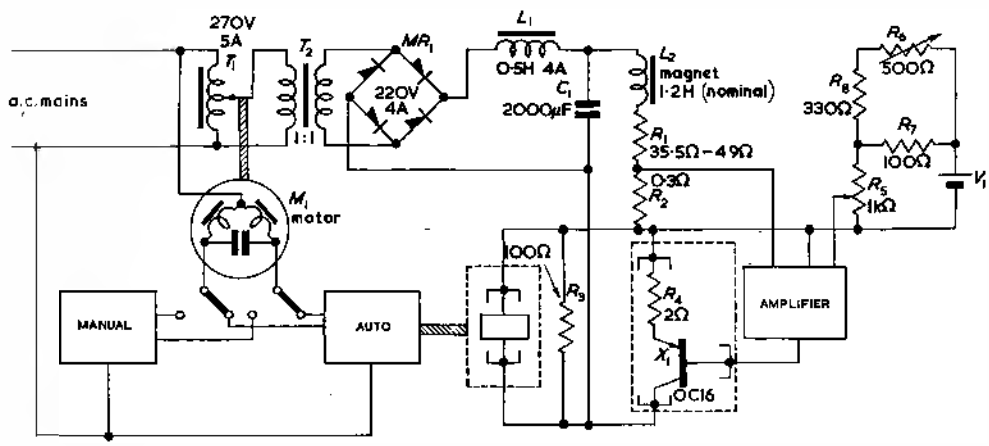


Fig. 1. Basic circuit of stabilizer
R_5 and R_6 are ten turn 'Helipots'

stops. If the potential across X_1 is more than about 12V, the second relay closes and the motor M_1 runs in the reverse direction until the potential across X_1 has fallen to about 7V. The third relay is a purely safety device and is normally actuated only if a major change in the current setting is made too rapidly. Should the potential across X_1 exceed 15V, the relay, which is of the 'lock-on' type, connects a 3Ω resistor in parallel with X_1, and causes the motor to run in the 'lower voltage' direction.

So that the magnet can be switched off without disturbing the current setting, a changeover switch S_1 gives facilities for manual control of the motor by means of push-button switches. To prevent damage to the system by careless operation, the 'lower voltage' button is of the lock-on type, but the 'raise voltage' button must be kept depressed by hand. All the motor switching is electrically interlocked so that, if the motor is asked to run in both directions simultaneously it will run so as to lower the Variac voltage.

The Transistor Stabilizer

If the highest stability is to be achieved, considerable attention must be paid to the reference resistor R_2 and the reference potential V_1, and to the elimination of drift in the amplifier. In order to keep the power dissipated in R_2 small, V_1 should be small. The lowest possible value

* *Natural Philosophy Department, Aberdeen University.*

of V_1 is determined by the drift to be expected in the amplifier; in the present design this drift is about 5μV. A 'Mallory' mercury cell is used for V_1. This type of cell has an e.m.f. of about 1·35V and a temperature coefficient of about 25μV/°C. Since a small current can be drawn from the cell without affecting the stability of its terminal voltage, it is convenient to vary the magnet current by means of a potentiometer across the cell, rather than by means of a potentiometer across the reference resistor. This former arrangement obviously keeps the dissipation in R_2 at a minimum; its disadvantage is that at low values of magnet current (<0·5A, say) any drift in the amplifier may affect the output appreciably.

The reference resistor R_2 consists of three resistors each of 0·9Ω and nominal rating 30W, connected in parallel. The resistors are wound by Rivlin Instruments Ltd, from 'Minalpha' wire which has a temperature coefficient of about 0·0005 per cent/°C.

Meters, not shown in Fig. 1, indicate the magnet current and the potentials across C_1 and X_2.

The Amplifier

The amplifier has three stages, each consisting of a pair of transistors connected in push-pull with a large common emitter resistance. Silicon transistors (type OC200) are used in the first stage to give low values of collector leakage current, and germanium r.f. transistors (type OC44) in the second to give a good high frequency response and simplify the problem of obtaining dynamic stability. Three emitter-followers (one OC71 and two OC16) in cascade are used to couple the amplifier to the five OC16's in parallel which constitute X_1. Drift in the amplifier is minimized by mounting the transistors of the first two stages in a copper block whose temperature is held constant to within ±0·1°C by an arrangement similar to that described by Kemhadjian[1]. The design of such amplifiers is fully discussed by Kemhadjian[2] and Chaplin and Owens[3].

The gain round the feedback loop is about 30 000 with the particular transistors used; with the worst transistors of the same types the loop gain would not be less than 10 000. With so large a gain, frequency response correction networks are necessary to give dynamic stability. Their design is complicated by the fact that the magnet coils are wound on brass formers which act as short-circuited turns, so that the inductance of the magnet varies with frequency; in addition stray capacitances give various series and parallel resonances, the lowest of these being at 2·5kc/s. The three stabilizing networks shown in Fig. 2 were initially calculated using the measured impedance of the magnet; the final values were adjusted experimentally to give the best response when a small step function e.m.f. was injected in series with the reference potential.

Mechanical Construction

The main consideration in layout of the stabilizer is the temperature rise of the various components. The prototype is built on an alloy ('Dexion') rectangular frame measuring about 30cm broad, 29cm deep and 150cm high, which is mounted on casters. The transformers T_1 and T_2, the motor M_1, and the rectifying and smoothing system are all mounted in the rear half of the frame, which is divided down the middle by a bright aluminium sheet. The remaining components are mounted on the back of panels on the front of the frame, these panels being hinged at one side for easy access. This gives a very good air circulation over vital components. The bottom panel is about 30cm high and acts as a heat sink for the power transistors. Spaced about 10cm above it is an 8cm panel carrying the transistor amplifier. The main panel, about 60cm high, is above this, the reference resistors being mounted at its lower end. The top panel carries miscellaneous power supplies.

To allow for possible modifications, the prototype was made unnecessarily spacious. Provided due attention is paid to cooling, its volume could be considerably reduced without affecting performance.

Performance

Changes in mains voltage of ±10 per cent, and in magnet resistance of 40 per cent, alter the magnet current by less than 1 part in 10^5. The response time, for a small disturbance, is about 1msec. After switching on from cold, the current normally drifts in the first fifteen minutes by less than 2 parts in 10^3, and in the following thirty minutes by less than 1 part in 10^4. Thereafter the drift depends mainly on ambient conditions. In a typical laboratory where the temperature does not vary by more than 1°C in an hour, the current normally remains constant to within ±2 parts in 10^5 over an hour, and within ±2 parts in 10^4 over 10 hours.

The system lends itself very well to direct control of the magnetic field via a nuclear magnetic resonance head.

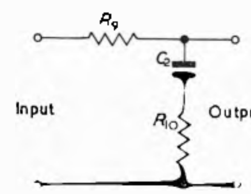


Fig. 2. Type of frequency response correcting network in amplifier

Three independent networks in cascade are used, having the following component values:

$R_9 = 3k\Omega$, $R_{10} = 220\Omega$, $C_2 = 0{\cdot}05\mu F$
$R'_9 = 3k\Omega$, $R'_{10} = 330\Omega$, $C'_2 = 25\mu F$
$R''_9 = 5k\Omega$, $R''_{10} = 470\Omega$, $C''_2 = 1\mu F$

The values given for R_9 are approximate, as they include the input impedance of a transistor stage

However, in the author's opinion, for most experiments the use of this technique merely adds complication without giving any real advantage.

Other Applications

The type of system described has many obvious applications other than the control of magnet current, and it seems worth while to enumerate its main advantages.

(1) Even when the input or output of the system is varied over a wide range, the power dissipated in the control element remains a small fraction of the power dissipated in the load.

(2) Because of the backlash in the coarse control system, the fine control system may be designed quite independently and given any reasonable desired characteristics.

(3) Because of the high efficiency, the temperature of the stabilizing apparatus does not greatly exceed the ambient room temperature. Its reliability is thereby much increased, and under most conditions it is possible to dispense with the cooling or thermostatting of certain components.

(4) The system lends itself very readily to operation over a control cycle covering a wide range of outputs by the addition of a single control voltage in series with the reference voltage.

(5) When very large direct currents are required, it is possible to gang three 'Variacs' and derive the current from the three-phase mains supply.

(6) On paper, at least, a suitable modification of the system seems to simplify the problem of producing an a.c. supply having a very high stability.

Acknowledgment

The author's thanks are due to Mr. W. J. Duncan who constructed the prototype apparatus.

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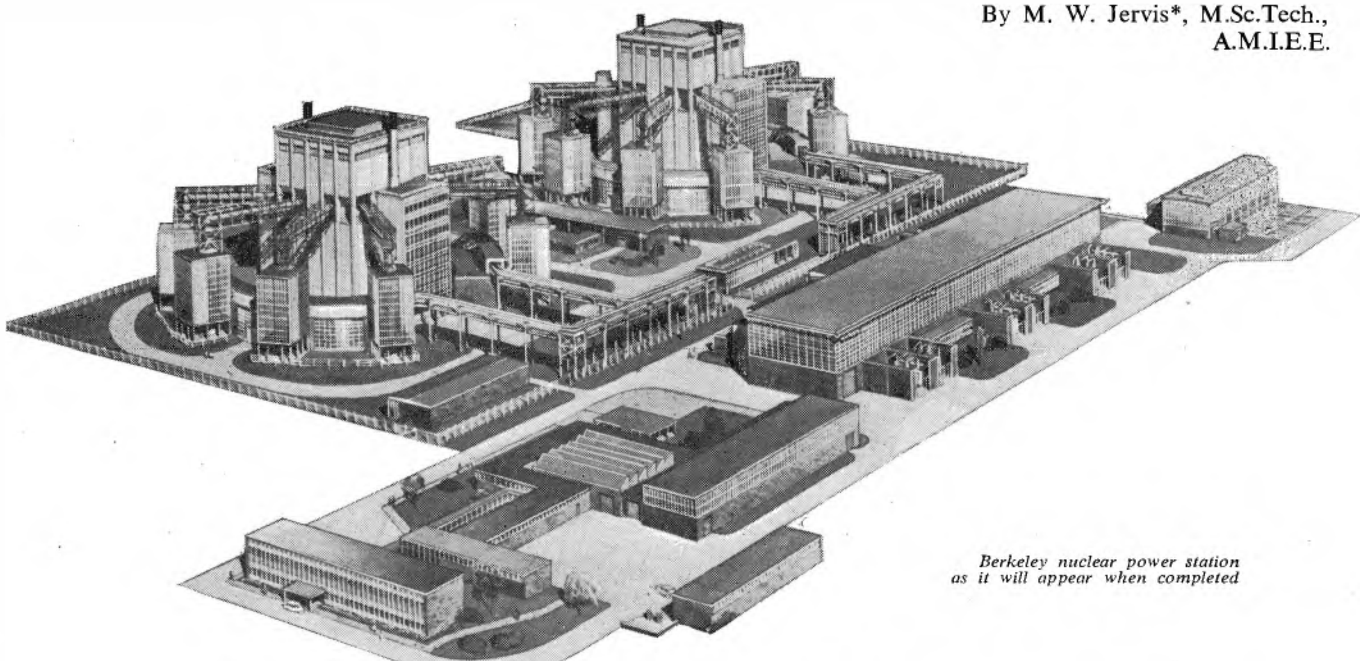
NUCLEAR POWER STATION INSTRUMENTATION

By M. W. Jervis*, M.Sc.Tech., A.M.I.E.E.



Berkeley nuclear power station as it will appear when completed

The control and protection systems of nuclear reactors include electronic equipment fed from thermocouples and nuclear detectors. Instruments for measurement and protection are reviewed with special reference to safety circuits and automatic data logging. Trends in design of shut-down amplifiers and television equipment are also discussed.

(Voir page 62 pour le résumé en français: Zusammenfassung in deutscher Sprache Seite 66)

THE instrumentation is an important part of the auxiliary equipment associated with nuclear reactors, providing indication of the power for control purposes and giving protection against fault conditions. Most of the instrumentation employs electronic techniques, some of which are particularly interesting since they have been developed specifically for nuclear reactor service.

Control and safety signals are obtained at full power from thermal detectors, usually thermocouples. Some safety signals are also obtained from nuclear measurements. At lower power levels this method is not reliable so that the reactor power is more readily measured in terms of the fission rate which is in turn proportional to the neutron flux[1,2,3].

Temperature Measurements

THERMOCOUPLES

Since the temperature range in a natural uranium graphite moderated gas cooled reactor is from 100 to 600°C and for various metallurgical and nuclear reasons, chromel-alumel couples are used. They take the form of mineral insulated pairs enclosed in a stainless steel sheath. In order to reduce the neutron absorption and the cost of the thermocouples inside the reactor, the diameter of the sheath is made as small as practicable from the mechanical viewpoint, i.e., about $\frac{1}{8}$in. This implies a fairly high resistance, about 2Ω/yd. This resistance together with that of any compensating cable which may be used, gives a total resistance in the region of 150 to 200Ω, with an output of 40μV/°C.

Since this resistance varies with temperature and, as it is relatively high, a direct deflexional system of measurement using moving-coil indicators or recorders is unsuitable and any measuring equipment should have a high input resistance compared to the thermocouple resistance.

The thermocouple system is extensive and in a power reactor about one thousand thermocouples may be installed.

Various systems of cold junction compensation are used, one convenient scheme being a temperature controlled enclosure, fitted near the reactor, and in which the cold junctions are installed. The thermocouple signals are then carried on copper wires for most of the distance between reactor and control room so that a minimum loop resistance is obtained.

POTENTIOMETRIC SERVO-OPERATED RECORDERS

The potentiometric servo-operated pen recorder[4,5] fulfils most of the requirements of a thermocouple measuring device. The self-balancing action ensures that very little error is caused by the resistance of the voltage source and gives a very high accuracy and stability. By using multipoint recorders a large number of points can be scanned in a reasonable time, e.g., 8 points in 40sec. Modern recorders incorporate mains driven stabilizers for the slidewire current so that the only electrical maintenance is that of checking the stability of this source every 1 000h. The recorders provide sufficient operating force to operate switches which can be used for high and low alarms or interlocking functions. By fitting re-transmitting slidewires, remotely operated indicators or small recorders can be used to show the same indication as the transmitting recorder.

* A.E.I.—John Thompson Nuclear Energy Co. Ltd.

This arrangement may be used where large recorders of high accuracy are required for reference purposes with small recorders or indicators on the control desk where space is at a premium.

This recorder system is augmented by the data logging system described later.

Excess Temperature Shut-down Amplifiers

Protective equipment is required which, when fed from certain thermocouple signals, e.g., from fuel elements, will operate contacts included in the safety circuit. Thus an abnormal temperature operates suitable alarms and trip initiation so that safety action is taken.

This operation is performed by shut-down amplifiers an essential feature of which is extreme reliability coupled with 'fail safe' features. As discussed in the section on safety circuits this means that should any fault arise in the equipment, for example due to valve failure, the fault will make itself evident by giving an alarm or trip signal.

The amplifier is also fitted with a trip margin indicator showing the difference between the setting of the trip level and the actual level of the quantity being measured. For example, if a thermocouple temperature is 375°C, the trip level may be set at 400°C, i.e., 25° trip margin. An amplifier trip is also operated if the trip margin exceeds a preset amount, i.e., an excess trip margin. This gives protection against open-circuit thermocouples and similar faults.

In addition to the trip action, facilities are also provided which give alarm signals before the trip level is reached so giving the operator time to take action before the reactor trip occurs. It will be seen that the nearness of the trip setting level to the actual level will be limited by fluctuations and variations from one signal to another.

These requirements can be met by a wide range of d.c. amplifier systems used in association with suitable backing-off voltage sources to set the trip level and output relay circuits. The requirement of extreme reliability makes circuits using thermionic valves rather unattractive and most available galvanometer type d.c. amplifiers have been found to be sensitive to vibration to an unacceptable degree.

More attractive solutions are the magnetic amplifier and the transistor chopper amplifier[6].

For the reference voltage source, Zener diode stabilizers are convenient and have adequate stability. Designs using these principles result in amplifiers of which several units can be stacked side by side in a standard 19in. G.P.O. type rack.

Power Indication by Neutron Flux Measurement

As previously mentioned the thermocouples are supplemented by nuclear measuring channels, the latter being the main method of power measurement at low levels.

Since the range of power to be covered is wide, several overlapping channels are used. The upper two decades are measured with the highest accuracy using neutron sensitive ionization chambers with two linearly scaled recorders, one having a backing-off supply to indicate departures from a selected value. The current at full power is usually in the range of 10 to 100μA.

High Impedance Potentiometric Recorders

The conventional recorder employs a transformer between the d.c. to a.c. mechanical chopper and the a.c. amplifier which drives the two-phase motor. By using a special chopper feeding directly into the valve amplifier it is possible to design a recorder which has a high input resistance[5]. Thus small currents can be measured in terms of the voltage drop across a fixed-value resistor through which the current is passed. Since the input terminal is a virtual earth, leakage effects are small and, owing to the excellent voltage stability of the arrangement, the voltage for full scale can be made relatively small thus enabling low-value load resistances to be used. This minimizes problems of leakage resistance and time-constants of the input resistance with the capacitance of the ion chamber cable. A typical recorder has a full scale sensitivity of 100mV corresponding to an input resistance of 10MΩ with an input of 10^{-8}A. The response time is 1sec full scale, with an accuracy of current measurement of 1 per cent.

By backing off most of the input current from a stabilized current supply the recorder can be made to indicate a deviation from a standard current. Typical ranges are +2 to 0 to −2 per cent of full power and +20 to 0 to −20 per cent of full power.

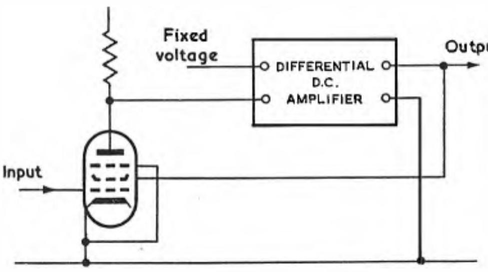


Fig. 1. Logarithmic d.c. amplifier

Logarithmic Wide Range Channel

An essential feature of nuclear reactor instrumentation is that the power must be measured at all times including shut-down. Since the shut-down power is in the region of six to seven decades less than the full power, this requirement necessitates the provision of an amplifier with a range covering many decades. It therefore becomes convenient to use a logarithmic amplifier the output of which is proportional to the logarithm of the input current.

The required logarithmic characteristic between input current and output voltage can be obtained by a diode working in the retarding field region. This simple arrangement has the disadvantage of an undesirable shift of characteristics with diode heater voltage. Most logarithmic amplifiers used in the U.K. employ a pentode circuit[1,2,3] illustrated in Fig. 1. The feedback d.c. amplifier holds the anode current almost constant by altering the screen voltage. The screen voltage then follows the grid voltage. The grid to cathode space of the valve acts as a diode and it can be shown that since heater voltage variations affect both anode and grid currents, compensation is obtained. This results in an amplifier with a better stability against mains voltage variations and a range of 5×10^{-12}A to 50μA.

Alternatively, the logarithmic characteristic can be obtained by a thermionic or semiconductor diode[7] used as the input resistor in a feedback d.c. amplifier. This arrangement has the advantage of virtual earth operation, e.g., short response time and relative insensitivity to input circuit leakage resistance to earth.

An important parameter to be measured during the start-up of a reactor is the doubling time, the power rising at an exponential rate.

i.e., $I = I_0 e^{t/T}$

where I = ion chamber current at a time t.

I_0 = initial ion chamber current.

T = reactor period.

The doubling time T_d is the time for the power to double itself, i.e., $I/I_0 = 2$.

$$\therefore \exp (T_d/T) = 2$$
$$T_d = T \ln 2$$
$$= 0{\cdot}693T$$

If the exponentially rising current is fed into a logarithmic amplifier then

$$V = K \log I.$$
$$= K \log I_0 e^{t/T}$$
$$= K(\log I_0 + t/T)$$

The output rises linearly with time and if differentiated will give a voltage proportional to $1/T$, the inverse of the doubling time. This signal can be used for control purposes and to initiate a reactor trip if the doubling time becomes dangerously short.

Low Power Counter Channels

The lower power limit for the operation of the logarithmic channels is fixed by spurious currents in the ionization chamber and by the difficulties caused by interference and leakage when measuring small currents under plant conditions. For such low power measurements, neutron sensitive counters are used feeding conventional pulse amplifiers usually employing 'ring of three' feedback sections. Discrimination against spurious pulses is obtained by amplitude discriminators and 'pile-up' of spurious pulses is reduced to acceptable levels by differentiation and integration of the pulses with time-constants in the region of $0{\cdot}1\mu$sec.

For experimental purposes, the pulses can be counted with scalers but for routine operation ratemeters are more convenient. The counting system has a lower power limit set by statistical accuracy at a rate of about 25p/sec. The upper limit depends on the type of counter and is between 5×10^3 to 5×10^5p/sec. This range is conveniently covered by a logarithmic ratemeter, two types being available. One uses a diode pump feeding the logarithmic pentode circuit previously mentioned and the other a multiple diode arrangement[8]. The first system has the advantage of relative simplicity and lower cost but the second has a superior transient performance which is particularly important if doubling time indication or trips are to be derived from the ratemeter output[3]. The transient response can be improved by a feedback circuit described by De Shong[9].

Excess Neutron Flux Shut-down Amplifiers

The excess temperature shut-down amplifiers mentioned previously are supplemented by neutron flux shut-down equipment, feeding into the safety circuits discussed later.

In this case the signal is obtained from an ionization chamber which will deliver a current of between 10 and 100μA under normal conditions. Two designs of shut-down amplifiers are in use[2], one uses a d.c. to a.c. conversion system and the other employs a straight direct coupled amplifier. Both these designs have a high degree of fail safe and most failures in them will cause either a trip or an alarm signal to be given. These designs use thermionic valves but the transistor chopper amplifiers used with thermocouples are also suitable for operation with a current input in the range required for operation at full power.

Safety Systems

The safety system of a nuclear reactor is an arrangement of relays, usually electromagnetic, which are connected to accept signals from the detectors and to reduce the reactivity of the reactor by automatically inserting neutron absorbing rods should any dangerous condition occur. For example the reactor trip may be initiated by the excess temperature or neutron flux shut-down amplifiers.

Fail Safe Principle

The most important design aspect of such a safety system is that it should 'fail safe' i.e., faults in the system should tend to shut-down the reactor rather than leave it in an unsafe condition.

In general, it is not possible to produce a perfect fail safe system, but it is possible to reduce the probability of unsafe failures to a very low level.

With electromagnetic relays it is usual to arrange for them to be excited so that their contacts are held closed for the normal state of the reactor. When an abnormal condition develops, e.g., high temperature, the relay is de-energized and the opening contacts initiate the reactor shut-down. It will be seen that such faults as failure of the supply to the relays or a break in the wiring or high resistance contacts will all initiate the shut-down.

A failure of equipment driving the relays can also be arranged to give the same effect, the scheme being typified by the excess flux shut-down amplifiers described by Gillespie[2].

One unsafe fault is that caused by welding of the relay contacts but the effect of this can be reduced by suitable design of the relay and by connecting contacts in series and by duplication of paths broken by the initiating signal.

Reduction of Spurious Shut-downs

In a small experimental reactor, shut-downs though annoying, are not an important economic factor. In large power reactors, however, there is a considerable loss of revenue, several thousand pounds per day, if the reactor is not operating. Even in a research reactor the cost of renting a single beam hole may be £100 per day.

In the simplest safety system any faults such as a valve failure can cause a reactor shut-down and with the large number of valves involved, the cost of spurious shut-downs, not due to reactor conditions at all, would be great. Under these conditions it can be shown to be economic to install a more complicated system which will reduce such spurious shut-downs. One such system employs the "two out of three" arrangement.

Three detectors are provided for each reactor condition e.g., excess neutron flux. If one of these gives a trip signal an alarm only is given and it is assumed that it is caused by an equipment failure, the individual equipment alarm indicating the faulty unit. If two or three trip signals are given, a reactor shut-down is initiated. In this case it is assumed that a genuine reactor fault has occurred. The probability of two equipment faults occurring simultaneously is acceptably small.

A typical arrangement is illustrated in Fig. 2. Each reactor condition has three relays *ABC, DEF,* etc. associated with it and give alarm signals via contacts A_2, B_2, C_2, etc. Contacts A_1, B_1, C_1, etc. are connected in each of three safety lines in which are connected relays *U,V,W,X,Y,Z,* and fed from three independent power supplies. The contacts U_1, U_2, etc., of these relays are connected in a two out of three manner in series with the safety rod holding system. It will be seen that a single spurious trip condition or failures of the equipment associated with one safety line, e.g. relay *A*, will give an alarm and open line 1 and also open contacts *U* and *X* in the rod holding circuit. The rod contactors remain energized through closed contacts *V,W,Y,Z* and a reactor trip is therefore not initiated. Failure of one safety line supply also gives an alarm only.

If a genuine excess flux condition arises in the reactor, however, and the de-energizing of say A is confirmed by the de-energizing of B, then two safety lines are tripped de-energizing U and V with X and Y. Since U_1, V_2 are now opened the rod holding line is opened, so shutting down the reactor. Welding of these contacts is protected against by the duplicate path $X_1 Y_2$.

Wiring failures short-circuiting say U or X to either supply bus bar causes one of them to be de-energized and give an alarm.

With such a system, if an equipment fault occurs, one safety line is opened so that the protection then operates on a one out of two basis. While the faulty unit is being replaced or repaired, its trip contacts can be shorted out using the shorting sockets, so re-energizing the line concerned. The initiating function, e.g. excess flux, then operates as a two out of two scheme, the other functions remaining as two out of three.

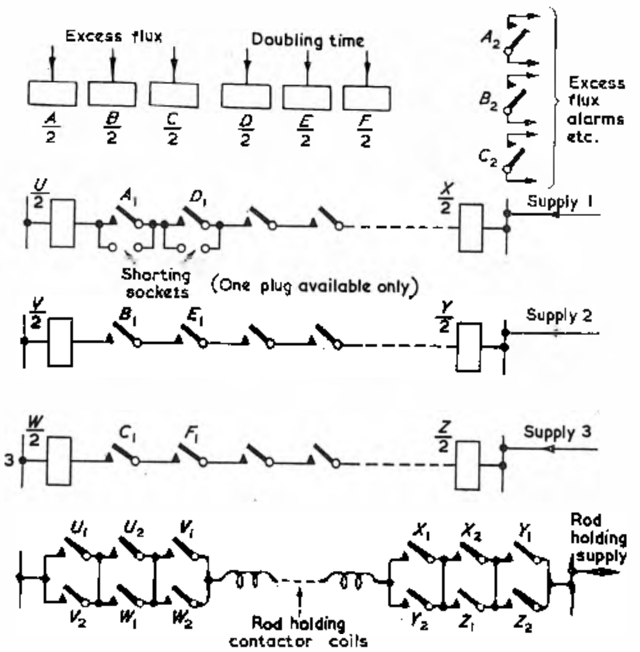


Fig. 2. Safety system using two out of three circuits

With such an arrangement faults in two unrelated instruments, e.g., A and E will initiate a reactor shutdown. This situation can be avoided by more complex schemes, for example by two out of three networks in each safety line.

In some arrangements of this type, which imply a large number of contacts, static switching units[7], appear to be more attractive than conventional relays.

Automatic Data Loggers[10,11]

When a large amount of information is to be displayed to the operator, the pen recorder arrangement has limitations. These become apparent mainly in the cases of thermocouples and burst cartridge detection equipment.

The fundamental point is that with recorders of the usual type all information is recorded continuously, so that when the plant is running normally, much redundant information has to be dealt with. Thus when an 'off normal' condition arises, the situation is somewhat confused by the unnecessary information presented. This situation can be improved by the use of automatic data loggers which suppress the print out of information and release it only for 'off normal' conditions, on demand by the operator or at pre-set intervals, (for example, once per shift).

This arrangement also has the advantage of reducing data storage space since the records produced fill up the whole surface of the paper with significant information.

Thermocouple Data Loggers

In view of the large number of thermocouple outputs to be measured, the potentiometric recorder system can be supplemented by an automatic data logger.

A typical scheme is shown in Fig. 3. The thermocouples are scanned by rotating switches or relay contacts and the signals amplified to a level where they can be checked for off normal conditions and the non-linearity of the thermocouple corrected. The voltage is converted to digital form, a variety of circuits being available for the purpose, and the digital signals fed to the printer. The print-out can be initiated for off normal conditions, on demand by the operator or at preset intervals, e.g. every eight hours. The record takes the form of a printed sheet giving time, point number, temperature and if the print-out has been initiated by an off normal condition.

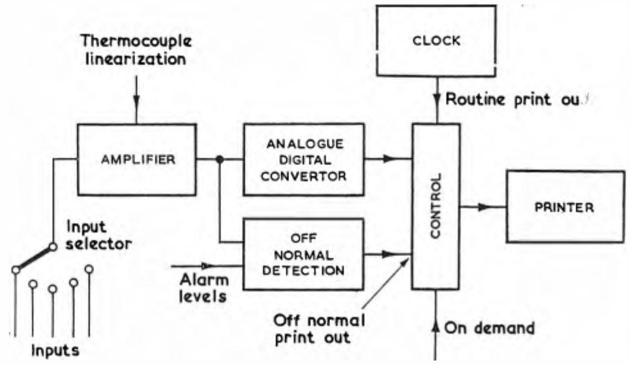


Fig. 3. Temperature data logger

Equipment which is acceptable for the service concerned would have a scanning time of about 2sec per point for some points, and rather faster, about 2min for a scan of a selected group of the more critical temperature points. The available accuracy including thermocouple errors is typically ± 1 to 2 per cent.

Fuel Element Cartridge Failure Detection

In a large power reactor such as Berkeley Power Station, the fuel elements are fitted in some 3 200 channels through which the CO_2 coolant passes. Burst fuel element cartridges are detected by the presence of gaseous fission products in these channels, each of which is fitted with a sample pipe leading outside the reactor. For reasons of economy, these pipes are grouped in fours and the resultant 800 groups scanned with 50-way rotary valves, moving at the rate of 30sec per position. Fission product concentration of the gas is measured by a precipitation technique with a scintillation counter, which delivers counts over 30sec counting periods[12].

The information to be examined therefore consists of 17 sets of counts, expected to be in the region of 400 pulses, which appear every 30sec. One complete reactor scan takes 50 of these 30sec periods, i.e. 25min, the process being repeated to give continuous monitoring of the reactor. Monitoring for one day therefore involves 48 960 measurements.

Potentiometric 54-point Recorder

A special recorder has been developed for the display of such measurements, the record being made in 54 rectangles 1in by 1½in on a chart moving at 1in/24h. The recorder is illustrated in Fig. 4. A special ratemeter is used to integrate the count over the 30sec counting period and convert it to a voltage proportional to the count. This voltage is then presented in turn to each of the 54 points of the recorder. For complete reactor coverage, 17 such recorders are required. High count alarms are provided either from the recorder or the ratemeter output. The limitations of the recorder system are imposed by the difficulty of the operator interpreting a large number of records, particularly in view of their small dimensions.

AUTOMATIC LOGGING OF COUNTS

In order to overcome these difficulties and provide an early warning of fuel element cartridge failure, a data

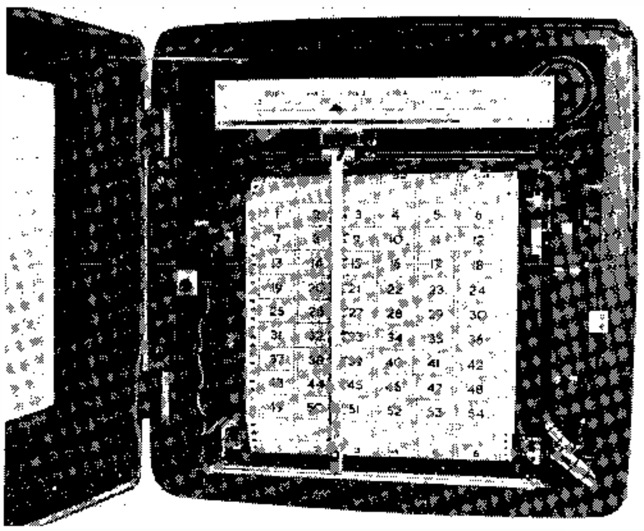


Fig. 4. Elliott 54 point recorder

logger and computer has been designed for Berkeley Power Station and has been described by Churchill and Hopkins[14]. The subject is also discussed by Goldbold[13] and Cain[11].

In the Berkeley arrangement the data is retained in digital form throughout and is handled by transistor circuits. The counts are stored on a magnetic drum store so that records for the previous 24 hours can be printed. Reference counts corresponding to alarm levels are also stored on the drum so that a signal is obtainable for off normal conditions. These operate the station alarm system and initiate a print-out of the inputs which are off normal. By this means, only significant information is presented to the operator.

One difficulty, which arises in this application of data loggers, is that the counts originate from spontaneous radioactive decay and are therefore at random and are subject to statistical fluctuations. This restricts the closeness of setting of alarm levels to the normal level, and lengthens the time between a rise in count rate and the initiation of the alarm. In some cases it can be shown[14] that it is desirable to take averages of counts to obtain 'smoothed' information and to make delayed differential measurements to supplement the simple differential tests where the current measurement is compared with the previous one taken.

