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Commentary

TELEVISION has had, during the last month or so, an unusual amount of publicity. The Commercial Television Bill has passed through its committee stages in the House of Commons ; the greatest international link-up so far attempted has been carried out ; a demonstration of colour adapted to British 405 line standards has been given in London.

The committee stage of the Television Bill has been somewhat slow and tortuous with a final curtailment after only nine clauses had been debated. But, although this may interest us as citizens, our only concern as engineers, is in the technical problems involved, and it is already apparent that most manufacturers are ready for operation in the higher frequency bands. A number of receivers are on the market completely equipped for the additional frequency bands, while others are available constructed in such a way that an adapter unit or tuning unit can easily be fitted. This type of multi-band receiver will doubtless be the main theme of the Radio Show at Earls Court in September.

The international exchange of programmes during the past month has been on an unprecedented scale and has involved a number of notable engineering achievements. Some of the major problems, such as the conversion of the different scanning frequencies, had already been solved and tested on previous international relays of which the transmission of pictures of the Coronation ceremonies was previously the most ambitious. In the present exchange the programme and technical resources of eight countries have been pooled. Between Rome and Belfast, the most distant points in the circuit, the signals have to travel no less than 2 000 miles via radio and cable links. It is gratifying to see that a very considerable amount of British manufactured equipment is being used at numerous parts of the link. This is true of, from the engineering viewpoint, perhaps the most spectacular part of the network, the microwave link across the Alps. It runs from Chasseral in Northern Switzerland, 5 000ft high in the Jura range, through a relay station 60 miles away and 12 000ft up on the Jungfraujoch and on to the summit of Monte Generoso in Southern Switzerland. This link, which will remain as a permanent installation, will connect the German and Italian television systems and will form part of the Swiss national network. Altogether some 80 relay stations with convertor units for four different line frequencies will be used, feeding 46 transmitters covering a total population of around 90 millions. This is a meritorious achievement both from the organizational and technical viewpoints and should pave the way for a permanent network and interchange of programmes in the fairly near future—a thing which could, and should, bring about a better understanding between the participating nations.

The demonstration of colour television was given by Marconi's Wireless Telegraph Co. Ltd., and is briefly described elsewhere in this issue. From this demonstration it is apparent that on the present 3Mc/s bandwidth allocation it is, to say the least, difficult to provide a fully compatible picture ; the picture received on a monochrome receiver being degraded rather more than would probably be acceptable to the average viewer. With an increase of some 50 per cent in the bandwidth an excellent degree of compatibility can be achieved. For channels IV and V this would present no problem as the T.A.C. have already proposed a channel width of 7·5Mc/s. However, apart from the considerations of bandwidth and the BBC's pledge to give 97 per cent national coverage in monochrome before the introduction of colour, the major technical problem is still the production of a colour cathode-ray tube at a price that would be acceptable to the general public. This still seems to be a good way off both here and in America.

Looking at these various activities collectively stresses the great difficulty of wise long-term planning in a sphere where development is taking place so rapidly. As pointed out in this journal a few months ago, it was a courageous decision at the time to decide on the development of the 405 line standard in this country ; but now only a few years later we have, theoretically, the lowest standard of definition in Europe. Looked at from another angle it is, without doubt, unfortunate that an international or at least an inter-European agreement could not have been reached on standards of definition, etc., so that programmes could have been exchanged without the need for all the convertors now necessitated. At the end of the last war this may have been possible but now, with so many receivers in use, it would be a formidable task to alter the standards in any one country. Great attention should, however, be given to the problems involved in international exchange before colour television progresses too far and, if possible, before the use of Bands IV and V become widespread.

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HUMAN RELATIONS in Industry is the title of an interesting report that has been issued jointly by the Department of Scientific and Industrial Research and the Medical Research Council. This report outlines the first year's work of the committee set up in March 1953 to co-ordinate and sponsor research work on human relations in industry with particular reference to their influence on productivity. The bulk of the finance for these projects comes from American conditional aid funds. The main job during the year has been the building up of a research programme, and out of 78 projects considered, twelve have already been approved plus another two to be financed by U.K. funds as they do not satisfy the criteria for conditional aid. While all the projects are of as much interest to our industry as to any other, there are several which are of especial interest from the engineering viewpoint. Among these are, " factors facilitating and restricting the introduction of new production techniques and methods in industry," " industrial education, training and promotion," and " effects of the introduction of automatic control principles on social attitudes and group relations in industry." The electronics industry has an intimate connexion with the programme in that part of the research into the implications of technological change is being carried out in several Scottish firms newly engaged on the development of electronic equipments. From the electronic engineering point of view, probably the most important researches are those into the effects of the introduction of automatic control, for this not only affects the productivity of our industry but, to an ever-increasing extent, its products, as a considerable proportion of modern automatic control is governed by electronic means. The effectiveness of the finest of automatic control equipment can easily be diminished, and even brought to nought, by an unco-operative attitude on the part of the workpeople. The method of introducing these techniques well deserves some study and it may amply repay those engaged in this branch of the art to follow the researches that are now in progress.

LEO

(Lyons Electronic Office)

By J. M. Pinkerton*, M.A., Ph.D., and E. J. Kaye*, B.Sc.(Eng.), A.C.G.I.

As announced in the April issue of ELECTRONIC ENGINEERING, *a large electronic digital calculating machine has been designed and built at Cadby Hall by J. Lyons & Company, Ltd., for use on their own clerical work. The first two parts of this article outline the history and principal features of the installation, which is believed to be the first of its kind in regular use, and discuss operating, maintenance and fault-finding procedures. The last part gives details of a foolproof checking device using relays for verifying the punching of telegraph tape used for input of data. The nucleus of the installation is a calculator developed from the EDSAC at the Cambridge University Mathematical Laboratory with the addition of a larger store and multiple high speed input and output channels. An extensive built-in system of marginal checking has greatly improved the serviceability of the equipment; occasional random intermittent faults occur in the 5 000 thermionic valves used, but they do not prevent a large output of accurate work. Data perforating errors are completely eliminated by the use of the checking device, provided it is properly maintained.*

THIS article is the first of three dealing with the history and design of LEO (Lyons Electronic Office) and the experience gained in operating it so far. A large number of automatic digital calculators using electronic circuit elements have now been described, but they were all designed to do scientific and technical calculations. In the offices of many large firms thousands of repetitions of simple arithmetical procedures following a prescribed routine are carried out every day. Lyons believed that this work could be done by an electronic calculator and LEO is believed to be the first installation put into service to have been specially designed for commercial clerical work of this kind.

The special features required of a machine intended for office work will first be discussed. There is no need for its speed to be any greater than that of the scientific machine, if by speed we understand the number of elementary calculations, e.g. additions or subtractions, performed per second. Indeed it has been found in programming clerical tasks experimentally for the scientific computors that only a few per cent of the inherent calculating speed of these machines could be utilized[1]. The reason is simply that the number of figures to be entered or recorded is great in relation to the number of individual arithmetical operations to be carried out on these figures, and the calculator is kept waiting both for fresh data to become available, and for the results to be discharged. Proposals have sometimes been made to accelerate the input process by recording at manual speed on magnetic tape or wire and reading at high speed into the machine, and the output by recording the answers at very high speed in the same way, and then reproducing results at leisure by medium or slow speed printers[2]. This may involve a delay of 15 to 30 minutes before the results can be inspected; experience to date suggests that this is undesirable in the office, where mistakes must be put right at the earliest possible moment. The problem has, however, been solved in LEO in another way by providing several independent medium speed channels for data and for results and by so designing the circuits of the various channels that each of the mechanical reading or recording devices can operate independently up to its maximum rate if required.

Again the necessity for producing results to time demands a very high standard of dependability, coupled with an efficient system of rapidly discovering and rectifying faults if they do occur. Measures taken to achieve these ends in LEO will be described in Part 2 of this article.

Clerical programmes tend to be longer than mathematical programmes, so the store in LEO has been made twice the size of that of a typical mathematical machine such as the EDSAC. This size permits a very large variety of jobs to be undertaken, although an even larger capacity would be useful for numerical information in certain cases.

For operating the calculator on routine work the simplest controls are all that are required, start, halt and restart being in effect the only manual controls needed. When trying out new jobs, or looking for faults it is very convenient to be able to advance a single order at a time or at slow speed. It is very desirable also to be able to inspect the contents of any selected portion of the store and the other registers. The control and monitoring facilities built into LEO are described in a later part of this article.

The execution of clerical work to time must depend on the availability of the data in a form the machine can assimilate, with a very low incidence of wrong figures. Because of the great volume of data this imposes very rigorous requirements on the recording process. Any individual wrong digit fed to the machine may cause a hold-up lasting half an hour or more; if the number of digits read may be as many as a million per week, some cheap and foolproof method of checking data is obviously essential. Part 3 in this series describes in detail a checking device that has been developed for verifying the perforation of telegraph tape, which is used as one vehicle for feeding data into LEO.

Historical Development

The story of LEO commences in the Autumn of 1947 when Mr. T. R. Thompson, a senior member of Lyons clerical department, visited the U.S.A. with a colleague to study war-time developments in office management and organization. While in the U.S.A. they inquired about the early electronic calculators such as ENIAC and the several other models in course of construction at that time and were convinced by what they heard of the feasibility of adapting an electronic calculator for clerical work. They also discovered that development was in progress at the Mathematical Laboratory at Cambridge, England, and soon after their return paid a visit to Dr. M. V. Wilkes and Professor D. R. Hartree at Cambridge. As a result

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* *J. Lyons and Company Ltd.*

Fig. 1. General view of LEO

On the left the Hollerith card feed, card punch and printing unit with the power supply cubicles behind, in the centre the table carrying the two Ferranti Mark I photo-electric tape readers, on the right the racks carrying the electronic panels. The ultrasonic delay lines are in the low box on the extreme right. The dark strips in the flooring outline the runs of the underfloor ducting. Space has been allowed for duplication of the three items of Hollerith equipment.

of discussion with them it was envisaged that a modified version of the projected EDSAC which was then being built by Dr. Wilkes, might be used for clerical work. By June 1949 the EDSAC[3,4] was working and Lyons then decided to build a re-engineered copy of it themselves.

It was realized that this would be of limited value for clerical work as it stood, but it was hoped that it could be modified to become an efficient instrument for the purpose. It was thought that while this plan might not achieve the best possible design, no better one could be made before a calculator had been put to use on real clerical work. The nucleus of a technical group was engaged and engineering construction of the basic calculator started in September 1949 and was completed by the Spring of 1951; a very great deal of information and advice was freely given by Dr. Wilkes and his staff during this stage of the work.

Starting at the same time as the engineering work on the calculator itself, two other lines of development were initiated. First there was set up a section of experienced office systems planners to study the art of transferring office work to the calculator and writing the programmes for it. This group worked in the closest possible collaboration with the engineers and influenced their designs in countless ways. It would be out of place, however, to attempt here any description of their work, which embraces both the accumulated clerical experience of Lyons over several decades, and the newer art of organizing and programming calculations with automatic machines.

Secondly development of the input-output system was started. Means of keeping the machine fed with information fast enough to keep it busy and recording the results fast enough to prevent it being held-up by an accumulation of results, were visualized by Lyons. The simple fundamental ideas involved were capable of being implemented in various ways using any of the known media on which data can be recorded such as punched paper tape, magnetic tape or punched cards. The possibilities of magnetic tape were extensively explored in collaboration with a large electrical firm. After extensive work lasting more than three years, it was reluctantly decided that this particular system did not promise to give, within a reasonable length of time, the desired high standard of performance, and with it the vital operating experience, and so that equipment was dismantled.