Television Equipment

Once the reactor has been operated at full power, the fuel is so radioactive that access to the core can only be effected by remote handling equipment. This access may be required when investigating and replacing damaged equipment. In many cases it is essential to have a view of the operation by using optical periscopes or television camera equipment. It is found that the latter are the more satisfactory in many cases[15].

Since the observation of rapidly moving objects is not required, the response time of the Vidicon or Staticon type tube is adequate. These result in a cheaper and smaller unit than the high resolution photo-emissive types. A head amplifier is fitted in the same container as the camera tube, the container being of convenient size and shape for lowering into a fuel element channel. The end of the container is fitted with grabs designed to pick up, in the field of view of the camera, damaged equipment inside the reactor. Lamps are fitted on the camera.

Because of neutron irradiation effects, present designs do not permit operation of the camera inside the reactor at full power. At shut-down the neutron irradiation is small though there is an intense gamma field, but satisfactory operation can be obtained. Owing to fission product decay the temperature may be in the region of 300°C. Cooling of the camera tube and associated components is provided by blowing CO_2 through the container down a pipe laid in the connecting cables.

The preferred standard is now a 625-line system using the variety of monitor tube sizes available in industrial television equipment. There have also been developments in colour and stereoscopic television which might be applied[15].

Miscellaneous

HEALTH PHYSICS INSTRUMENTS

A large number of measurements have to be taken to ensure the safety of the personnel near plant from the health physics viewpoint[16]. The requirements of these activities have prompted the development of portable electrometer d.c. amplifiers for use with ionization chambers, and the logarithmic circuit described earlier is commonly used with installed wide range equipment[17]. Very small portable transistorized ratemeters have been developed for use with geiger counters and scintillation counters[18].

TELEMETERING OF PLANT MEASUREMENTS

The distance between the central control room and the plant measuring points of pressure, flow, etc., is typically several hundred yards. Some means of transmitting this information is required and both electrical and pneumatic systems, are in use[19]. There is a preference for the electrical system, however[13], and though some operate at a relatively high power level and do not requireamplifiers, mostschemes include at least one thermionic valve in the chain. In an effort to meet the requirements of other industries, some telemetering equipment is fully transistorized and operates from a 12V battery.

Discussion

The equipment available at the present time is adequate but there is a general tendency towards making it smaller and more reliable. For example, the difference in accuracy between a 6in wide chart and a 10in chart is probably not significant in many cases, but has a great effect on the panel size required.

In the case of nuclear instrumentation the main consideration is reliability. It will be noticed that if a safety line is tripped, the reactor works on a one out of two basis and to avoid spurious trips it is important to clear the original fault as soon as possible. This indicates the necessity for the rapid replacement of a faulty unit should one fail. One arrangement for facilitating this operation is to sub-divide the various units into relatively small blocks with plug-in connexions[20].

Because of their excellent record of reliability and low heat generation, transistors are attractive and are often associated with printed circuits to save space and reduce cost. It should be pointed out, however, that in fixed equipment there is little justification for sacrificing accessibility of components for space saving. Transistors are being used in the excess temperature trip units and the burst fuel element cartridge equipment logger, but have not yet come into general use elsewhere, e.g. in excess neutron flux trip amplifiers. Since many of the requirements imply high impedances, valves are still found more suitable. Transistors have the advantage of being able to run from a d.c. battery supply which can be made very reliable.

The safety circuits employ electromagnetic relays and though these are bulky and consume appreciable power, they have an excellent reliability record. It is theoretically possible to replace these, in some cases, by non-linear magnetic or semi-conducting devices[7], but the advantages are not very significant, except in complex systems.

The automatic data loggers overcome many of the difficulties associated with recorders, but it remains to be seen if they are convenient under actual plant operating conditions. At present the cost of loggers is also not competitive with simple recorders, but the facilities provided are in general superior. There is not yet sufficient confidence in data loggers for their outputs to be fed directly into the safety circuits, but with the introduction of faster and more reliable machines, such a scheme might have advantages in some cases.

Acknowledgment

The author thanks the management of A.E.I.—John Thompson Nuclear Energy Co. Ltd for permission to publish this article.

Figure 4 is published by courtesy of Elliott Nucleonics Limited.

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Anglo-French Computer Alliance

A new company, to be known as De La Rue Bull Machines Ltd, has been formed between the De La Rue Co. Ltd of Great Britain and the Compagnie de Machines Bull of Paris who claim to be the largest producers of computer equipment in Europe and the second largest in the world. The new Company have opened showrooms at 114-118 Southampton Row, London, W.C.1, and their object is to make available throughout the British Commonwealth the comprehensive range of punched card and computer equipment which is manufactured by the French company.

Compagnie de Machines Bull was founded in 1931 to manufacture punched card accounting equipment; they entered the electronic computer field in 1952 with a small-sized computer known as the Gamma 3 which employs germanium diodes. This was followed by the Gamma 3B which is a basically similar machine with the addition of a magnetic drum memory.

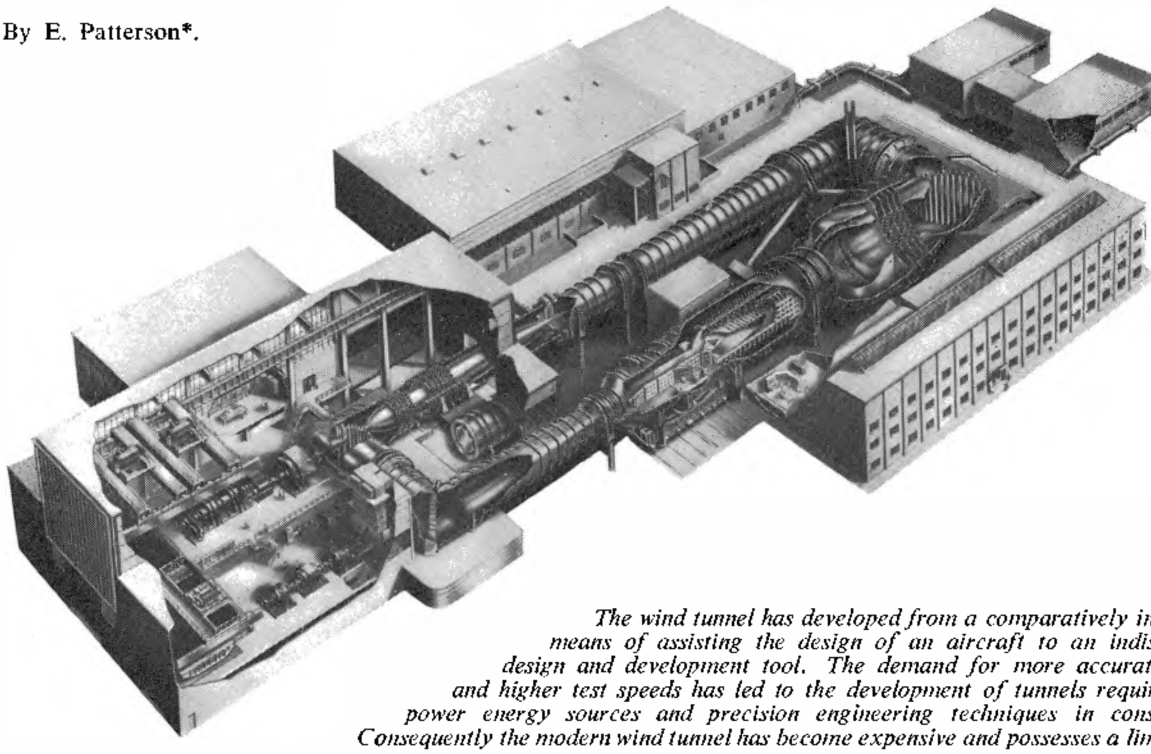
The latest computer of the Company is the Gamma 60 a large flexible and expandable machine employing germanium diodes, transistors and printed wiring throughout. The unit of information transfer in the Gamma 60 is a word of 24 bits. This may be 24 bits representing data in binary form or six decimal digits or four alpha-numeric characters. The computer is equipped with three memory devices; a high speed memory consisting of magnetic cores, a magnetic drum for medium access and magnetic tape for high capacity slow access. The magnetic core memory consists of from one to eight standard blocks, each block holding 4 096 words and consisting of twenty-four 64×64 core planes. The access time is 11μsec. The intermediate access memory consists of a magnetic drum having 128 tracks the capacity of each track being 200 words. The drum revolves at 3 000rev/min and the access time depends on the position of the address with respect to the read-write head at the instant the contents of that address are called for; thus it can vary from 0 to 20msec, the average access time being 10msec. The magnetic tape memories provide a very high capacity and utilize ½in wide tape in standard lengths of 3 300ft; this is run at 75in/sec with a packing density of 200 per inch, the capacity of each tape being 2 000 000 words. The number of tape units is variable and unlimited but generally lies between six and twenty-four units.

One of the design objectives has been to provide full utilization of the computer and, to this end, it is possible to execute data processing functions on items at different stages of evolution in the same problem (simultaneous vertical operation) or to execute simultaneously the data processing functions of several different problems (simultaneous parallel operation) on a time sharing basis.

A variety of input and output equipment is available for use with this computer; the input usually being by means of punched cards, which can be read at the rate of 300 cards/minute, or punched paper tape. The output is normally by means of an in-line printer which can print at the rate of 300 lines/min.

Wind Tunnel Data Handling

By E. Patterson*.



The wind tunnel has developed from a comparatively inaccurate means of assisting the design of an aircraft to an indispensable design and development tool. The demand for more accurate results and higher test speeds has led to the development of tunnels requiring high power energy sources and precision engineering techniques in construction. Consequently the modern wind tunnel has become expensive and possesses a limited life.

These factors coupled with increased confidence in wind tunnel results and a greater understanding of testing techniques has resulted in the demand for more results and higher accuracy. In this article an attempt is made to present for the non-specialist a survey of the requirements that have led to the evolution of the data handling system from the manual and visual recording methods of a decade ago to the fully automatic high speed systems of the present generation of wind tunnels.

The difficulties that have arisen due to the limitations of space available in the model for instrumentation and the fundamental properties of the transducer are discussed.

(Voir page 62 pour le résumé en français: Zusammenfassung in deutscher Sprache Seite 66)

THE function of a wind tunnel has not changed since the earliest experiments of the Wright Brothers. It provides the means whereby a model aeroplane or guided missile is subjected to tests from which the values of the aerodynamic characteristics may be assessed. The evaluation of these characteristics enables the performance of the full scale aircraft or weapon to be deduced.

However, the range of heights and velocities at which airborne vehicles operate has now extended speeds into the low Mach number regime for aeroplanes and into the high Mach number regime for missiles.

This does not mean that problems in the low-speed region have been solved; on the contrary new and more difficult ones have arisen, as aerodynamic shapes have changed to meet the higher speed demands.

In order to apply the wind tunnel results to the full-scale aeroplane, conditions in the wind tunnel must be as near as possible to those experienced by the full-scale model in flight. The criterion for this correspondence is embodied in the non-dimensional parameter called Reynolds number.

$$\rho V l / \mu$$

where ρ = air density, V = local velocity, l = length characteristics of both model and full-scale vehicle. μ = viscosity of air.

This number is of the order of 300×10^6 for a full-scale aeroplane at 60 000ft and flying at a Mach number of 2 where l is the total length.

The wind tunnel operator may thus attempt to obtain compatibility in Reynolds number by varying either the pressure in the tunnel, the flow velocity, or the size of the model. In subsonic wind tunnels this can be achieved by varying wind speed, model size, or tunnel pressure. In supersonic tunnels, however, variation of these parameters generally alters the local Mach number, thereby changing the test conditions.

It is obvious that to meet all the test conditions for a modern aircraft in one tunnel would be extremely complicated and expensive. The normal practice therefore is to design a new wind tunnel for a selected range of velocity or Mach number. The wind tunnels in Great Britain may be broadly classified into three categories, subsonic, transonic and low supersonic, and high supersonic. (As typified by the R.A.E. Bedford 13ft × 9ft tunnel, Aircraft Research Association 9ft. × 8ft tunnel and the R.A.E. Bedford High Supersonic Speed Tunnel now under construction.)

As the Mach number of a wind tunnel increases so the power required to drive it increases enormously, while

* *Guided Weapons Division, English Electric Aviation Ltd.*

The above photograph shows the 8ft × 8ft high speed wind tunnel at R.A.E., Bedford.

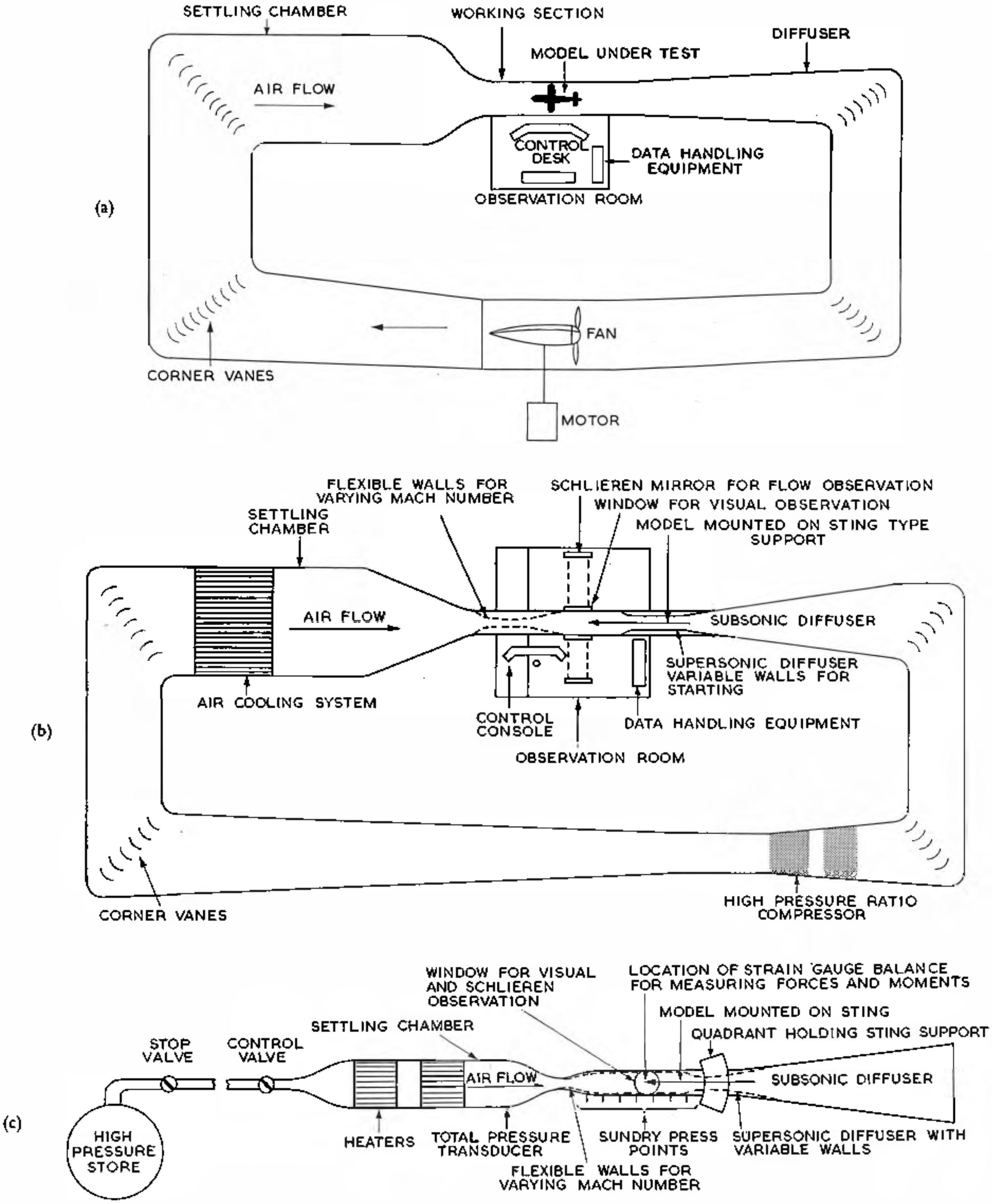


Fig. 1. (a) Typical continuous running wind tunnel
(b) Large continuous supersonic wind tunnel
(c) Intermittent supersonic wind tunnel

because of the greater pressures and loads the cost of construction is much higher.

In general, therefore, for economic reasons, as the speed increases the tunnel tends to become smaller, though large high-speed tunnels do exist at Tullahoma in the U.S.A. and the R.A.E. Bedford. These, however, are extremely expensive to run.

As a result intermittent tunnels have developed. These operate from a high-pressure store of air, which means a running time limited to the order of a minute.

Fig. 1 illustrates three types of wind tunnel:

(a) Continuous running subsonic tunnel.

(b) Continuous running supersonic tunnel.

(c) Intermittent supersonic tunnel.

The Need for the Rapid Recording of Test Results

Economic Factors

A large tunnel is extremely expensive to construct, has a limited life, and in addition to a high running cost may be the only one in the country to cover a particular speed range.

A high rate of data extraction thus promises more tests in a given time and less cost per test. In addition tests may be planned on recent results without the necessity of replacing the model in the tunnel and recalibrating the balance (for details see later); a tedious process in which previous test conditions might not be precisely reproduced.

CONTROL FACTORS

A transonic tunnel though running continuously rarely maintains a selected transonic condition for a long period, and it is particularly desirable to obtain as many results as possible while a particular flow condition persists.

LIMITED RUNNING TIME

Since the intermittent tunnel has a limited running time a high-speed recording system is almost essential to avoid numerous runs, together with time wasted while the high pressure store is pumped up.

It is almost essential for the best results that the wind tunnel instrumentation and data handling system be designed as one system. In particular since under some conditions extremely low pressure differences must be recorded sufficient time must be allowed for the appropriate transducers to settle before readings are recorded.

Measurement of Forces

FORCES AND MOMENTS ON THE MODEL: THE WIND TUNNEL BALANCE

The direction and point of action of the resultant force upon a model in a wind tunnel is unknown. This force may be replaced by three forces acting at a point along mutually perpendicular axes and three moments acting about mutually perpendicular axes.

The wind tunnel balance Fig. 2 is therefore designed to measure these forces and moments with reference to a known system of axes (wind or body axes). The forces measured are usually Lift, Drag, Sideforce, and the

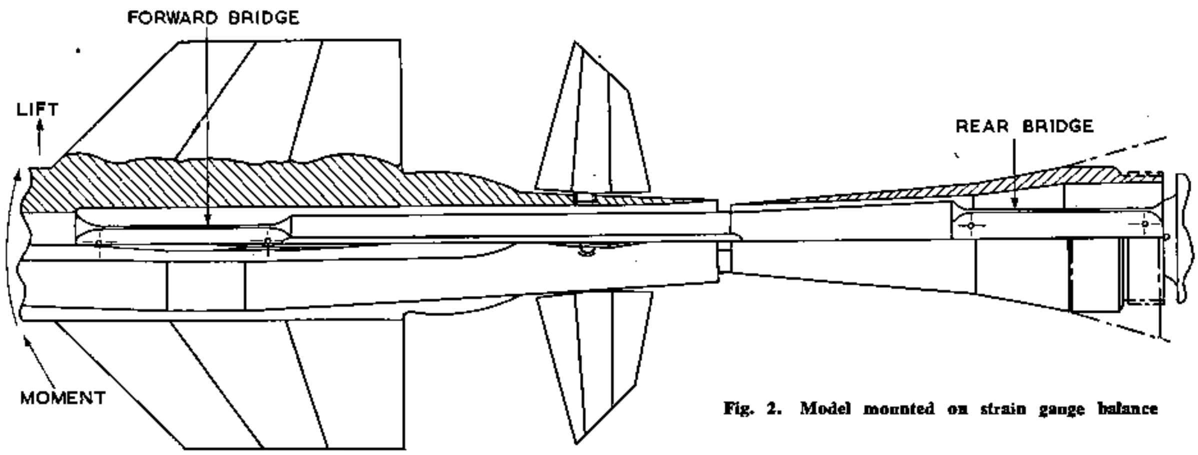


Fig. 2. Model mounted on strain gauge balance

moments—Pitch, Roll and Yaw. These forces may vary in magnitude from pounds to tons, depending upon the size of the model, and wind tunnel conditions.

The elements of the balance measuring these components should ideally be independent of one another. In practice, however, interaction occurs between the various elements, and a careful pre-test calibration is necessary to evaluate these interaction factors.

Most present tunnels of the high-speed type utilize a sting as a model mounting (Figs. 1 and 2). This sting carries at the end a strain-gauge balance to which the model is rigidly attached.

Forces exerted on the model are thus expressed as electrical signals of the appropriate strength[3].

Model vibration is transmitted as noise superposed on the information signal. On systems utilizing a.c. excitation of the strain gauges this effect is more significant.

Space within the model mounting is extremely limited, with little space available for special precautions such as screening, etc.

MEASUREMENT OF PRESSURES

Since the magnitude of the forces on the model are ultimately due to the primary energy of the airflow a knowledge of the reservoir pressure is necessary (Fig. 1(c)). This, together with pressure measurements taken along the walls of the wind tunnel, enables the flow conditions in the model vicinity to be evaluated.

The study of a new type of wing or body shape often requires the measurement of pressures on the surface and

The Development of Automatic Recording Systems

During the war and in the immediate post-war period the main obstacle governing the rate at which test data could be obtained from a wind tunnel was the fact that it was impossible to process all the data at the rate it was being produced. On the R.A.E. 10ft. × 7ft. wind tunnel during the war there were twenty computers with electric typewriters operating; the delay on completing a test and computing the final answers was six weeks. Of this time half was due to the delay transcribing the data from the balance and manometers to the calculating machines. The method used was to photograph the dials of self-balancing a.c. bridges and manometer tubes and utilize the services of a skilled group of readers[1].

The introduction of the electronic digital computer meant that, while the computation of the data no longer represented a serious delay, the time occupied in reading the tunnel instruments still represented a considerable fraction of the total time.

This, together with the reasons already outlined, has produced during the last ten years in the U.S.A. and Britain strenuous efforts to develop automatic high-speed data read-out systems.

The tendency has been to develop digital systems, in order to conserve accuracy and present the raw data in a form acceptable to the digital computer.

Analogue systems have however been developed for work in which transients are studied, for instance fuel flow and jet pipe temperature conditions for changes in throttle setting on gas turbine engines[2].

base of the model. If the number of points is large some form of pressure sampling switch may be required in order to economize in pressure tube runs or transducers. Multiple pressure measurements are not therefore generally made at the same time as force measurements, a special sting arrangement is usually designed if it is required to do so.

Wind tunnel pressures are usually measured by self-balancing capsule manometers or pressure transducers containing an unbonded strain-gauge bridge. Since the pressures at a point may change from a fraction of an atmosphere to several atmospheres, depending on the particular test conditions prevailing, a single information channel may have signals of widely varying amplitude for different test conditions.

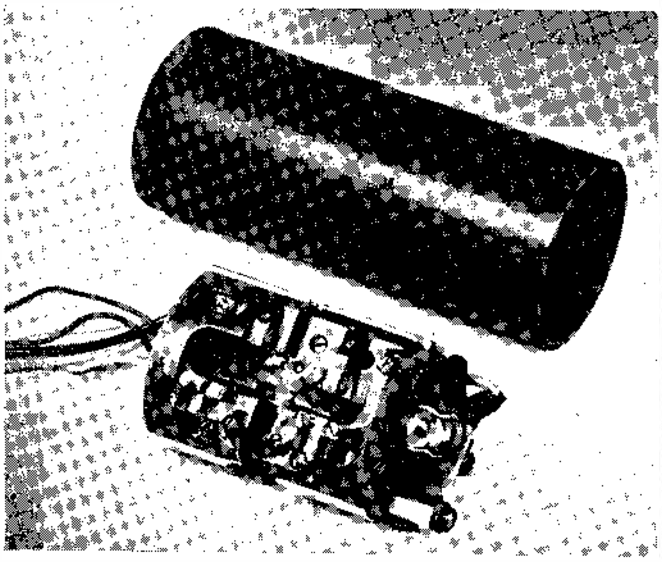


Fig. 3. Digital inclinometer

Calibration Problems

The calibration of the wind tunnel is usually carried out to an order of accuracy greater than routine experimental results require[4], e.g. Mach number to 0·1 per cent, flow direction to 0·05°, which means that the data system must accommodate this condition, at greatly increased cost, or a special technique must be employed for the calibration period. For an intermittent tunnel this is clearly extremely tedious.

A special problem has arisen due to the fact that the model support bends when lift or side forces become severe. In such a condition the model support attitude measured at the base is not the attitude of the model in the flow. Measuring angle of roll from inside the model support has posed similar problems. Techniques employing Moire fringe systems or coded disks are being developed as digital transducers seem to offer the only solution to high accuracy and repeatability requirements in the limited space available inside wind-tunnel models and their supports[5]. (Fig. 3.)

The output of these instruments is digital, which requires a special input to the digital portion of the data system (Fig. 7).

The Design of the Data System

Overall Requirement

A completely integrated data system must be capable of taking the data in its raw form from the wind tunnel strain gauges, balance and pressure indicating instruments and processing it, producing eventually a corrected curve of the required variables plotted to a reasonable scale, or tabulated in figures to the required decimal place.

The primary design considerations are the demanded speed and accuracy of read-out, though the cost and delivery times of commercial equipment must be taken into account.

Since the wind tunnel instrumentation market is relatively small in Britain compared with the U.S.A. most systems at the moment operating in Great Britain have been built by wind tunnel technicians to a specification utilizing modified commercially-available equipment.

Table 1 illustrates the type and quantity of data required

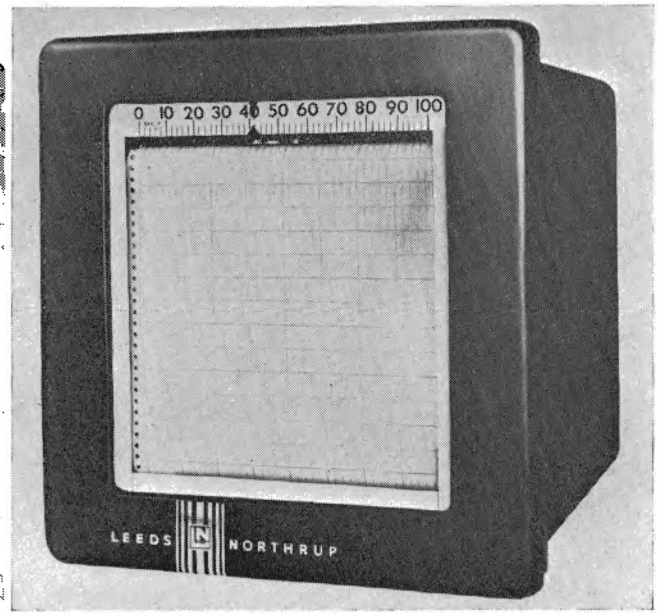


Fig. 4. D.C. self-balancing bridge and recorder

from a wind tunnel test, together with the number of decimal digits per channel. Table 2 illustrates the pre-test data obtained from calibrations necessary for the reduction of the experimental data.

The number of digits per channel is usually a compromise between the demanded accuracy and the capability of the system.

TABLE 1

TEST DATA	NUMBER OF CHANNELS	NUMBER OF DIGITS PER CHANNEL
Forces and moments (See Fig. 4)	6–8	3
Stagnation or source pressure	1	3
Wing pressure ..	9	3
Body base pressure ..	1	3
Sting incidence ..	1	3
Model roll angle ..	1	3

TABLE 2

PRE-TEST DATA	NUMBER OF CHANNELS	NUMBER OF DIGITS PER CHANNEL
Mach number ..	1	3
Atmospheric pressure	1	4
Test number	1	3
Run number	1	3
Model number ..	1	3
Time	1	3
Range or scale values	1	
Calibration factors } Interaction factors }	These may amount to as many as 50 numbers	

The pre-test data need not be fed into the system during a test run, though for ease of reference they may be required to be transcribed into the raw data record if this is not the same medium, e.g. the raw data may be punched on cards, and the experimental data recorded on magnetic tape.

The Form of the Data

Except where coded disks or digital transducers of a particular type exist inside the model or model support the data is usually in the form of a voltage. Since strain gauges have a low power dissipation the maximum voltage level available for full load is of the order of millivolts; in order to obtain high accuracy recording instrumentation must therefore be capable of discriminating between voltages in the microvolt region.

It is essential therefore in order to maintain accuracy to convert these voltages to digital form before performing any computations on the data. For slow systems this is readily achieved by a.c. or d.c. servo-controlled self-balancing bridges of the type produced by several commercial firms[6,7,8]. (Fig. 4.)

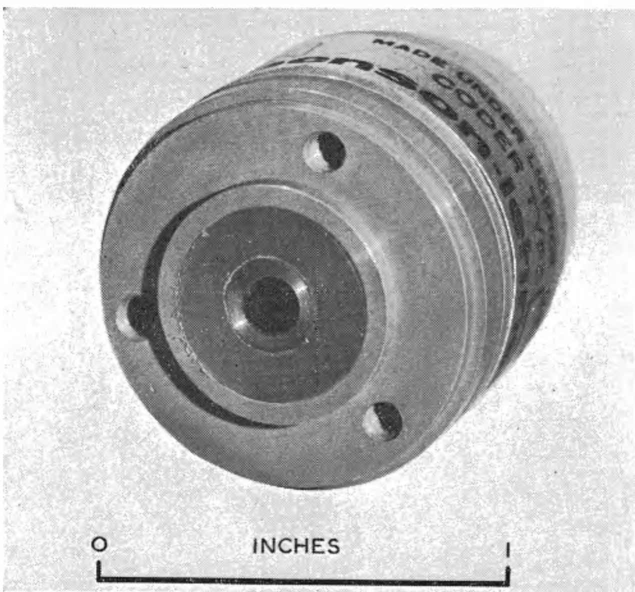


Fig. 5. 0-200 digital shaft encoder

The attachment of a shaft encoder Fig. 5 to the slide wire enables the reading to be converted into any one of the available digital codes, while a trace record is produced by the pen or print wheel on the front of the instrument. The time taken for recorders of this type to balance is of the order of 1 to 2sec. Higher speeds may be attained by sacrificing some accuracy which for the standard type is of the order of 0·2 per cent full scale. Systems requiring a higher speed of read-out generally employ electronic analogue-digital convertors[5,9], Fig. 6. These are now becoming commercially available in the U.K. through Benson-Lehner G.B. and Mullard Ltd. Times of reading for these instruments are of the order of 50μsec for an eleven-figure digit.

The use of these instruments in conjunction with high-speed electronic commutators or sample-and-hold amplifiers enables a large number of readings to be obtained in a short time. Once the data is in digital form the subsequent operations depend on the test facility requirements. Whereas the section of the system (Fig. 7) performing the analogue-digital conversion is generally determined by the required repetition rate and accuracy of read-out, the configuration of the digital portion depends upon the ability of the computer input to absorb the data flow from the tunnel.

The standard computer input mechanisms of punched tape and punched card are not fast enough to handle the data directly from the analogue-digital convertor. Indeed this form of 'on line' operation is not necessarily desirable, as the computer is usually required to perform other jobs as well as data reduction, and may be situated at a distance[10].

In addition the nature of the computations performed on the data usually means that a considerable portion of the storage space of the smaller computer is allocated before the data is fed in.

The second part of the data system has a twofold purpose: to transcribe the data on to cards or tape in a form acceptable to the computer utilizing the minimum amount of tape or number of cards and to display the recorded raw data either as numbers, decimal or binary or uncorrected curves; this is known as intermediate read-out.

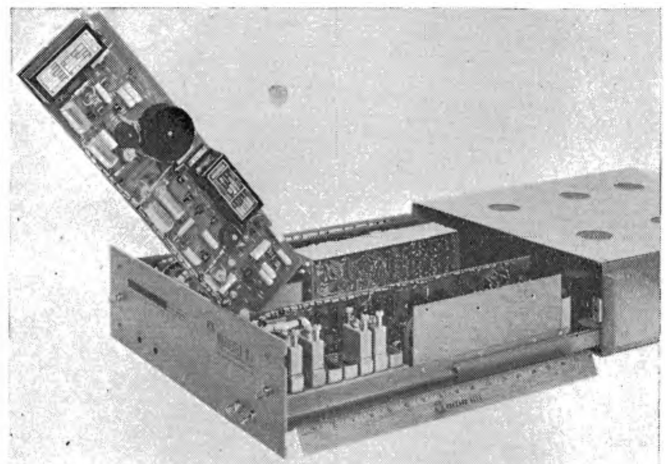


Fig. 6. High speed analogue-digital convertor

The provision of this facility is highly desirable, as a quick look at the raw data is usually sufficient to ensure that the pressure transducers and strain-gauge balances are giving sensible outputs. It is not unknown for a strain gauge to become detached from a balance, or a wire to break, or part of the recording mechanism to fail.

Chart recorders of the type shown in Fig. 4 provide a ready-made record, though the curves plotted against time instead of a familiar variable require a certain amount of interpretation.

The provision of printed characters as intermediate read-out is generally more difficult, requiring some form of translator to convert the output code of the analogue-digital convertor to a decimal form.

The code into which the data is converted from an analogue voltage is generally a compromise between these requirements and the code required for the computer input. Data can be fed into the computer in codes other than that for which the input system was designed. Extra programming effort is required in order to achieve this and storage space must be utilized, reducing the space available for data.

Data Storage

Since tape punches and card punches operate at a comparatively low speed the data must be temporarily stored before being passed to the card or tape.