In the meantime an alternative method of putting the original concept of the input-output scheme into practice was attempted. In this case standard mechanical units were chosen which had already proved their reliability in use over a period. Photo-electric tape readers were supplied by Ferranti Ltd[5], and a card reader, card punch and printing unit by the British Tabulating Machine Co., Ltd. The circuits for linking these mechanical units with the calculator and for using data and producing results, in forms adapted to each unit, were designed by Lyons.

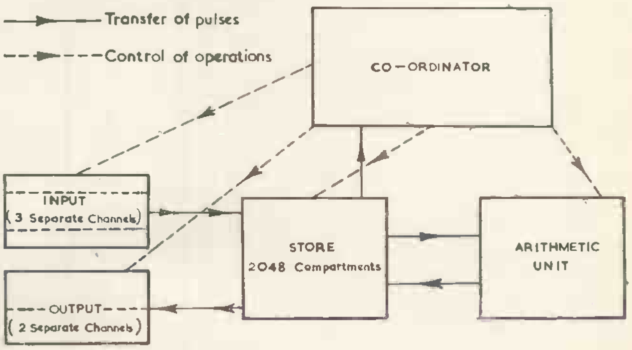
By the Autumn of 1953 the alternative system was clearly working well enough experimentally to warrant full scale operational trials on clerical work and it was decided to make it a permanent feature of the installation. This involved major alterations to the layout of the calculator room, including laying a new floor with concealed ducts carrying the numerous cables to the individual feeding and recording units. This work was completed on Christmas Eve 1953, by which date the evolution of LEO Mark 1 can be considered to have been substantially completed.

The following sections give general information about LEO; it will be apparent to many readers that some of the details are the same as for the EDSAC. However, since only a limited amount of information about the technical features of the EDSAC is readily available it is thought best to include these points here.

How LEO Operates

A highly simplified block schematic of LEO is shown in Fig. 2. The basic units comprise the store, which holds the instructions as well as the data for the problem, a number of input channels enabling instructions and data to be fed to the store, an arithmetic unit which carries out the calculations and operations required on the data in the store, and a number of output channels for recording the results. The automatic nature of the calculator demands that the instructions for any problem should be fed to the

Fig. 2. Diagram of basic units of LEO



store at the beginning and should then be carried out one after the other in the correct sequence. Control of the execution of the programme instructions is vested in the co-ordinator in the following way.

The control sequence is divided into two stages. During stage 1 the next order to be carried out is transferred from the store to a short register known as the Order Register. The compartment of the store from which this order is taken is specified by the number held in another short register called the Sequence Register. Stage 2 then commences, during which the order in the order register is decoded and carried out. When the order has been carried out, an end pulse is produced by the circuits concerned, e.g. the arithmetic circuits in the case of the "Add" order. This pulse causes unity to be added to the contents of the sequence register. It also initiates the next stage 1 so that the number in the sequence register having been increased by "1", the next order is selected from the following compartment of the store.

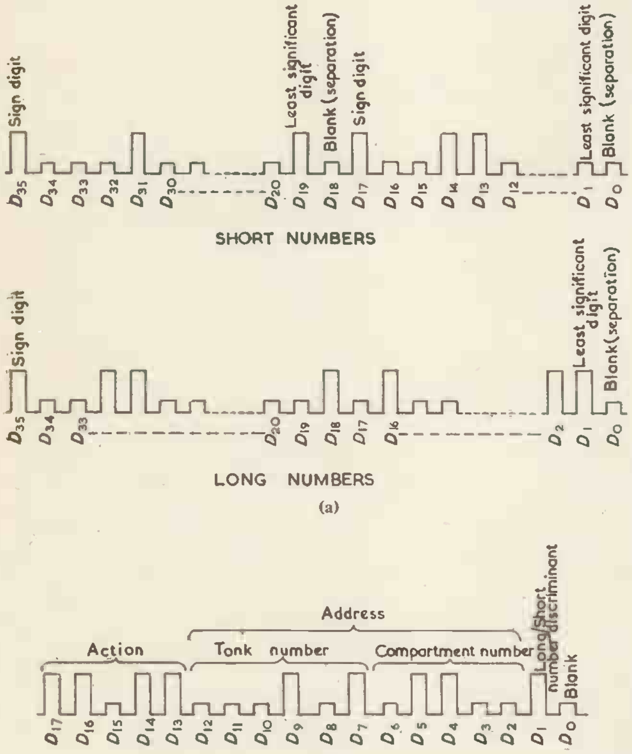


Fig. 3. Diagram showing form of numbers and orders

In this way the orders are carried out one after the other. If no other method of operation were possible, however, the machine would soon stop, having carried out all the orders in the store. In fact, orders permitting a change of sequence are provided and these orders are conditional. That is, the contents of the accumulator are used to decide whether the sequence is to be changed or not. The conditions for changing sequence may be chosen to be that the accumulator contents are positive, negative, zero or not-zero. If the condition is satisfied the contents of the order register are transferred into the sequence register, and consequently the next order to be carried out will be selected from the compartment of the store given by the address digits of the sequence changing order.

Numbers and instructions are held in the calculator in binary code. The construction of short and long numbers is shown in Fig. 3(a). The short number occupies a single compartment of the store and consists of 17 binary digits, the most significant of which is the sign digit. Long numbers occupy two adjacent compartments and comprise 35 binary digits. The digits are represented by pulses of 1μsec duration and repetition rate of 514kc/s. The pulse positions are numbers D_0 to D_{35}. The D_0 position is always blank in order to provide time for switching. In the case of short numbers, both D_{18} and D_0 positions are left blank.

A typical instruction is shown in Fig. 3(b). Like the short number it consists of 17 binary digits. There are two main classes of instruction, those which require access to the store during stage 2 and those which do not. The five most significant digits of the instruction represent the action required. Where access to the store is required the next eleven digits specify the address of the storage location. The least significant digit indicates whether the operand of the order is to occupy a single or double compartment of the store. For orders not requiring access to store the address digits can be used for other purposes appropriate to the particular order (e.g., for multiple left and right shifts one digit is used to indicate how many positions the number in the accumulator is to be shifted).

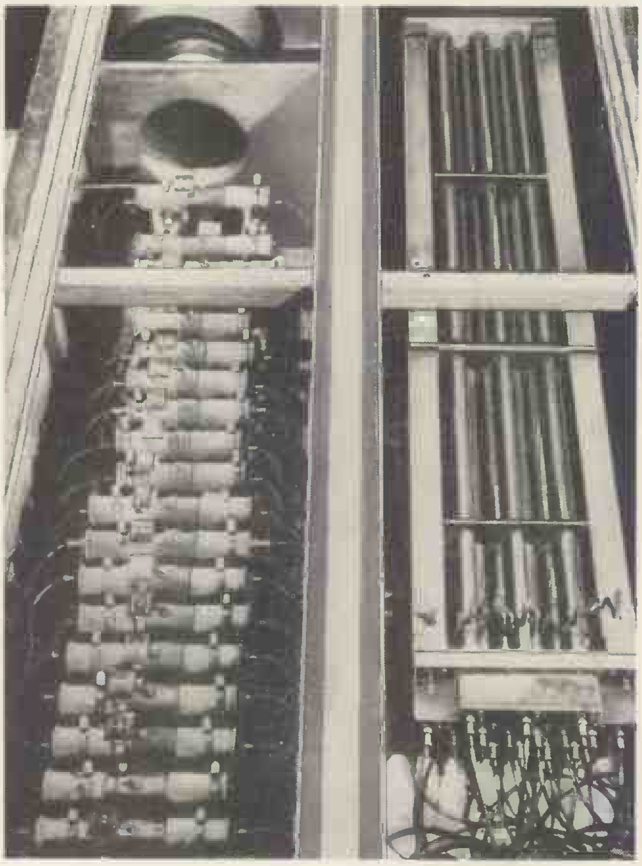


Fig. 4. Photograph of part of the interior of delay line vault with lids removed

On the right is a battery of 16 long delay lines showing the filler tubes and coaxial cables plugged into one of the matching unit assemblies; on the left are all the short delay lines each holding one short or long number. At the back is the fan used for circulating air round the interior of the box.

Engineering Features of Design

THE STORE

The store in LEO is closely similar to that of the EDSAC[3], but is of twice the size; it will therefore hold up to 2 048 orders or short numbers. It uses 64 mercury delay lines each having a capacity of 32 short numbers or orders assembled in five batteries of 16 lines each. There are thus a number of spare lines. The batteries are housed in a thermally insulated vault (Fig. 4), through which the air is kept circulating. One line is used in conjunction with an automatic frequency control circuit[6] to control the frequency of the system to 9 parts in 10^5. Since installing this system it has not been found necessary to employ temperature control, although the vault has been fitted with heaters and a thermostat which can be used if required.

A carrier frequency of 13·5Mc/s is amplitude modulated by 1μsec pulse trains in an electronic unit associated with each line. The signals are fed through a coaxial cable from the storage unit and applied via a matching unit to the X-cut transmitting crystal; an ultrasonic pulse travels through 64 inches of mercury to an identical receiving crystal. The total delay is 1·12msec.

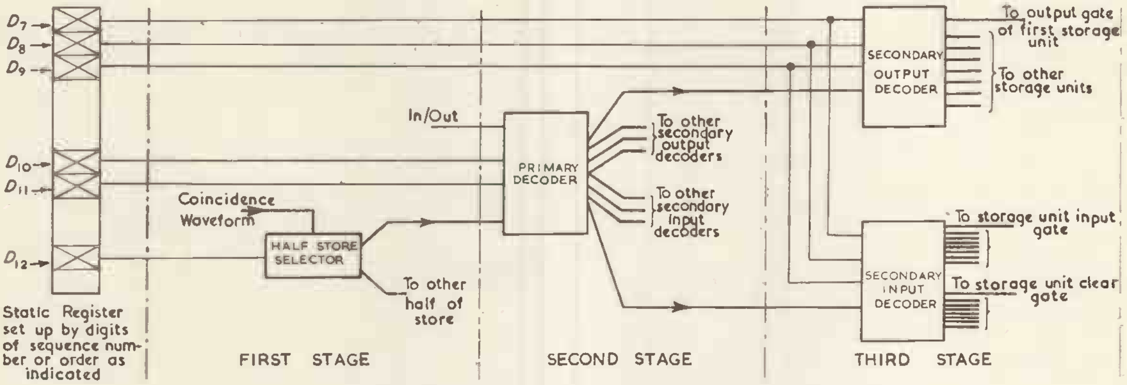


Fig. 5. Simplified diagram of decoding system

The heavy lines show the route taken by the coincidence waveform.