Common storage elements are relay contacts, magnetic tape, punched paper tape, magnetic cores, diodes, two-state binary switches, and magnetic drums. The selection of a particular element for a system depends on the speeds of read and write required at that point in the system. This pause in data flow affords at the same time an opportunity to re-arrange the data in order that the arrangement of the digits on the card may match the computer input, e.g. The English Electric DEUCE prefers to accept data in the form of 32-bit words, two words at a time, 64 digits in all.

The function of the store may be expressed as follows: It enables,

(a) Data to be extracted from the system while a test is in progress.

(b) Data to be held while an operation such as card punching is taking place in order to transfer it sequentially into the card.

(c) Data to be translated from one code to another.

COMPUTER INPUT—A SPECIAL PROBLEM

For slower data-handling systems the problem of transferring data from the store to the computer input medium is merely one of delaying the transport of the data until sufficient is available in the store at one time to enable a complete card to be punched. The number of data points that can be accumulated on one card is primarily a question of the number of digits per reading—the fundamental accuracy of the reading. Another determining factor is the type of code in which the data is recorded.

Punching in decimal requires fewer digits but utilizes columns as well as rows. Binary utilizes only rows, as does binary-coded decimal (Fig. 8).

The arrangement of digits in a row is governed by the computer field or the number of digits read into the computer from the card on the receipt by the computer input mechanism of the appropriate signal.

For systems recording data at a rate greater than the ability of the appropriate punch to prepare cards or tape, a more permanent intermediate storage medium is required, for example magnetic tape. Transferring data from a high-speed recording medium of this nature into a slower form such as cards remains an expensive undertaking.

The cost of such an item in a data system may at the moment be a considerable percentage of the whole. On the other hand a system utilizing direct input to the computer store sacrifices the advantage of a quick look at the experimental data, while if a failure of some sort has occurred and the results are invalid then valuable computer time will have been wasted. This portion of the system is therefore going to remain the most expensive for a considerable time to come.

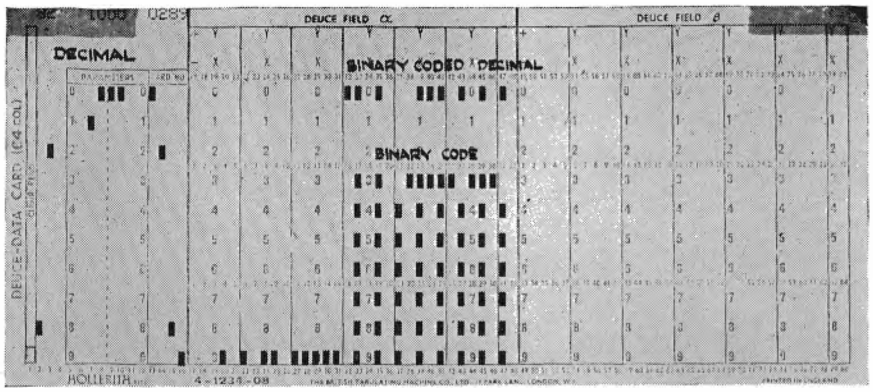


Fig. 8. Hollerith card as used by DEUCE showing data punched in three different codes

PRE-TEST DATA

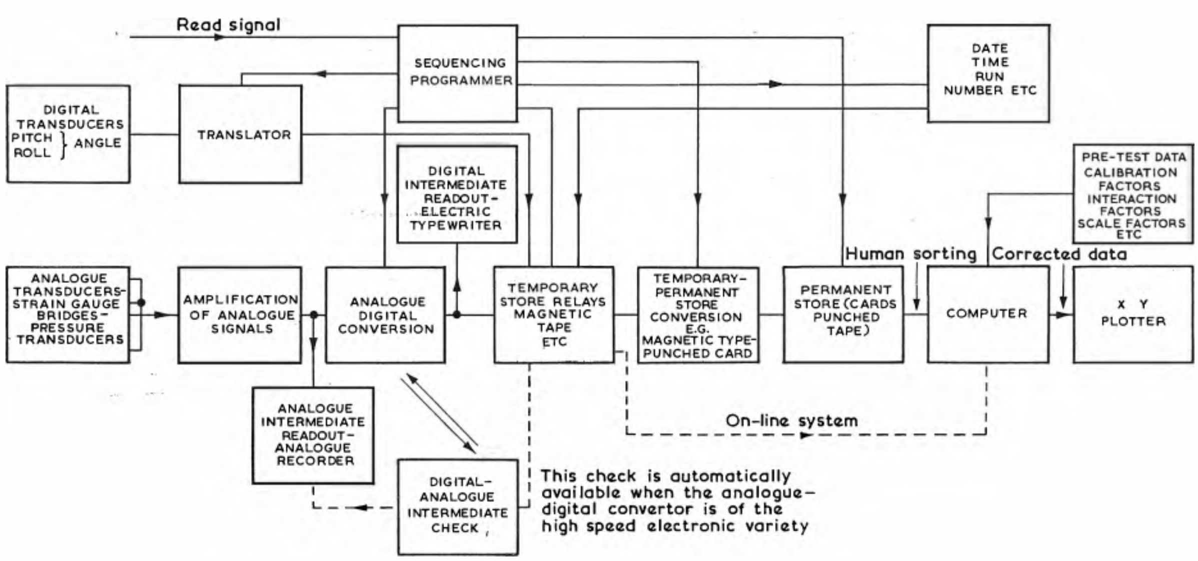
The pre-test data outlined in Table 1 are all the constants that may be evaluated before a test. In particular the calibrations of the model balance performed before the test, together with the degree of interaction on the balance between loads applied in different directions, are used in every computation that takes place.

It is essential therefore that no error should occur in the transfer of this data to the computer store. In some installations the constants are set up on a board and automatically recorded with the test data.

This for more complicated tests, however, can become an expensive switching procedure. Moreover, in a high-speed system utilizing magnetic tape it is difficult to ensure that the pre-test data has been correctly transferred on to the intermediate storage. The usual procedure therefore is to feed these pre-test data separately into the computer before the reduction is undertaken.

The decision as to whether the scale factors are automatically recorded or fed in with the pre-test data is largely dependent on the ability of the wind tunnel operator to

Fig. 7. Functional diagram of wind tunnel data handling system



foresee the loads and pressures experienced during the test. For a test in which certain parameters vary widely with time automatic or manual scale changing may be necessary, together with automatic recording of the scale value.

PREPARATION OF CORRECTED CURVES

The cards or tape available from the computer once the reduction is complete contain corrected data. This is generally printed at the same time by the computer tabulator. However, for purposes of comparative assessment curves of such variables as the lift coefficient as a function of drag coefficient are required. These are prepared with the help of plotters, available on the commercial market (Fig. 9), capable of plotting on both X and Y axes data supplied on punched cards.

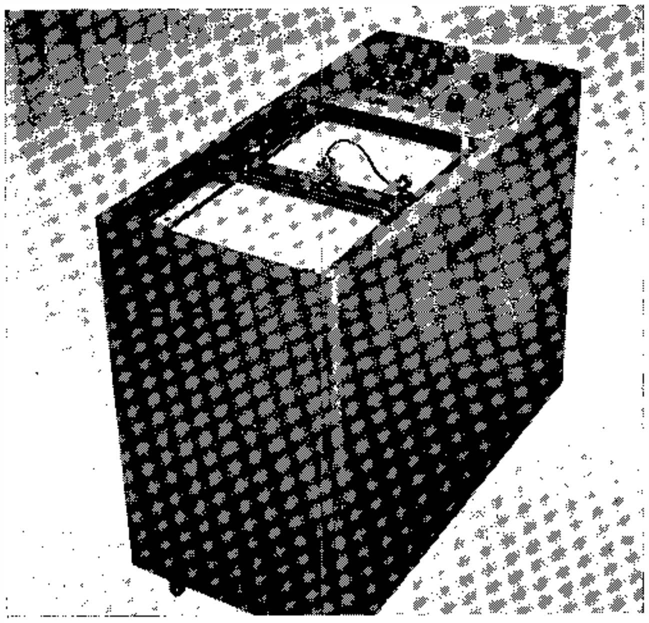


Fig. 9. Typical XY plotter

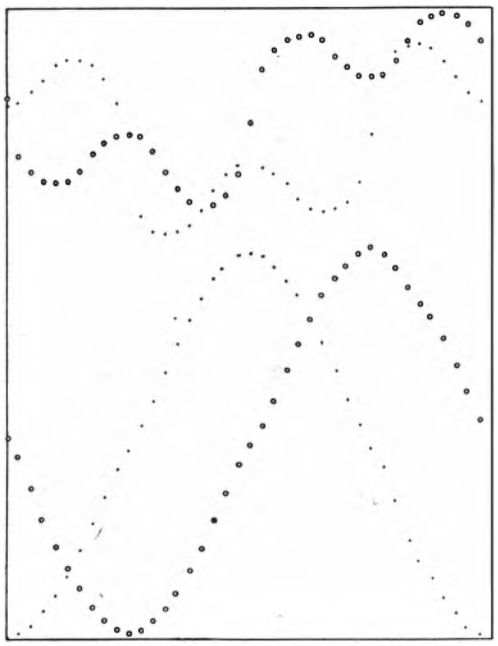


Fig. 10. Record of the wind tunnel test results from XY plotter

Fig. 10 shows typical wind tunnel results produced on an XY plotter.

Future Wind Tunnel Data Systems

With the rapid development in computer techniques associated with similar progress in solid-state electronics the present relatively clumsy systems will rapidly become obsolete. The complex control and data handling systems developed for the present generation of tunnels will undoubtedly be replaced by an integrated system controlled by a computer-controller. This will be programmed to start the tunnel, check the data, adjust the tunnel parameters to suit the demanded test procedure and finally produce corrected test results.

Such a controller will inevitably prove expensive, but may repay the initial cost several times over in the life of the tunnel. Maintenance will be restricted to the replacement of standard sub-units.

Automatic machine-tool control systems may be expected to expedite the production of wind tunnel models which, for the large models, at the moment take up to eighteen months to produce.

Further wind tunnel developments are not clear. Undoubtedly the existing tunnels and shock tubes fulfil most of the present and future requirements of our atmosphere, though as control systems become more sophisticated the need for precise evaluation of static aerodynamic coefficients may diminish.

Testing may therefore become more concerned with the evaluation of dynamic characteristics of an aircraft.

Acknowledgments

This article is published by permission of the Director of Engineering, the English Electric Co. Ltd. The author would like to acknowledge the help given in preparing the article by colleagues in the Company. In particular the author would like to express his thanks to Mr. A. C. Southgate for helpful suggestions.

Acknowledgment is made to the following for permission to reproduce photographs: Fig. 3, Hilgar Watts Ltd; Fig. 4, Integra, Leeds and Northrup Ltd; Fig. 5, Benson Lehner (G.B.) Ltd; Fig. 6, Packard Bell Computer Corp., California, U.S.A. and Benson Lehner (G.B.) Ltd; Fig. 9, Dobbie McInnes Ltd.

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The Construction of a Digital-Computing System from a Basic Transistor Circuit

By P. L. Cloot* and G. E. Jackson*

It is possible to built a complete digital-computing system by interconnecting a number of identical basic circuits. One method uses a basic circuit consisting of one transistor, one capacitor and three resistors, and a special-purpose computer with a built-in program for binary-decimal conversion has been constructed to demonstrate the application of the method.
An account is given of the logical design of this machine, of the circuit design, and of its mechanical construction. It has proved possible to use printed wiring throughout, and to make the computer extremely compact.

(Voir page 62 pour le résumé en français: Zusammenfassung in deutscher Sprache Seite 66)

MUCH emphasis in the design of digital-computing circuits is currently placed on increasing their speed of operation, and for mathematical computation using large universal machines this increase in speed is still needed. However, in the next few years digital techniques will be applied to the solution of a large range of problems in which speed is of far less importance than reliability and simplicity. Such problems arise in the fields of data-handling and process control, where the speed at which information is to be handled is limited by some physical process and the amount of computation to be performed is small. Simple systems using frequencies sometimes as low as 50c/s are required for data transmission and for automatic traffic control, while the control of manufacturing operations or the monitoring or processing of data referring to such operations may require digit rates of no more than a few kilocycles per second.

The special-purpose computers required for these operations must be as simple as possible to design and maintain, and their reliability is in some cases far more important than that of universal machines solving mathematical problems, since an error may well have immediate physical consequences. A basic transistor circuit for use in such systems has already been described[1], and the present work is an account of the design, construction and performance of a special-purpose computer built to demonstrate the application of principles there put forward. The computer consists of 335 identical basic circuits, and performs a built-in program for the conversion of decimal numbers to and from the binary scale. This problem was chosen as one requiring a variety of computer functions, the correct operation of which could easily be verified.

The use of the basic circuit reduces the preparation of circuit diagrams to the observation of a few rules, (see Appendix 1) and makes it possible to use a very simple circuit notation. Only five different components are used altogether (excluding input/output equipment and power supplies), and all the components may be contained on identical plug-in units, with the result that manufacturing costs should be reduced. Conventional wiring may be used to interconnect plug-in units, but the uniformity of the method lends itself to the use of printed wiring techniques, and, where the preparation of drawings can be justified, it is possible to print all the wiring for a complete computer. Such a step is only possible if it is certain that no modifications will be made to the wiring, and therefore requires that the circuits must be reliable. The use of such a simple basic circuit makes it possible to design a reliable system, and allowance can be made for any desired component tolerance.

Since a transistor is used for logical functions, the cost of the components for a computer using this method may be about twice the cost for a machine in which diodes are used, but the advantages the basic circuit offers in ease of design, construction and maintenance justify its use.

The computer now to be described operates serially at about 7·5kc/s using a twelve-digit word, and as it has been constructed for demonstration purposes the number of controls has been kept to a minimum, only three ten-position switches and two push-buttons being used. Indicator lights are used for output indication, and the only further requirements are two power supplies.

Any three-figure decimal number may be set up on the switches, and the operation of one push-button adds the binary equivalent of this number into the accumulator, the contents of which are displayed on ten indicator lights. If the capacity of the accumulator (1023) is exceeded a warning light is switched on and the accumulator is reset to zero. At any time operation of the other push-button will re-convert the contents of the accumulator to decimal form, and display the result on three sets of lights corresponding to the hundreds, ten and units. This reconversion resets the accumulator to zero, and the decimal display is reset next time the first push-button is operated.

The Basic Circuit

The basic circuit from which the computer is constructed is shown in Fig. 1(a). Visual indication is provided when required by a Hivac type 12S4 light in series with a 390Ω resistor connected to the output terminal, with R_a disconnected from the negative supply. Since all the basic circuits are identical an abbreviated notation may conveniently be used for the circuit diagrams, and this notation is illustrated in Fig. 1(b). Its advantage when specifying complicated systems will become apparent in due course. A line connected to a base represents R_b and C in parallel, unless the two input terminals are connected to different points, in which case the line represents R_b only, and a conventional capacitor symbol is used for C. The negative supply is represented by a horizontal bar, and a vertical line connected to it represents R_c if it is connected to a collector, and R_h if connected to a base. The current supply provided through R_a, which is connected to every transistor, is omitted from the abbreviated notation, as also are connexions between emitter and earth, which are

* *Formerly Metropolitan-Vickers Electrical Co. Ltd.*

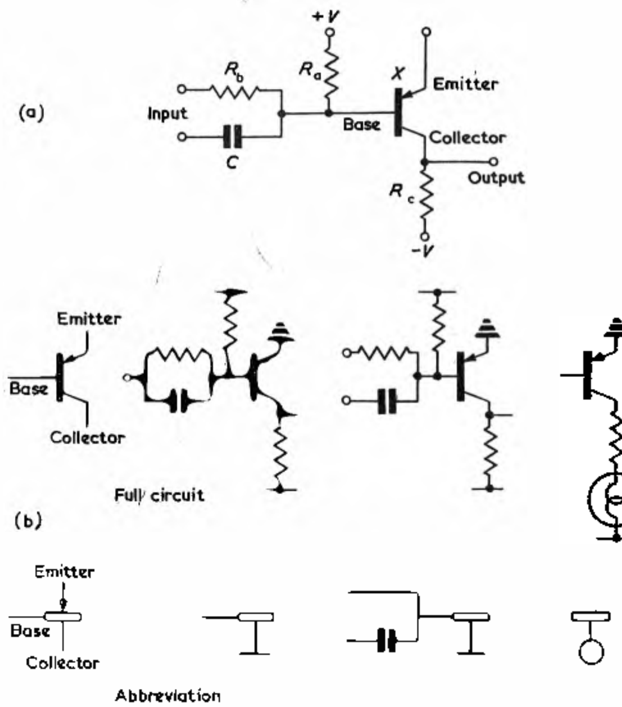


Fig. 1. The basic circuit

(a) Components
$R_a = 120k\Omega \pm 10$ *per cent*, $R_b = 18k\Omega \pm 10$ *per cent*,
$R_c = 1{\cdot}2k\Omega \pm 10$ *per cent*, $C = {\cdot}001\mu F \pm 10$ *per cent*,
$V = 15V \pm 10$ *per cent*, $X = OC76$
(b) Abbreviated notation

to be understood wherever no other connexion is made to the emitters. A line from a collector terminated in a ring represents an indicator light connected to the negative supply.

The basic circuit can use any components provided the manufacturers' ratings are not exceeded, and provided that the appropriate values are used to calculate the design rules (see Appendix 1).

Logical Design

The logical system used in the computer is now described so that the functions of the circuits comprising it may be understood. Fig. 2 is a schematic diagram of the machine, and Figs. 3, 4 and 5 show the circuits used to realize it. In Fig. 2, the accumulator accepts a binary number X from sets of gates which are controlled by the program. The capacity of the accumulator is ten binary digits, the eleventh (the most significant digit) being used to indicate overflow in conversion to binary, and sign in the reconversion, while the twelfth is included to allow time for logical functions between words.

Operation of button A causes program steps H, T and U to open gates which allow the binary equivalents of a hundred, ten and one to be passed to the accumulator once every word. The number of words from the operation of button A is counted, and the program steps are switched off after a number of words determined by the positions of the corresponding decimal switches. It so happens that the 'ones' required to represent these binary equivalents all occur in different digit periods, so the three program steps may be allowed to occur simultaneously. Thus the time required for the conversion of any three-digit decimal number is the number of word-periods equal to the largest digit. Whatever number is set up on the decimal switches is added to the binary total every time button A is operated until the capacity of the accumulator is exceeded, when a warning light is switched on, and the register reset to zero. The warning light is reset by the next operation of button A or B, and at all times the contents of the register are displayed on a set of ten indicator lights.

When button B is operated the binary total is reconverted to decimal form: program step h is switched on, and the binary equivalent of a hundred is subtracted from the total (by adding its complement) until the sign of the remainder becomes negative, when the program is shifted to t, which adds ten until the sign becomes positive again. The program is then shifted to step u, which adds the complement of one to the total until the sign again becomes negative, and finally one is added into the register to reset it to zero, since it contains minus one at the end of step u. The digits of the decimal equivalent are linearly related to the number of additions performed at each programe step, so they may conveniently be displayed on indicator lights operated by three pulse-separator circuits, one for each decimal digit. The maximum time required for the reconversion of any number up to 1 023 is 31 word periods.

Circuits

The basic circuits which comprise the computer have only two steady states; the transistor is either saturated

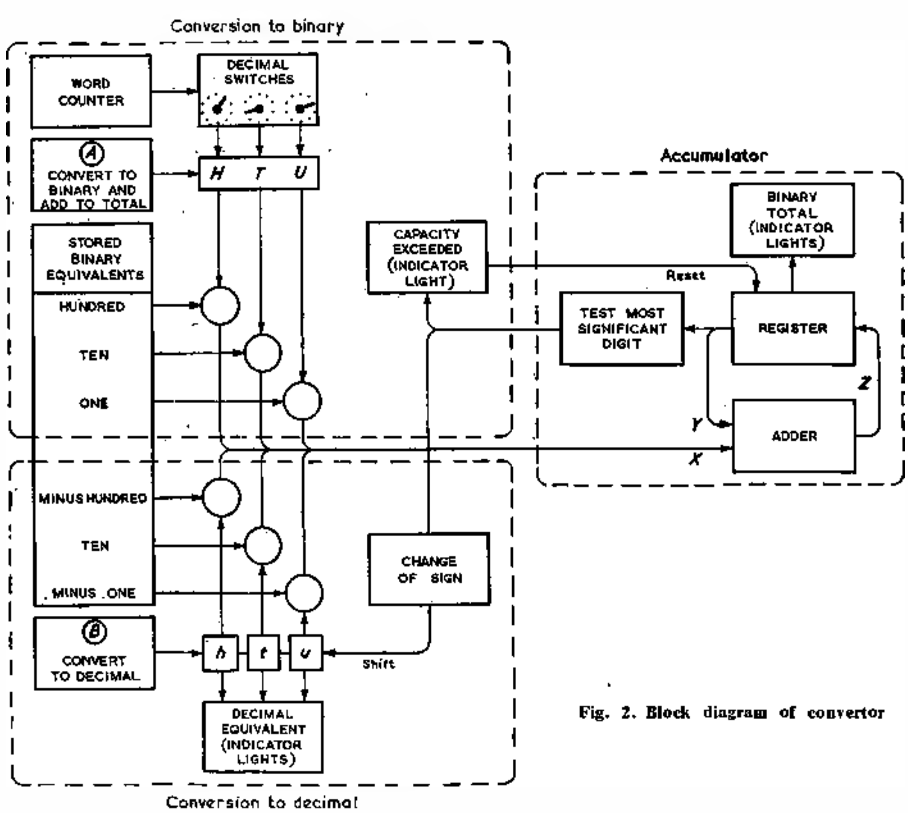


Fig. 2. Block diagram of convertor

or cut off. The convention is adopted that the collector potentials in these two states represents 'zeros' and 'ones' respectively, and that the state of a bistable circuit is defined by the potential at its right-hand collector.

By interconnecting groups of basic circuits, all the circuits required in the construction of a computing system may be formed, and details of the construction and operation of these are given elsewhere[1]. The description now given of the circuits of the convertor is restricted to the interconnexion of such groups of basic circuits.

Timing Circuits

The timing circuits illustrated in the upper half of Fig. 3 operate continuously, while those in the lower half operate once each time a program is carried out. A multivibrator (see Appendix 2) produces a square wave of about 7·5kc/s which is divided by two to produce the 'clock' waveform C and a narrow pulse S. The C waveform is divided by twelve by four scale-of-two circuits with suitable feedback, and then used to set the first stage of a 12-stage pulse-separator. The pulse separator output is shifted on by the S waveform, and twelve serial timing waveforms (P_0-P_{11}) are generated.

When button A or B is operated, a single pulse M is generated by the 'manual' circuit to occur during the first half of P_{11}, and this is used to initiate one of the two built-in programs. M occurs each time button A is operated, but only the first time B is operated after A.

The 'word-counter' is a pulse-separator circuit whose first stage is set by M, and which is shifted on once every word by the pulse R. This causes the signals H_d, T_d and U_d to rise from a negative value to earth for one word period after a number of words determined by the positions of the corresponding decimal switches.

The Accumulator

The accumulator consists of an adder, two one-digit delay circuits and a register, as shown in Fig. 4. The register is formed by eleven bistable circuits, together with gates for setting up their states to correspond to the digits of waveform Z, and gates to sample their states and present them as waveform Y. The number stored in the register appears at Y and is passed to the adder, where any number appearing at X is added to it. The left-hand delay circuit produces W, the carry waveform delayed by one digit ready to pass back to the adder input. It is necessary to delay the sum Σ by one digit period also, so that the number in the register can be used before any change in Σ affects its contents.

To prevent incorrect operation due to switching delays and transients, the adder outputs are sampled by a narrow pulse G, which occurs in the middle of each digit period. By using indicator lights in the left-hand collector circuits of the register, a one is indicated by a light being on. No light is required for the most significant digit, the function of which is to indicate overflow or change of sign.

The Program

The program steps for the conversion to binary are represented by the outputs H, T and U of three bistable circuits shown at the top of Fig. 5. These are switched simultaneously to their 'one' state by the operation of button A, and remain on until reset by H_d, T_d and U_d, i.e. for a number of words determined by the decimal switches. These permit the binary equivalents of a hundred (P_2, P_5 and P_6), ten (P_1 and P_3) and one (P_0) which are stored permanently, to appear at X so that they are added to the total in the register the appropriate number of times. If the capacity of the accumulator is exceeded a 'one'

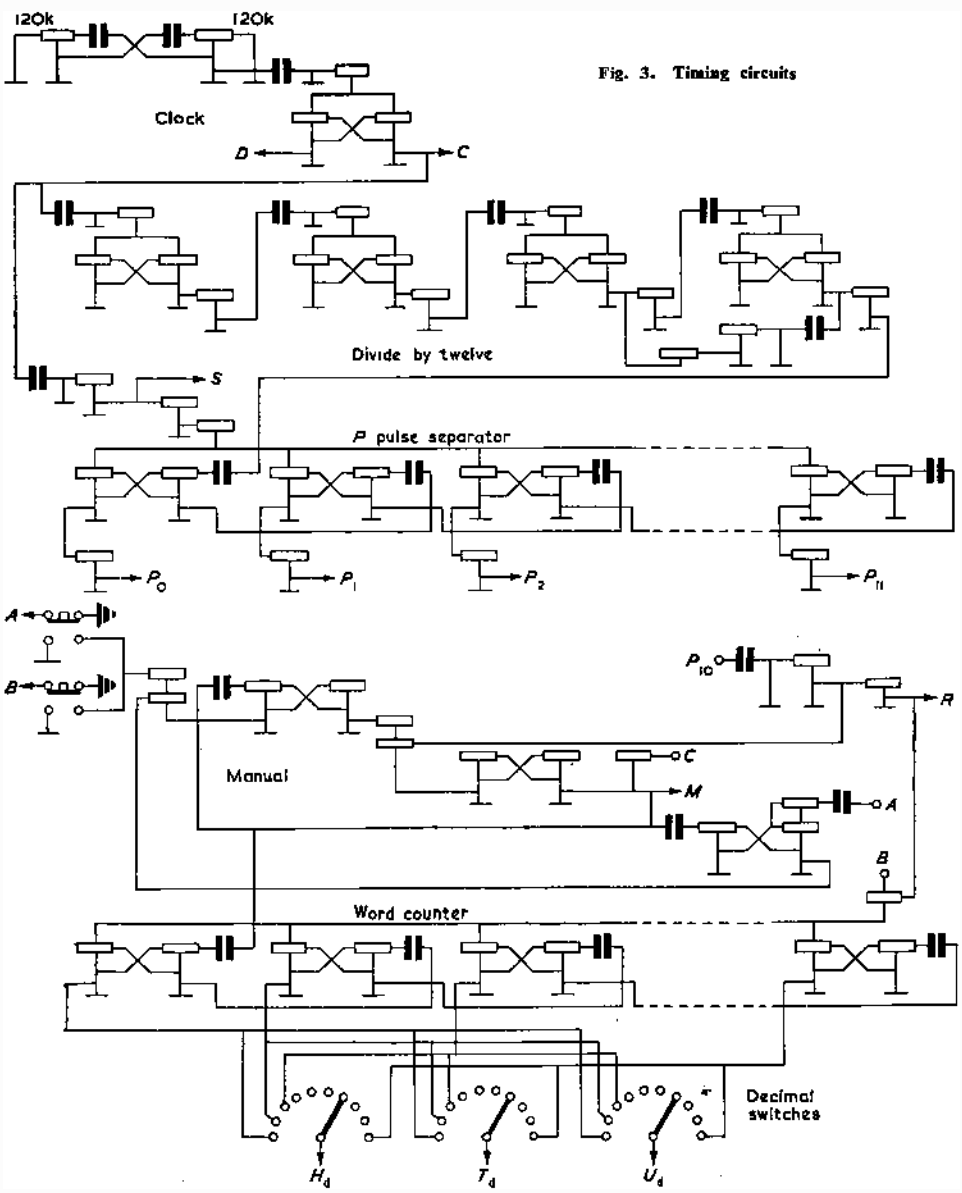


Fig. 3. Timing circuits

appears at the adder output Σ during P_{10} and the 'test' circuit changes state. This switches on the 'capacity exceeded' circuit which resets the accumulator to zero by clamping Z to earth, and this circuit is reset when M next occurs.

When button B is operated program step h is switched to its 'one' state and the complement of a hundred (P_2, P_3, P_4, P_7, P_8, P_9 and P_{10}) appears at X. Thus one hundred is subtracted from the binary total each word period until the sign of the total becomes negative, when the ''test' circuit changes state and shifts the program from h to t. This allows ten to appear at X until the total becomes by program steps t and u respectively. Operation of button A resets the indicators to zero. Since the capacity of the accumulator is 1 023, the hundreds indicator has eleven lights, while the others only require ten.

Mechanical Construction

The physical form of the computer, which is shown in Fig. 6, was governed by the decision to use printed wiring throughout. The machine was made in four sections, each section consisting of 22 identical plug-in units, the sockets for which were interconnected by two layers of printed 'back-wiring'. One end of each of the four sections

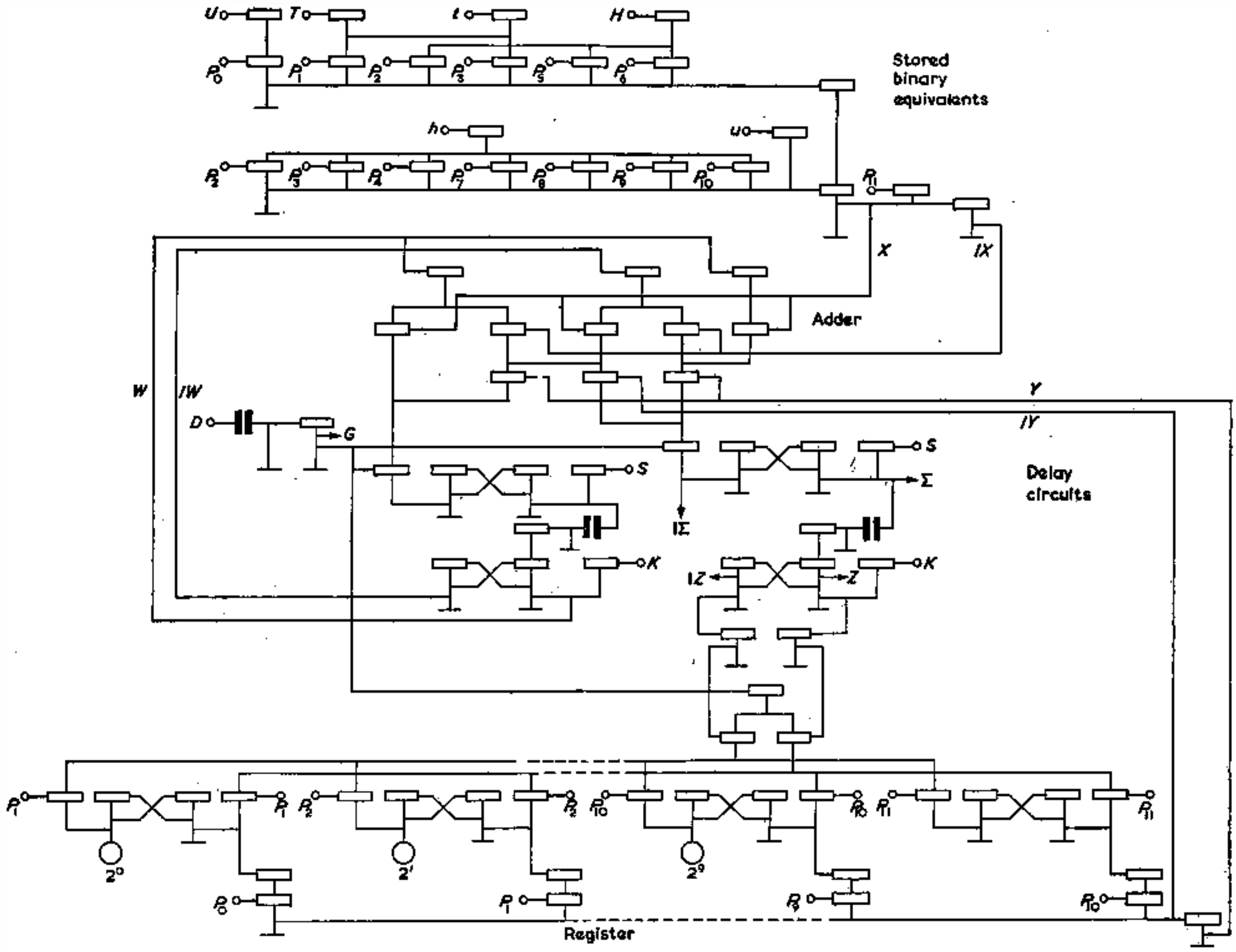


Fig. 4. Stored binary equivalents and accumulators

positive again, when the program shifts to u. The complement of one is represented by all the P pulses except P_{11} (to prevent carry-over from one word to the next), and is added to the total until it contains minus one. Step u then remains on until the beginning of P_1 in the next word, so that one is added to the total, leaving the register contents at zero at the end of the program.

The Decimal Equivalent

The decimal equivalent calculated by this program is set up on three pulse-separator circuits shown at the bottom of Fig. 5, which include suitably labelled lights. The first stage of the hundreds indicator is set to 'one' by M, and is shifted on once every word by R until h is reset. The tens and units indicators operate in a similar manner, except that their first stages are set to 'one' plugged into a further printed wiring board on which all the input/output equipment was mounted, and the wiring between the sections was completed by another printed board making interconnexions between their other ends. When two layers of printed wiring were used a spacer 1/16in thick was glued between the boards to allow room for the soldering on the bottom layer. This laminated construction resulted in a back-wiring panel with negligible warp.

The Plug-in Units

Each of the 88 plug-in units contains four separate basic circuits as shown in Fig. 1(a). The components are mounted on a printed wiring board, with all terminals brought out to a row of 22 contacts along one edge. Each terminal is brought to a separate contact, with the exception of that connected to R_8, which is common to all four circuits, as this point is always connected to the positive supply line. Thus 21 contacts are used for connexions, and the remaining one is available for polarizing the plug. The order in which the terminals are brought out was arranged so that the common circuits (e.g. pulse-separator, scale-of-two, bistable, monostable) could be formed with one layer of printed back-wiring, and the second layer of back-wiring used for supplies and interconnexions between the sections. The relative positions of components on the plug-in units was to a large extent governed by the order of the output contacts, but load resistors were placed so that a negligible proportion of the heat dissipated in them flowed over the transistors.

Design of the Back-wiring

The dimensions of the back-wiring panels were determined by those of the sockets which were used (Electro-Methods type KKM22S), and the 484 holes needed in each panel were located accurately by means of a drilling jig. As the socket pins were held rigidly by the back-wiring, it was necessary to ensure that the pins were in line, and that the plug-in units were held in a vertical position. This was done by inserting the units before soldering the back-wiring panels, and by locating the units in a notched bar fixed to the underside of each panel. This bar may be seen in Fig. 7, which shows one of the four sections of the machine.

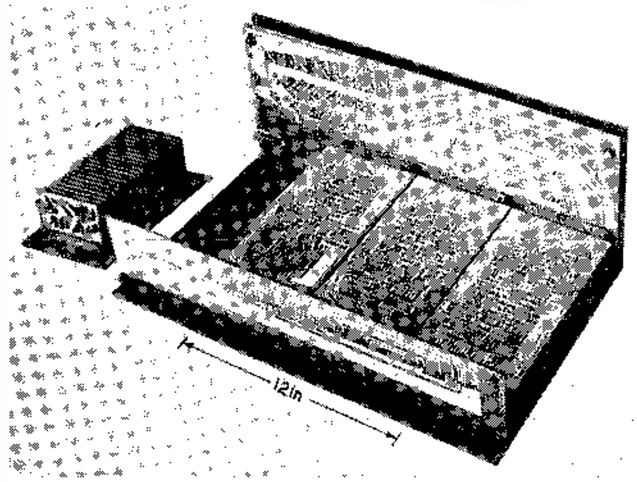


Fig. 6. The complete binary/decimal convertor

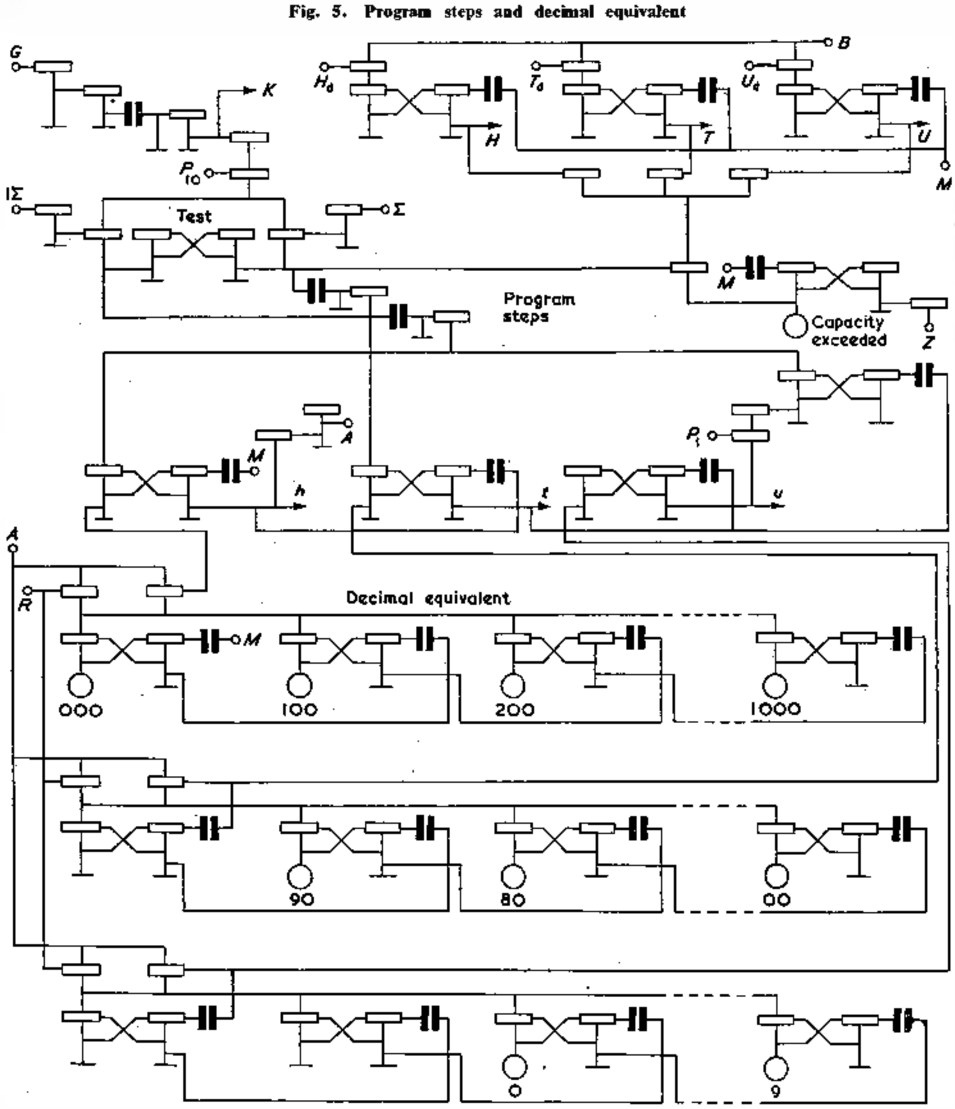
One of the most difficult tasks in designing the computer was to prepare the wiring diagrams from the circuit diagrams of Figs. 3, 4 and 5. Although the currents carried do not in general exceed 10mA, it was decided that a minimum conductor width of 1/32in should be used, and this meant that not more than three conductors could pass between two rows of socket pins. It was possible for a conductor to pass between two adjacent pins on a socket provided no connexion was made to either of these pins. A further restriction was imposed by the number of connexions which could be made to each section; 22-pin sockets were used to connect the sections to the end-wiring panels, so it was necessary to arrange that not more than 43 contacts were needed by any one section. In addition it was desirable that each section should contain the same number of plug-in units.

Bearing these restrictions in mind, the wiring diagrams were prepared so that only two layers of back-wiring were required. The front-end wiring containing the input/output equipment needed only a single layer, while a double layer was used for the rear-end wiring. A typical portion of a backwiring drawing is shown in Fig. 8.

Volume and Layout

One result of the method of construction used is that a high component density can

Fig. 5. Program steps and decimal equivalent



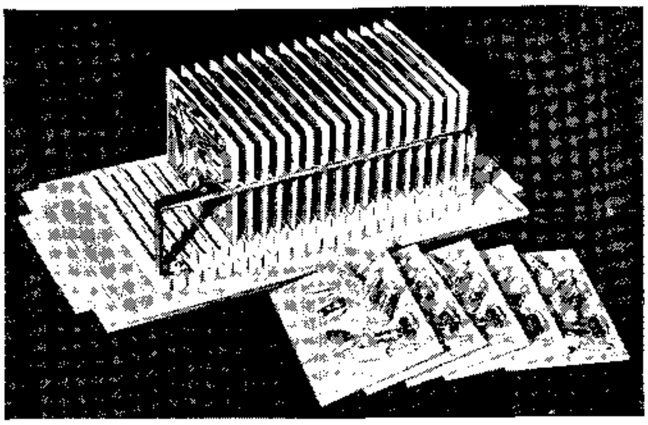


Fig. 7. One section of the convertor

be achieved, and the complete machine occupies a volume of about $\frac{1}{4}$ft^3. The temperature rise in the machine is higher than would normally be encountered because of the layout chosen to display the printed wiring.

CONSTRUCTION PROCEDURE

Two aspects of the use of printed wiring throughout a complete computer which may well frighten those already engaged in computer construction are that the basic circuits, once completed, cannot be altered, and that their interconnexions must be right first time.

The reliability of the basic circuit technique should allay the first of these fears, since very wide margins can be allowed on all component tolerances (see Appendix 1). The second fear is, however, well-founded, since mistakes in logical design will always occur in any but the simplest systems, as will other errors in design and manufacture. In order to ensure that the printed wiring was correct in the present machine, the following procedure was adopted. The logical design of the machine was planned (Fig. 2) and the circuit diagrams (Figs. 3, 4 and 5) were prepared following the design rules (Appendix 1). These circuits were then divided between the four sections so that each would contain the same number of plug-in units and require not more than 43 external connexions, as described previously. The other restrictions given earlier were then applied while the wiring diagrams were prepared.

A prototype computer using conventional wiring was built from these diagrams, and the mistakes found in the logical design were rectified. In this instance six modifications were necessary, and the corresponding changes in the wiring diagrams were made. Drawings from which printed wiring could be made were then prepared, and these drawings checked against the existing conventional wiring of the prototype. Four independent checks were carried out to ensure that no error had escaped unnoticed, but even so it was a considerable relief when the wiring had been printed and the machine assembled to find that it worked!

Performance

The computer was first shown at the Physical Society Exhibition in January 1958, and has since been demonstrated a number of times. There are 2 112 plug-and-socket connexions in the machine, and in spite of some of these having been made and broken several hundred times no contact trouble has yet been experienced. No steps were taken to strengthen the copper at the contacts, and although production equipment would probably have additional plating on the contact areas it is unlikely that such equipment would be dismantled more than a few times in the course of its existence.

With the supply lines at +15V and −15V the currents drawn from the positive and negative supplies are 48mA and 1·7A respectively, so the total power dissipation is about 25W.

The machine continues to operate correctly until both the supply voltages are reduced to 6·2V or until the negative line is reduced to 9·5V with the positive line at 15V. With the negative line at 15V the positive line can be reduced to 5·0V before any failure occurs.

By increasing the supply voltages to 18V the power dissipated is increased by 44 per cent. At this voltage the air temperature in the middle of the machine rises to about 60°C, but the machine still functions correctly.

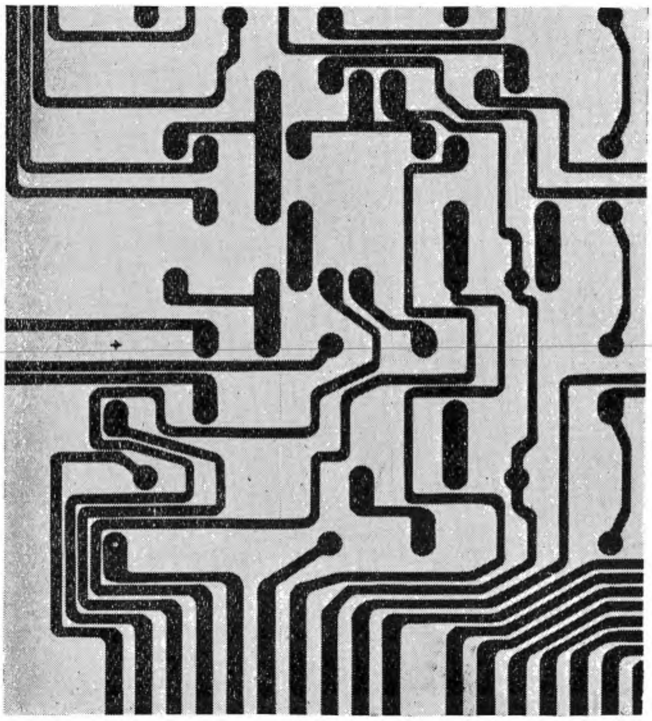
The machine operated correctly with an external oscillator used to supply the clock signal for any frequency up to 19·3kc/s.

Conclusions

Electrically, this project has demonstrated that a reliable system may be designed economically using the basic circuit technique. It must be remembered that the method is only suitable for special-purpose computers where speed is not the most important factor. The advantage of the abbreviated circuit notation is apparent from Figs. 1, 3, 4 and 5, by means of which about 1 800 components and their interconnexions are specified completely.

Mechanically, the computer has shown how compactly a system may be assembled, and has proved that it is quite practicable to print all the wiring in a digital system of considerable complexity. The consequent elimination of wiring errors during the assembly of a large number of machines will appeal to those engaged in the production of identical complex systems. If a variety of systems is to be produced it may prove economical to form blocks of circuits which are common to most of them by printing one layer of back-wiring only, and to interconnect these blocks with conventional wiring. Furthermore, the plug-in units have already proved useful in the laboratory for

Fig. 8. Portion of a back-wiring drawing



experimental work, with all the back-wiring done with conventional wire.

Although there is no evidence so far that the large number of plugs and sockets used is liable to cause trouble, there is no reason why a form of construction should not be considered in which all joints are soldered, in view of the anticipated reliability of the system. Once a system has been assembled, the only possible causes of failure are the drift of a component value outside the limits chosen in calculating the design rules, or the mechanical failure of an interconnexion.

Several other systems have been evolved using basic circuits, and the present circuit may profitably be compared with them. Directly-coupled transistor logic[2,3] uses even simpler units, and can operate at much higher speeds, but it uses many more transistors, and cannot perform timing functions. Another approach is that of the Neuron[4], which uses a core to carry out logical functions, while several theoretical analyses of basic circuits have been carried out [5,6,7]. An abbreviated notation has been evolved for use with directly-coupled transistor circuits[8], and another approach to the problem of printing back-wiring has been described[9], which requires less skill in its design than the present one.

Acknowledgment

The authors wish to thank Sir Willis Jackson, F.R.S., Director of Research and Education, Metropolitan-Vickers Electrical Co. Ltd, for permission to publish this article.

APPENDIX

(1) THE DESIGN RULES

The design rules governing the interconnexion of basic circuits may be expressed in terms of:

n, the number of input terminals driven from one output

p, ,, ,, ,, ,, ,, of an OR gate

m, ,, ,, ,, ,, ,, ,, ,, ,, AND gate

These quantities may be related to the circuit component values and four transistor parameters as follows:

$$n \leqslant \beta_s(1 - (R_c/V)\, i_k) - R_b/R_c$$

$$p \leqslant (1/i_k) \cdot (V/R_c)\left[1 - (1/\beta_s)\left((R_b/R_c) + n\right)\right]$$

$$m \leqslant \frac{VR_b - v_k(R_a + R_b)}{v_s R_a}$$

where

β_s = current gain of a basic circuit, expressed as collector current/input-terminal current for a transistor just saturated at a collector current of 10mA.

v_s = the potential difference between the emitter and collector of a saturated transistor.

i_k = collector current flowing in a transistor in its 'off' state.

v_k = the amount by which the base potential must be raised above the emitter potential to reduce i_k to a minimum.

Because of transients which may occur, an output terminal which drives any input to an AND-gate but the top one must not be connected to a two-state circuit. Positive steps only should be used with a.c. couplings, and two monostable circuits should not be directly cascaded.

From the maker's specification for the type OC76 transistor the limits to be taken for these parameters are:

$\beta_s > 30$

$v_s < 0{\cdot}2$V

$i_k < 15\mu$A at 25°C

$v_k < 0{\cdot}5$V

Tests on a batch of 52 transistors confirmed that their parameters fell well within these limits. The choice of transistor was determined by availability and the need to operate indicator lamps, and it was not known when the machine was planned that the low-voltage lights used would be obtainable.

With a ± 10 per cent tolerance on all component values and on the supply voltages, and a maximum permitted temperature of 55°C, the design rules restricting the interconnexion of basic circuits are:

$n \leqslant 8$

$p \leqslant 12$

$m \leqslant 5\ (m + n \leqslant 11)$

In the computer the maximum values occurring for n, p and m are 6, 11 and 4 respectively.

(2) CIRCUIT NOTES

An astable circuit suitable for use as a clock generator may conveniently be made by cross-coupling two basic circuits using their capacitors only, and returning the resistors R_3 to the negative supply. With the transistors used the frequency of oscillation of this circuit is about 7·5kc/s, the exact value depending on the transistor parameters. The abbreviated circuit notation has been modified in the 'clock' circuit to describe this, but has nowhere else been altered.

The state of the 'test' bistable circuit in Fig. 5 corresponds to that of the last stage of the register, i.e. to the sign of the number stored, and each time it changes state a shifting pulse is generated by one of two monostable circuits, this pulse being used to shift on the program steps h, t and u. The transistors of the monostable circuits use the load resistors of the left-hand transistors of whichever bistable circuit is in the 'one' state.

The use of indicator lights with 390Ω in series in place of 1 200Ω collector load resistors results in a non-linear resistance of value between about 650Ω (cold) and 950Ω (hot). It was found that both the pulse-separator and register circuits functioned satisfactorily with 15V supplies with a resistance of not less than 200Ω in series with the lights. About 8·9V was dropped across each lamp when 390Ω was used, and a further increase in the resistance would have reduced the illumination obtained by an excessive amount. In any production equipment separate indicator transistors would undoubtedly be used.

A dummy stage at the beginning of the 'tens' and 'units' decimal equivalent pulse-separator circuits in Fig. 5 is necessary since the program steps are shifted on just before the R pulse. The second dummy stage in the 'units' circuit is needed since the units program step is held on until after P_1 of the next word, so a further R pulse is allowed through.

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Analysis of the Transistor Cascode Configuration

By J. R. James*

Fixed component neutralization as used in the production of tuned amplifiers is often difficult to achieve, due to the spread in transistor parameters. A transistor cascode amplifier does not require neutralization but has less gain than two stages in the grounded emitter configuration. This article investigates to what extent the internal feedback and gain are reduced.

(Voir page 62 pour le résumé en français: Zusammenfassung in deutscher Sprache Seite 66)

FIRST the Y parameters (see Appendix 1) of the grounded emitter amplifier will be compared with those of the cascode amplifier. The relationship between the two configurations is established using matrix algebra. Also the theoretical reduction in the gain and internal feedback of the cascode configuration is derived. Next a practical case will be considered in order to verify the theoretical relationships and finally the use of the circuit will be discussed.

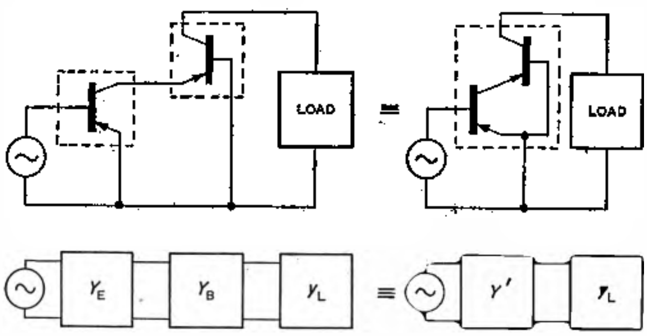

Fig. 1. The cascode configuration considered as a composite transistor

Derivation of the Y Parameters of a Cascode Amplifier from the Grounded Emitter and Grounded Base Parameters

It is assumed that the Y parameters of the transistors to be used have been measured, at the desired working point and frequency of operation, for both grounded emitter and grounded base configurations. Let them be Y_E and Y_B respectively where, in matrix form:

$$(Y_E) = \begin{vmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{vmatrix} \text{ and } (Y_B) = \begin{vmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{vmatrix}$$

Fig. 1 shows how the cascode configuration can be regarded as a grounded emitter amplifier in cascade with a grounded base amplifier. The network presentation is also shown.

As shown in Appendix 2, the A matrix of the cascode circuit can be derived from the product of the A matrices of the grounded emitter and grounded base configurations. Therefore first of all the Y matrices (Y_E) and (Y_B) must be converted into the A matrices (A_E) and (A_B). The following notation will be used:

$$(A_E) = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \qquad (A_B) = \begin{vmatrix} a & b \\ c & d \end{vmatrix}$$

Then, if (A') is the A matrix of the cascode amplifier:

$$(A') = (A_E)(A_B) = \begin{vmatrix} Aa+Bc & Ab+Bd \\ Ca+Dc & Cb+Dd \end{vmatrix}$$

On writing the elements of the A matrices in terms of the measured Y parameters (see Appendix 1):

$$(A') = \begin{vmatrix} \dfrac{y_{22}\{Y_{22}+y_{11}\} - y_{12}y_{21}}{Y_{21}y_{21}} & \dfrac{\{Y_{22} + y_{11}\}}{Y_{21}y_{21}} \\[2ex] \dfrac{Y_{11}y_{22}\{Y_{22}+y_{11}\} - Y_{12}Y_{21}y_{22} - Y_{11}y_{12}y_{21}}{Y_{21}y_{21}} & \dfrac{Y_{11}\{Y_{22}+y_{11}\} - Y_{12}Y_{21}}{Y_{21}y_{21}} \end{vmatrix}$$

Using once again the relationship between the A and Y matrices the Y matrix (Y') of the cascode amplifier can be formed from the elements of the A matrix (A').

$$(Y') = \begin{vmatrix} \dfrac{Y_{11}\{Y_{22}+y_{11}\} - Y_{12}Y_{21}}{\{Y_{22}+y_{11}\}} & \dfrac{-Y_{12}y_{12}}{\{Y_{22} + y_{11}\}} \\[2ex] \dfrac{-y_{21}Y_{21}}{\{Y_{22}+y_{11}\}} & \dfrac{y_{22}\{Y_{22}+y_{11}\} - y_{12}y_{21}}{\{Y_{22} + y_{11}\}} \end{vmatrix}$$

In order to simplify the expression the following approximations are used:

(1) $\{Y_{22} + y_{11}\} \simeq y_{11}$

(2) $Y_{11} \gg Y_{12}$

(3) $y_{11} \simeq -y_{21}$

It can be shown[1] using H parameters that $h_{21} = (y_{21}/y_{11}) = -\alpha$. Now the current gain α of a grounded base amplifier is almost unity. Therefore $y_{11} \simeq -y_{21}$.

(Y') is now simplified as follows:

$$(Y') = \begin{vmatrix} Y_{11} & Y_{12}(y_{12}/y_{11}) \\ Y_{21} & y_o \end{vmatrix}$$

where $y_o = y_{22} - \dfrac{y_{21}\,y_{12}}{Y_{22} + y_{11}}$

The expression for the Y matrix of the cascode amplifier will now be used to investigate stability and gain.

The Stability Factor of a Cascode Amplifier

Using the derived Y parameters for the cascode configuration, the stability factor (Appendix 3) is evaluated in terms of the load admittance. A typical cascode stage operating in a multi-stage amplifier is shown in Fig. 2. It has the following features:

(1) The load admittance Y_L is a variable in the hands of the designer. It is controlled by the inter-stage transformer ratio.

(2) Reactive components across input and output terminals are tuned out at the centre frequency f_o of the pass-band.

(3) The input is driven from a constant current source. This simulates the preceding stage which is assumed

* *Semiconductors Ltd.*

to be another cascode amplifier with almost zero output admittance.

Derivation of Required Transfer Functions of the Amplifier

It is now convenient to derive expressions for the internal voltage feedback ratio and the forward voltage gain of a cascode amplifier with load. The power gain is also extracted and will be used later.

The A matrix (A'') for the amplifier with load is given by:

$$(A'') = (A')(a) =$$

$$\begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} \begin{vmatrix} 1 & 0 \\ Y_L & 1 \end{vmatrix} = \begin{vmatrix} A'+B'Y_L & B' \\ C'+D'Y_L & D' \end{vmatrix}$$

(A') and (a) are the A matrices of the cascode configuration and load admittance Y_L.

$$\text{Voltage gain} = V_2/V_1 = \frac{1}{\{A' + B'Y_L\}} \quad \text{Since } I_2 = 0$$

$$\text{Current gain} = \frac{Y_L}{\{C' + D'Y_L\}}$$

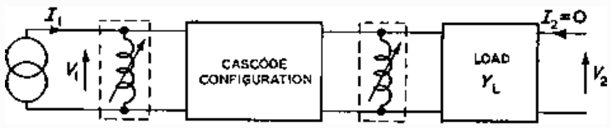

Fig. 2. The input and output circuits of a typical cascode amplifier

$$\text{Power gain} = \text{Voltage gain} \times \text{Current gain} = \frac{Y_L}{\{A'+B'Y_L\}\{C'+D'Y_L\}}$$

Using H parameters[3] it can be shown that:

$$V_1/V_2|_{I_1=0} = H_{12} = \{A'+B'Y_L\} - (B'/D')\{C'+D'Y_L\}$$

As one is driving from a constant current generator H_{12} can be taken as the fraction of voltage fed from output to input terminals.

Stability Factor S

S is now given. (Re denoting real part)

$$S = \text{Re}\left\{\frac{1}{H_{12}\{\text{voltage gain}\}}\right\} = \text{Re}\left\{\frac{D'}{D' - \dfrac{B'\{C'+D'Y_L\}}{\{A'+B'Y_L\}}}\right\}$$

The A matrix (A') of the cascode configuration is now written in terms of the Y parameters derived previously.

$$(A') =$$

$$\begin{vmatrix} A' & B' \\ C' & D' \end{vmatrix} = \begin{vmatrix} -(y_o/Y_{21}) & -(1/Y_{21}) \\ \dfrac{\{Y_{11}y_o - Y_{21}Y_{12}(y_{12}/y_{21})\}}{-Y_{21}} & -(Y_{11}/Y_{21}) \end{vmatrix}$$

On writing S in terms of the Y parameters and taking $y_o = 0$ and the real parts of Y_{11} and Y_L:

$$S = \text{Re}\left\{\frac{y_{21}G_{11}}{Y_{12}Y_{21}y_{12}}\right\} G_L = kG_L \qquad k = \text{Re}\left\{\frac{y_{21}G_{11}}{Y_{12}Y_{21}y_{12}}\right\}$$

The stability factor has been expressed in terms of G_L and a constant, at the frequency of resonance f_o of the input and output circuits. The amplifier will oscillate when $G_L k = 1$, the frequency of oscillation being slightly removed from f_o.

From the analysis it may be concluded, therefore, that the load conductance is determined by the stability factor desired. The derived expression for S becomes inaccurate for smaller values of G_L.

The Power Gain of the Cascode Amplifier

In order to acquire a figure of merit for the cascode configuration a comparison is made with the power gain of the grounded emitter configuration (Appendix 3).

Using the expression derived in the previous section and writing it in terms of Y parameters:

Power gain of cascode amplifier =

$$\frac{|Y_{21}|^2 G_L}{\left\{G_{11}y_o - \dfrac{Y_{21}Y_{12}y_{12}}{y_{21}} + G_{11}G_L\right\}\{y_o + G_L\}}$$

$$\text{Putting } y_o = 0 \text{ and } \frac{Y_{21}Y_{12}y_{12}}{y_{21}} = 0$$

$$\text{Power gain} = \frac{|Y_{21}|^2}{G_{11}G_L} = P_c$$

The power gain P_e of a grounded emitter amplifier is:

$$P_e = \frac{|Y_{21}|^2}{4G_{11}G_{22}}$$

K is defined as follows:

$$K = 10 \log (P_c/P_e) = 10 \log 4n_1$$

where $n_1 = (G_{22}/G_L)$

When $n_1 = 1 \quad K = 6\text{dB}$

$n_1 = 2 \quad K = 9\text{dB}.$

The expression for K increases in inaccuracy as n_1 is increased.

Evaluation of a Practical Case

Using the relationships between G_L, gain and stability, an estimation of cascode stability at a given gain can be produced which will be increasingly pessimistic with increasing gain, due to the approximations made in the analysis.

For example the stability factor which allows the cascode amplifier to have 25 per cent less gain than two stages of conventional grounded emitter amplification is given by:

$$S = \text{Re}\ \{(y_{21}/y_{12}) \cdot (Y_{21}/Y_{12})\}\ 1/\{P_e\}^{3/2}$$

$$\text{Since } G_L = 4G_{22}/\{P_e\}^{\frac{1}{2}}$$

For the type SB346 at 20Mc/s, $P_e \simeq 34$

$G_L = 0{\cdot}68\ G_{22}$

$S \simeq 6$

Due to measuring errors in the Y parameters and approximations made above, the calculation of S is liable to large errors and is only quoted as approximate. A value of 6 is quite adequate for most amplifiers.

Summary of Results of the Analysis

(1) The cascode input admittance is practically equal to that of a grounded emitter amplifier.

(2) A similar result applies to Y_{21}.

(3) The output admittance is practically equal to h_{22} and for most cases can be assumed to be zero. However, as the stability factor of the amplifier is made smaller, negative conductance appears at the output terminals in shunt with h_{22} (h_{22} is the output admittance of a grounded base amplifier with the input terminal open circuited. It can be shown that $h_{22} = y_{22} - (y_{12}y_{21})/y_{11}$).

(4) The internal feedback in the cascode configuration is typically one-fiftieth of that in the unneutralized grounded emitter configuration.

(5) The cascode amplifier can only be treated as unilateral at lower gain levels. The stability factor is inversely

proportional to the gain. For a given stability factor the gain is fixed.

(6) As the stability factor is lowered, the output admittance becomes increasingly negative. A point is reached where the bandwidth is noticeably reduced. If an amplifier is designed around this operating point, the bandwidth will be very dependent on individual transistors, and also the response curves will not be additive in the normal manner.

(7) The calculation of this operating point from the analysis requires very accurate values of the Y parameters and it is believed that the experimental approach is more accurate.

Consideration of a Practical Case to Verify Analysis

Two transistors of the type SB346 were measured at $I_o = -0{\cdot}25$mA, $V_o = -3$V at a frequency of 20Mc/s. The averages of the two sets of readings are as follows with all admittances in millimhos.

	Grounded Emitter	Grounded Base	
Y_{11}	1·14 + j1·43	6·48 − j3·11	y_{11}
Y_{22}	0·32 + j0·71	0·32 + j0·71	y_{22}
$-Y_{12}$	0·08 + j0·26	0·35 + j0·71	$-y_{12}$
$-Y_{21}$	−3·42 + j5·03	6·28 − j3·14	$-y_{21}$

From the measurements the following points are apparent:

(1) $Y_{22} = y_{22}$

(2) $-y_{12} \simeq y_{22}$

(3) $y_o = y_{22} - \dfrac{y_{21}y_{12}}{y_{11} + Y_{22}} \simeq 0$

This result is subject to accumulative measuring errors.

(4) $y_{11} \simeq -y_{21}$

(5) The maximum unilateralized matched gain in the grounded emitter configuration, based on average values is 14·3dB.

Using the measured data it was decided to test the conditions suggested in the analysis. The operating point is not optimum for the stability power gain product and thus the results are slightly pessimistic for SB346 transistors.

The optimum collector current would be about 0·5mA.

THE DESIGN OF A CASCODE AMPLIFIER WITH $G_L = G_{22}$

Design Details

Centre frequency 20Mc/s
Bandwidth per tuned circuit 2Mc/s
Overall bandwidth (2 tuned circuits) .... 1·3Mc/s
Transformer ratio .... 2·4:1
Unloaded Q (Q_U) 26
Loaded Q (Q_L) 10
Added capacitance (C) 21pF
Loss per coil .... 4·2dB

Using 26 s.w.g. enamelled wire and tunable ferrite cup cores, the primary winding was 12 turns and the secondary 5 turns.

The ferrite cup cores had considerable loss at 20Mc/s and the following comment is in order. In conventional grounded emitter amplifiers maximum gain is always achieved when the reflected load resistance is made equal to the collector output resistance, independent of any shunt coil loss resistance. Lossy coils reduce the gain and improve the stability factor.

In the following experiments the pre-determined value of resistance presented to the collector circuit is composed of both coil loss and reflected load resistance. The stability factor which is dependent on G_L is not influenced by the coil loss that only reduces the power gain of the cascode amplifier.

Results of Measurements

The amplifier was stable and easily adjusted. The bandwidth appears quite normal indicating that the negative output admittance is of a small order.

Overall bandwidth .... 1·45Mc/s
Overall gain .... 11·3dB
Overall gain of cascode amplifier without losses .. 19·7dB
Maximum gain of grounded emitter amplifier .... 14·3dB

The difference in gain of 5·4dB is very close to the predicted value of 6dB.

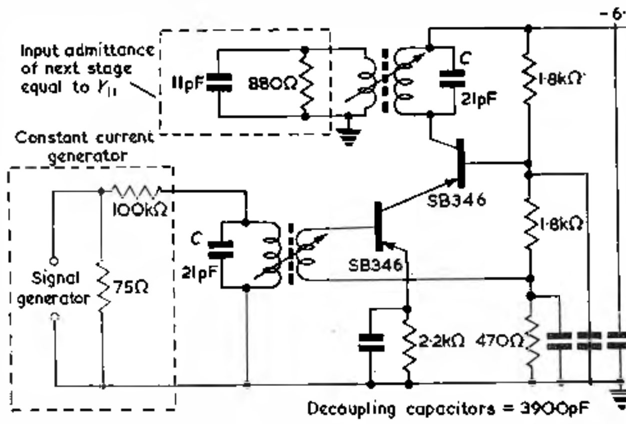

Fig. 3. Circuit diagram of experimental cascode amplifier

THE DESIGN OF A CASCODE AMPLIFIER WITH $2G_L = G_{22}$

The circuit is similar to that in Fig. 3.