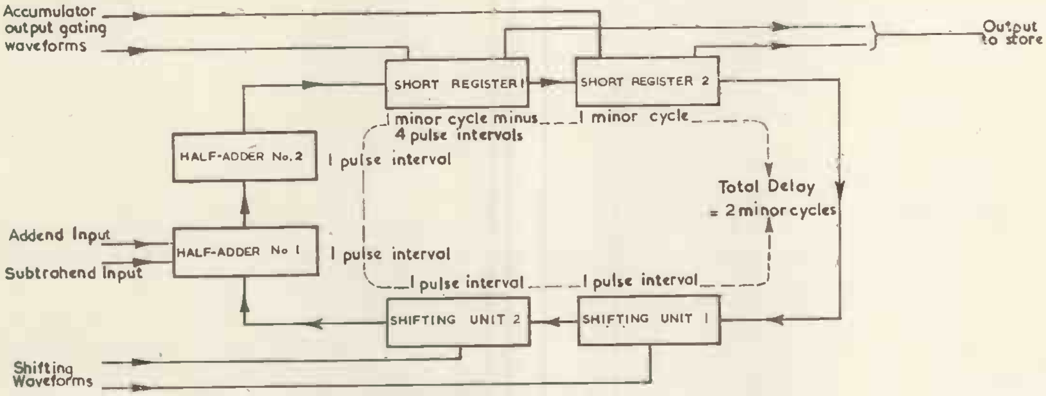


Fig. 6. The accumulator loop

Electrical pulses from the receiving crystal are fed, via another matching unit and coaxial cable back to the storage unit. Here they are amplified, detected, reshaped, gated with master clock pulses and sent back to the transmitting end of the line. This arrangement has been described by Wilkes and Renwick[3].

Pulses may be gated in and out of the circulation by input, output and clear gates. The input and output gating waveforms are timed by a coincidence circuit in the co-ordinator, and directed to the input or output gate of one of the 64 storage units by a decoding network, controlled by the address digits of the instruction. These digits are set up on the so-called static register and control the path taken by the coincidence waveform through the decoder. Decoding is carried out in three stages (Fig. 5); the first determines which half of the store is required, the second which group of eight units in that half of the store and whether input or output and the third to which unit of that group of eight the coincidence waveform should be routed. In stage 1 output from the store is always involved, in stage 2 the choice of input or output is governed by the instruction itself. "Add" and "Subtract" for example call for output, whereas "Transfer" (to store) obviously calls for input.

Where input is called for, the inverse of the routed coincidence waveform to a particular storage unit is generated in the final decoder and applied to the clear gate of this storage unit, thus ensuring that the old contents are always cleared when new information is being fed in.

In the filling of the delay batteries a novel wetting agent for making contact between the crystals and mercury has been successfully used in place of alcohol which was found to evaporate. This is a mixture of five parts of glycerine and two parts of water, and has resulted in a very stable and consistent performance from all the delay lines over a considerable period.

ARITHMETIC UNIT

The arithmetic unit consists of an accumulator, in which addition and shifting are carried out, a complementor, used for subtraction, and multiplicand and multiplier registers used not only in multiplication but also as special purpose registers for other instructions. The arithmetic processes used resemble in certain respects those of the familiar 3-register type of desk calculating machine. The fact that the binary system is used has the effect of making certain simplifications[7].

The accumulator (Fig. 6) is a loop two minor cycles in length, thus accommodating the complete results of a multiplication of two long numbers. It includes two "half adders," two short registers and two shifting units. A half-adder[8] is a combination of logical circuit elements adapted to add together binary digits from not more than two sources. Thus it will add "1" to any binary number but will not in general form the complete sum of two binary numbers bigger than one, since it cannot deal simultaneously with the "carry" digits. Two half-adders can, however, be readily combined to do the complete operation of adding two numbers. It is convenient to use two half adders rather than a whole adder as half adders can be used in conjunction with two other short registers in the calculator, where only unity has to be added to a binary number. Numbers always enter the accumulator loop via the two half-adders and are therefore automatically added to the previous contents. In subtraction, the subtrahend is routed through the complementor, and the resulting complement of the number is added into the accumulator. A number may be extracted during any minor cycle by opening the gate in the appropriate short register.

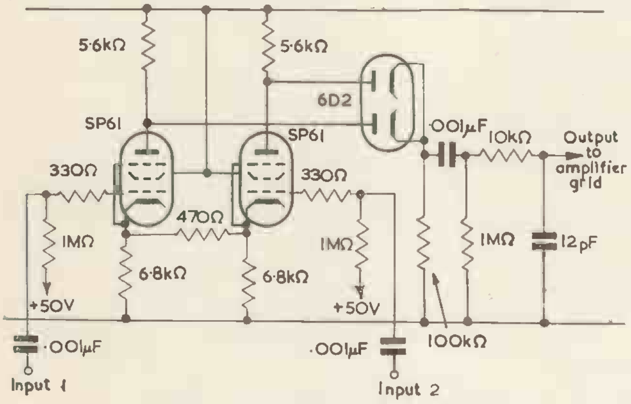


Fig. 7. Coincidence seeking circuit

The number in the accumulator may be shifted by one position to left or right by lengthening or shortening the loop by one pulse interval. Shifting waveforms lasting two minor cycles applied to the accumulator shifting units, cause the pulses either to pass through an additional delay of one pulse interval or to by-pass a delay of one pulse interval normally in circuit. For a shift of more than one place the shifting waveform lasts for $2n$ minor cycles, where n is the number of shifts.

In binary arithmetic, multiplication is essentially a series of additions and shifts. A separate order is required to transfer the multiplier to the multiplier register and multiplication is then carried out by inspecting the digits in the multiplier register one at a time and adding the contents of the multiplicand register to the accumulator whenever a "1" is present in the multiplier. The contents of the multiplicand register are shifted after each step of the process in a special unit, i.e., the multiplicand shifting unit.

The timed waveforms and control pulses required to operate the units described above are produced by 13 subsidiary control units, which unfortunately are too elaborate to describe in detail.

Circuits are provided for testing the contents of the accumulator to see if they are positive, negative or exactly zero, and emitting a sequence changing pulse in place of an end pulse if a sequence changing order of the appropriate type so demands.

THE CO-ORDINATOR

The logical arrangement of the co-ordinator closely resembles that of the EDSAC[9]; in LEO it consists of four control units and two coincidence units.

The coincidence units emit the timed waveform for selecting the required compartment or double compartment from the store. The correct timing of this waveform is obtained by comparing digits D_2 to D_6 inclusive of the sequence or order patterns with the corresponding digits from a "counter register" into which "1" is added regularly every half minor cycle. The pulse patterns in the positions D_2 to D_6 in this register therefore represent in turn the binary numbers 0 to 31, and may be thought of as enumerating the compartments as they circulate in the various long storage lines. The two pulse trains are applied simultaneously to the inputs of a coincidence seeking circuit, a balanced circuit with two inputs and one output (Fig. 7). If the inputs are identical, no output is produced and "coincidence" is established, i.e., the coincidence waveform is emitted by a special flip-flop. If they differ, one or more pulses are produced at the output which are used to prevent the setting of the coincidence waveform flip-flop. In stage 1 the sequence and counter register patterns are compared, and the coincidence waveform selects the compartment of the store from which the next order is to be taken. In stage 2, for those orders which require access to the store, coincidence is established between the counter register and the order register. During stage 2 the orders are decoded and recoded to form waveforms which operate gates in the arithmetic and input and output units. This arrangement resembles that of the EDSAC[9].

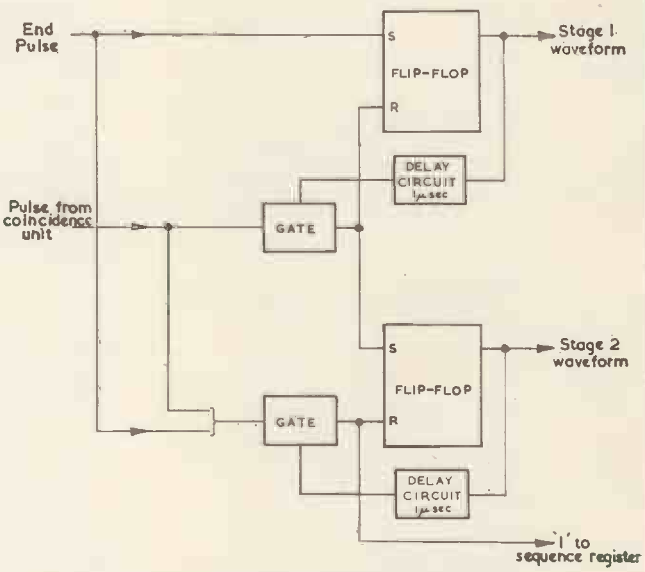


Fig. 8. Stage 1-2 control circuit simplified

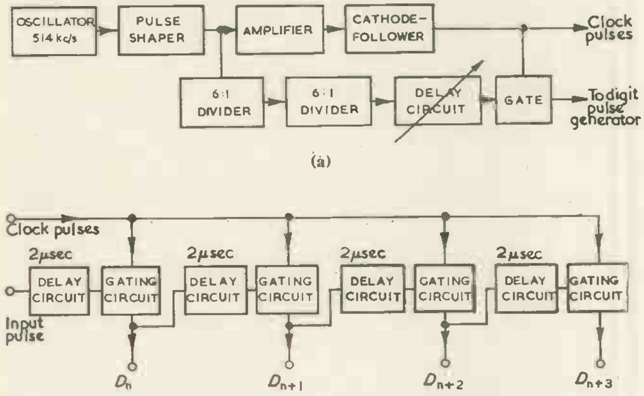
The principal control unit of the co-ordinator contains two flip-flops emitting the stage 1 and stage 2 waveforms. (A simplified block schematic is shown in Fig. 8.) The stage 1 flip-flop is set by the end pulse of the previous order. Its output is used to open a gate which permits the contents of the sequence register to be applied to the coincidence circuit. A pulse following the completion of the coincidence waveform resets the stage 1 flip-flop and sets the stage 2 flip-flop, whose output is used to open a gate to route the contents of the order register to the coincidence circuit. This flip-flop is reset either by a pulse from the coincidence unit following the completion of the coincidence waveform (in the case where access to the store is required by the order) or by the end pulse of the order.

Another co-ordinator control unit controls the addition of "1" to the sequence register, and emits the waveform which permits the transfer of the contents of the order register to sequence register in the case of a sequence changing order. A further unit is concerned with releasing the sequence number or order to the static registers at the commencement of stage 1 and stage 2 respectively.

INPUT AND OUTPUT

Originally the input and output equipment of LEO was very similar to that of the EDSAC, namely, a low speed mechanical reader for input from punched paper tapes at 10 rows of holes per second, and a teleprinter, modified for parallel five-wire operation and printing 7 characters per second. This equipment is now obsolescent. The present system provides three independent high speed input channels from two Ferranti photo-electric tape readers and a Hollerith card feed, and two independent high speed output channels operating a Hollerith card punch and printing mechanism of a Hollerith tabulator. It is a special feature of the circuit design that all these devices can operate simultaneously with one another and with calculation if necessary.

Data can be read from the punched tapes at 130 rows of holes per second, a row of holes representing one decimal digit. Combinations are reserved to indicate the end of a number, the end of a block of numbers and minus sign. Blank tape and "all holes" are ignored by the input circuits; characters may thus be "erased" by overpunching with the "all holes" combination during punching or checking.



(a)

(b)

Fig. 9. Clock pulse generator and digit pulse generator

Punched cards are used for reading in the programme of instructions and data brought forward. The card feed reads at the rate of 200 cards per minute, each carrying up to twelve binary numbers of 35 digits. Although numbers are usually punched on cards in the binary form they may also be punched in the Hollerith positional code if desired.

The Hollerith printing mechanism has 80 print bars arranged in two fields of 40 and is fitted with slugs corresponding to the figures from 0 to 11. Signals from the calculator are set up on 35 relays which in turn set up any selected 35 print bars during one tabulator cycle. On receipt of a signal from the calculator all 35 lines can be switched by relays to an alternative selection of print bars, so that printing can take place, for example, either on the left-hand or right-hand side of the paper. Thus if no line feed signal is sent between the changeover, up to 70 columns can be printed on each line. Printing takes place at the rate of up to 100 lines per minute.

The card punch operates in a similar manner to the tabulator, the signals from the calculator being set up on another set of 35 relays which operate the punch magnets. These relays are grouped together with the tabulator relays in a dust-tight box and are mounted on small plug-in panels for ease of replacement and maintenance. Cards can be punched at the rate of 100 cards per minute.

PULSE GENERATOR

All pulses are formed from a single source of master clock pulses in the clock pulse generator unit (Fig. 9(a)). The sine wave output of a 514kc/s Franklin oscillator is applied to a two stage squaring circuit to form the clock pulses. As explained previously the frequency is automatically controlled and the phase relation between the delayed and undelayed pulses in the store is displayed on a special frequency monitor oscilloscope mounted on the monitoring control desk. A single triangulated pulse is shown, the apex of the triangle being brightened symmetrically when phasing is correct. Any drift in either direction causes an asymmetry in the pattern.

The input pulse to the digit pulse generators is formed by a 36-way divider, composed of two 6-way phantastron dividers in series, which employ a cathode-follower in the anode-grid feedback loop to diminish recovery time, thus giving increased stability. In order to overcome the time delay in the divider circuits, the output of the second divider is applied to an adjustable delay circuit before gating out one of the clock pulses. This pulse is applied to the first of a series of digit pulse generators. The block schematic of one of these is shown in Fig. 9(b). Each pulse in turn is delayed by 2μsec (one pulse interval) and gates out the next clock pulse.

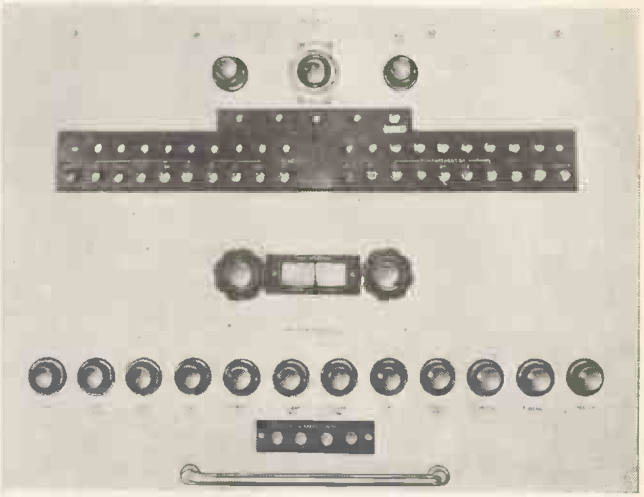


Fig. 10. Close-up of operating controls

At the top are the buttons for inserting pulse patterns by hand, in the centre the two selector switches for choosing the storage line to be inspected on an oscilloscope, and at the bottom the push buttons mentioned in the text.

The clock pulses which are used extensively as timing pulses throughout the whole machine, and certain digit pulses which are widely used as control pulses, are distributed to other units of the calculator from a distributing unit consisting of a number of cathode-followers.

OPERATING CONTROLS AND MONITORING

By means of push-buttons mounted on a central control panel (Fig. 10) it is possible to START and HALT the calculator. The START button causes a fixed programme of initial or starting instructions to be read in from a selector switch[10]. These orders then allow the programme tape to be read. Additional START buttons are provided for use when taking in programmes via the Hollerith card feed or Ferranti tape reader. In these cases special starting instructions are located on the first few cards or at the beginning of the tape. After being halted the calculator may be made to continue one order at a time by means of a button marked SINGLE STEP or at one of three intermediate speeds by three SLOW SPEED buttons. Normal operation can be resumed by pressing a RESTART button. The store, sequence register and accumulator can be cleared by three further buttons. Pressing the REPETITION button causes the calculator to repeat one order indefinitely and pressing REPETITION STEP causes it to repeat the order in the next storage location. These are chiefly useful for fault finding. By means of a further row of buttons a number or order may be inserted manually into any compartment of the store.

The contents of the store may be monitored on an oscilloscope which displays on a raster the contents of one of the long lines of the store[11]. A multi-way switch enables the contents of any of the 64 storage lines to be inspected. The contents of the accumulator, the counter and the slow speed input channel are depicted on separate cathode-ray tubes. The contents of the multiplicand and multiplier registers are displayed on one double-beam tube, and of the sequence and order registers on another.

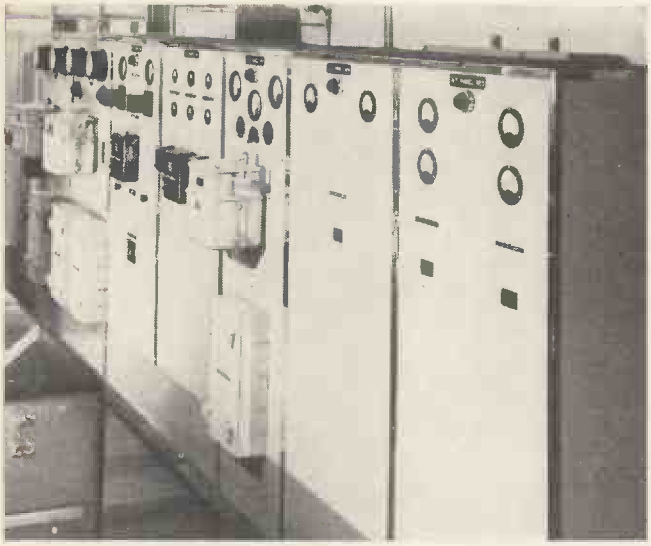


Fig. 11. General view of the power supply cubicles

The various rectifier sets are mounted in separate cubicles; the voltage controlled motor alternator set is in another room in the basement. All incoming feeders are filtered to remove mainsborne interference, and room services are kept separate from calculator power wiring.

POWER SUPPLY

The total power consumption of LEO is of the order of 30kW. The heaters are supplied from an 18kVA regulating transformer which can raise and lower the voltage slowly over a period of two minutes, either automatically or under manual control.

Three-phase rectifier sets provide +250V D.C., and −200V D.C., supplies (Fig. 11). There are two +250V supplies, the first a 30A supply for general H.T. requirements and the second a 2½A supply for special purposes (H.T. for flip-flops and amplifiers) where better smoothing is called for. Similarly there are two −200V supplies, one of 7A and the other 1·5A. Auxiliary −50V D.C. and +110V D.C. rectifier sets feed relay circuits and punched card equipment respectively.

The power for the H.T. rectifiers is derived from a 12kW alternator driven by a 20 h.p. induction motor. Two generators, with changeover facilities permit servicing and provide standby facilities.

An electronically controlled automatic voltage regulator, controlled from one of the outputs of the rectifier set, maintains the output voltage stable to within ±½ per cent.

MECHANICAL FEATURES

The electronic part of LEO consists of 228 easily replaceable units mounted in fixed racks. The units slide into the rack between guides, and power is connected from a terminal block on the rack to an 8-pin plug on the side of the unit. The racks can hold up to twelve units and carry power wiring and inter-unit pulse wiring. This pulse wiring terminates on tag strips fixed to the rack framework. Pulse connexions between the tag strip and the unit are made by flying leads, carrying spade terminals which can be connected to the screw terminals on the tag strip. The pulse leads can be seen in Fig. 12 supported on a gantry on the valve side of the chassis. Thus any unit can be replaced in a few minutes by a spare. The layout has been arranged so that the components are readily accessible. The chassis can accommodate up to 28 valves, but generally only 20-25 valve positions are used. Current monitoring points are provided on a central gantry. Each chassis carries H.T. and L.T. fuses and one or two heater transformers for up to 15A.

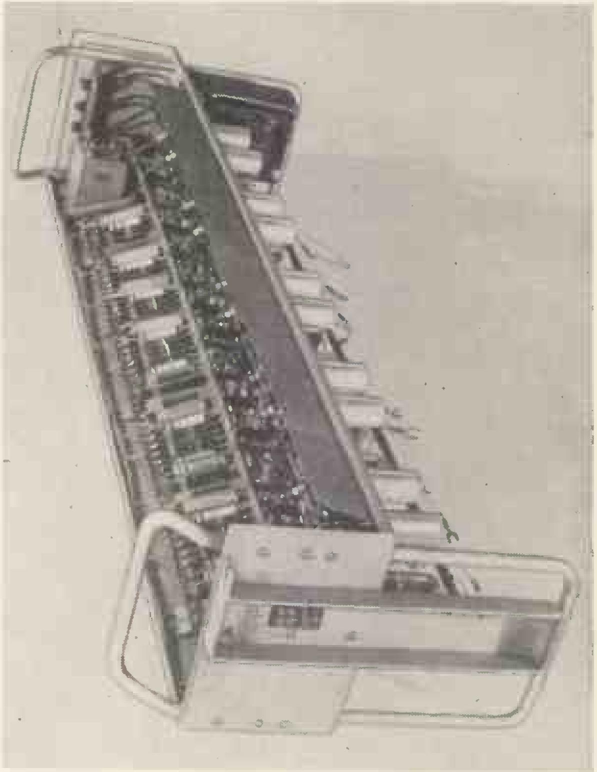


Fig. 12. A typical unit showing component mounting, valves, beater transformer, pulse leads ending in spade tags and power supply plug

Long runners at either end guide the unit into the rack and carry its weight when in position.

The racks are nine feet high and are fitted at the top and bottom with ventilation ducting. Each is fitted with a set of removable covers so that the units are totally enclosed. The intake fan on the ventilation system forces cool filtered air past the valves through a grille in the lower duct, and the warm air is extracted through the top duct by an extract fan. A false floor has been constructed around the four rows of racks to a height of 1ft 6in above ground level so as to cover the lower ventilation ducts and conduit runs and bring the top unit in the rack within reach.

The calculator is connected to the input-output equipment by many multi-way cables which run in shallow concealed ducts under the floor.

Preliminary Conclusions

The installation of LEO Mark I has now been in use for long enough to allow tentative conclusions as to its utility to be drawn, and give an indication of the improvements desirable in future models. Conclusions based on our operating experience will be given at the end of Part 2. Here we shall deal with the engineering aspects of our experience.

The general physical construction of the machine should be such as to keep it and the operators as cool as possible, and give easy access to all parts. It should be possible to dismantle it into easily portable sections and re-erect it again on another site without extensive building alterations, e.g., to bury wires under the floor or install air ducts for ventilation. It will be evident that LEO Mark I does not fully satisfy this requirement.

To simplify maintenance all parts should be easily replaceable on a plug-in system. The tag connexions used in LEO Mark I have some disadvantages; it takes rather too long to change a unit and faults have sometimes occurred through tags working loose or being left undone. Spares should certainly be provided for all repeated units such as storage units, but if they are to be provided for others it is vital that they should be completely mechanically and electrically interchangeable; otherwise they are worse than useless.

In order to maintain the installation in service with the least possible interruption complete duplication of all mechanical devices such as tape and card readers, punches, printers and generators is considered essential. When failures occur in equipment of this type there is often considerable delay before a spare part can be obtained, or the mechanism dismantled to fit it and reassembled and tested. A rapid changeover to the standby should therefore be possible, by the use of switches or plugs and sockets.