Design Details

Centre frequency 20Mc/s
Bandwidth per tuned circuit 2Mc/s
Overall bandwidth (2 tuned circuits) .... 1·3Mc/s
Transformer ratio .... 3·75:1
Unloaded Q (Q_U) 18
Loaded Q (Q_L) 10
Added capacitance (C) 11pF
Loss per coil .... 7·1dB

Using 33 s.w.g. enamelled wire and tunable ferrite cup cores, the primary winding was 15 turns and the secondary 4 turns.

Results of Measurements

The input transformer tuned correctly but the output transformer most certainly showed signs of negative capacitance and resistance. The Q of the coil had increased from 10 to 14 and the value of negative resistance was calculated to be about 25kΩ with a negative capacitance of about 2pF. Allowance for the increase in the output impedance was made in the gain measurement.

Overall bandwidth .... 1·1Mc/s
Overall gain .... 12·9dB
Overall gain of the cascode amplifier without losses .... 27·1dB
Maximum gain of grounded emitter amplifier .... 14·3dB

The difference in gain of 12·8dB is 3·8dB in excess of the predicted figure. This is not surprising since in the theoretical estimation it was assumed that the feedback term was negligible.

The Design of a Cascode Amplifier with $G_L \ll G_{22}$

The circuit is similar to that in Fig. 3 except that no extra capacitance C was added to the transformers. The Q's of the coils were made very high and G_L was equal to 0·02 millimhos.

Results of Measurements

Any attempt to tune the amplifier resulted in oscillation. The circuit was taken no further.

Conclusions

The analysis has been reasonably substantiated by the practical results. Using SBT346 transistors at 20Mc/s, the experiment shows that it is possible to design a cascode amplifier (G_L slightly less than G_{22}) with unilateral properties, and 25 per cent less gain in dB than two stages of conventional neutralized grounded emitter amplification.

Numerous reports of the cascode circuit suggest the general rule, that a cascode circuit designed with any type of transistor will provide unilateral characteristics in exchange for about 25 per cent less gain in dB than two stages of grounded emitter amplification at the same frequency.

In assessing costs it should be noted that the cascode circuit has four resistors, three capacitors and one transformer less than the conventional two stage grounded emitter amplifier. Therefore all in all the cascoded amplifier may cost about the same as a conventional type.

It is believed that the cascode amplifier gives more gain for a given volume and weight, than any other transistor configuration.

Acknowledgments

The author is indebted to the Management of Semiconductors Limited for permission to publish this article.

It is believed that the transistorized cascode circuit was first used by S. H. Bowers of S.R.D.E., Christchurch.

Appendix

Derivation of Transistor Parameters in Matrix Form

Because a transistor is an active network, four terminal network theory is used in transistor c.w. circuit analysis.

A four terminal active or passive network is completely defined by equation (1).

$$\left.\begin{aligned} V_1 &= AV_2 - BI_2 \\ I_1 &= CV_2 - DI_2 \end{aligned}\right\} \quad \dots\dots\dots\dots\dots (1)$$

A, B, C and D are constants of the network, V_1, I_1 and V_2, I_2 are the input and output voltages and currents. Equation (1) is often written in matrix notation as shown in (2).

$$\begin{vmatrix} V_1 \\ I_1 \end{vmatrix} = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} V_2 \\ -I_2 \end{vmatrix} \quad \dots\dots\dots (2)$$

The array of constants is referred to as (A) or the A matrix of the network. Note that if the network is passive $[A]$ is equal to unity and in that case $AD - BC = 1$.

Equation (1) could have been written as follows (3) and in matrix form (4)

$$\begin{aligned} I_1 &= Y_{11} V_1 + Y_{12} V_2 \\ I_2 &= Y_{21} V_1 + Y_{22} V_2 \end{aligned} \quad \dots\dots\dots\dots\dots (3)$$

$$\begin{vmatrix} I_1 \\ I_2 \end{vmatrix} = \begin{vmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{vmatrix} \begin{vmatrix} V_1 \\ V_2 \end{vmatrix} \quad \dots\dots (4)$$

Here the Y terms are all constants whose dimensions are those of mhos and are therefore called admittance parameters. The array of Y parameters is referred to as (Y) or the Y matrix of the network. Note that if the network is passive $Y_{12} = Y_{21}$.

The relationships between Y and A parameters is as follows:

$$\left.\begin{aligned} Y_{11} &= (D/B) \qquad & Y_{12} &= \frac{-\{AD - BC\}}{B} \\ Y_{21} &= -(1/B) \qquad & Y_{22} &= (A/B) \end{aligned}\right\} \dots (5)$$

There are six ways of writing equation (1) to produce six interdependent matrices. Once any one matrix has been measured, the others can be calculated.

In practice the Y parameters are easiest to measure. Equation (3) can be re-arranged as follows to indicate the method of measurement.

$$\left.\begin{aligned} Y_{11} &= (I_1/V_1)|_{V_2=0} \qquad & Y_{12} &= (I_1/V_2)|_{V_1=0} \\ Y_{21} &= (I_2/V_1)|_{V_2=0} \qquad & Y_{22} &= (I_2/V_2)|_{V_1=0} \end{aligned}\right\} \dots\dots (6)$$

Each measurement requires a pair of terminals of the network to be shorted out and this can be easily performed with large capacitors. Measurements can be made on an admittance bridge, connected as a two terminal device for Y_{11} and Y_{22}, and as a three terminal device for Y_{12} and Y_{21}. It will be found that some Y parameters are common for two different configurations. For example, as mentioned earlier Y_{22} (grounded emitter) is equal to y_{22} (grounded base).

Use of Matrix Algebra

Matrix Algebra is a very powerful tool when applied to transistor c.w. circuits. The following deals only with the portion used in the text.

Fig. 4 shows how two cascaded networks can be resolved into one. Writing the matrix form for the networks in full:

$$\begin{vmatrix} V_1 \\ I_1 \end{vmatrix} = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} V_2 \\ -I_2 \end{vmatrix} \quad \text{and} \quad \begin{vmatrix} V_2 \\ I_4 \end{vmatrix} = \begin{vmatrix} a & b \\ c & d \end{vmatrix} \begin{vmatrix} V_3 \\ -I_3 \end{vmatrix}$$

As $-I_2 = I_4$:

$$\begin{vmatrix} V_1 \\ I_1 \end{vmatrix} = \begin{vmatrix} A & B \\ C & D \end{vmatrix} \begin{vmatrix} a & b \\ c & d \end{vmatrix} \begin{vmatrix} V_3 \\ -I_3 \end{vmatrix} = |A'| \begin{vmatrix} V_3 \\ -I_3 \end{vmatrix}$$

Using matrix multiplication:

$$|A'| = \begin{vmatrix} Aa + Bc & Ab + Bd \\ Ca + Dc & Cb + Dd \end{vmatrix}$$

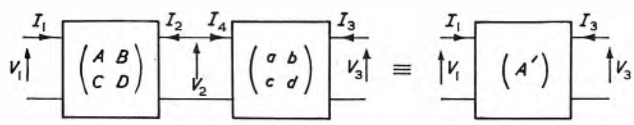

Fig. 4. The reduction of cascaded four-terminal networks

For details of the theory of matrix algebra see Aitken[2] and Bell and Brewster[3] as regards application to transistor circuit analysis.

Calculation of Transistor Performance from its Parameters

Once any set of transistor parameters is known, the performance can be assessed. Here only the use of the Y parameters will be considered. It can be shown that the maximum matched gain of a unilateralized grounded emitter amplifier, where n is the transformer ratio and shunt neutralizing is used, is as follows:

$$10 \log \left\{ \frac{|Y_{21} - Y_{12}|^2}{4\{Y_{11} - Y_{12}n\}\{Y_{22} - (Y_{12}/n)\}} \right\} \dots\dots (7)$$

In practice Y_{12} can be neglected, at least as regards the gain calculation. There is also a power loss due to the finite Q of the unloaded coil and sometimes a mismatch load admittance y_L. The gain equation then becomes:

$$10 \log \frac{|Y_{21}|^2}{4Y_{11}Y_{22}} - \left\{ 10 \log \left(\frac{1}{1-(Q_L/Q_U)}\right)^2 + 10 \log \frac{\{y_L + Y_{22}\}^2}{4y_L Y_{22}} \right\} \dots\dots\dots (8)$$

Q_L = loaded Q of the coil

Q_U = unloaded Q of the coil

As the amplifier is tuned one is only concerned with the real parts of Y_{11}, Y_{22} and y_L.

The term unilateralized implies that the input and output terminals are not coupled in the reverse direction, at any frequency. Neutralization employs less components but only causes Y_{12} to be zero over a narrow band of frequencies centred at the operating frequency. The admittance of the neutralizing network is equal to $-Y_{12}n$ (which is usually resolved into a series resistor and capacitor) and is fed from the transformer secondary.

A designer must know the design centre of Y_{12} for the transistor in use. If fixed component neutralizing is to be used, the maximum difference ΔC between the fixed capacitor and the actual series capacitance component of $-(1/Y_{12}n)$ that is likely to occur in a large batch of transistors, is calculated.

Next, the extra capacitance ΔC_o which, when added to the fixed capacitor on a correctly neutralized amplifier will cause the stage to oscillate, is calculated from circuit details.

Once ΔC and ΔC_o have been determined the effects of extreme misneutralization can be assessed. The stability factor S is defined as:

$$S = \frac{\text{Loop gain required for oscillation}}{\text{Actual loop gain}}$$

$$= Re \left\{ \frac{1}{\text{Actual loop gain}} \right\}$$

Or in terms of misneutralization:

$S \simeq (\Delta C_o / \Delta C)$

As S becomes smaller so the interaction between the tuned circuits increases. The bandwidth becomes narrower and the peak is pulled to one side. A stability factor as low as four may be met in practice, dependent of course on the application for the amplifier. The product of the power gain and stability factor is optimum at a certain collector current.

For more details of the above, see Wolfendale[4].

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2. Aitken, A. C. Determinants and Matrices. (Oliver and Boyd, 1958.)
3. Bell, J. S. Brewster, K. An Introduction to Matrices and their Use in Transistor Circuit Analysis. *Electronic Engng. 31*, 98 (1959).
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AUTOMATIC CABLE TESTING

The De Havilland cable test set provides, in easily portable form, the facilities for checking the continuity and insulation of multi-core cable looms normally available only in fixed or cumbersome equipment. Although initially designed for checking electrical systems in aircraft, the unit, which weighs only 19lb is of value in any type of installation where cabling is already in place, or where the cable runs are in confined spaces.

Either a continuity or an insulation check can be carried out from one end of a cable run, the far end being terminated by a small unit weighing less than ½lb. A test is initiated by a press-button and the instrument automatically selects each wire in turn. The identification of the core undergoing test is indicated in a window which is illuminated by a red light if failure occurs, in which case the selector stops at the faulty core. Successful completion of a test sequence is indicated by the extinguishing of a separate indicator lamp.

The outlet capacity of the unit is 25 cores but this can be extended by the use of adaptors.

A single outlet from the test set can be adapted for use with any cable by means of a suitable coupler supplied against the customer's requirements. In the case of a connector having a multi-position keyway (e.g. Plessey Mk. IV) the coding is checked by a clearly marked movable keyway on both the coupler and termination units.

A high impedance source of 500V is used for the insulation tests and this provided by a transistor convertor. The continuity tests are made with a 960c/s square wave which provides 120mA on short-circuit.

The cable testers are normally supplied with fail limits set at 5Ω and 1MΩ on continuity and insulation respectively.

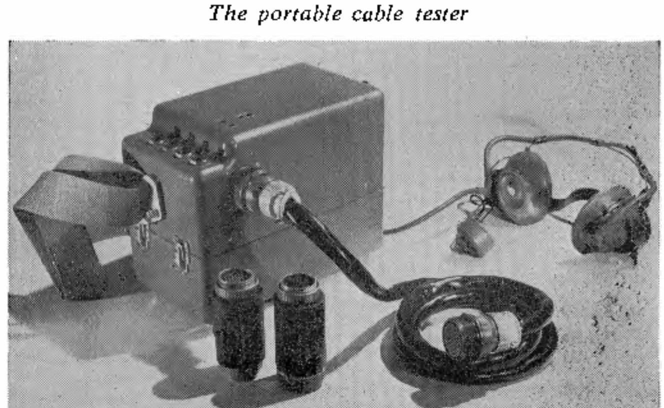
To enable long cable runs to be tested in conditions where the termination unit is more conveniently attached by a second operator, an intercommunication amplifier is incorporated in the instrument, connexion being made via the cable under test. Standard service style headsets may be used.

When this system is in use the operators receive an additional audible signal as each test is made and can distinguish when a cable failure is detected.

In its portable form the cable tester is mounted on a strap which can conveniently be used either as a neck-sling or a carrying-handle. Power is supplied by a lightweight battery of a type having no free electrolyte, and of sufficient capacity for about sixteen hours of normal use. Couplers and termination units can be carried in pouch-belts. For difficult situations, where access to the cable to be tested is limited, an extension cable can be used.

A charging unit can be supplied with the test set. Internal regulation of the unit ensures that in four hours the battery will be fully charged, yet there is no risk of overcharging however long the equipment is left. State of charge is indicated by a meter; an a.c. power unit is available as a replacement for the battery when the test set is in use on the bench or near a mains supply.

The portable cable tester



Short News Items

The National Radio and Television Exhibition is to be held at Earls Court, London, from 24 August to 3 September 1960 with a pre-view for overseas and other specially invited visitors on 23 August. This will be the 27th National Radio Show.

A Consultative Committee has been appointed to advise the Department of Scientific and Industrial Research on the services of the National Lending Library for Science and Technology. Literature is now being collected for the National Lending Library for Science and Technology by the D.S.I.R. Lending Library Unit at 20 Chester Terrace, Regent's Park, London N.W.1. The Library will be located near Boston Spa, Yorkshire, and its transfer will take place in the first half of 1961. Its collection of scientific literature, which will become the largest in the U.K. will be available to any organizations through loan and photocopying services.

Ferranti Ltd have received orders for two general-purpose Pegasus Electronic computers. The first will be installed at the Road Research Laboratory of the Department of Scientific and Industrial Research where it will be used for all aspects of road research calculations, in particular, problems associated with road traffic and safety. The second Pegasus has been ordered by The Steel Company of Wales. Intended primarily for research studies, the computer is likely to be installed in the Operational Research Department at the Abbey Works, Port Talbot, within the next few months. The total value of both machines exceeds £150 000 and these latest orders bring the total number of Pegasus sold to 30.

The British Council will hold a course on digital computers in London from 7 to 20 February 1960 for industrial and research scientists from overseas. The only previous course on the subject organized by the British Council in 1957, brought experts from Australia and all over Europe including Poland and Yugoslavia. The course, which will be directed by Dr. Andrew Booth, Head of the Department of Numerical Automation at Birkbeck College, will concentrate on recent improvements in computer design and programming techniques, and will be closely linked with practical work in industry. The fee for the course is £47 and accommodation will be in London hotels. Further particulars can be obtained from The British Council, 65 Davies Street, London W.1.

The British Broadcasting Corporation has placed a contract to the approximate value of £115 000 with Marconi's Wireless Telegraph Co. Ltd for the supply of television translators, low power television transmitters and amplifiers, and frequency-modulated sound translators and amplifiers. These equipments will be used to extend the coverage of the BBC television and v.h.f. sound broadcasting services to areas where reception is at present non-existent or unsatisfactory. In all, some eighty-eight equipments are to be supplied, as follows:

- 10 – 10W Television Translators
- 4 – 10W Television Transmitters
- 8 – 500W Television Amplifiers
- 6 – 100W Television Amplifiers
- 30 – 10W Frequency-Modulated Translators
- 30 – 1kW Frequency-Modulated Amplifiers

The BBC has also ordered a further two 100kW twin-channel high frequency sound broadcasting transmitters from Marconi's Wireless Telegraph Co. Ltd for use at the Daventry station. These will replace two existing transmitters on the BBC External Services. The new equipments are a departure from conventional practice in that the penultimate r.f. and final r.f. amplifier and modulator valve stages are vapour-cooled. Two 100kW h.f. transmitters of generally similar design are already on order for the BBC station at Rampisham in Dorset, the main difference being that the Rampisham transmitters employ vapour cooling only on the final r.f. amplifier and modulator stages.

Marconi engineers, in the four weeks prior to 3 November, completed the installation of nine broadcasting stations (seven television and two sound) in three continents. The value of the contracts is £600 000. The installations were carried out in Australia (two television stations and associated studio equipment), Nigeria (two television stations and associated studio equipment), Sweden (one television station), Northern Ireland (one television station and associated studio equipment), Denmark (one television station), Kenya (one sound broadcasting station) and Great Britain (one sound broadcasting station). In the television field alone Marconi's have, during the past ten years, sold over £10 000 000's worth of equipment, including 94 television transmitters, 34 outside broadcast vehicles and over 500 image orthicon cameras.

The Soviet Union has placed an order with Mullard Equipment Ltd for a 4MeV linear accelerator designed for X-ray treatment of deep-seated tumours. It is the first British equipment of its kind to be ordered by the U.S.S.R. and will be installed in Moscow. The machine will be similar in design to those built by the company for hospitals in the U.K. but will incorporate a number of technical improvements. These will give the machine a larger X-ray field for a given output, reduce the time needed to set-up for treatment, and confer greater flexibility in control.

The Institution of Mechanical Engineers is arranging an informal discussion on 'The Computer in Production'. The purpose of the meeting is twofold:

(1) To introduce chartered mechanical engineers and managers to the latest techniques involving the application of computers in production.

(2) To provide a forum for managers, engineers and users to present their views to manufacturers of computers.

The meeting will be held on Monday, 21 March, and Tuesday, 22 March 1960, and will commence at 10 a.m. continuing until 8 p.m. on the first day and 10 a.m. to about 4 p.m. on the second day. Visits to computer centres and to installations where computers are being used on production problems will be arranged to take place on Monday and Tuesday, 21 and 22 March. This meeting will be open to members and visitors, and is aimed primarily at management level; the subject treatment is also likely to be of interest to specialists in computers. Those who wish to attend the meeting should apply to The Secretary, The Institution of Mechanical Engineers, 1 Birdcage Walk, Westminster, London S.W.1.

The 1 000ft television mast at Hörby in South Sweden has been equipped with a unique cableless lift, designed by AB Almakverken, Skelleftea. The Alimak lift is intended for high altitudes where icy winds and snow make the conventional cable-driven lifts unserviceable. It has attracted keen interest, especially in London, where the BBC is planning to build a 1 900ft high television mast. The run up and down the Hörby mast takes 15 minutes. A two-cylinder two-stroke engine developing 10 h.p. is placed under the lift basket and drives two gear wheels travelling on a pegged bar. The lift's reliability in operation is reported to be nearly 100 per cent. In case of a breakdown of the engine while the lift is running there are small openings in the basket floor which facilitate simple engine repairs. This new type of lift operates independently of altitude.

A new electronically controlled position system, which when used in conjunction with a conventional drill, or other tool, enables very high degrees of accuracy to be obtained without a skilled operator, has been producing jet engine components at the Derby factory of Rolls-Royce Limited's Aero Engine Division for the past five months. The system, which has been developed by E.M.I. Electronics Ltd in collaboration with Optical Measuring Tools Ltd uses a 30in rotary table, and results obtained have been so satisfactory that Rolls-Royce has now placed orders for two more.

The Council for Scientific and Industrial Research has authorized changes in the terms of reference of the Radio Research Station, D.S.I.R., and has appointed Mr. J. A. Ratcliffe, C.B.E., F.R.S., to be the new director from 1 October 1960 when the present director, Dr. R. L. Smith-Rose, C.B.E., retires. The Radio Research Station has earned for itself an international reputation for its detailed studies of the propagation of radio waves by way of the ionosphere and the troposphere. Recently the programme has been reviewed and its scope has been extended so as to take advantage of the new techniques provided by rockets and artificial earth satellites. Under its new terms of reference the station will undertake investigations of the upper atmosphere and outer space by both radio and non-radio methods. Half the total staff effort of the station (amounting to about 80 scientists and assistants) will be made available for this purpose. The necessary additional staff is being recruited. The work of the station has already been enlarged to include the use of radio and optical methods for tracking satellites, and steps have been taken for the provision of a radio telescope. It is the intention to extend the space research further and, at the invitation of the present Director, Mr. Ratcliffe will assist in planning the future research programme, pending taking up his appointment.

The Rt. Hon. Reginald Bevins, M.P., Postmaster-General, has approved the appointment of Mr. A. H. Mumford, O.B.E., Deputy Engineer-in-Chief, to be Engineer-in-Chief in succession to Brig. Sir Lionel H. Harris, K.B.E., T.D., who is retiring on 31 January 1960. The Postmaster-General has also approved the appointment of Captain C. F. Booth, C.B.E., Assistant Engineer-in-Chief, and Mr. D. A. Barron, Assistant Engineer-in-Chief, to be Deputy Engineers-in-Chief from 1 February 1960.

A composite exhibit of British audio equipment is being arranged for the British exhibition in New York in June 1960. This is being organized by the Audio Manufacturers' Group of B.R.E.M.A., which was formed early this year, and the possibility of developing other overseas markets by concerted group action is under consideration. Apart from export promotion, other group activities cover technical standards and codes of practice designed to benefit the industry, the trade and the general public and to avoid confusion caused by the vague term 'high fidelity' and its exploitation. A statistical service has also been started. The secretary of the group is Mr. S. E. Allchurch, O.B.E., 49 Russell Square, London, W.C.1.

A new German Code for Semiconductors has recently been published by Siemens, Telefunken and Valvo. This has been evolved as it was felt that the currently used OC numbering has become too cumbersome and in any case does not provide a description of the semiconductor. The new code is as follows: Two groups are distinguished: Domestic semiconductor types are designated by a group of two letters and three figures while industrial semiconductors are marked with three letters followed by two figures.

First letter signifies:
- A = Germanium diodes and germanium pnp transistors
- B = Silicon diodes and silicon pnp transistors
- N = Germanium npn transistors

Second letter indicates:
- A = Diodes including variable capacitance diodes
- C = L.F. transistors
- D = L.F. power transistors
- F = R.F. transistors
- L = R.F. power transistors
- P = Photosensitive semiconductors (photo-diodes, photo-transistors)
- S = Switching transistors
- T = Thyristors, Shockley diodes, controlled rectifiers
- Y = Power diodes
- Z = Reference and Zener diodes

Serial numbers between 100 and 999 have been allocated to domestic semiconductors. Industrial elements will have a series of combinations commencing with Z 10 to Z 99 and ending with A 10 to A 99, whereby the letter represents the third code letter.

Ronald L. McFarlan, consultant to the DATAmatic Corporation and the Raytheon Manufacturing Co., has been elected president for 1960 of the Institute of Radio Engineers. Dr. McFarlan succeeds Ernst Weber, president of the Polytechnic Institute of Brooklyn, as head of the international society of 76 000 electronic engineers and scientists. In recognition of the rapid growth of the institute's activities, both here and abroad, the IRE will for the first time in its history have two vice-presidents in 1960, one residing in North America and the other from abroad. The vice-president representing overseas countries for 1960 will be J. A. Ratcliffe, head of radio research at the Cavendish Laboratory in Cambridge, England. The vice-president representing North America will be J. N. Dyer, vice-president of the Research and Engineering Division of Airborne Instruments Laboratory, Melville, N.Y.

Elliott - Automation announce that negotiations are proceeding with Manufacture de Machines Du Haut-Rhine S.A. ("Manurhin") of Mulhouse, France, with a view to arrangements being made for the manufacture in France of automation equipment. Manurhin is an old established engineering business with a large manufacturing plant at Mulhouse and in other parts of France. It is proposed that Elliott-Automation will take a financial interest in Manurhin.

Pye Ltd of Cambridge have recently introduced an electronic lung for the treatment of poliomyelitis. Called the Barnet Ventilator, it has been designed to replace the iron lung and is a joint venture by several companies of the Pye Instrument Group. The instrument is manufactured by W. Watson & Sons Limited, a member of the Pye Instrument Group. Treatment of poliomyelitis cases by means of the Barnet Ventilator gives the patient considerable freedom. Instead of being encased in a box the patient is linked to the Ventilator by two plastic tubes. Breathing is sustained by the alternation of positive and negative pressure, air being pumped into the lungs during the positive phase and extracted during the negative. The number of respirations per minute, the ratio of inspiratory to expiratory time and the volume of air entering and leaving the lungs are matters of very great importance. By using the Barnet Ventilator any, or all, of these facilities can be instantly and precisely adjusted within physiological limits. The iron lung is large and heavy, and when it is necessary to move a patient serious transport problems arise. The Barnet Ventilator, on the other hand, is very portable and weighs only 56lb. It has built-in batteries from which its transistorized circuit will run for up to twenty hours without recharging. Thus the polio patient can be moved from one hospital to another or by air between continents without difficulty.

Electronic Associates Incorporated of Long Branch, New Jersey, U.S.A., manufacturers of Precision Analogue Computing Equipment (PACE) announce the formation of Electronic Associates Limited. The new company is British and is entirely British staffed. The head office and works are at Victoria Road, Burgess Hill, Sussex. The company is equipped to carry out the studies of all types of systems, to design and construct special purpose analogue computers and simulators based on PACE modules, and to supply the fully transistorized range of TR.10 equipment, 'Addaverter', analogue-digital and digital-analogue convertors, as well as the 'Variplotter' transistorized analogue and digital plotting boards.

The Saab Aircraft Company and the Atvidaberg group of industries have decided to establish collaboration in the field of electronics. The two Swedish companies already operate special departments for the manufacture and development of electronic equipment. The collaboration scheme aims at rationalizing production and marketing of commercial electronic products, primarily equipment for data-processing machines.

The Non-Destructive Testing Group of the Institute of Physics will hold a meeting in London on 2 to 4 May 1960 jointly with the Société Français de Métallurgie. The programme will have the general theme of the relationship between structure and physical properties of materials and will include recent advances in non-destructive testing techniques. Further details will be available shortly from The Secretary, The Institute of Physics, 47 Belgrave Square, London, S.W.1.

The Radio and Electronic Industry's annual dinner was held in London on 18 November last under the joint auspices of the Radio Industry Council and the Electronic Engineering Association. The chairman was Lord Brabazon of Tara and the guest of honour Lord Adrian.

The Portuguese Air Force has ordered from the Telecommunications Division of Elliott Brothers (London) Limited, a member of the Elliott - Automation Group, fourteen of the new Elliott VB 2001A ground-to-air u.h.f. radio stations. This ground station has been developed to meet the need for a simple, inexpensive alternative to the more complex equipment which, although providing a multiplicity of channels, does so at a considerably higher cost. The Elliott VB 2001A is a switched-channel, crystal controlled transmitter/receiver operating in the 225 to 400Mc/s band. It is designed for simple frequency simplex operation offering u.h.f. ground-to-air communication facilities where four channels of communication will meet operational requirements.

'This is the BBC' is the title of a documentary film made by the BBC Television Service which has recently been released in London. It deals with the work that goes on during a typical twenty-four hour period in the BBC with its radio and television studios and transmitting stations throughout the British Isles and offices in most of the capital cities of the world.

The Post Office coastal radio services for shipping have now been strengthened by the addition of v.h.f. installations at the Humber (Mablethorpe) coast radio station and at the Land's End station, serving important sea areas within a range of 40 to 50 miles. Similar v.h.f. services have already been provided on the Clyde, and at North Foreland and Niton (I.O.W.).

A Flight Simulator for the Comet IVB aircraft has been installed at the B.E.A.'s training centre at Southall by the Air Trainers Link Division of General Precision Systems Ltd of Aylesbury, Bucks. Acceptance of the flight simulator was preceded by a series of tests carried out to the satisfaction of the B.E.A. training centre and a team from the Ministry of Aviation, which had the task of evaluating the performance of the equipment so as to approve its use for the issue of flight instrument rating renewals to captains and first officers designated to the Comet airliners.

The "Kongressgesellschaft für ärztliche Fortbildung" (Congressional society for advanced medical training) has now published the first German "Medizinische Tonbandzeitung" (tape recorded medical journal) in the Medicus-Verlag Berlin. The tape with the original recording is copied by means of a Telefunken installation which at present consists of twenty "Magnetophon" home tape recorders, and this procedure is repeated until sufficient recorded tapes are available for all subscribers. This new idea of providing information will probably be adopted by others in the future and it can be expected that the "Medizinische Tonbandzeitung" will soon be followed by other journals of this kind.

A new building for the Department of Electronic Engineering of the University College of North Wales was opened recently by Sir Willis Jackson. A sum of £100 000 was provided by the University Grants Committee for the new building which will provide accommodation for 120 students and 15 postgraduates. Research in the Department comprises study of valves and transistors and of semiconductors for amplifiers at frequencies employed in the microwave band. Other research efforts are concerned with electronic instruments for rocket and artificial satellite operation. The present head of the Department is Professor M. R. Gavin.

Hughes Aircraft Company, one of the largest American electronic firms, have announced that they have received permission from the British Board of Trade to establish an electronics manufacturing plant at Glenrothes, Fife, Scotland, which lies to the North of Edinburgh. The factory which will be built by Glenrothes Development Corporation to Hughes' specifications is scheduled to begin production by September 1960 on semiconductor devices and allied electronic components.

An English Electric DEUCE computer has recently been installed in the Department of Applied Mathematics of the University of Liverpool. The Department until recently has been able to deal with only a fraction of the requests made for its services but with the addition of the computer the staff has now been increased and will undertake the threefold task of (1) training students and research workers in the uses, potentialities and limitations of computers, (2) investigating and developing the use of these machines, and (3) providing a computing service for the university and elsewhere.

The English Electric Valve Co. Ltd have announced that Collins Radio Company have placed a \$100 000 order for their klystron type K350 which will be used in American-built Doppler navigation equipment. Technical discussions between the two companies have been going on for some months and shipments of tubes to Collins' specifications will commence immediately.

The Fifth London International Audio Fair will be held at the Hotel Russell, Russell Square, London, W.C.1, from Thursday to Sunday, 21 to 24 April, 1960. The international character of the Fair will be emphasized this year as a result of the recent relaxation of U.K. import restrictions. Invitations for overseas visitors and full information can be obtained from Audio Fairs Limited, 22 Orchard Street, London, W.1.

A delegation from West Germany consisting of twenty-two members of industry, commerce, science, banking, insurance and transport visited the United Kingdom from 30 November to 4 December last at the invitation of the British computer industry and with the support of the Board of Trade and the British Embassy in Bonn. The programme comprised visits to Ferranti Ltd, the English Electric Company Ltd, E.M.I. Electronics Ltd, Standard Telephones and Cables Ltd, International Computers and Tabulators Ltd, Associated Electrical Industries Ltd, Elliott Bros. (London) Ltd and the National Cash Register Company Ltd. It is expected as a result of this visit that a substantial volume of sales of computers to West Germany will follow in the next few years.

BOOK REVIEWS

The Atlantic Cable

By Bern Dibner. 96 pp. Demy 4to. Burndy Library, Norwalk, Connecticut. 1959. Price $2.50.

THE story of the laying of the early Atlantic telegraph cables in 1857-58 and 1865-66 is one which has been told many times before, but it is a story of such imaginative enterprise, courage and determination in the face of a long series of heartbreaking disasters that it should certainly be told anew to each succeeding generation.

The present publication by the Burndy Library from the pen of Bern Dibner is a magnificent one. Not only is the text itself a fascinating account of the whole vast enterprise but, filling less than a hundred pages, it is free from much of the trivial detail which tended to clutter up some of the earlier accounts. In addition, the many illustrations have clearly been selected with the greatest care and the beauty of their reproduction, the typesetting and the high-quality paper all combine to make the whole publication a masterpiece of the publishers art. All concerned are to be warmly congratulated.

Almost 13 years were to elapse from the original conception of the scheme early in 1854 to its successful achievement in 1866. Throughout this long period, the main inspiration and driving power was provided by that great American, Cyrus W. Field who, in furthering the organization, was to make more than 40 crossings of the Atlantic in conditions far less comfortable than those of today. If the driving force was Fields, however, the technical skills, the engineering and the electrical work were almost entirely British.

The earlier attempts to lay a trans-Atlantic cable were those made in 1857-58 when H.M.S. *Agamemnon* and the U.S. frigate *Niagara*, then the largest ship in the American Navy, were used for the purpose. With a cable of unsuitable design and the occurrence of a whole chapter of accidents, the laying of a cable was in fact completed in August 1858, but after working imperfectly from the outset, it failed altogether after only a few weeks.

For a variety of reasons, it was not until 1865 that a further attempt could be made. With a cable of greatly improved design and the use of Brunel's white elephant, the Great Eastern which had been specially converted for the purpose, a fresh expedition was launched, but after laying almost two-thirds of the cable a fault occurred and the cable broke at a point where the Atlantic is more than two miles deep. Attempts were made to grapple for it but with unsuitable gear they proved unsuccessful and, once again, the attempt had to be abandoned till the following year. Final success came in July 1866 when, at last, a perfect cable was laid and, only a few weeks later, the cable dropped the previous year was successfully raised, spliced and continued forward to Newfoundland, thus providing a second circuit linking the old world with the new.

In comparison with all the disasters encountered by Cyrus Field and his contemporaries, the laying three years ago of the two telephone cables across the Atlantic proceeded with almost monotonous regularity. This uneventful completion of a vastly more difficult undertaking serves to illustrate how well the experience of the pioneers has been used and developed—but unless one reads of and realizes all the difficulties which were formerly encountered, it is difficult to appreciate the magnitude of modern achievement.