The tolerances and power rating of all components should be carefully specified. Ideally the circuit would be tested with the most unfavourable combinations of limiting values. A suitable factor should be allowed for the inevitable falling off in valve emission, and both valves and resistors should be used at a fraction of their maker's ratings. We have in fact derated resistors to 50 per cent and valve dissipations to 80 per cent of the normal figures. We have also tried to ensure that valves had available twice the necessary current emission before the onset of grid current, to ensure that a valve with only 50 per cent of the new emission would still function in the circuit.

Perhaps the most important conclusion is that the simpler the conception and the design of any item of calculating equipment, the better it will be understood by the operators who use it and the engineers who maintain it. A calculating system can be and should be made from a relatively small number of simple circuit elements whose design should be carefully studied and then fixed. If adjustable controls have to be provided they should be as tolerant of wrong adjustment as possible, and set up in accordance with a prescribed set of instructions.

Acknowledgments

It is obvious that a project of this size could not have been carried through without the enthusiastic co-operation of many individuals, and the authors wish to acknowledge the help given to the project by all their colleagues and those in the many other companies and organizations who took part. In particular they wish to record their indebtedness to Mr. T. R. Thompson for his wise direction and unfailing encouragement during the whole course of this work. Thanks are also due to J. Lyons & Company Ltd., for permission to publish these articles.

(*To be continued*)

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A New Impedance Matching Arrangement*

The problem of coupling two lines or networks of differing impedances so that reflexions at the coupling are avoided is a common one in the electronic art and usually presents no difficulties. An aspect of the problem that is not frequently met and is not so easily solved is that in which there is to be no change of signal level across the coupling and where signal transfer is to occur in both directions. Clearly it is not possible to use purely passive couplings since these will result in a change in the intensity of the signal; and in general with valve couplings the signal is only transmitted in one direction.

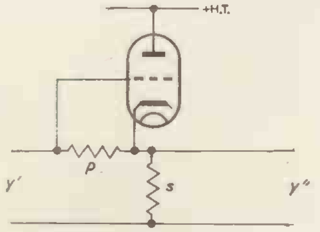

Fig. 1. The circuit described

It has been found that the problem may be solved by a form of cathode-follower circuit provided that the circuit parameters are appropriately chosen. The connexions of the arrangement are shown in Fig. 1. With this arrangement if y' and y'' represent the respective characteristic impedances of the lines or circuits to be coupled, as indicated in the diagram, y'' being larger than y', and if p and s are the conductances of the resistors connected between grid and cathode and between cathode and ground, it may be shown that the conditions for no reflexion are:

$$y'y'' = ps$$

and

$$p = \frac{\alpha g}{2(1-\alpha)} + \sqrt{\left(\frac{\alpha^2 g^2}{4(1-\alpha)^2} + \frac{y'^2}{1-\alpha}\right)}$$

where

$$\alpha = y'/y''$$

and where g is the mutual conductance of the valve. In these circumstances and if g is large compared with y'' then the change in signal intensity in transfer through the circuit is small for both directions of transmission and the arrangement provides a satisfactory practical solution of the problem.

If the value of g/y'' is sufficiently high the required value of s approaches zero and the resistor connected between cathode and ground may accordingly be omitted. It may also be shown that if g is not too small the resistor connected between cathode and ground may be transferred so as to lie in shunt with the admittance y', suitable adjustments being made in the values of p and s.

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* *A communication from E.M.I. Ltd.*

Recording Television and Sound Signals on Magnetic Tape[*]

A system for recording and reproducing television signals by means of magnetic tape is discribed . This system is applicable to both colour and monochrome pictures. For monochrome pictures two tracks on a ¼in tape are used while for colour, five tracks on a ½in tape are used. The tape speed of 30ft/sec is maintained constant by an electronic servomechanism. The recorded and reproduced frequency band is over 3Mc/s.

THE system to be described will record and reproduce both monochrome and colour television pictures, and was demonstrated at the RCA Laboratories at Princeton, New Jersey, in December 1953.

Tape

The tape used in this development consists of a cellulose acetate base coated with a red iron oxide. The acetate base has a thickness of ·0017in and has an iron oxide coating of about ·0004in thickness. The width of the tape used for colour television reproduction is ½in—equivalent to 12·7mm; for monochrome only ¼in width tape is required, so that two parallel programmes may be recorded on a ½in tape. The coercive force of the tape used in the demonstration was 250 oersteds, with residual magnetization of 770 gauss.

Tape Transport Mechanism

The tape transport mechanism has been designed to keep any sudden speed changes to a minimum in order to eliminate jitter in the pictures. The order of constancy required can be appreciated when it is realized that a sudden speed change of one part in a million will put a jog of about 5mm (1/5in) in the picture on a 30cm (12in) kinescope. Furthermore, any slow drifts in speed have to be limited to considerably less than one picture element per scanning line.

The recording and reproducing equipment.

A schematic diagram of the tape transport system is shown in Fig. 1. The basic speed of the tape feed is determined by a capstan driven at approximately 30 revolutions per second, and having a circumference of 30cm or 1ft. Sudden changes in capstan speed are filtered out by a flywheel. The bearings on this flywheel assembly require to be very smooth and perfectly aligned, and both static and dynamic balance of all parts must be made with high precision. Even with accurate tape speed established by the capstan, tension in the tape supply and take-up must be held very exact or momentary changes in tape position will be introduced by stretch in the tape. Constant tension on the supply reel is maintained by driving a generator from the supply reel shaft and using feedback to control the generator load to a constant tension load. The control must hold over a speed range of from 30rev/min with a full reel to over 600rev/min when the reel is empty. The take-up reel is motor driven and has its feedback circuit arranged so that a constant tension on pull-out is obtained. Both supply and take-up tensions are held constant whether the reels are empty or full. In the diagram it will be seen that there are four fixed idler pulleys to guide the tape from the supply reel over the heads and capstan, and one to the take-up reel. A rubber surfaced idler is sprung against the capstan to act as a depressor in holding the tape on the capstan for speed determination.

The tape reels are an important part of the transport mechanism; they must not have excessive inertia if a practical starting time is to be achieved, and must be accurately balanced to enable full advantage to be taken of the constant tension drives. The playing time of a full reel is dependent on the diameter of the reel, the thickness of the tape, and its running speed. The present reels are 17in in diameter, and have a hub of 8in diameter. With a tape thickness of ·0021in a full reel contains approximately 7 000ft of tape. This length of ½in tape weighs approximately 4·3lb and will play for about four minutes at 30ft/sec, equivalent to about 20 miles per hour. A 15 minute period is normally considered desirable for television programming, and an objective of current research is to achieve this playing time with reels 19in in diameter.

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[*] *This article is based on a lecture given by C. G. Mayer, RCA European Technical Representative, at the Conference on Sound Recording, Paris, 1954. The engineers responsible for this development were Dr. H. F. Olson, W. D. Houghton, A. R. Morgan, J. Zenel, M. Artyt, J. G. Woodward and J. T. Fischer, all of RCA Laboratories Division, Princeton, U.S.A.*

Recording and Reproducing Heads

The enormity of the problem of recording video signals on magnetic tape will be apparent to anyone acquainted with sound recording on tape. Simple calculation shows that a frequency of 4Mc/s recorded on a tape travelling at 30ft per second, results in a wavelength on the tape of less than 1/10 000in. Obviously the effective gap length of the heads must be considerably less than the wavelength to be recorded, and there is a very real problem in producing heads having the exceedingly small gap dimensions needed for this purpose. Moreover, head gaps must be very carefully aligned in order to permit tapes to be recorded on one set of heads and reproduced on another without loss of overall performance.

When one considers that some 16 to 18 octaves of frequency range must be covered, it will be realized that to obtain the desired electrical and magnetic characteristics of the heads is indeed a formidable problem. The magnetic material must be such that a high permeability is maintained over the whole frequency range; likewise the electrical impedance of the coil which surrounds the magnetic path of the head must remain reasonably constant, and be entirely free from resonances, especially in the higher frequency range. The physical configuration of the heads must also satisfy a number of conditions. Firstly, the assembled head must be stable with time against variations due to temperature and humidity. Secondly, the head must have good wear resistance to the abrasive effect of the passage of tape. Thirdly, the head must be physically small to allow of grouping for multiple channel working such as is used in recording and reproducing of colour pictures. There are also several other mechanical requirements to be met involving the mounting of the heads, shielding of the electrical connexions, head position adjustments and so on. Notwithstanding these difficulties, it has been possible to develop a set of heads that appear to give a reasonable solution to all the problems.

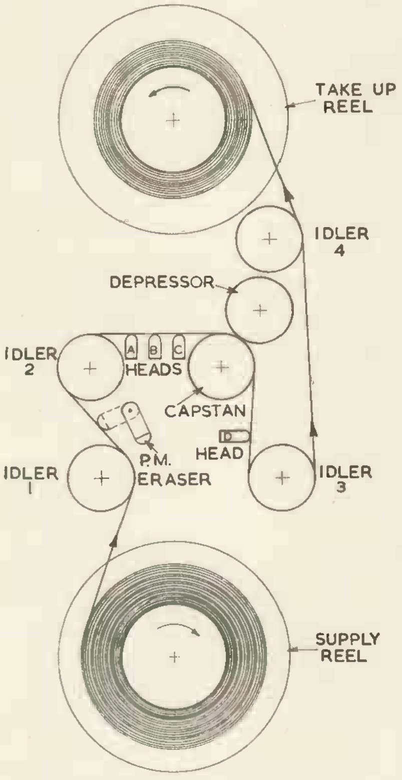


Fig. 1. Arrangement of the tape transport mechanism

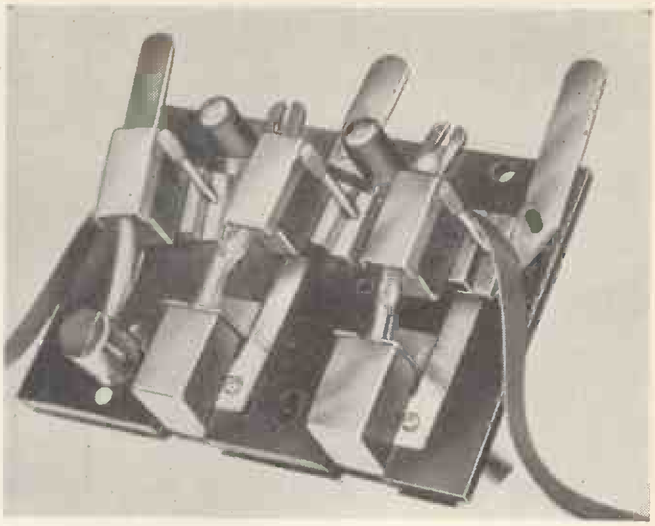


Fig. 2. The sound and video recording and reproducing heads

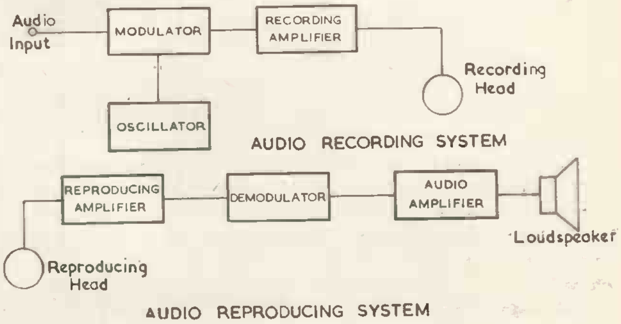
Fig. 2 is a photograph showing the present arrangement of the head assembly for recording colour video signals on tape. The left-hand head is for recording sound. The central head is for video recording and is made up of four elemental heads to provide four channels. The right-hand head is for video reproducing and also contains four elemental heads. For the sake of expediency, the sound reproducing head is placed at a point following the tape drive capstan. In a final design both video and sound heads would probably be incorporated in a single unit.

Tests have established that the frequency response of the heads is uniform with a reasonable signal-to-noise ratio up to approximately 3·5Mc/s, and that the impedance of the elemental head is free of resonances to the highest frequency. The wear properties of the heads, although not completely studied, have proved satisfactory.

Audio Recording and Reproducing System

In conventional magnetic tape recording systems used for audio frequency work, the tape usually moves past the heads at a speed in the neighbourhood of 15in per second. With such systems careful design and adjustments are necessary to enable frequencies, say above 10 000c/s, to be handled satisfactorily, because of the extremely short wavelength of these higher audio frequencies. In video recording where tape speed is nearly 25 times as great, the situation with respect to recording audio frequencies is reversed. It is now more difficult to record and reproduce the lower audio frequencies at useful levels above noise, because of the extremely long wavelengths of the lower frequencies. For example, a 100c/s tone recorded by the video tape system has a wavelength of nearly 4in, while the same tone recorded on a conventional audio tape

Fig. 3. The audio recording and reproducing system



recorder has a wavelength of only 1/10in or less. A consideration of this problem, together with the necessity for complete absence of crosstalk between the audio track and the adjacent video tracks, has led to the use of a modulated carrier method of recording the audio signals in the present system.

A block diagram of the audio system is shown in Fig. 3. It will be seen that the signal recorded on the tape is a carrier which is amplitude modulated by the audio signal, and which requires demodulation for reproduction. The recording and reproducing amplifiers both employ tuned circuits, and have a pass-band centred at the carrier frequency, which is 150kc/s. The audio heads are essentially similar to those used for the video channels.

Video Recording and Reproducing System for Colour Television Signals

The block diagram of Fig. 4 shows the basic components required for recording a composite colour video signal such as may be obtained from a microwave link or from the video output of a television receiver. The composite video signal is fed to a colour demodulator which produces, as separate outputs, the three colour video signals (red, green and blue) and also the associated synchronizing information. The four signals thus obtained pass through recording amplifier units to their respective recording heads. The sound or audio signal modulates a carrier as previously described, and passes through a fifth recording amplifier to the audio recording head.

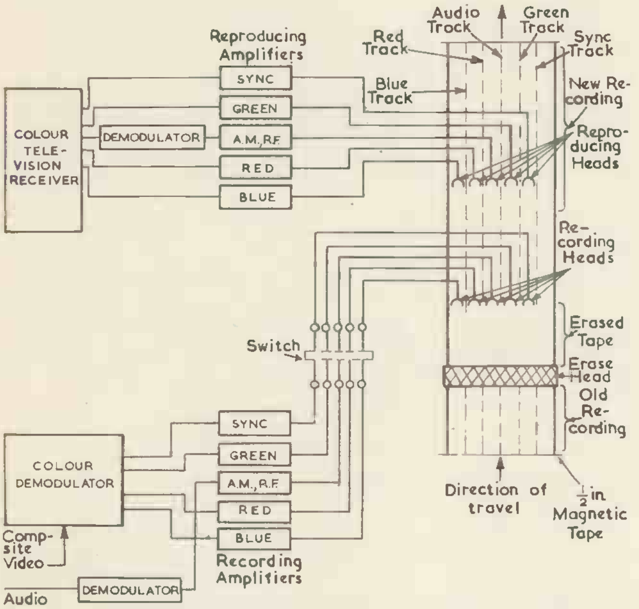


Fig. 4. Recording and reproducing colour video signals and audio signals

The recording amplifier units are designed to provide both phase and frequency compensation in order to obtain the desired flux patterns for recording, and in this way the signals are recorded on five separate tracks on the magnetic tape.

As indicated in the diagram, the tape travels in an upward direction, and it will be seen that an erase head is provided to remove all previous information from the tape, and to condition the tape for recording.

The erase head consists of a specially designed permanent magnet which subjects the individual elements of the tape to reversing magnetic fields and leaves the tape in a fixed magnetic condition. This head is physically removed from the tape path when the erasing operation is not desired.

The tape then travels past the recording heads where new information is stored on the tape in the form of a flux pattern corresponding to the signal. The energized tape next passes the five reproducing heads in which electrical signals are generated corresponding to the flux patterns stored on the tape. These signals can be used for reproducing or monitoring purposes. Since the reproducing heads do not change the flux pattern, any desired number of reproductions may be obtained merely by running the tape through the machine with the erase head removed and the recording heads de-energized.

Each of the recording amplifiers contains a special biasing unit which supplies an appropriate signal to the tape so that the full magnetic amplitude range may be used for the video signal. That is, the "black" level of the video wave is made to occupy a particular value on the magnetic characteristic of the tape. The "white" signal components then vary the magnetic change relative to this value. The signals derived from the magnetic tape are essentially in the form of the output signals from a television colour camera. In order to use these signals to modulate a television transmitter, it is necessary to combine them to form the proper composite signal for transmission, just as is done with camera signals at a studio.

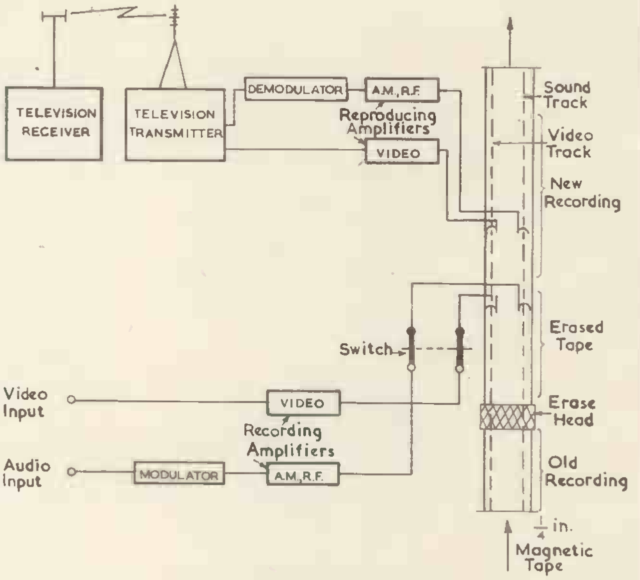


Fig. 5. The arrangement for monochrome recording and reproducing

One difference exists in the use of magnetic tape output, for here the synchronizing signals are related to the information recorded on the tape.

Video Recording and Reproducing System for Monochrome Television Signals

When black and white television signals are to be recorded only two tracks on a ¼in tape are required. As indicated in Fig. 5 one track is used to carry the complete video signal and the other is used for the associated audio signal. The signals are treated in a similar way to those already described for colour, but now the output from the reproducing amplifier is the complete video signal which, together with the demodulated audio signal, may be applied to a television transmitter, and the transmission received by conventional black-and-white television receivers.

Comparison of Photographic Film and Magnetic Tape Systems for Recording and Reproducing Television Programmes

Conventional kinescope recording is illustrated in Fig. 6.

Here the television picture is displayed on a kinescope and a special motion picture camera is used to photograph the kinescope image and record the programme sound. The film is then chemically processed, and usually a print made before the pictures can be reproduced. Reproduction requires another installation, which may be a continuous motion flying-spot film scanner or a motion picture projector with a special television camera. The process is time consuming, and the quality limited since the pictures must encounter all the hazards of both the television system and the photographic process.

Fig. 7 shows a diagram of the magnetic tape recording method which has been described. The tape requires no processing. The programme may be reproduced from the tape by using the same unit which recorded it. As in motion picture practice, when a lengthy programme is to be recorded and reproduced, a number of tape transport units with suitable switching may be used.

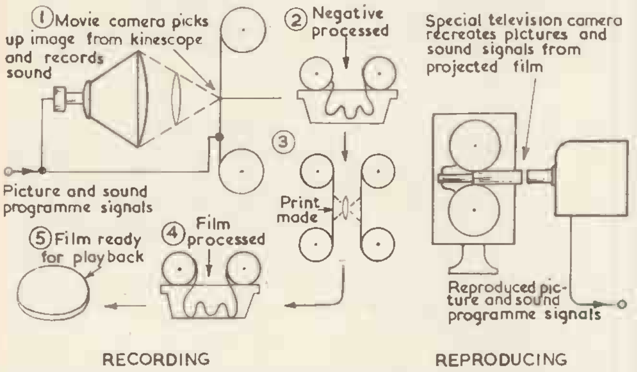


Fig. 6. The system used for recording and reproducing a television programme by means of photographic film

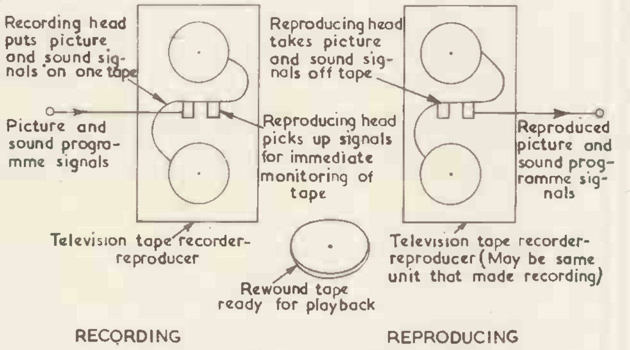


Fig. 7. The system for recording and reproducing a television programme by means of magnetic tape

Comparative estimates of operating costs (which include payroll, cost of tape or film and amortization of equipment) are highly favourable to tape methods. Although magnetic tape today costs more per minute of programme time than 35mm colour film, the fact that tape needs no processing before playback compensates for the expense of raw tape, and it is clear that the magnetic tape method offers substantial economies in both time and cost.

Recording black-and-white programmes on film is estimated to be at least five times as costly as it would be on $\frac{1}{4}$ in. magnetic tape, assuming that the tape would be re-used many times. This is possible since it is easy for the programme to be electronically "wiped off."

Even greater economies are estimated for making the original tape recording of colour television programmes, which under normal operating circumstances could be handled for only five per cent of the cost entailed in colour film recording.

Demonstration of Recording and Reproducing Television Signals by Means of Magnetic Tape

In the colour demonstrations at Princeton all of the programme material originated in an N.B.C. studio in New York. A similar demonstration was given in black and white. In the case of the colour demonstrations, the picture was picked up by means of an RCA colour television camera and the output fed to standard studio type video equipment to produce a composite video colour signal which was transmitted by microwave radio relay to the RCA laboratories. The sound channel used standard studio type audio equipment and the audio signal was carried by telephone line to Princeton. At the laboratories the composite colour video signal was demodulated to give the red, blue and green video signals, and the synchronizing signal, required for the input of the recording system. In reproducing the signals from the tape, the outputs of the reproducing heads were amplified and fed to a switching arrangement by means of which the direct signals could be compared side by side with those reproduced from the tape.

Two colour television receivers, each with an RCA tri-colour kinescope, were connected so that both receivers could be switched to the direct signals or both to the reproduced signals, or one receiver to the direct signal and one to the reproduced signal. As a part of the demonstration a live programme was relayed to both receivers, and during the performance one receiver was switched to the signal reproduced from the magnetic tape. The time delay introduced by the tape is the time taken to travel from the recording to the reproducing head. Since this takes only four milliseconds, the delay was imperceptible and the test demonstrated the fidelity of the magnetic system.