G. R. M. Garratt

Automation Systems

173 pp. 23 figs. Medium 8vo. Engineering Publishers, New York. Interscience Publishers, London. 1959. Price $5.00.

THIS is a record of some of the proceedings at the second E.I.A. conference on Automation Systems held at Arizona in 1958; the scope of the conference was very wide indeed and the book covers from electronic to banking automation and automation in the aircraft industry to social aspects.

The individual papers are, however, authoritative in their particular fields. Mr. Oldfield's systems concepts and Mr. Bright's economic aspects are very good. The application papers both in the business and engineering fields show that remarkable advances have been made in the individual fields, though there still seems many areas between these that must be filled in before the automatic factories of the future can become an accomplished fact.

It is also encouraging to note that our friends in the U.S. have become aware that not all systems of automation have been an unqualified success from the economic point of view and one is led to wonder if the system studies were in these instances as carefully carried out as they should have been.

While the conference set itself an almost impossible task of evaluating the progress of automation not only from a technical but also an economic and social point of view in three days, nevertheless the techniques are moving at such a fast pace today, a critical examination of this type seems a useful and worthwhile purpose. It is therefore good reading for all levels of engineers and students alike in both technical and social fields.

In addition many production executives could well benefit from a few hours spent in a potted version of a very big subject.

A. W. Pearson

Solar Energy

By F. M. Branley. 103 pp. 30 figs. Demy 8vo. Edmund Ward (Publishers) Ltd. 1959. Price 10s. 6d.

THE rapid exhaustion of the world's fossil fuels to supply the ever-increasing demand for power, coupled with the realization that even nuclear power production will not solve all our future problems in this direction, lends interest to the alternatives. Solar energy is certainly one of these. Indeed, viewed in the broadest sense as the source of the earth's heat, the prime requirement for vegetative growth, the cause of the rain for water power, or of the wind for wind power, it is easily the most important.

For the last four years there has been a very active Association for Applied Solar Energy with headquarters in Phoenix, Arizona, and having a world-wide membership. Mr. Branley's little book outlines, in an attractive way with excellent clear diagrams, many of the applications with which the Association is concerned. He deals with solar space heating, water heating and distillation, solar cookers and furnaces, solar engines, heat pumps, solar batteries and thermo-electric devices, with the culture of algae and with wind power and power from marine heat.

His style is lucid and the book is easily readable by the non-technical reader for whom it is intended. One can criticize the author's enthusiastic exaggeration of the possibilities in some directions and his inaccuracies about developments lying outside his own personal knowledge as an American astronomer. But, on the whole, his text is sound and what he has to say may whet the reader's appetite for fuller and more precise information on the subject.

E. W. Golding

Automation Today and Tomorrow

By L. Landon Goodman. 280 pp. Demy 8vo. Iota Services Ltd. 1959. Price 40s.

IN the first half of this book the author sets out to make a statement in a few words of what is available today in the field of automatic control, as such, this book serves a useful purpose.

However, it may be that the reader will find that the possible links between the various individual items are glossed over, if mentioned at all.

The second half of the book is no doubt valuable, for a very complete Bibliography of available papers is given, well divided and collected under the headings of applications.

This book is undoubtedly of greatest value to the products engineers and others who want to know and to keep up with the current position in automation without too deep a knowledge of technical subjects concerned.

A. W. Pearson

Semiconductors

Edited by N. B. Hannay. 752 pp. 358 figs. Medium 8vo. Reinhold Publishers, New York. Chapman & Hall Ltd., London. 1959. Price 120s.

THIS volume represents a welcome addition to the present semiconductor textbook range. One has generally been accustomed to books on semiconductors dealing extensively with mathematical or physical theory but which contain very little information about the physical chemical aspects. In this book an interesting selection has been made of essential topics which are not generally treated.

The volume opens with a description of the concepts used in semiconductor theory, together with an account of pn junctions and transistors. The various types of imperfections possible in single crystals are dealt with in the next section and later their inter-action and chemical physical effects are discussed. These interactions are of importance in understanding the behaviour of semiconductors, in particular when they are subjected to high temperatures, which are needed to diffuse impurities in a reasonable time. Crystal growing, diffusion processes, lifetime behaviour and surface theory are also treated. A variety of compound semiconductors is described and—in addition to the usual intermetallics—oxides, sulphides and organic semiconductors are dealt with. Lastly, there is an interesting chapter on semiconductor electrodes, which outlines the phenomena which occur during the electrolysis of semiconductors. In the manufacture of transistors a knowledge of the electrolytic behaviour of, for example, germanium and silicon is of considerable importance. The final stability and current amplication will depend on the etching treatment.

Semiconductor device design and practice has opened up a vast range of problems, particularly of a physical chemical nature and this book will be a valuable help to those working in this field.

M. SMOLLETT

Mathematics Applied to Electrical Engineering

By A. G. Warren. 464 pp. 50 figs. Demy 8vo. 2nd Edition. Chapman & Hall Ltd. 1958. Price 70s.

THIS is the second edition of the well-known text by A. G. Warren on mathematics necessary for the solution of problems met with in electrical engineering.

The first edition has now been available to engineers for twenty years and during this period has satisfied the requirement of engineers both as students and research workers. That a second edition should be called for is indicative of its excellence.

The preparation of the second edition of this book has given an opportunity for a thorough revision of the text. In the majority of chapters the material is unchanged but the presentation has been improved in places and some omissions remedied. Two of the chapters, those on the Operational Calculus and Fourier Analysis, have been completely rewritten.

The approach to the Operational Calculus has been strengthened by the introduction of the methods of Carson, Jeffreys and Bromwich while retaining some of the original penetrating ideas of Heaviside. To this end a new chapter on functions of a complex variable has been added which many engineers will find useful in other contexts.

In the chapter on Fourier methods harmonic analysis has been deleted (it is perhaps a cause for regret that this could not have been retained) to make room for a discussion of the Fourier integral theory.

Other additions are sections on analogues and analogue computers and further application of Bessel functions to physical problems.

There are one or two small misprints but these will cause little or no trouble to the reader. In places there are passages which could lead to rumours of discontent in the remote world of the pure mathematician; happily these will not trouble the engineer.

The book has been and remains, in this new addition, an excellent text to guide the electrical engineer in an assessment of the correct application of mathematics to electrical problems.

The printing of the book is of a very high standard.

W. N. EVERITT

Reliable Electrical Connections 1958

286 pp. 110 figs. Medium 8vo. Engineering Publishers, New York. Interscience Publishers, London. 1959. Price $7.75.

ELECTRONIC and electrical reliability is dependent on reliable electrical connexions. The great need for reliability in electronic equipment has stimulated considerable effort in finding ways of making electrical connexions more and more reliable. One of the difficulties has always been the compilation of data on faults which occur in contacts.

For three successive years a conference has been held in the U.S.A. under the auspices of the 'Electronic Industries Association on Reliable Electrical Connections'. The papers read at these conferences have just been published in a book, and the 32 papers contained in this book form an extremely useful reference to the present state of the art of making reliable electrical connexions.

While it is not possible to detail the 32 papers, an example of their varied subjects is given by the following few extracts:—

"Behaviour of Soldered Joints in Printed Circuits under Vibration."

"Designing Reliability into Electrical Connectors."

"Soldered Joint Reliability in Etched Circuit Assemblies."

"Ultrasonic Welded Aluminium-Copper Junctions as Electrical Connections."

"Soldering Techniques in Defense Electronics."

"Evaluation of Electrical Connections."

"Printed Circuit Connector Reliability."

"Application and Reliability of Connect-Disconnect Plugs."

"Solderability of Pigtail Leads."

"Practical Quality Control Measures Insure Wire-Wrap Reliability."

"Contacts for Electrical Connectors."

In reading all these papers, five main aspects become evident:

(1) The trend to make greater use of non-alloyed pressure connexions.
(2) The emphasis on the great number of variables in alloyed connexions. The need to reduce and control these variables and the problem of quality control, especially the human factor. These problems have caused (1) above.
(3) The variability of test methods and specification of connexion quality and reliability. The need for standardization so that results at different centres can be correlated.
(4) The complexity of the science of contact surfaces and materials for non-alloyed surfaces.
(5) The inferences that plugs and sockets are weak links in electronics and must reduce potential reliability.

There is no doubt that this book presents an excellent picture of progress over a very wide field of contact problems and should be most useful to all those concerned in the design of electronic equipments.

G. W. A. DUMMER.

ELECTRONIC EQUIPMENT

A description, compiled from information supplied by the manufacturers, of new components, accessories and test instruments.

(Voir page 59 pour la traduction en français: Deutsche Übersetzung Seite 63)

VELOCITY PICK-UP AMPLIFIER

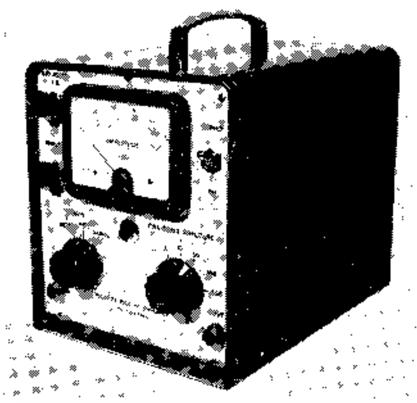
(Illustrated below)

Sir W. G. Armstrong Whitworth Aircraft Ltd, Hucclecote, Gloucester

This unit is primarily designed to convert the output of a seismic or non-seismic velocity pick-up into an easily read meter presentation.

The meter is provided with two scales having full scale calibrations of 100 and 30 divisions, and a scale length of 3·25in. Full scale deflexion may be obtained for amplitudes of from 0·3 to 300 thousandths of an inch, in the frequency range 1·5 to 1500c/s.

An important feature of the equipment is that calibration facilities are included in the specification, enabling long and short term variations in the performance to be compensated.



Construction is of the mains driven portable type, having provision for co-axial input from the pick-up and an output socket for connexion to a high impedance recorder or oscilloscope.

When despatched the unit is calibrated to give full scale deflexion on the ×10 range from a 1·6V r.m.s. signal at 50c/s. The input resistance is 100kΩ on all ranges.

EE 17 751 *for further details*

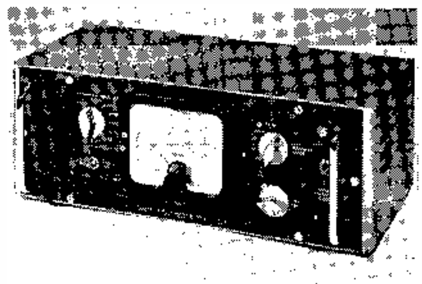
VALVE-VOLTMETER

(Illustrated above right)

Airmec Ltd, High Wycombe, Buckinghamshire

Airmec have recently introduced a new and improved version of their valve-voltmeter type 712, which is to be known as the type 217. The redesign has resulted in a wider frequency response, improved probe design, and more convenient lead stowage, but the completely balanced circuit of the earlier model has been retained, giving a very high degree of stability.

Voltage measurements from 0 to 150V may be made in the frequency range 10c/s to 80Mc/s at high accuracy, and with reduced accuracy to 200Mc/s.



Positive and negative direct voltages up to 500V may also be measured at an impedance of 40MΩ, and six resistance ranges are provided covering 100Ω to 100MΩ. The meter deflexion is zero for zero ohms and full scale for infinite resistance, avoiding the confusion inherent in the usual reversed ohmmeter scale.

A low-capacitance high-impedance probe with an input impedance of 2MΩ is provided for use at the higher frequencies. For use at d.c. and low frequencies the probe is mounted on the front panel of the instrument, bringing into operation the d.c. terminals, and a spring-loaded drum automatically winds up the probe lead through a hole in the case.

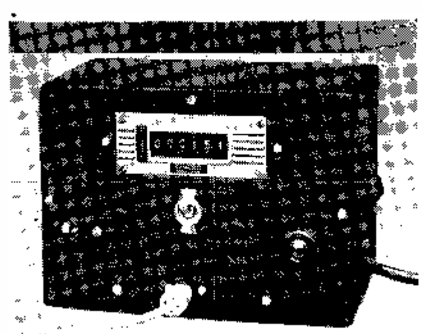
EE 17 752 *for further details*

ELECTRONIC COUNTER

(Illustrated below)

B. & F. Carter & Co. Ltd, Albion Works, Bolton, Lancashire

An electronic counter has recently been added to the existing range of 'Albion' counting instruments and measuring machines. This unit known as the type 24, comprises an instrument case housing, the counter and thermionic valve circuit including step-down transformer, relay and potentiometer tuning control. There is also a pilot light and main switch. The mains lead may be connected to any convenient supply and a second lead is provided for a counting medium. The unit can be supplied in three forms, with probe, induction coil (for components passing through), or photo-electric cell unit.



In operation the tuning potentiometer is adjusted to suit the components being counted, each count alters the valve characteristics thus operating a relay which in turn energizes the electromagnetic counter. The counter has six figure wheels and a finger operated reset protrudes through the base. The unit is rated up to 250 counts per minute.

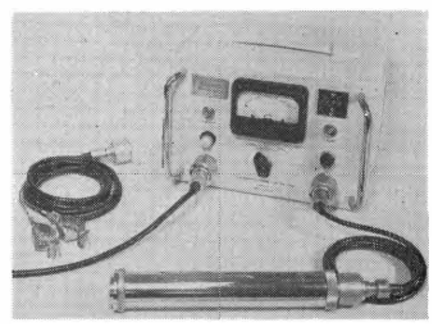
EE 17 753 *for further details*

GAMMA EMISSION DETECTOR

(Illustrated below)

Plessey Nucleonics Ltd, Weedon Road, Northampton

To detect plutonium at maximum permissible body burden level or even less, Plessey Nucleonics have developed a mains or battery operated portable detector, the P.N.I. 1080. This instrument is essentially a detector of low energy gamma radiation.



As well as being capable of detecting minute amounts of plutonium 239 in the human body, with slight modification and recalibration the instrument can also detect the presence of americum, a radioactive substance which will be contained in the plutonium manufactured by reactors in this country. With another slight modification, the 1080 can detect uranium 235 which also emits low energy gamma rays.

The complete equipment consists of a detector probe connected by up to 6ft of cable to an indicating unit.

The probe consists of a thin, thallium activated, sodium iodide scintillator mounted on the end of a multiplier photo tube. A chain of resistors is mounted on the inside of the probe in order to provide the correct potential on the dynodes and a cable matching network ensures optimum signal pulse transfer from the probe to the indicator unit.

For hospital use the probe may be enclosed in a polythene container.

The indicator unit of the P.N.I. 1080 consists of a pulse amplifier, a pre-set but adjustable single channel pulse amplitude analyser, a variable and stabilized e.h.t. supply for the photo tube, and a display system. All circuits in the indicator unit use transistors.

EE 17 754 *for further details*

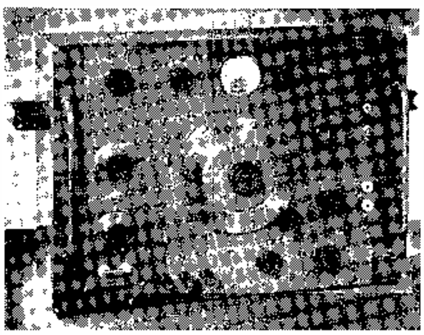
UNIVERSAL BRIDGE

(Illustrated below)

Metrix Instruments Ltd, 54 Victoria Road, Surbiton, Surrey

The Metrix universal bridge type 626 is a stable, robust and comprehensive instrument for the direct measurement of a very wide range of values of resistance, capacitance, inductance, power factor and Q, at 50c/s, 1kc/s and with an external source up to 10kc/s. For resistance measurements, d.c. excitation is also supplied.

A separate, adjustable and metered d.c. supply is incorporated for the measurement of incremental inductance, and electrolytic capacitors may be measured with up to 500V d.c. applied.



In addition to the bridge circuit with its accurate and stable standards, the instrument includes a 1kc/s oscillator and selective amplifier combined with a magic eye as a null detector. This offers the advantage of constant sensitivity over the whole range without risk of overloading the null indicator. A ring modulator allows the use of the amplifier when the bridge is excited by d.c.

In addition to direct measurements, facilities are provided for the connexion to external standards or reference components so that the instrument can be used as a comparator bridge if required.

In order to reduce manipulations to a minimum and for ease of operation, careful consideration has been given to the general layout of the instrument and to the rational grouping of the controls.

The ranges covered are as follows: resistance 0·01Ω to 10MΩ, capacitance 1pF to 100μF; inductance 10μH to 1 000H; Q·0 to 12.

EE 17 755 *for further details*

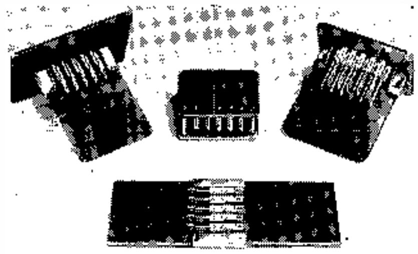
PRINTED CIRCUIT CONNECTORS

(Illustrated above right)

N.S.F. Ltd, 31-32 Alfred Place, London W.C.1

The basic design of the NSF-Varicon connector contact, with a fork-like construction having four mating surfaces, has been employed to produce a range of printed circuit connectors capable of meeting almost any application the designer may envisage.

The contacts are supplied on a disposable plastic strip accurately posi-



tioned for the insertion of the contact legs into holes in the printed circuit board in readiness for the staking operation to follow. The standard spacing of contacts is at 0·200in. Other spacings may be provided at a small additional tooling cost. Maximum number of contacts on a single strip is at present 20.

Staking of the contacts to the printed circuit is carried out with special tools designed to shave ·009in of materials at both sides of the contact leg, compressing this material tightly against the copper printed circuit. This staking and the subsequent dip soldering of the board results in a solid low resistance contact of unsurpassed reliability. Over 65lb are required to tear a contact from the board if staked and soldered, 50lb if staked only, and 25lb if soldered only.

To ensure correct engagement of the contacts, it is necessary to provide board guides which, in the case of large sizes, should be an integral part of the equipment. For small size boards a range of brackets is available.

A printed circuit connector kit is available to meet the needs of engineers who wish to build experimental assemblies. The kit contains contacts, brackets and staking tools for the assembly of various connectors. The kit is contained in a small plastic box.

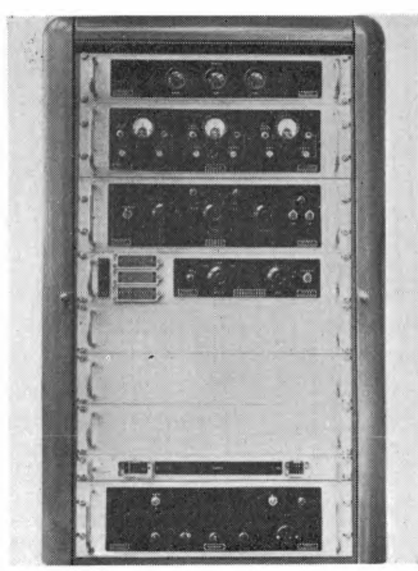
EE 17 756 *for further details*

MULTI-CHANNEL MILLIVOLT RECORDER

(Illustrated below)

Southern Instruments Ltd, Frimley Road, Camberley, Surrey

This multi-channel digital millivolt recorder is designed to record multi-



channel strain gauge or thermocouple outputs and will give a full scale decimal digital output for inputs ranging from 15 to 50mV. 288 channels may be automatically sampled in turn. The output can be recorded on a Creed tape punch or an I.B.M. electric typewriter. Single outputs may be fed to an illuminated numerical display.

The equipment is rack mounted in a substantial cabinet 3½ft (107cm) high. Unit construction is used throughout and the rack contains the display unit, channel selectors, digitizer chassis, control unit, output unit and power unit.

The accuracy is 1 part in 999 of full scale output, i.e. a limiting resolution of 15μV.

This equipment is manufactured by Bristol Aircraft Limited and distributed by Southern Instruments Limited.

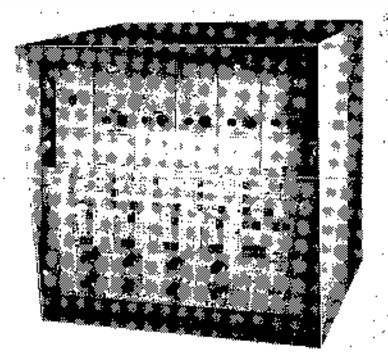
EE 17 757 *for further details*

ANALOGUE TRAINING DEVICE

(Illustrated below)

The Solartron Electronic Group Ltd, 45 Thames Street, Kingston, Surrey

A new, simple analogue training device, the TY 963 analogue Tutor, has been announced by the Solartron Electronic Group.



As the name implies, this new addition to the Solartron 'SPACE' analogue computer range is in fact a simplified analogue computer intended for educational applications. It is capable of representing any form of the linear second-order differential equation using the built-in computing components and demonstrating, for example, the effects of velocity and acceleration limits using external diodes as additional computing impedances. Within the limitations imposed by the total complement of five amplifiers, a wide range of physical systems may be represented. These include simple servos, electrical networks, the motion of a particle under gravity, and so on.

The computer is virtually 'student proof' in that the unit will suffer no permanent damage should incorrect operation be programmed by unskilled users.

Incorporating five operational d.c. amplifiers, the Analogue Tutor is a fully self-contained unit, complete with stabilized power supplies and adequate patching and control facilities. Interchangeability of component assemblies—a feature of all Solartron 'SPACE' series analogue computers—permits elements from the

Analogue Tutor to be incorporated into more complex analogue computer installations at any time should this be required.

EE 17 758 *for further details*

PRINTED RESISTORS

(Illustrated below)

Mills & Rockleys (Production) Ltd, Swan Lane, Coventry, Warwickshire

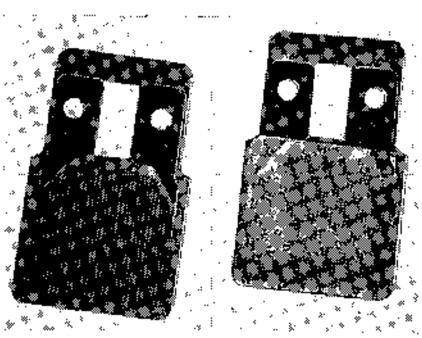
These resistors are designed and produced to meet specific customer requirements and have particular application where space is limited and/or where high heat dissipation is required derived from a flat surface area. Two examples of application are first, the inclusion of a resistive component into an existing switch design which does not permit conventional resistors being used, and second a flat contact cooled mains dropping resistance for use in radio and television receivers where a metal chassis is used as a heat sink.

The specification of the electrical paper base material is as follows:

Breakdown voltage $-1{\cdot}5$kV.
Thickness ·006in.
Upper temperature limit 150°C.

The specification of the resistance element will vary to meet particular requirements and can be cupro-nickel, nickel-chrome, etc. which is bonded and cured on to the base electrical paper.

The bond strength between resistance element and base is extremely high and will not permit peeling without damaging the component.



Where the resistance element requires complete insulation the electrical paper can be bonded across the exposed element.

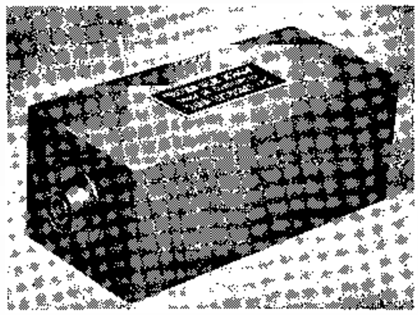
EE 17 759 *for further details*

DELAY NETWORKS

(Illustrated above right)

Lexor Electronics Ltd, 25 Allesley Old Road, Coventry, Warwickshire

Lexor Electronics have recently announced the introduction of a range of standard delay networks. Covering an impedance range of 50 to 880Ω, delays are available from 50mμsec to 1400mμsec and provide a total of over 200 standard combinations. The networks are assembled from carefully designed *m*-derived *LC* sections mounted in convenient forms for laboratory use or incorporation into equipment. Loss is less than 1dB for all types; rise-times are 3 to 10 per cent and phase response is



linear up to 70 per cent of cut-off frequency.

These units are available in either steel or wooden instrument cases or encapsulated in resin.

In addition to the standard range of delay networks, a specialist design service has been inaugurated to enable delay lines and networks to be produced to customers' specification.

EE 17 760 *for further details*

TRANSISTOR POWER SUPPLY

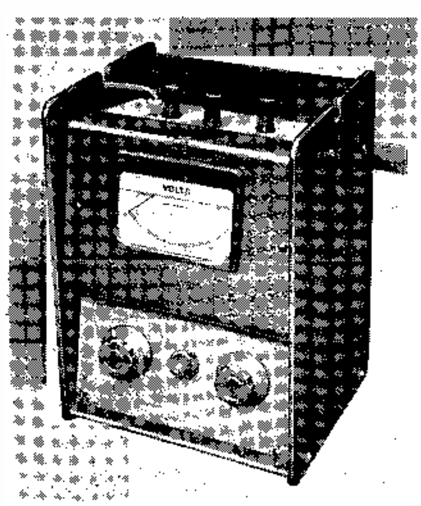
(Illustrated below)

Marconi Instruments Ltd, St. Albans, Hertfordshire

The TF1303 is a portable unit for supplying highly stabilized power to low-voltage circuits, particularly those using transistors.

The shunt-stabilized output voltage is monitored by a built-in large-scale meter and is continuously variable from 2·5V to 24V. The maximum available output current is dependent upon the voltage being delivered and varies from 1·25A at 2·5V to 0·2A at 24V. A power-limiting switch restricts the output to a maximum of 12W, 2W, or 500mW; this affords protection against the likelihood of accidental transistor burn-out in an experimental circuit. In addition, the shunt stabilization allows the output terminals to be short-circuited without damage to the unit.

The output circuit of the unit is completely isolated from both the supply mains and chassis. Either terminal may, therefore, be connected to earth; or, alternatively, the supply may be arranged to float at a potential not exceeding



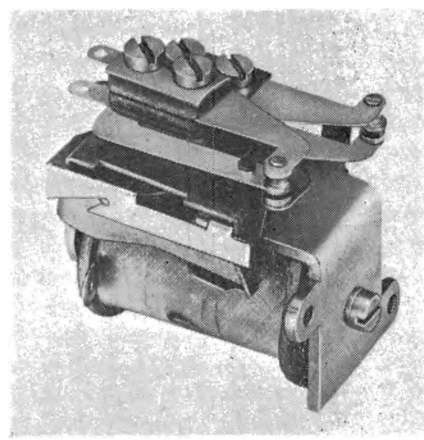
100V with respect to earth. This means that it is possible to connect two or more units in series, in order to obtain higher voltages.

The d.c. supply is derived from a mains transformer, via a full-wave rectifier comprising two germanium-junction diodes and is fed to the output terminals via a series resistor. A high-power transistor connected across the output forms a shunt regulator under the control of a transistor amplifier. This determines the proportion of the rectified voltage developed across the series resistor.

The amplifier controlling the power transistor utilizes a conventional circuit with four d.c. coupled transistors. The voltage appearing across the output terminals is applied to the base of the first transistor via a potentiometer. This potentiometer is adjustable from the front panel and forms the output-voltage control.

Load regulation of the unit is better than 0·01V and the ripple content is less than 0·5mV. It may be operated at ambient temperatures of up to 45°C.

EE 17 761 *for further details*



IMPULSE RELAY

(Illustrated above)

Magnetic Devices Ltd, Newmarket, Suffolk

The type 596 impulse relay is the latest addition to the Magnetic Devices range and has dimensions of approximately 1 1/16 in × 1½ in × 1¼.

Unidirectional voltage impulses to the relay will alternately operate and release the spring set on one side of the relay while the contacts on the other side will follow the armature.

The relay can be supplied wireable or plug in, enclosed or hermetically sealed.

In the open version up to two changeover contacts can be supplied on each contact stack.

In the enclosed or sealed versions a maximum of three changeovers is available, only 1 being on the impulse side.

Coil voltages up to 150V d.c. can be provided for.

A version of this relay suitable for use on a.c. can be supplied, the necessary blocking rectifier and smoothing capacitor being mounted on an insulated board fitted over the top of the relay.

EE 17 762 *for further details*

LETTERS TO THE EDITOR

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

A Transistorized L.T. Regulator

Dear Sir,—With reference to the article in the November issue of Electronic Engineering entitled 'A Transistorized L.T. Regulator' by J. H. Deichen, I would like to make the following comment:

In the table at the end of the article giving the values for Fig. 3, the value given for V_4 is not absolutely 6·8V ±5 per cent since the manufacturer specifies voltage limits of 6·45 to 7·20V. Similarly the spread of V_3 is specified as 12·4 to 14·00V. One should also bear in mind that these limits are specified at 20mA and variance from this value of current will produce variations in diode voltage. The figure for V_o could, in addition, be further modified by variations in V_{eb} over a spread of OC35 transistors.

Yours faithfully,
D. J. Collins,
Guildford.

The Author replies:

Dear Sir,—I would like to thank Mr. Collins for pointing out the facts about the absolute values of voltages relating to my article. He is quite right in his facts. Actually I had not intended to go into the question of component tolerances as there are a number of variables as is the case in any other circuit with respect to static voltages. I had, in fact, given the table in question as a guide rather than as a specification. The ±5 per cent I gave is really the range given by the manufacturers, and I included it in the table to distinguish them from the ±10 per cent and ±15 per cent ranges which are also manufactured. Of course if MR_2 has a ±5 per cent range given then the output must be similar. I apologize for using the word **tolerance** in my text regarding the reference voltage variation, it should, of course, be voltage range and the 6·16 and 6·84 are not absolute values but simply gives the range one can expect. The actual tolerances for the Zener diodes are indeed for 20mA and the output voltage is dependent on the V_{eb} of the transistor. I think I am right in saying the difference in output taking into consideration all the tolerances will still be within the ±10 per cent tolerance quoted for some valve heaters except, perhaps, on the upper limits in which case a series resistor can be added. One should bear in mind that as the output is regulated it is not necessary to allow for mains variation and transformer secondary tolerance.

These static voltages do not, of course, appreciably affect the degree of regulation.

Yours faithfully,
J. H. Deichen,
Bushey, Herts.

High Speed Photography

Dear Sir,—In taking a series of photographs of rapidly moving objects, it is convenient to use a cine camera and a stroboscope lamp running in synchronism. The duration of the stroboscope flash gives a short enough exposure to 'freeze' most movement while avoiding the complexity of high frame rate cameras. As this facility may only be required infrequently any device used to synchronize the lamp to the camera should:

(1) Not affect camera performance.
(2) Be removable to allow normal operation of camera.
(3) Be compatible with a wide range of stroboscope lamps.

Conditions (1) and (2) suggest a non-contacting pick-off while condition (3) can be achieved by a contact being made momentarily.

The circuit of a device to fulfil these requirements is shown in Fig. 1. A phototransistor type OCP71 is mounted inside the body of the camera behind the shutter, opposite the spare position of the lens turret which is 120° in advance of the film gate position. The light from a small lamp on the photo-transistor causing a negative going pulse to be impressed on the base of transistor OC75.

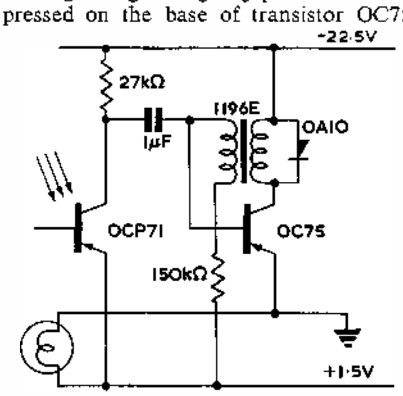


Fig. 1. Circuit of flash synchronizer

This transistor together with the coils of a high speed relay (Siemens type H96E) form a monostable blocking oscillator. The armature of the relay is drawn in during the oscillator voltage pulse and released after the oscillator has regained its stable mode.

The relay operates not more than 2msec after interruption of the light and remains in the operate position for about 3msec; these times being adequately short with regard to the highest frame rate used (64 frames/sec).

Acknowledgment is made to British Nylon Spinners for permission to publish this note.

Yours faithfully,
D. J. L. Lewis,
British Nylon Spinners Ltd.,
Pontypool.

Electrometer Amplifiers

Dear Sir,—I would like to support Mr. Hitchcox is his statement in your August issue that the 5kΩ resistors used by Mr. Boronkay in the cathode arms of his meter bridge seriously degrade the performance of the type of circuit he describes. This drove me into using (in a design described some time ago*) the potential-divider intervalve coupling recommended by Mr. Hitchcox, notwithstanding the slight disadvantage mentioned by Mr. Boronkay.

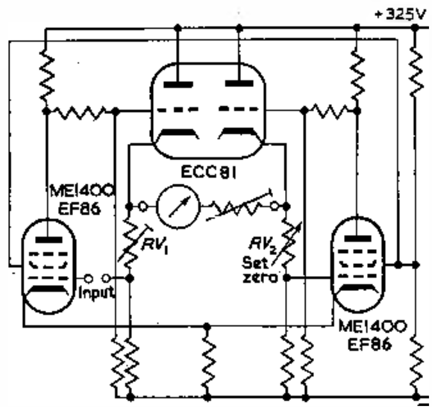


Fig. A. The electrometer circuit

While very similar in appearance to Mr. Hitchcox's Fig. 1, my circuit (Fig. A) differs in not tying the cathodes of the voltage amplifiers to a low-resistance point. They are connected to the negative line through a common high resistance. This forms the coupling between the two halves of the amplifier, which therefore does not depend on coupling via the meter—it continues to give the same output voltage even if the meter is open-circuited—and possesses remarkable stability and independence of changes in valve characteristics. Since the resistance in series with the meter is variable in steps for range changing, the 'earthy' input terminal is connected to the cathode side of the meter, making a more symmetrical arrangement.