The status of research and engineering problems, as they relate to video tape recording, can be summarized by quoting the words of Dr. Engstrom, Executive Vice-President in charge of the RCA Laboratories Division:—

"While some technical problems still must be surmounted before video tape equipment can be made available commercially, RCA considers that the toughest of them have been conquered and that further development is certain to solve the remainder."

New Television Relay Cable

The proposed introduction of supplementary television programmes has presented a number of problems to wire relaying companies. Much work has already been done in distributing the single programme at present available and additional programmes could follow the established practice, by using a different carrier frequency. This, however, would necessitate the provision of variable tuning facilities in each subscriber viewing unit.

BICC have developed a new range of precision cables in which the crosstalk interaction has been reduced to a very low level. Using these cables, British Relay Wireless and Television Limited have engineered a television relay system capable of distributing a television programme on each pair of a screened quad cable at a common carrier frequency, thus reducing the subscriber's selective apparatus to a simple switch.

The network, now being erected to serve the area of South East London, comprises two screened quads which between them provide four vision channels on a common carrier frequency and five audio channels, the fifth audio channel being the circuit provided between the screens of the two cables.

Polythene is used for the insulation, filling, belting and sheathing of these precision quads which have plain copper conductors and a lapped copper tape screen. A feature of this new range is that the three larger cables, intended for the main distribution network of a system, have the same characteristic impedance.

The Zinc Coating of Paper for Capacitors by Vacuum Evaporation

By L. Holland* and K. Hacking*

The production of "self sealing" capacitors has been facilitated by the use of metallized paper prepared by the vacuum evaporation process. Both zinc and aluminium are commercially deposited on to capacitor tissue and it is shown that zinc can be evaporated at higher rates and at higher gas pressures than aluminium. Zinc atoms possess very low binding energies to non-metallic surfaces and it is necessary to pre-coat the paper surface with nucleating film, for example, the silver monolayer, to increase the binding energies and aid the condensation of a fine grain deposit. Zinc coatings oxidize more rapidly if deposited on to wet paper and it is advantageous to thoroughly pre-dry the paper prior to coating. The design of a degassing and zinc metallizing plant is described. The metallizing plant is capable of processing a 5 000ft length of 5in width paper in a total cycle time of 35 minutes. Interesting features of the exhaust system on both apparatus is the use of a booster diffusion pump and a gas-ballast pump.

MANSBRIDGE[1], as early as 1905, first pointed out the advantages of constructing capacitors from metallized paper. Capacitors constructed from such a foil or paper have roughly one-third the volume of their equivalent fabricated from aluminium foil and paper. It has been claimed that such capacitors possess the useful property of "self-healing" whereby the thin metal coating is volatilized and removed by arcing in the neighbourhood of an insulation breakdown either when temporarily overloaded or under normal working conditions. There has been an extensive use of metallized paper in capacitor manufacture during the last decade, largely stimulated by the need for miniature components in the electronic and communication fields. At present it is difficult to assess fully the advantages and limitations of metallized paper capacitors because there has been insufficient publication of performance data, but undoubtedly they have proved of great value where component size and weight are major considerations.

Production of zinc coated paper, prepared by vacuum deposition techniques, was first commenced in Germany[2] prior to the last war. Many capacitors were made from this paper and successfully used during the war. Also, in 1940, patents[3] were granted in this country for methods of producing aluminized foils. At the end of the war, interest in zinc coated paper was stimulated in America, and several companies[4,5] designed and constructed production plant.

In spite of the interest generally shown in metallized paper capacitors and the extensive use of zinc and aluminium coatings, there is no information in the published literature giving comparative data for the performance of these two metals when used under service conditions. The physical and chemical properties of thin coatings of aluminium and zinc are discussed below, in order to assess the relative advantages of the respective coatings when used in paper capacitors; however, the advantages claimed for a particular metal remain conjectural in the absence of experimentally determined performance data. This account is primarily concerned with the problems encountered in the metallizing of capacitor tissue in vacuo with zinc and the equipment and techniques used for obtaining sufficiently low gas pressures to enable volatile materials such as paper to be metallized. Here again, there is little useful information in the published literature, and thus the equipment described, although not novel in principle, has required considerable development investigation.

Requirements of Metallized Foil

The principal desirable properties of a metallized foil suitable for use in capacitor manufacture are that:

(1) The applied metal film is continuous and of sufficient thickness to form a good electrical conductor, but is capable of being rendered discontinuous should electrical breakdown occur in a localized area.

(2) It is uniform in thickness over the coated areas.

(3) It adheres well to the substrate, but does not penetrate it (e.g. the disadvantage found in Mansbridge foil, where the metal is sprayed on the substrate).

(4) The metal used is resistant to short-term atmospheric exposure.

In addition, it is a necessary factor in the production of such a foil that the electrical and physical properties of the substrate are not impaired by the process.

By careful design of the metallizing and associated equipment it is possible to achieve the correct working conditions for producing metallized foil having the first three of the above properties. The last, and, to some extent, the first are properties determined by the choice of metal.

A guide to plant design is best afforded by a study of the mechanism of film formation and the effects of varying the conditions under which the formation takes place.

Choice of Metal to be Evaporated

In general, the method used in producing a metallized foil is to vaporize the metal under vacuum conditions such that it condenses in the form of a thin film of uniform structure on the paper to be coated. The problem resolves into executing this process in a dynamic but controlled manner, whereby large quantities of paper are coated at economical speeds.

There are several metals which can be evaporated in vacuum on to capacitor paper, of which aluminium and zinc have found most favour on a production basis. The final choice between these metals is arrived at by considering the merits of each in relation to the production of the foil and the subsequent processing.

SUITABILITY FOR THE EVAPORATION PROCESS

Aluminium is by far the most difficult to evaporate in large quantities economically. This is largely due to the fact that at its effective evaporation temperature ($\simeq$1 200°C) it will either chemically react or form alloys with any refractory material or metal used as a support or crucible for the molten metal. Apart from these reactions, which have been partly reduced by novel source design[6,7,8] the maximum rate of deposition is limited to relatively low values in comparison with zinc or cadmium for a given power input.

The evaporation of zinc or cadmium presents no problem of heater source reaction and, because of their much greater volatility, there are practically no source limitations on the speed at which papers can be coated. Com-

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pare, for example, the source temperatures (1 000°C; 260°C; 340°C) necessary for Al, Cd and Zn, respectively, at which the vapour pressure is 10^{-2}mm Hg. Both in Germany[2] and America[4] speeds of 5 to 8 metres/sec have been obtained with zinc coating plant. It is not possible to form by evaporation good quality aluminium films at residual gas pressures greater than 5×10^{-4}mm Hg. Above this order of pressure the deposit develops a coarse aggregated structure lowering its electrical conductivity. The purity of the aluminium film also critically depends upon the nature and pressure of the residual gas. Thus aluminium films deposited at gas pressures as low as 10^{-4}mm Hg in a kinetic pumping system have been found to be contaminated by aluminium oxide formed by oxygen absorption during deposition. Aluminium films deposited at that pressure are, however, sufficiently compact to serve as conducting coatings, but at a pressure above 5×10^{-4}mm Hg both desirable film properties are lost, as can be observed by the discoloured and non-metallic appearance of the coatings.

In order to maintain a low chamber pressure ($\ll 5 \times 10^{-4}$mm Hg) while continuously aluminizing paper, it is necessary to pre-degas the paper thoroughly and to use very high pumping speeds to remove the water vapour which continues to be desorbed at low pressures. Thorough pre-drying of the paper is also essential, because the chemically active aluminium vapour atoms are known to react readily with water vapour either while in transit or at the condensing surface. Thus when aluminium is deposited on to wet materials, aluminium oxide is formed with the evolution of hydrogen. Aluminium is also known to form a stable nitride, and this may also be present in deposits condensed at high gas pressures. With zinc, the conditions for producing highly conducting coatings are not so critically dependent on gas pressure as with aluminium, e.g., good quality zinc films can be deposited on paper at gas pressure up to 5×10^{-1}mm Hg. As shown further on, the structure of zinc coatings depends to a great degree on the vapour intensity and the nature of the substrate surface. Very high molecular intensities may be obtained in zinc vapour beams, and it is very probable that residual gas molecules cannot easily diffuse into the interspace between the source and condensing surface and thereby become absorbed in the film during deposition. Zinc has apparently been used in preference to cadmium solely for economic reasons, otherwise the evaporation characteristics of these metals are similar.

Comparative Life of Zinc and Aluminium Metallized Capacitors

It is not easy to assess the relative merits of zinc and aluminium metallized paper for capacitor productions in the absence of comparative performance data. In view of the lower temperature required to evaporate zinc, it might be expected that 'self healing' occurs more easily and efficiently than with aluminium, since at the point of electrical breakdown more zinc would be volatilized for a given current density. Further, the oxide layer which grows on the surface of aluminium is compact and known to depress the free evaporation of the metal. During arcing it is probable that a quantity of metal oxide will be formed at the point of breakdown. In this respect aluminium should be superior, since its oxide (Al_2O_3) has exceptionally good insulation, whereas that of zinc (ZnO) has semi-conducting properties.

Thin aluminium films have the advantage of being more strongly resistant to oxidation than zinc, because they are protected by a thin but non-porous Al_2O_3 layer of some 40Å thickness. Zinc metallized paper capacitors would require suitable impregnation to prevent undue corrosion of the metal. No difficulty is experienced under controlled conditions where the capacitor manufacturer operates the coating plant, because the zinc metallized paper can be stored for a reasonable period before use, but it is improbable that the metallized paper could be marketed for winding capacitors, as is possible with aluminized paper.

Zinc, the Present Choice

To summarize, it can be said that for the production of metallized paper zinc evaporation has the following useful virtues over aluminium:—

(1) Higher coating speeds are attainable.

(2) No source reactions.

(3) No obvious deleterious effects produced in the metal film by a considerable rise in the coating chamber pressure.

Zinc Deposition Technique

Zinc contained in a suitable crucible is electrically heated in a vacuum chamber which is continuously pumped. Under these conditions metal is volatilized from its surface at a rate depending mainly on the temperature. At temperatures above its melting point (420°C) the vapour pressure of zinc rises steeply with temperature, and the vapour effusing from the crucible aperture is condensed directly to the solid state on a suitably prepared surface. If, now, the paper to be coated is passed continuously over the crucible aperture, a thin film of metallic zinc can be formed on the surface.

Critical Temperature—Beam Intensity Relation

Early experiments by R. W. Wood[9] with cadmium vapour and also by Knudsen[10] with mercury vapour showed that there exists, for a particular non-metallic receiving surface and beam intensity, a critical substrate temperature, above which condensation does not take place. This effect was interpreted by Wood as being due to reflexion of the impinging atoms when the receiving surface was held above the critical temperature. Later experiments by Langmuir [11] confirmed the existence of a critical temperature and associated critical intensity. Further, he gave strong evidence that the phenomenon was not one of reflexion but of condensation and re-evaporation, i.e., the incident vapour atoms linger on the receiving surface for a finite period. According to this theory, a vapour atom has an "average life" on a surface on which it impinges before it re-evaporates. If the "average life" of an atom is sufficiently long for a subsequent atom to arrive at the surface and adjacent to the first, so that an atom pair is formed, the energy now required, to evaporate off either of the atoms is considerably increased. This atom pair, therefore, has an even longer "average life," and so the film builds up until finally nearly all the atoms arriving are held at the surface. On this interpretation it is clear, also that the greater the number of initial atoms impinging on the substrate in a given interval of time, the greater is the possibility of forming atom pairs from vapour atoms which are mobile on the substrate. The "average life" of an initial atom depends on the latent heat of evaporation of the atom from the surface and on its temperature. For a full discussion of the dependence on the latent heat of evaporation and its influence on the structure of the condensed film, see Appleyard[12].