No doubt these differences are accounted for by the different purpose of the circuit, which is to establish an exact 1 to 1 voltage ratio between the input and output terminals, with a nearly infinite input resistance and nearly zero (about 2Ω) output resistance. In this way, any d.c. voltmeter can be connected to the output terminals and used without re-calibration.

Exact adjustment of this 1 to 1 ratio, together with zero setting, is accomplished by R_1 and R_2, which being only about 0·3kΩ are free from the objections to high resistances in these positions.

Over some years this circuit has been found a most satisfactory and stable basis for electronic test meters.

Yours faithfully,
M. G. Scroggie,
Bromley, Kent.

*Scroggie, M. G. Valve Voltmeter Without Calibration Drift. *Wireless World*, 58, 14 (1952).

Meetings this Month

THE BRITISH COMPUTER SOCIETY LIMITED

Date: 5 January. Time: 6.15 p.m.
Held at: Northampton College of Advanced Technology, St. John Street, London, E.C.1.
Lecture: The First Year's Experience with a Large Computer in a Life Assurance Office.
By: R. L. Sutton.
Date: 27 January. Time: 2.30 p.m.
Held at: Above address.
Lecture: Storage Elements for Very High Speed Computers.
By: Dr. G. G. Macfarlane.

Belfast Branch
Date: 14 January. Time: 7.15 p.m.
Held at: 29 University Square, Belfast.
Lecture: The Use of a Computer in Business Planning.
By: C. M. Berners-Lee.

Birmingham Branch
Date: 13 January. Time: 6.30 p.m.
Held at: Large Theatre, Electrical Engineering Department, The University, Edgbaston, Birmingham.
Symposium on The Use of Computers for the Solution of Logical Problems:
(a) Examination timetables
(b) Railway timetables

Hull Branch
Date: 13 January. Time: 7.30 p.m.
Held at: Hull Chamber of Commerce, Samman House, Bowlalley Lane, Hull.
Lecture: Sorting and Summarizing Methods for Computers.
By: C. M. Berners-Lee.

Leeds Branch
Date: 6 January. Time: 6.30 p.m.
Held at: University Computing Laboratory, Eldon Hall, Woodhouse Lane, Leeds.
Lecture: Application of a National-Elliott 405 to Accounting.
By: P. J. Lown.

Liverpool Branch
Date: 28 January. Time: 6.30 p.m.
Held at: Mathematical Institute, University of Liverpool.
Lecture: Avoiding Mistakes by Oversight in an Industrial Programme.
By: A. Young.

Manchester Branch
Date: 18 January. Time: 7 p.m.
Held at: Manchester College of Science and Technology, Sackville Street, Manchester.
Lecture: Some applications of Monte Carlo.
By: Dr. J. W. Howlett.

Middlesbrough Branch
Date: 4 January. Time: 7.30 p.m.
Held at: Constantine Technical College, Borough Road, Middlesbrough.
Lecture: Experience with a Computer.
By: N. C. Pollock.

Newcastle Branch
Date: 5 January. Time: 7 p.m.
Held at: University Computing Laboratory, 1 Kensington Terrace, Newcastle.
Lecture: Commercial Experience with a Computer.
By: N. C. Pollock.

THE BRITISH INSTITUTION OF RADIO ENGINEERS

All London meetings will be held at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, commencing at 6.30 p.m.
Date: 27 January.
Lecture: Training for Operating and Maintaining Television Broadcasting Equipment.
By: K. R. Sturley and A. E. Robertson.

Computer Group
Date: 13 January.
Lecture: A Proposed Space-Charge-Limited Dielectric Triode.
By: Dr. G. T. Wright.

Radar Group
Date: 6 January.
Lecture: Some new possibilities in Civil Underwater Echo-ranging—Current Research at the University of Birmingham.
By: Professor D. G. Tucker.

Merseyside Section
Date: 11 January. Time: 7 p.m.
Held at: University Club, Liverpool.
Lecture: High Frequency Propagation—its present and future use for Communication Purposes.
By: A. F. Wilkins.

South Western Section
Date: 27 January. Time: 7 p.m.
Held at: The School of Management Studies, Unity Street, Bristol 1.
Lecture: An Equipment for Automatically Processing Time Multiplexed Telemetry Data (Timtape).
By: R. O. R. Chisholm.

BRITISH SOUND RECORDING ASSOCIATION

Date: 15 January. Time: 7.15 p.m.
Held at: Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2.
Lecture: Stereophonic Hearing.
By: Professor C. Cherry.

THE INSTITUTE OF PHYSICS

Liverpool and North Wales Branch
Date: 14 January. Time: 7 p.m.
Held at: The University, Liverpool.
Lecture: Electronic Applications of Super-conductivity.
By: Dr. E. Mendoza.

THE INSTITUTION OF ELECTRICAL ENGINEERS

All London meetings will be held at Savoy Place, commencing at 5.30 p.m.

Ordinary Meeting
Date: 28 January.
Lecture: Radio Communications by Means of Satellites.
By: A. W. Lines.

Electronics and Communications Section
Date: 11 January.
Lecture: A Quadrature Network for Generating Vestigial-Sideband Signals.
By: G. G. Gouriet and G. F. Newell.
Lecture: The Input Impedance of Rectifier Modulators.
By: Professor D. G. Tucker.
Lecture: Rectifier Modulators with Frequency-Selective Terminations, with particular reference to the Effect of Even-Order Modulation Products.
By: D. P. Howson and Professor D. G. Tucker.
Date: 27 January.
Lecture: The Oral Presentation of Scientific Material.
By: A. Clow.
Date: 29 January.
Lecture: Beam-Type Parametric Amplifiers: Some Aspects of Design and Use.
By: R. B. Dyott and C. R. Russell.

Mersey and North Wales Centre
Date: 4 January. Time: 6.30 p.m.
Held at: Donnan Laboratories, Vine Street, Liverpool.
Lecture: Silicone Electrical Insulation.
By: J. H. Davis.
Date: 18 January. Time: 6.30 p.m.
Held at: Above Address.
Lecture: Radio Aspects of the International Geophysical Year.
By: R. L. Smith-Rose.
Date: 25 January. Time: 6.30 p.m.
Held at: Town Hall, Chester.
Lecture: The Characteristics and Protection of Semiconductor Rectifiers.
By: D. B. Corbyn and N. L. Potter.

North-Eastern Centre
Date: 11 January. Time: 6.15 p.m.
Held at: Neville Hall, Westgate Road, Newcastle-on-Tyne.
Lecture: Research on the Performance of High-Voltage Insulators in Polluted Atmospheres.
By: J. S. Forrest, P. J. Lambeth and D. F. Oakeshott.

Northern Ireland Centre
Date: 12 January. Time: 6.30 p.m.
Held at: David Keir Building, Queen's University, Stranmillis Road, Belfast.
Lecture: Generator/Motor Problems in Pumped-Storage Installations.
By: J. H. Walker.

North Staffordshire Sub-Centre
Date: 18 January. Time: 7 p.m.
Held at: Technical College, Stafford.
Lecture: The Selection of Insulation Levels and Tests for High-Voltage Transformers.
By: G. B. Harper.

North Western Utilization Group
Date: 12 January. Time: 6.15 p.m.
Held at: Engineers' Club, Albert Square, Manchester.
Lecture: The Characteristics and Protection of Semi-conductor Rectifiers.
By: D. B. Corbyn and N. L. Potter.

South-East Scotland Sub-Centre
Date: 19 January. Time: 7 p.m.
Held at: Carlton Hotel, North Bridge, Edinburgh.
Lecture: Generator/Motor Problems in Pumped-Storage Installations.
By: J. H. Walker.

South Midland Electronics and Communications Group
Date: 25 January. Time: 6 p.m.
Held at: James Watt Institute.
Joint meeting with the Birmingham Centre of the Institution of Post Office Electrical Engineers.
Lecture: Long-Distance Waveguide Communication.
By: F. J. D. Taylor.

South-West Scotland Sub-Centre
Date: 20 January. Time: 6 p.m.
Held at: Institution of Engineers and Shipbuilders, 39 Elmbank Crescent, Glasgow, C.2.
Lecture: Subscriber Trunk Dialling.
By: D. A. Barron.

Western Centre
Date: 11 January. Time: 6 p.m.
Held at: The University, Bristol.
Lecture: The Application of Low-Pressure Resins to Some High-Voltage Switchgear Designs.
By: T. R. Manley, K. Rothwell and W. Gray.

Western Supply Group
Date: 18 January. Time: 6 p.m.
Held at: South Wales Institute of Engineers, Park Place, Cardiff.
Lecture: The Design of Electro-Mechanical Auxiliaries Directly Associated with Power-Producing Reactors.
By: A. E. Harwood, P. Scott and B. H. Stonehouse.

THE TELEVISION SOCIETY

Date: 8 January. Time: 7 p.m.
Held at: Cinematograph Exhibitors' Association, 164 Shaftesbury Avenue, London, W.C.2.
Lecture: Problems of U.H.F. Television: Transmission Propagation and Reception.
By: T. M. J. Jaskolsky, R. A. Rowden and K. Moulding.

Leicester Centre
Date: 19 January. Time: 7.30 p.m.
Held at: College of Technology and Commerce, The Newarke, Leicester.
Lecture: The Electrical Synthesis of Music.
By: A. Douglas.

PUBLICATIONS RECEIVED

ENGINEERING EDUCATION IN THE REGION is a booklet which should be of interest to persons concerned with the training of engineers, or with advising school-leavers in their choice of courses of further education in London and the Home Counties. The courses listed are those which the colleges propose to offer during the academic session 1959/60. The Secretary, Regional Advisory Council for Technological Education: London and Home Counties, Tavistock House South, Tavistock Square, London W.C.1.

VENNER LIGHTWEIGHT SILVER-ZINC ACCUMULATORS is the title of a catalogue which describes and illustrates the various features of these accumulators. Copies obtainable from Publicity Department, Venner Accumulators Limited, Kingston By-Pass, New Malden, Surrey.

THE BRITISH IRON AND STEEL RESEARCH ASSOCIATION'S ANNUAL REPORT 1958 contains the fifteenth annual report and accounts of the Council, covering the year ended 31 December 1958. Summaries of the investigations of the Divisions and Departments, together with the usual appendixes, make up the rest of the report. British Iron and Steel Research Association, 11 Park Lane, London W.1.

R-L-C COMPONENTS HANDBOOK by D. Mark complements the theory of R, L and C by presenting the physical aspects of the components possessed of these properties. The book is divided into six chapters, two each for R, L and C. John F. Rider Publisher, Inc, 116 West 14th Street, New York 11. Price $3.50.

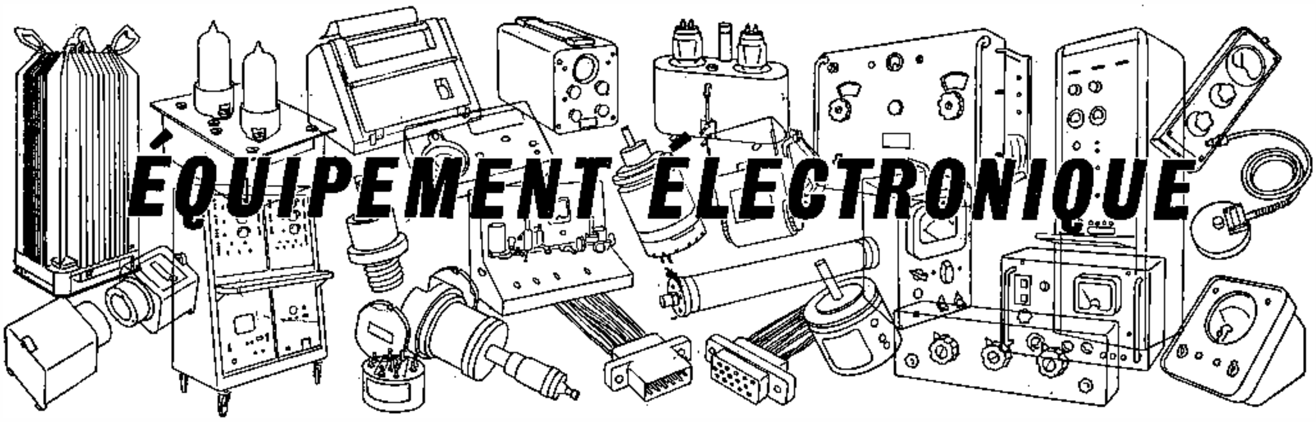
ANNUAL REPORT 1958-9 OF THE BRITISH STANDARDS INSTITUTION covers the period from 1 April, 1958 to 31 March, 1959, and copies are obtainable from the Institution, British Standards House, 2 Park Street, London W.1. Price 7s. 6d.

A TREATISE ON LISSAJOUS FIGURES AND TCHEBYCHEFF POLYNOMIALS by T. Riabokin is a research report issued by the University of Minnesota, Institute of Technology, Department of Aeronautical Engineering, Minneapolis 14, U.S.A.

MARCONI INSTRUMENTS 1959 is a catalogue of the telecommunication measurement equipment and industrial electronic instruments manufactured by Marconi Instruments Ltd, St. Albans, Herts. This edition incorporates a greatly improved indexing system.

(Pages 59 to 66 French and German Sections)

ÉQUIPEMENT ÉLECTRONIQUE



Une description basée sur des renseignements fournis par les fabricants de nouveaux organes, accessoires et instruments d'essai

Traduction des pages 54 à 56

AMPLIFICATEUR DE CAPTEUR DE VITESSE

(Illustration à la page 54)

Sir W. G. Armstrong Whitworth Aircraft Ltd, Hucclecote, Gloucester

Cet instrument a été étudié principalement pour convertir la sortie d'un capteur de vitesse séismique ou non-séismique en indication d'appareil de lecture facilement lisible.

L'appareil de lecture comporte deux échelles à étalonnages de 100 et 30 divisions, la longueur de l'échelle étant de 83 mm. Une déviation totale peut être obtenue pour des amplitudes de 0,3 à 300 millièmes de pouce, dans la gamme de fréquences de 1,5 à 1500 Hz.

Cet instrument se distingue, entre autres, par le fait que l'étalonnage est inclus dans la spécification, ce qui permet de compenser des variations à long terme et à court terme dans le fonctionnement.

Il est du type portatif à fonctionnement sur secteur, prévu pour une entrée coaxiale du capteur et muni d'une douille de sortie pouvant être connectée à un enregistreur à haute impédance ou à un oscilloscope.

A la livraison, l'instrument est étalonné pour une déviation totale sur la gamme X10, à partir d'un signal efficace de 1,6 V à 50 Hz. La résistance d'entrée est de 100 kΩ sur toutes les gammes.

EE 17 751 *pour plus amples renseignements*

VOLTMÈTRE ÉLECTRONIQUE

(Illustration à la page 54)

Airmec Ltd, High Wycombe, Buckinghamshire

La société Airmec vient de présenter une nouvelle version perfectionnée de son voltmètre électronique type 712, qui appartiendra au type 217. Cette modification a eu pour résultat une réponse de fréquence plus étendue, un meilleur dessin de la sonde et plus d'espace pour le conducteur, mais le circuit complémentaire équilibré du modèle original a été gardé, assurant ainsi un degré de stabilité très élevé.

Les mesures de tensions de 0 à 150 V peuvent être effectuées dans la gamme de fréquences de 10 Hz à 80 MHz avec grande précision, et avec moindre précision jusqu'à 200 MHz. Des tensions directes positives et négatives allant jusqu'à 500 V peuvent également être mesurées à une impédance de 40 mégohms. Six gammes de résistance sont prévues, allant de 100 ohms à 100 mégohms. La déviation est de zéro pour zéro ohm, et elle est de l'échelle totale pour une résistance infinie, évitant ainsi la confusion inhérente à l'échelle ohmétrique inversée habituelle.

L'appareil est muni d'une sonde haute impédance basse capacité, avec impédance d'entrée de 20 mégohms, pour l'usage aux fréquences élevées. Lorsque cette sonde est utilisée pour les basses fréquences et le courant continu, elle est montée sur le panneau avant de l'instrument, actionnant ainsi les bornes c.c., tandis qu'un barillet à ressort remonte automatiquement le conducteur de la sonde à travers une ouverture dans le coffret.

EE 17 752 *pour plus amples renseignements*

COMPTEUR ÉLECTRONIQUE

(Illustration à la page 54)

B. & F. Carter & Co. Ltd, Albion Works, Bolton, Lancashire

Cette société a récemment ajouté un compteur électronique à sa gamme d'instruments de comptage et de mesure "ALBION". Cet appareil, désigné par le type 24, comprend un coffret à instruments, le compteur proprement dit et le circuit à lampes thermoioniques, ainsi que le transformateur abaisseur, le relais et la commande d'accord potentiométrique. Il a, en outre, une lampe-témoin et un interrupteur principal. Le conducteur de secteur peut être relié à n'importe quelle source d'alimentation voulue, un second conducteur étant fourni pour le comptage. L'appareil est livré sous trois formes, soit avec sonde, avec bobine d'induction (pour les composantes passantes) ou avec élément à cellule photoélectrique.

Durant le fonctionnement, le potentiomètre d'accord est réglé de façon appropriée aux composantes comptées, chaque opération de comptage modifiant les caractéristiques des lampes, actionnant ainsi un relais qui, à son tour, amorce le compteur électromagnétique. Le compteur a des engrenages à six chiffres, et un réenclanchement actionné au doigt émerge du vase. Les caractéristiques nominales de l'appareil sont de 250 comptages par minute.

EE 17 753 *pour plus amples renseignements*

DÉTECTEUR D'ÉMISSIONS GAMMA

(Illustration à la page 54)

Plessey Nucleonics Ltd, Weedon Road, Northampton

Pour détecteur le plutonium au niveau de charge maximum permissible au corps humain, ou même à un niveau moindre, la société Plessey Nucleonics a réalisé un détecteur portatif fonctionnant sur secteur ou batterie, le P.N.I. 1080. Cet instrument est essentiel comme détecteur de rayonnement gamma de basse énergie.

Il est non seulement capable de détecteur des quantités infinitésimales de plutonium 239 dans le corps humain, mais il peut aussi, avec une légère modification et un réétalonnage, détecter la présence d'américum, une substance radioactive qui se trouvera dans le plutonium fait par les réacteurs d'Angleterre. Une légère modification supplémentaire lui permet de déceler l'uranium 235, qui émet également des rayons gamma à basse énergie.

L'appareil complet comprend une sonde de détection, reliée par un câble de 2 m de long à l'indicateur.

La sonde consiste en un cristal à scintillations en iodure de sodium, activé au thallium et monté sur l'extrémité d'une cellule photoélectrique multiplicatrice. Une chaine de résistances est disposée à l'intérieur de la sonde, de manière à fournir le potentiel exact aux dynodes, cependant qu'un réseau adapté au câble garantit une transmission optimum de l'impulsion de signal de la sonde à l'indicateur.

A l'usage des hôpitaux, la sonde peut être enfermée dans un étui en polythène.

L'indicateur du P.N.I.1080 comporte un amplificateur d'impulsions, un analyseur d'amplitude d'impulsion à canal unique, préréglé mais ajustable, un bloc d'alimentation très haute tension variable et stabilisée pour la cellule photoélectrique et enfin, un système d'affichage. Tous les circuits de l'indicateur sont à transistors.

EE 17 754 *pour plus amples renseignements*

PONT UNIVERSEL

(Illustration à la page 55)

Metrix Instruments Ltd, 54 Victoria Road, Surbiton, Surrey

Le pont universel Metrix type 626 est un instrument stable, robuste et complet, pour la mesure directe d'une gamme très étendue de valeurs de résistance, de capacité, d'inductance, de facteur de puissance et de Q, à 50 Hz, 1 kHz, avec une source extérieure allant jusqu'à 10 kHz. Pour les mesures de résistance, l'excitation c.c. est également fournie.

Un élément d'alimentation c.c. est incorporé à l'instrument et il peut être réglé pour mesurer l'inductance incrémentale. Des condensateurs électrolytiques peuvent être mesurés avec un courant continu appliqué pouvant atteindre 500 V.

En plus du circuit de pont, aux normes stables et précises, l'instrument comprend un oscillateur et un amplificateur sélectif de 1 kHz combine avec un oeil magique faisant fonction d'indicateur de zéro. Ceci présente l'avantage d'une sensibilité constante sur toute la gamme, sans risque de surcharger l'indicateur de zéro. Un modulateur en anneau permet d'employer l'amplificateur lorsque le pont est excité par c.c.

En dehors des possibilités de mesure directe, l'instrument peut aussi être relié à des étalons extérieurs ou à des composantes de référence, de sorte qu'il peut être employé comme pont comparateur si nécessaire.

En vue de réduire les manipulations au minimum et de faciliter son emploi, l'agencement de cet instrument a été l'objet d'une étude minutieuse, ceci s'appliquant notamment à la disposition rationelle des commandes.

Les gammes couvertes par le pont universel Metrix sont: résistance 0,01 Ω à 10 MΩ; capacité 1 pF à 100 μF; inductance 10 μH à 1000 H; Q,0 à 12.

EE 17 755 *pour plus amples renseignements*

CONNECTEURS DE CIRCUITS IMPRIMÉS

(Illustration à la page 55)

N.S.F. Ltd, 31-32 Alfred Place, London, W.C.1

La conception de base du contact connecteur N.S.F.-Varicon, qui est fabriqué en forme de fourche ayant quatre surfaces d'accouplement, a été employée pour produire une gamme de connecteurs de circuits imprimés pouvant s'appliquer à n'importe quel usage que le fabricant pourrait envisager.

Les contacts sont fournis sur bande plastique, calculée avec précision pour permettre l'insertion des pieds des contacs dans les ouvertures de la plaquette de circuit imprimé, qui est ainsi prête à être fixée. L'espacement courant des contacts est de 5mm. D'autres espacements peuvent être ménagés, moyennant un léger supplément. Le nombre maximum de contacts sur une seule bande est actuellement de 20.

Le fixage des contacts sur le circuit imprimé s'effectue avec des outils spéciaux prévus pour raser 0,23 mm de matériau sur les deux côtés du pied de contact, comprimant étroitement le matériau contre le circuit imprimé de cuivre. Ce fixage, ainsi que la soudure par immersion de la plaquette, donnent un contact solide à faible résistance d'une sûreté à toute épreuve. Pour arracher un contact de la plaquette, après fixage et soudure, il faudrait une charge de plus de 29 kgs. Cette charge ne serait que de 23 kgs si le contact n'a été que fixé, et de 11 kg s'il n'a été que soudé.

Afin d'assurer l'enclenchement correct des contacts, il est nécessaire d'avoir des guides de plaquette qui, dans le cas des grands formats, font corps avec l'équipement. Il existe un choix de supports pour les plaquettes de petit format.

Une trousse de connecteurs de circuits imprimés est fournie sur demande pour répondre aux besoins des ingénieurs désirant construire des assemblages expérimentaux. La trousse comporte des contacts, des supports, des outils de fixage pour l'assemblage des divers connecteurs. Cette trousse est enfermée dans une petite boîte en matière plastique.

EE 17 756 *pour plus amples renseignements*

MILLIVOLTMÈTRE À VOIES MULTIPLES

(Illustration à la page 55)

Southern Instruments Ltd, Frimley Road, Camberley, Surrey

Ce millivoltmètre numérique à voies multiples a été conçu pour l'enregistrement des sorties à voies multiples d'extensomètres ou de thermocouples, et il donne une sortie numérique décimale totale pour des entrées allant de 15 à 50 mV. 288 canaux peuvent être échantillonnés automatiquement à tour de rôle.

La sortie peut être enregistrée sur perforeuse à bande magnétique Creed ou sur machine à écrire électrique I.B.M. Des sorties simples peuvent être transmises à un indicateur numérique éclairé.

L'appareil est monté sur bâti dans une armoire spacieuse de 107 cm de haut. La construction par éléments est employée de façon générale et le bâti contient l'indicateur, les sélecteurs de canaux, le châssis numérique, l'élément de contrôle, l'élément de sortie et l'élément d'alimentation.

La précision est de 1 partie dans 999 de la sortie totale, c'est à dire un pouvoir séparateur limiteur de 15 μV.

L'équipement est construit par Bristol Aircraft Limited et il est distribué par Southern Instruments Ltd.

EE 17 757 *pour plus amples renseignements*

DISPOSITIF D'ENSEIGNEMENT ANALOGIQUE

(Illustration à la page 55)

The Solartron Electronic Group Ltd, 45 Thames Street, Kingston, Surrey

Un nouveau dispositif d'enseignement analogique, le TY963, se caractérisant par sa simplicité, vient d'être créé par le Groupe Solartron.

Ainsi que l'indique son nom, ce "dernier-né" de la série des calculateurs analogiques Solartron SPACE est, en fait, un calculateur analogique simplifié, destiné à des fins éducatives. Il peut représenter n'importe quelle forme d'équation différentielle de second ordre linéaire, à l'aide des composantes encastrées, et démontrer, par exemple, les effets des limites de vitesse et d'accélération, en utilisant des diodes extérieures comme impédances de calcul additionnelles. Dans les limites imposées par le jeu complet de cinq amplificateurs, il peut représenter une gamme étendue de systèmes physiques. Ces derniers comprennent de simples servo-mécanismes, des réseaux électriques, le mouvement d'une particule sous la gravité, etc.

Le calculateur est virtuellement "à l'épreuve des étudiants", en ce sens que l'appareil ne subira aucun endommagement permanent en cas d'utilisation incorrecte par des usagers inexpérimentés.

Comportant cinq amplificateurs c.c. opérationnels, ce "maître de calcul analogique" est un appareil entièrement complet par lui-même, doté de sa propre alimentation stabilisée, ainsi que de moyens adéquats de commande et d'ajustage. Grâce à l'interchangeabilité des assemblages de pièces—propre à tous les calculateurs analogiques de la série Solartron SPACE—des éléments du dispositif d'enseignement analogique peuvent être incorporés dans des installations de calcul analogique plus compliquées, à n'importe quel moment, s'il y a lieu.

EE 17 758 *pour plus amples renseignements*

RÉSISTANCES IMPRIMÉES

(Illustration à la page 56)

Mills & Rockleys (Production) Ltd, Swan Lane, Coventry, Warwickshire

Ces résistances sont prévues et produites pour répondre à des conditions particulières d'emploi et elles sont spécialement indiquées pour les emplacements à espace restreint, ainsi que lorsqu'une dissipation élevée de chaleur, provenant d'une aire à surface plane, est nécessaire. Deux exemples d'application type sont, premièrement, comme composante résistive dans un commutateur ne permettant pas l'utilisation de résistances classiques et, deuxièmement, comme résistance de chute de secteur refroidi à contact plat, pour récepteurs radio et de télévision, dans lesquels un châssis métallique est employé comme source froide.

La spécification du matériau de la base à papier électrique est comme suit:

Tension de rupture: −1,5 kV

Epaisseur: 0,15 mm

La spécification de l'élément de résistance varie selon les conditions requises et il peut être en cuivre-nickel, nickel-chrome, etc. aggloméré et durci sur le papier électrique de la base.

La solidité d'adhérence de l'élément de résistance à la base est très élevée et un écorçage ne pourrait se faire sans endommager la composante.

Lorsque l'élément de résistance nécessite un isolement complet, le papier électrique pourra être aggloméré à travers l'élément exposé comme dans les spécimens.

EE 17 759 *pour plus amples renseignements*

RÉSEAUX À RETARD

(Illustration à la page 56)

Lexor Electronics Ltd, 25 Allesley Old Road, Coventry, Warwickshire

La société Lexor Electronics Ltd vient d'annoncer la réalisation d'une gamme de lignes à retard classiques. Couvrant une gamme d'impédances de 50 à 880 ohms, les retards prévus vont de 50 mμsec à 1400 mμsec et fournissent un total de plus de 200 combinaisons étalonnées. Les réseaux sont assemblés à partir de sections lc à dérivation m, montées de façon appropriée à l'emploi en laboratoire et à l'inclusion dans une installation. La perte est inférieure à 1 dB pour tous les types. Les temps de montée sont de 3 à 10% et la réponse de phase est linéaire jusqu'à 70% de la fréquence de coupure.

Ces éléments sont livrés soit en coffrets d'acier ou de bois, soit sous moulage de résine.

En plus de la gamme classique de réseaux à retard, la susdite société a inauguré un service d'études spécialisé, afin d'assurer la production de réseaux et de lignes à retard répondant aux spécifications des clients.

EE 17 760 *pour plus amples renseignements*

ALIMENTATION DE TRANSISTORS

(Illustration à la page 56)

Marconi Instruments Ltd, St. Albans, Hertfordshire

Le TF 1303 est un élément portatif fournissant une alimentation hautement stabilisée aux circuits basse tension, notamment ceux à transistors.

La tension de sortie shuntée est contrôlée par un appareil de mesure incorporé, à grande échelle, et elle est à variation continue de 2,5 V à 24 V. Le courant de sortie maximum pouvant être obtenu dépend de la tension livrée et varie de 1,25 A à 2,5 V, et de 0,2 A à 24 V. Un interrupteur limiteur de puissance restreint la sortie à un maximum de 12 W, 2 W ou 500 mW. Ceci garantit la protection contre la possibilité d'un claquage accidentel de transistor dans le circuit expérimental. En outre, la stabilisation shunt permet de court-circuiter les bornes de sortie sans endommager l'appareil.

Le circuit de sortie de l'élément est complètement isolé tant du secteur d'alimentation que du châssis. L'une ou l'autre des bornes peut, donc, être reliée à la masse. En variante, l'alimentation peut être effectuée de façon à flotter à un potentiel ne dépassant pas 100 V par rapport à la masse. Ceci veut dire qu'on peut relier deux ou plusieurs éléments en série pour obtenir des tensions plus élevées.

L'alimentation c.c. est obtenue d'un transformateur de secteur, par le truchement d'un redresseur biphasé comprenant deux diodes à jonction au germanium, et elle est transmise aux bornes de sortie à travers une résistance série. Un transistor à grande puissance, relié à travers la sortie, forme un régulateur de shunt contrôlé par un amplificateur à transistor. Ceci détermine la proportion de tension redressée développée à travers la résistance série.

L'amplificateur contrôlant le transistor de puissance utilise un circuit classique à quatre transistors couplés c.c. La tension apparaissant aux bornes de sortie est appliquée à la base du premier transistor à travers un potentiomètre. Ce potentiomètre est réglable à partir du panneau avant et constitue la commande de tension de sortie.

La régulation de charge de l'élément est supérieure à 0,01 V et la composante ondulée est inférieure à 0,5 mV. Enfin, il peut être utilisé à des températures ambiantes allant jusqu'à 45°C.

EE 17 761 *pour plus amples renseignements*

RELAIS D'IMPULSIONS

(Illustration à la page 56)

Magnetic Devices Ltd, Newmarket, Suffolk

Le relais d'impulsions type 596 est la toute dernière création de l'assortiment de dispositifs magnétiques de cette société et ses dimensions sont approximativement de 27 mm × 38 mm × 44 mm.

Les impulsions de tension unidirectionnelle vers le relais, actionnent et déclenchent, tour à tour, le ressort fixé sur un des côtés du relais, tandis que les contacts de l'autre côté suivent l'armature.

Le relais peut être à fils ou à fiches, fermé ou hermétiquement scellé.

Pour la version ouverte, il peut être fourni jusqu'à deux contacts commutateurs pour chaque jeu de contacts.

Pour les versions fermées ou scellées, il existe un maximum de trois commutateurs, dont l'un est sur le côté des impulsions.

Des tensions de bobinage allant jusqu'à 150 V c.c. peuvent être prévues.

Il existe enfin, une version de ce relais pour courant alternatif, le redresseur de blocage et le condensateur de filtrage étant montés sur une plaquette d'isolement fixée au dessus du relais.

EE 17 762 *pour plus amples renseignements*

Résumés des Principaux Articles

Identification automatique des caractères par D. A. Young

Résumé de l'article aux pages 2 à 10

Après avoir donné, en matière d'introduction, un aperçu de certains des principaux systèmes d'identification automatique des caractères, actuellement en cours de production ou encore au stade de la mise au point, l'auteur examine les caractéristiques sémantiques fondamentales ainsi que les limites des formes de caractères. Il démontre que, par une analyse de ces facteurs limiteurs, on peut formuler des définitions de types de caractères qui se laissent particulièrement bien traduire en termes de logique discriminatoire. Nous espérons pouvoir donner dans un prochain numéro des détails de quelques circuits logiques, tout particulièrement appropriés à ce genre d'analyse, qui ont été appliqués à la réalisation de systèmes universels d'identification de caractères.

Les caractéristiques et l'application des tubes stabilisateurs à effet corona par E. Cohen et R. O. Jenkins

Résumé de l'article aux pages 11 à 15

La décharge corona utilisée pour la stabilisation de tension s'effectue dans l'hydrogène entre un cylindre cathodique et une anode à fil axial. En dehors des effets thermiques qui s'accentuent dans les tubes à tension élevée, la décharge corona se comporte à peu près comme une tension constante en série avec une résistance. Ces deux paramètres dépendent des rayons des électrodes et de la pression de gaz. Les caractéristiques des tubes à enveloppes subminiature B7G et B9A s'étendant

sur une gamme de 350V à 7 kV sont indiquées dans cet article. Ces tubes conviennent à l'emploi dans des circuits fournissant des courants dans la gamme de 0,02 à 1mA, et les auteurs donnent un aperçu de leurs diverses applications.

Le tambour enregistreur magnétique du calculateur électronique 'MERCURY' par K. I. Turner et J. E. Thompson

Résumé de l'article aux pages 16 à 21

Le calculateur universel à action rapide 'MERCURY' comprend, comme enregistreur principal, un nombre de tambours magnétiques (jusqu'à 8 tambours en tout) pouvant stocker un million et demi d'éléments d'informations. Chacun de ces tambours est logé, de même que les circuits nécessaires, dans un coffret incorporé. Le choix électronique de la piste de lecture ou d'écriture permet d'effectuer le branchement entre pistes en moins de 20 µsec. Le synchronisme entre tambour et calculateur est réalisé au moyen d'une commande de vitesse électronique.

Un stabilisateur de courant transistorisé pour électro-aimant par J. C. S. Richards

Résumé de l'article aux pages 22 à 23

On peut utiliser des transistors d'alimentation pour commander des courants importants, mais leur tension nominale maxima est inférieure au niveau voulu. On peut, cependant, pallier cette insuffisance de tension par l'emploi d'un système de commande électro-magnétique auxiliaire à l'entrée d'un stabilisateur. Un élément de ce genre, fournissant 4A à 200V, est décrit dans cet article. Dans des conditions d'utilisation normales, le courant demeure stable à ± 2 parties de 10^5 pendant plus d'une heure et ± 2 parties de 10^4 pendant plus de dix heures.

L'équipement électronique des centrales nucléaires par M. W. Jervis

Résumé de l'article aux pages 24 à 29

Les dispositifs de commande et de protection des réacteurs nucléaires comportent des matériels électroniques alimentés par thermocouples et détecteurs nucléaires. L'auteur examine l'appareillage de mesure et de protection, particulièrement en ce qui a trait aux circuits de sûreté et à l'enregistrement automatique des données. Il discute également des tendances actuelles dans la construction des amplificateurs de fermeture et des appareils de télévision.

Traitement des données de souffleries aérodynamiques pour avions par E. Patterson

Résumé de l'article aux pages 30 à 36

La soufflerie s'est développée à partir d'un auxiliaire relativement imprécis pour l'étude des avions en un outil indispensable à leur construction. La demande de résultats plus précis et de plus grandes vitesses d'essai a conduit à la réalisation de souffleries nécessitant des sources d'énergie de grande puissance et des méthodes précises de construction. La soufflerie actuelle est devenue, par conséquent coûteuse et d'une durée limitée.

Ces facteurs, alliés à la confiance accrue accordée aux souffleries, ainsi qu'à une plus grande compréhension de la technique d'essai, ont eu pour effet, à leur tour, d'accroître la demande de résultats supplémentaires et de précision plus élevée encore.

Cet article s'attache à présenter au non-spécialiste un aperçu des exigences qui ont conduit le système de traitement des données à se développer des méthodes d'enregistrement visuel et manuel d'il y a une dizaine d'années aux systèmes automatiques de grande rapidité de l'époque actuelle.

Les difficultés qui ont surgi et qui sont dues à l'espace restreint disponible dans le modèle pour l'instrumentation, ainsi que les propriétés fondamentales du transducteur, sont discutées en conclusion.

La construction d'un système de calcul numérique à partir d'un circuit de base à transistor par P. L. Cloot et. G. E. Jackson

Résumé de l'article aux pages 37 à 43

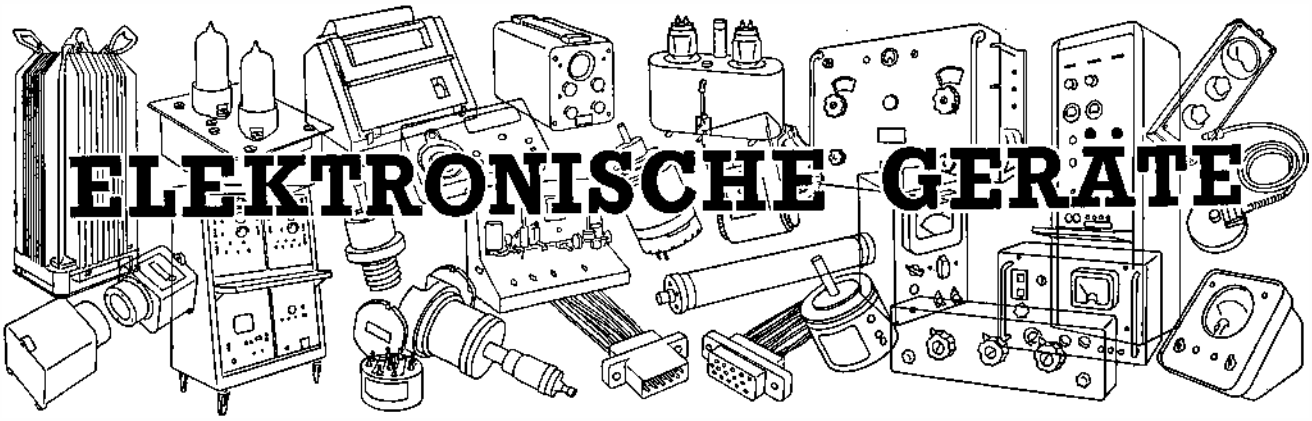
On peut construire un système complet de calcul numérique en reliant entre eux un nombre de circuits de base identiques. L'une des methodes préconisées utilise un circuit de base se composant d'un transistor, d'un condensateur et de trois résistances. L'application de cette méthode a été démontrée par la construction d'un calculateur à usage particulier, avec programme incorporé pour les conversions de données binaires en données décimales. Les auteurs expliquent la conception logique de cette machine à calculer, le dessin de son circuit et sa construction mécanique. On a pu réussir à employer un câblage entièrement imprimé et à rendre le calculateur extrêmement compact.

Analyse de la disposition en cascade de transistors par J. R. James

Résumé de l'article aux pages 44 à 48

Il est souvent difficile de réaliser la neutralisation des pièces fixes dans la production d'amplificateurs accordés, en raison de l'étalement des paramètres des transistors. Un amplificateur à transistors en cascade ne nécessite pas de neutralisation mais il a moins de gain que deux étages dans la configuration à émetteur à la masse. Cet article examine dans quelle mesure sont réduits la réaction interne et le gain.

ELEKTRONISCHE GERÄTE



Beschreibung neuer Bauelemente, Zubehörteile und Prüfgeräte auf Grund der von Herstellern gemachten Angaben.

Übersetzung der Seiten 54 bis 56

VERSTÄRKER FÜR GESCHWINDIGKEITSWANDLER

(Abbildung Seite 54)

Sir W. G. Armstrong Whitworth Aircraft Ltd, Hucclecote, Gloucester

Das Gerät wurde in erster Linie zur Umwandlung der Ausgangsspannung seismischer und nichtseismischer Geschwindigkeitswandler in leicht lesbare Messgerätanzeigen entwickelt.

Das Messgerät hat zwei 82,5 mm lange Skalen, die bei Vollausschlag für 100 und 30 Teilstriche geeicht sind. Vollausschlag kann für Amplituden von 7,5 μ . . . 7,62 mm für einen Frequenzbereich von 1,5 . . . 150 Hz erreicht werden.

Wichtig sind die im Pflichtblatt vorgesehenen Eichmöglichkeiten, die den Ausgleich lang- und kurzfristiger Leistungsschwankungen ermöglichen.

Das Gerät ist tragbar und netzbetrieben. Es hat einen koaxialen Eingang für den Wandler und einen Ausgangssockel zum Anschluss eines Schreibers oder Oszillografen hoher Impedanz.

Vor dem Versand wird das Gerät geeicht, um für ein Signal von 1,6 V_{eff} und 50 Hz Vollausschlag zu geben. Der Eingangswiderstand für alle Bereiche ist 100 kΩ.

EE 17 751 *für weitere Einzelheiten*

RÖHRENVOLTMETER

(Abbildung Seite 54)

Airmec Ltd, High Wycombe, Buckinghamshire

Airmec hat vor kurzem eine neue, verbesserte Ausführung des Röhrenvoltmeters Type 712 herausgebracht, das als Type 217 bezeichnet wird. Die Neukonstruktion ergibt einen breiteren Frequenzgang, verbesserte Messkopfkonstruktion und bequemere Kabelaufbewahrung, hat jedoch die völlig ausgeglichene Schaltung früherer Modelle beibehalten, die eine sehr hohe Stabilität ergibt.

Spannungsmessungen von 0 . . . 150V können im Frequenzbereich von 10 Hz . . . 80 MHz mit grosser Genauigkeit und bis zu 200 MHz mit geringerer Genauigkeit ausgeführt werden. Positive und negative Gleichspannungen können auch bei einer Impedanz von 40 MHz gemessen werden. Sechs Widerstandsmessbereiche sind für Messungen von 100Ω . . . 100MΩ vorgesehen. Der Zeigerausschlag ist null für null Ohm, und Vollausschlag zeigt endlosen Widerstand an, wodurch die durch die umgekehrte Ohmskala hervorgerufene Verwirrung vermieden wird.

Für hohe Frequenzen ist ein Messkopf niedriger Kapazität und hoher Impedanz vorgesehen, dessen Eingangsimpedanz 2 MΩ ist. Für Gleichspannungs- und niederfrequente Messungen wird der Messkopf auf die Frontplatte montiert und die Gleichstromklemmen werden benutzt; hierbei rollt eine federnde Trommel automatisch das Messkopfkabel durch ein Loch im Gehäuse auf.

EE 17 752 *für weitere Einzelheiten*

ELEKTRONISCHER ZÄHLER

(Abbildung Seite 54)

B. & F. Carter & Co. Ltd, Albion Works, Bolton, Lancashire

Die bestehende Auswahl der „Albion" Zähler und Messmaschinen wurde vor kurzem durch einen elektronischen Zähler erweitert. Dieses als Type 24 bezeichnete Gerät umfasst einen Zähler und Röhrenkreis einschliesslich Untersetzer, ein Relais und Einstellpotentiometer in einem Gehäuse. Eine Signallampe und ein Netzschalter sind auch vorgesehen. Das Anschlusskabel kann mit jedem bequemen Netz verbunden werden. Ein zweites Kabel verbindet mit dem Zählkopf. Dieser kann in drei Ausführungen geliefert werden: als Fühler, Spule (für den Durchgang von Bauelementen) oder Fotozelle.

Im Betrieb wird das Potentiometer entsprechend den zu zählenden Teilen eingestellt. Jeder Zählstoss ändert die Röhren-Betriebsdaten und regt dadurch ein Relais an, das seinerseits einen elektromagnetischen Zähler betätigt. Der Zähler hat sechs Zahlenscheiben. Eine Löschungsvorrichtung mit Fingerbedienung ist von der Basis aus zugänglich. Die Zählgeschwindigkeit beträgt bis zu 250 Zählungen pro Minute.

EE 17 753 *für weitere Einzelheiten*

GAMMA-STRAHLUNGSANZEIGER

(Abbildung Seite 54)

Plessey Nucleonics Ltd, Weedon Road, Northampton

Plessey Nucleonics hat einen tragbaren, netz- oder batteriebetriebenen Anzeiger P.N.I. 1080 zur Anzeige von Plutonium entwickelt, der den höchstzulässigen Körperpegel oder sogar geringere Mengen anzeigt. Das Gerät ist im wesentlichen ein Anzeiger für Gamma-Strahlungen geringer Energie.

Ausser der Anzeige kleinster Mengen Plutonium im menschlichen Körper kann das Gerät mit geringen Abänderungen und Nacheichung auch die Gegenwart von Amerikanum entdecken, das als radioaktive Substanz in dem in England in Reaktoren hergestellten Plutonium vorhanden ist. Mit einer weiteren kleinen Abänderung kann der 1080 auch Uranium 235 anzeigen, das Gammastrahlen geringer Energie abgibt.

Das Gerät besteht aus einem Messkopf, der durch ein 1,80 m langes Kabel mit dem Anzeigegerät verbunden ist.

Der Messkopf besteht aus einem dünnen, mit Thallium aktivierten Jodnatrium Szintillator, der einem Photomultiplier vorgebaut ist. Im Messkopf ist eine Widerstandskette eingebaut, um die richtigen Spannungen an die Multiplieroberflächen zu liefern. Ein Kabelausgleichsnetzwerk garantiert, dass optimale Signalimpulse vom Messkopf an das Anzeigegerät weitergeleitet werden.

Für Verwendung in Krankenhäusern wird der Messkopf in einen Polyäthylenbehälter gekapselt.

Das Anzeigegerät des P.N.I. 1080 besteht aus einem Impulsverstärker, einem eingestellten aber regelbaren Einkanal-Impulsamplituden - Analysator, einer variablen und stabilisierten Hochspannungsquelle für die Photoröhre und einem Anzeigesystem. Alle Kreise des Anzeigegerätes sind transistorisiert.

EE 17 754 *für weitere Einzelheiten*

MEHRZWECK-BRÜCKE

(Abbildung Seite 55)

Metrix Instruments Ltd. 54 Victoria Road, Surbiton, Surrey

Die Metrix Mehrzweck-Brücke Type 626 ist ein stabiles, widerstandsfähiges und umfassendes Gerät zur Direktmessung von Widerstand, Kapazität, Induktivität, Leistungs- und Gütefaktor über einen sehr weiten Grössenbereich mit 50 Hz, 1 kHz und von Fremdquellen bis zu 10 kHz. Für Widerstandsmessungen wird auch Gleichstrom abgegeben.

Eine getrennte, regelbare Gleichstromquelle mit Messgerät ist zur Messung zusätzlicher Induktivität und von Elektrolytkondensatoren mit Gleichspannungen bis zu 500 V eingebaut.

Ausser der Brückenschaltung mit ihren stabilen und genauen Normalen hat das Gerät einen 1 kHz Oszillator und einen selektiven Verstärker mit einem magischen Auge als Nullanzeige. Der Vorteil dieser Anordnung ist konstante Empfindlichkeit über den ganzen Bereich ohne Risiko, dass die Nullanzeige übersteuert wird. Wenn die Brücke gleichstromerregt ist, kann der Verstärker durch einen Rufmodulator benutzt werden.

Zusätzlich zu den direkten Messungen sind auch Anschlussmöglichkeiten für externe Normale und Bezugselemente vorgesehen, so dass das Gerät als Vergleichsbrücke eingesetzt werden kann.

Um die Handhabung soweit wie möglich einzuschränken und zu erleichtern, wurde das Gerät besonders sorgfältig ausgelegt und die Bedienungsgriffe rationell zusammen angeordnet.

Die Messbereiche sind: Widerstand 0,01 Ω . . . 10 MΩ; Kapazität 1 pF . . . 100 μF; Induktivität 10 μH . . . 1000 H; Q 0 . . . 12.

EE 17 755 *für weitere Einzelheiten*

STECKVERBINDUNGEN FÜR GEDRUCKTE SCHALTUNGEN

(Abbildung Seite 55)

N.S.F Ltd, 31-32 Alfred Place, London, W.C.1

Die grundsätzliche Bauart des NSF-Varicon-Kontaktes, eine gabelartige Konstruktion mit vier aufeinander arbeitenden Flächen, fand zur Herstellung einer Serie von Steckverbindungen für gedruckte Schaltungen Verwendung, die allen Anwendungsmöglichkeiten gerecht wird, die ein Konstrukteur sich vorstellen kann.

Die Kontakte werden auf einem plastischen Bandträger geliefert, der nach der Montage weggeworfen wird. Sie sind auf dem Band genau in der Stellung befestigt, in der sie in Löcher in der Schaltungskarte eingepresst und dann genietet werden. Der genormte Kontaktabstand ist 0,2 Zoll (5,1 mm). Andere Kontaktabstände können für geringe zusätzliche Werkzeugkosten hergestellt werden. Die höchste Kontaktzahl für eine Leiste ist im Augenblick 20.

Das Nieten der Kontakte wird mit besonderen Werkzeugen ausgeführt, die an beiden Seiten der Kontaktenden 0,23 mm abschaben und das Material fest gegen das Kupfer der Schaltungskarte zusammendrücken. Dieses Nieten und das folgende Tauchlöten der Karte ergeben eine feste Verbindung geringeren Widerstandes und unübertroffener Betriebssicherheit. 29,5 kg sind notwendig, um genietete und gelötete Kontakte aus der Karte herauszureissen, 22,7 kg für nur genietete Verbindungen und 11,4 kg für nur gelötete.

Einwandfreier Eingriff der Steckverbindung erfordert Karten-Führungen, die für grössere Verbindungen im Gerät eingebaut werden sollen. Für kleinere Verbindungen ist eine Auswahl von Führungswinkeln lieferbar.

Für Ingenieure, die Versuchsanordnungen zusammenstellen wollen, ist ein Baukasten für diese Steckverbindungen lieferbar. Kontakte, Winkel und Nietwerkzeuge für die verschiedenen Verbindungen werden in einem kleinen plastischen Kasten geliefert.

EE 17 756 *für weitere Einzelheiten*

MEHRKANAL-MILLIVOLT-SCHREIBER

(Abbildung Seite 55)

Southern Instruments Ltd, Frimley Road, Camberley, Surrey

Dieser Mehrkanal - Millivolt - Digitalschreiber ist für Anzeige mehrkanaliger Dehnungsstreifen- und Thermoelementspannungen bestimmt und gibt für 15 ... 50 mV Eingangsspannung einen massstäblichen dezimalen Digitalausgang. 288 Kanäle können automatisch hintereinander abgetastet werden. Der Ausgang kann entweder mittels einer Creed Lochstreifenstanze oder einer I.B.M. elektrischen Schreibmaschine registriert werden. Einzelausgangsspannungen können eine beleuchtete Zahlenanzeige speisen.

Das Gerät ist in einem stabilen, 1,07 m hohen Schrank in ein Gestell eingebaut. Das Bausteinprinzip findet volle Anwendung, und das Gestell enhält Anzeigegerät, Kanalwähler, Digitalumwandler, Steuergerät, Ausgangsstufe und Netzanschluss.

Die Messgenauigkeit beträgt für Endanzeige 1 Teil in 999, d.h. die Auflösungsgrenze ist 15 μV.

Das Gerät wird von der Bristol Aircraft Limited hergestellt und durch Southern Instruments Limited vertrieben.

EE 17 757 *für weitere Einzelheiten*

ANALOG-AUSBILDUNGSGERÄT

(Abbildung Seite 55)

The Solartron Electronic Group Ltd. 45 Thames Street, Kingston, Surrey

Solartron Electronic Group hat ein neues, einfaches Analog-Ausbildungsgerät, den Analog-Tutor TY 963 herausgebracht.

Wie schon der Name andeutet, ist dieses neueste Gerät in der Solartron „SPACE"-Analogrechnerserie ein vereinfachter Analogrechner für Schulungszwecke. Mit Hilfe eingebauter Rechner-Bausteine kann jede Form geradliniger Differenzialgleichungen zweiter Ordnung dargestellt werden. Z.B. können die Einflüsse von Geschwindigkeit und Beschleunigungsgrenzen durch Verwendung externer Dioden als zusätzliche Rechnerimpedanzen aufgezeigt werden. Innerhalb der durch eine Gesamtausrüstung mit fünf Verstärkern gesetzten Grenzen kann eine weite Auswahl physikalischer Systeme dargestellt werden, z.B. einfache Servo-Einrichtungen, elektrische Netzwerke, die Bewegung eines Teilchens unter Schwerkrafteinfluss usw.

Der Rechner ist praktisch „studentensicher", d.h. er erleidet keinen Dauerschaden, sollte schlechtes Programmieren zu fehlerhafter Operation führen.

Der Analog-Tutor ist ein in sich geschlossenes Gerät mit fünf Operationsverstärkern, stabilisiertem Netzanschluss, ausreichenden Stecker-Schaltverbindungen und Steuervorrichtungen. Auswechselbarkeit der Bausteine, ein Merkmal aller Solartron „SPACE"-Analogrechner, ermöglicht jederzeit Verwendung der Analog-Tutor-Bausteine in komplizierten Analogrechner-Anlagen, falls es wünschenswert erscheint.

EE 17 758 *für weitere Einzelheiten*

GEDRUCKTE WIDERSTÄNDE

(Abbildung Seite 56)

Mills & Rockleys (Production) Ltd, Swan Lane, Coventry, Warwickshire

Diese Widerstände werden für besonderen Kundenbedarf entwickelt und hergestellt. Sie finden besonders Verwendung in begrenztem Einbauraum und dort, wo hohe Wärmezerstreuung erforderlich ist, die durch die flache Oberfläche erreicht wird. Als Beispiele werden aufgeführt: Einbau in eine bestehende Schalterkonstruktion, die die Benutzung herkömmlicher Widerstände nicht erlaubt, und Widerstände mit hohem Spannungsabfall für Radio- und Fernsehempfänger, die durch flachen Kontakt Wärme zum Chassis abführen.

Das als Träger verwandte elektrische Papier entspricht folgenden Vorschriften:

Durchschlagsspannung	1,5 kV
Stärke	0,15 mm
Höchsttemperatur	150°C

Für das Widerstandselement wird den Sonderaufgaben entsprechendes Material gewählt; u.a. werden Nickelkupfer und Nickelchrom mit dem Papierträger verbunden und ausgehärtet.

Die Klebefestigkeit zwischen Widerstandselement und Träger ist ausserordentlich hoch, und Abziehen ist ohne Beschädigung des Bauelementes unmöglich.

Wenn vollständige Isolation erforderlich ist, kann elektrisches Papier in der abgebildeten Weise über das blossliegende Widerstandselement geklebt werden.

EE 17 759 *für weitere Einzelheiten*

VERZÖGERUNGSNETZWERKE

(Abbildung Seite 56)

Lexor Electronics Ltd, 25 Allesley Old Road, Coventry, Warwickshire

Vor kurzem hat Lexor Electronics Ltd. die Einführung einer Reihe von Verzögerungsnetzwerk-Bausteinen angekündigt, die über 200 Kombinationen im Impedanzbereich 50 ... 880Ω mit Verzögerungen von 50 ... 1400 ns ermöglicht. Die Netzwerke werden aus m-abgeleiteten LC-Bausteinen zusammengestellt, die in geeigneter Weise für Laborgebrauch oder Einbau in Geräte lieferbar sind. Für alle Typen sind die Verluste geringer als 1 dB; die Anstiegszeiten liegen zwischen 3 ... 10%, und der Phasengang ist bis zu 70% der Grenzfrequenz geradlinig.

Die Bausteine sind entweder in Messgerätgehäusen aus Stahl oder Holz, sowie in Gussharzausführung lieferbar.

Ausser dieser Reihe von Verzögerungsnetzwerk-Bausteinen wurde auch ein Entwicklungsbüro für Verzögerungsnetzwerke eingerichtet, mit dessen Hilfe Verzögerungslinien und -netzwerke in Sonderausführung für Kunden hergestellt werden können.

EE 17 760 *für weitere Einzelheiten*

TRANSISTOR-NETZGERÄT

(Abbildung Seite 56)

Marconi Instruments Ltd, St. Albans, Hertfordshire

Das TF 1303 ist ein tragbares, hochstabilisiertes Stromversorgungsgerät für Niederspannungs-Schaltungen, besonders wenn sie mit Transistoren bestückt sind.

Die serienstabilisierte Ausgangsspannung ist zwischen 2,5 ... 24V regelbar und wird auf einem eingebauten Messgerät mit Grossskala angezeigt. Der Ausgangshöchststrom hängt von der abgegebenen Spannung ab und schwankt von 1,25 A bei 2,5V bis 0,2 A bei 24 V. Ein Leistungs-Grenzschalter beschränkt die Höchstleistung auf 12 W, 2 W oder 500 mW und gibt gegen die Wahrscheinlichkeit Schutz, dass Transistoren in Versuchsschaltungen ausbrennen. Selbst Kurzschluss der Ausgangsklemmen beschädigt das Gerät infolge der Serienstabilisation nicht.

Der Ausgangskreis des Gerätes ist vollständig von Netz und Chassis isoliert. Jede der Klemmen kann daher geerdet werden. Andererseits können sie auch so angeordnet werden, dass sie gegenüber Erde einen Spannungsunterschied bis zu 100 V aufweisen. Dadurch wird es möglich, mehrere Geräte in Serie zu schalten, um höhere Spannungen zu erreichen.

Der Gleichstrom wird einem Netzumspanner über einen Vollweg-Gleichrichter entnommen, der aus zwei Germanium-Flächendioden besteht, und wird den Ausgangsklemmen über einen Serienwiderstand zugeleitet. Ein parallel zu den Ausgangsklemmen liegender Hochleistungstransistor bildet einen Nebenschlussregler, der durch einen Transistor-Verstärker gesteuert wird. Er legt den Anteil der gleichgerichteten Spannung fest, der als Spannungsabfall am Serienwiderstand auftritt.

Der den Leistungstransistor steuernde Verstärker ist nach einer der üblichen Schaltungen aufgebaut und benutzt vier gleichstromgekoppelte Transistoren. Die an den Ausgangsklemmen auftretende Spannung wird über ein Potentiometer an die Basis des ersten Transistors gelegt. Dieses Potentiometer ist von der Frontplatte aus regelbar und dient zur Einstellung der Ausgangsspannung.

Die Leistungsregelung des Gerätes ist besser als 0,01 V; die Restwelligkeit ist geringer als 0,5 mV. Das Gerät kann in Umgebungstemperaturen bis zu 45° C arbeiten.

EE 17 761 *für weitere Einzelheiten*

IMPULSRELAIS

(Abbildung Seite 56)

Magnetic Devices Ltd, Newmarket, Suffolk

Die neueste Erweiterung des Magnetic Devices-Programms ist das Impulsrelais 596, dessen Abmessungen ungefähr 27 × 38 × 44 mm sind.

Der Federsatz an einer Relaisseite wird durch die einseitig wirkenden Spannungsimpulse abwechselnd betätigt und losgelassen, während die Kontaktfedern der anderen Seite dem Anker folgen.

Das Relais kann für Einlöten oder Einstecken, gekapselt oder luftdicht verschlossen geliefert werden.

Ohne Gehäuse ausgeführt, kann das Relais mit zwei Umschaltkontakten für jeden Federsatz geliefert werden.

Für die gekapselte und hermetisch verschlossene Ausführung sind höchstens drei Umschaltungen möglich und nur eine an der Impulsseite.

Spulenspannungen bis zu 150 V Gleichstrom können benutzt werden.

Eine für Wechselstrom geeignete Ausführung kann geliefert werden. Der notwendige Sperrgleichrichter und Glättungskondensator sind auf einem Schaltbrettchen über dem Relais untergebracht.

EE 17 762 *für weitere Einzelheiten*

Zusammenfassung der wichtigsten Beiträge

Automatisches Klarschriftlesen von D. A. Young

Zusammenfassung des Beitrages auf Seite 2-10

Die Einführung gibt eine Übersicht einiger der wichtigsten automatischen Klarschrift-Lesesysteme, die zur Zeit entweder im Produktions- oder Laborstadium sind. Danach werden die grundsätzlichen semantischen Eigenschaften und Grenzen der Schriftzeichenmuster diskutiert. Es wird gezeigt, dass eine Analyse dieser Grenzeigenschaften ermöglicht, Umgrenzungen von Schriftzeichenmustern zu formulieren, die sich besonders zur Übersetzung entsprechend den Begriffen der unterschiedlichen Logik eignen. Für einen späteren Beitrag sind Einzelheiten logischer Schaltungen, die sich besonders für diese Analysen eignen, sowie ihre Anwendung für ein vielseitiges Klarschrift-Lesesystem vorgesehen.

Kennlinien und Verwendung von Korona-Stabilisatorröhren von E. Cohen und R. O. Jenkins

Zusammenfassung des Beitrages auf Seite 11-15

Die für Spannungsstabilisation benutzte Koronaentladung tritt zwischen einem Kathodenzylinder und einer axialen Drahtanode in Wasserstoff auf. Mit Ausnahme der Wärmewirkung, die in Röhren für höhere Spannungen wichtig wird, verhält sich die Entladung wie eine konstante Spannung in Serie mit einem Widerstand. Diese beiden Parameter hängen von den Radien der Elektroden und dem Gasdruck ab. Kennlinien der Röhren mit Subminiaturkolben B7G und B9A werden für den Bereich von 350 V.....7 kV angegeben. Die Röhren sind für Schaltungen geeignet, die Strom von 0,22.....1 mA abgeben. Verschiedene Anwendungsbeispiele werden beschrieben.

Der Magnettrommelspeicher des „Mercury"-Rechners von K. I. Turner und J. E. Thompson

Zusammenfassung des Beitrages auf Seite 16-21

Der Mehrzweck-Schnellrechner Mercury hat als Hauptspeicher bis zu acht Magnettrommeln, die bis zu 1,5 Millionen Digitalstellen (Bits) aufnehmen können. Jede der Trommeln ist mit den zugehörigen Schaltungen in einem unabhängigen Gehäuse untergebracht. Der elektronische Spurenzugriff für Schreiben und Lesen ermöglicht die Umschaltung von Spuren in weniger als 20 μs. Trommel und Rechner werden durch elektronische Geschwindigkeitsregelung synchronisiert.

Transistorisierter Stromstabilisator für einen Elektromagneten von J. C. S. Richards

Zusammenfassung des Beitrages auf Seite 22-23

Leistungstransistoren können für die Regelung grosser Stromstärken eingesetzt werden, jedoch ist die max. Nennspannung geringer als wünschenswert. Diese Spannungsbegrenzung kann durch Verwendung eines elektromechanischen Reglerhilfssystems überkommen werden. Ein Gerät dieser Art wird beschrieben, das bis zu 4 A bei 200 V abgibt. Unter normalen Zuständen bleibt der Strom während einer Stunde innerhalb ± 2 Teile in 10^5 konstant. Uber eine zehnstündige Periode ist die Stabilität ± 2 Teile in 10^4.

Elektronische Geräte in der Kernkraftwerk-Instrumentierung von M. W. Jervis

Zusammenfassung des Beitrages auf Seite 24-29

In den Regelungs- und Uberwachungssystemen für Kernreaktoren befinden sich auch elektronische Geräte, die von Thermoelementen und kernphysikalischen Nachweisgeräten gespeist werden. Mess- und Schutzgeräte werden unter Berücksichtigung von Schutzschaltungen und automatischer Datenaufzeichnung überprüft. Entwicklungsrichtungen für Stillegungsverstärker und Fernsehanlagen werden auch besprochen.

Messwerterfassung im Windkanal von E. Patterson

Zusammenfassung des Beitrages auf Seite 30-36

Der Windkanal ist von einem verhältnismässig ungenauen Hilfsmittel der Flugzeugkonstruktion zu einem unentbehrlichen Konstruktions- und Entwicklungswerkzeug geworden. Die Forderung für genauere Resultate und höhere Testgeschwindigkeiten führte zur Entwicklung von Kanälen, die hohe Kraftquellen und Konstruktionsmethoden des Präzisions-Maschinenbaues benötigen. Dadurch wurde der moderne Windkanal teuer und hat nur eine beschränkte Lebensdauer.

Diese Faktoren haben zusammen mit erhöhtem Vertrauen auf die Windkanalresultate und besserem Verständnis der Testmethoden zu Forderungen nach mehr Resultaten und grösserer Genauigkeit geführt.

Dieser Beitrag versucht, dem nicht auf diesem Gebiet Spezialisierten einen Uberblick über die Anforderungen zu geben, die innerhalb einer Dekade zur Entwicklung von Handaufzeichnung und Sichtanzeige zu vollautomatischen Schnellerfassungssystemen der heutigen, modernen Windkanäle geführt hat.

Durch die Raumknappheit für die Instrumentierung des Modells sind Schwierigkeiten aufgetreten. Die grundsätzlichen Eigenschaften der Messwertwandler werden diskutiert.

Aufbau eines Digitalrechnersystems aus einer Transistor-Grundschaltung von P. L. Cloot und G. E. Jackson

Zusammenfassung des Beitrages auf Seite 37-43

Es ist möglich, ein vollständiges Digitalrechnersystem durch Verdrahtung einer Anzahl identischer Grundschaltungen zusammenzustellen. Eine Methode verwendet eine Grundschaltung, die aus einem Transistor, einem Kondensator und drei Widerständen besteht. Ein Sonderzweckrechner mit einem eingebauten Programm für Binär-Dezimalumwandlung wurde gebaut, um die Anwendbarkeit der Methode vorzuführen.

Der Beitrag beschreibt die logische Konstruktion der Maschine, die entwickelte Schaltung und den mechanischen Aufbau. Es war möglich, durchweg gedruckte Schaltungen zu verwenden und den Rechner äusserst kompakt zu gestalten.

Analyse einer Transistor-Kascodenschaltung von J. R. James

Zusammenfassung des Beitrages auf Seite 44-48

Bei der Fertigung abgestimmter Verstärker ist es infolge der Streuung der Transistor-Parameter oft schwierig, mit festen Bauelementen die notwendige Neutralisation zu erreichen. Ein Kascodenverstärker benötigt keine Neutralisation, hat aber eine etwas geringere Verstärkung als zwei Stufen in Emitter-Schaltung. Der Beitrag untersucht, inwieweit die interne Gegenkopplung und die Verstärkung herabgesetzt werden.