The "average life" of a vapour atom depends upon the temperature and nature of the condensing surface. When atoms of the volatile metals zinc, cadmium or mercury impinge on glass or other non-metallic surfaces, the forces binding the condensed atoms to the substrate are very weak, and thus, for film condensation to ensue, either the substrate must be cooled to very low temperatures, or the beam intensity must be made very high.

PRE-SENSITIZING WITH METAL NUCLEI

Langmuir[11] showed that, by sensitizing the surface with nuclei of cadmium atoms formed at a temperature below the critical temperature, subsequent exposure to a cadmium vapour beam allowed a visible deposit to be formed at substrate temperatures very much above the critical temperature. This phenomenon was turned to advantage in early work on molecular beam techniques, when zinc vapour beams could be made to condense by pre-sensitizing the target with evaporated silver, which unlike zinc can be deposited using very low beam intensities. A full account of this is given by Fraser[13]. The method of artificially pre-sensitizing a surface to increase the binding energy of zinc atoms, as developed for molecular beam experiments, was applied to the zinc coating of capacitor papers in 1938 and formed the subject of a German patent[14]. An invisible deposit of a metal such as silver, copper or tin, whose atoms easily key to the surface, owing to their greater heat of evaporation, is first applied and forms the necessary nuclei for the rapid condensation of subsequent zinc atoms.

In Fig. 1 is shown a zinc metallized glass plate photographed in transmitted light. One half of the plate has been pre-sensitized with a silver deposit, of surface density equivalent to molecular thickness, and the whole area then exposed to zinc vapour. The zinc beam intensity was sufficient to obtain a deposit on the unsensitized area, but it can be seen that the film is not only more dense on the sensitized half, but also very uniform, whereas the film on the remaining half is not uniformly distributed but varies in density in accordance with local variation in the binding energy.

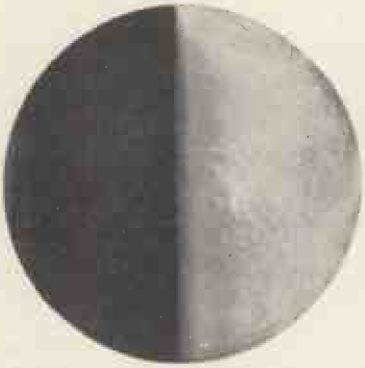

Fig. 1. A transmission photograph of zinc coated glass plate

One half has been pre sensitized with an invisible deposit of silver and the whole exposed to a molecular beam of zinc. The deposit is seen to be denser and more uniform on the sensitized glass

Zinc films formed on untreated paper which has not been pre-sensitized with other atomic nuclei, but by the forced condensation from a high intensity beam, are very granular and have a matt appearance. These films also have an abnormally high electrical resistivity, which is further evidence of large grain size.

EFFECT OF RESIDUAL GAS PRESSURE ON FILM GRANULATION

Levinstein[15] has made electron diffraction studies of the effect of the residual gas pressure on the formation of zinc films on glass. He finds that films formed in a poor vacuum are much more uniform, and of smaller grain size, than similar films formed in a good vacuum (0·001mm Hg or less). This effect he attributes to the greater number of inter-atomic collisions that naturally occur at the higher residual gas pressures, causing the formation of aggregates of atoms in transit which, when striking the receiving surface, are more stable than single atoms. The result is a uniform spread of nuclei facilitating condensation of subsequent atoms and preventing the growth of large grains. It should be remembered that this latter effect of residual gas pressure might not be of importance when the surface is already pre-sensitized with other atomic nuclei. The authors have found that there is no directly visible difference between zinc films formed on paper at various pressures in the range 10^4 to 5×10^{-1}mm Hg when the surface is pre-sensitized with silver.

ZINC VAPOUR DIFFUSION

At the vapour pressures required for fast coating speeds, the mean free path of zinc atoms within the vapour beam is very short. For instance, at a vapour pressure of 0·1mm Hg the mean free path may be of the order of 0·5mm which is sufficiently short to cause a certain amount of zinc vapour to diffuse throughout the coating chamber, in spite of the fact that the crucible may be designed to make the effusing molecular beam directional. This vapour diffusion creates a problem in connexion with the shielding of the spooling mechanisms and the adequate insulation of electrical lead-in terminals to the vacuum chamber. However, since the residual gas pressure need not be of a low order for satisfactory coating, the rotating components of the spooling mechanism can be lightly lubricated with low vapour pressure oils or greases. These also serve to prevent undue build-up of zinc layers on bearing surfaces. Static parts in the neighbourhood of the crucible aperture are, unfortunately, prone to be coated in the long run, and measures to facilitate the cleaning or replacement of these parts are necessary.

METHODS OF PROVIDING UNMETALLIZED MARGINS

For the subsequent construction of the capacitor it is necessary to provide the metallized foil with uncoated edge margins. The metal can either be removed from the foil after deposition, by an electrical burn-off technique[16,17], or prevented from condensing on certain areas of the foil during metallization. Zinc vapour will not condense on a surface which is greasy and this effect can be utilized to provide clear unmetallized bands during coating by printing the paper prior to coating, with a thin film of wax[18]. The writers have found that a low vapour pressure fluid such as a silicone diffusion pump oil also prevents zinc condensation.

Masking areas of the paper with stationary metal templates in order to prevent zinc vapour from reaching the paper is impracticable unless the accumulation of zinc on the template edges can be prevented by deliberately maintaining a contaminated surface to prevent condensation from commencing*. Also there is a tendency for zinc vapour to diffuse, as explained above, and the edge of the uncoated margin will not be sharply defined unless the paper and mask are in good contact.

An alternative scheme to the foregoing is to place a mask over the silver source to prevent a nucleating film from being condensed at the paper edge and afterwards to expose the whole of the paper surface to the zinc beam. The very low rate at which the silver is evaporated does not produce thick deposits on the mask, and a zinc film will not condense on the non-nucleated surface, i.e. providing the rate of arrival of zinc atoms at the non-nucleated paper surface does not exceed the critical value required for condensation to ensue. The rate of deposition of the zinc atoms is a function of the beam intensity and the paper speed, and at very high coating rates a granular zinc film will form on the unsilvered surface.

** It is of interest to note that scattered zinc vapour may not always condense on the water-cooled metal components of a coating jig, e.g., the water-cooled lead in electrodes, although it may condense under the same conditions on the uncooled components. It would be expected that the lower surface temperature of the water-cooled components would aid condensation, but this is offset by the fact that the cooled surfaces are contaminated by oil films condensed from the residual atmosphere in the coating chamber.*

For comparison purposes, Fig. 2 shows the pumping characteristics of (a) a normal vapour pump, (b) a "booster" type vapour pump and (c) a rotary oil pump. Along the ordinate is plotted the logarithm of the "through-put" in litre microns/sec and as abscissae the logarithm of the pressure in mm Hg, i.e. mass of gas exhausted per unit time at a given pressure.

From these curves it can be seen that the "booster" pump has an effective pumping speed which is some fifty to a hundred times that of the mechanical pump in the pressure range 0·2 to 0·02mm Hg, i.e. in the pressure region where moisture liberation is rapid.

A reduction in the overall drying time could be achieved by constructing an automatic continuous wind and rewind mechanism for the rolls of paper inside the drying chamber. However, for economic reasons and the fact that the width of the paper to be subsequently metallized did not exceed 5in a drying unit was constructed, utilizing the pumps described above, and the paper pre-dried in the rolled state.

Vacuum Degasing Plant

This unit consists of a long cylindrical chamber, approximately 9in inside diameter and 2ft long, with a plate door at one end, mounted horizontally on a metal framework. Projecting internally from the closed end along the long axis of the chamber is a cantilever rod on which the rolls of paper are supported. Around the outside of the chamber are wrapped web type heaters, which are temperature controlled by a variable auto-transformer. These heaters are capable of raising the temperature of the inset rolls from ambient to 120°C if desired. The chamber is pumped, via a high vacuum valve, by the 6in booster pump backed by a mechanical pump. A McLeod gauge and a Pirani gauge are connected to the drying chamber, so that approximate readings can be made of the total pressure of the mixture of gases and vapours (Pirani) and of the partial gas pressure (McLeod).

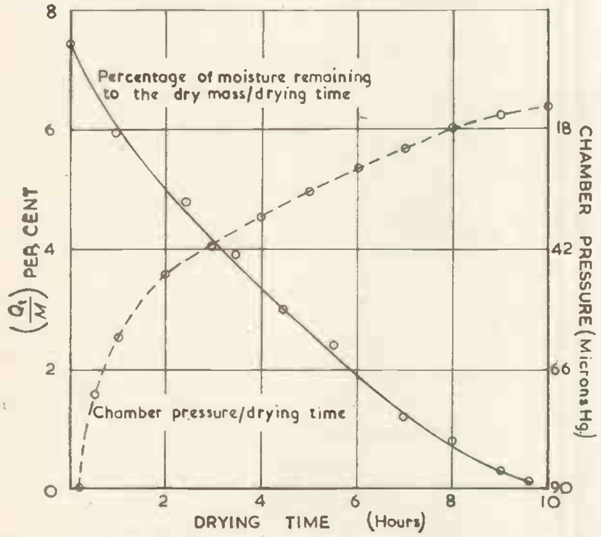

Fig. 3. The drying rate and chamber pressure for a roll of unlacquered capacitor paper (Kraft) at 70°C, indicating the performance of the drying unit

Performance

Fig. 3 shows the measured desorption rate of a roll of unlacquered 9 micron capacitor tissue, 4in wide, at a mean temperature of 70°C when dried in the unit described above. The initial weight of the roll was 1 655g. Along the left-hand ordinate is plotted the water remaining, expressed as a percentage of the dry weight of the roll; and along the right-hand ordinate the chamber pressure in microns Hg, as measured with a Pirani gauge, with the time in hours as abscissae.

With paper temperatures of 100°C or greater it was observed that the drying rate increased but the partial gas pressure, as measured by the McLeod gauge, also was higher. This was interpreted as indicating a certain amount of paper decomposition with the evolution of gas plus water vapour, because Murphy[19] has observed that water vapour is formed by the thermal decomposition of paper at a temperature of 100°C or above.

For metallizing purposes, a roll of capacitor paper was considered dry when the pressures as measured by the two types of gauge were of the same order of magnitude. When the dried paper was transferred to a metallizing plant, exhausted by a 1 000lit/sec oil diffusion pump, an ultimate pressure was obtained less than 0·002mm Hg, and this value was maintained throughout the coating operation.

The drying period for unlacquered paper was found to average 8 hours. This time was considerably increased if one surface of the paper was lacquered, as would be expected, since the lacquer tends to seal one of the surfaces from which desorption takes place. If, however, a lacquer known to be impervious to moisture was used for sealing both surfaces of the tissue, then moisture desorption might be completely prevented and degasing rendered unnecessary. The lacquering technique for preventing volatile desorption has already become a routine procedure in the metallizing of cellulose acetate mouldings by vacuum evaporation[22].

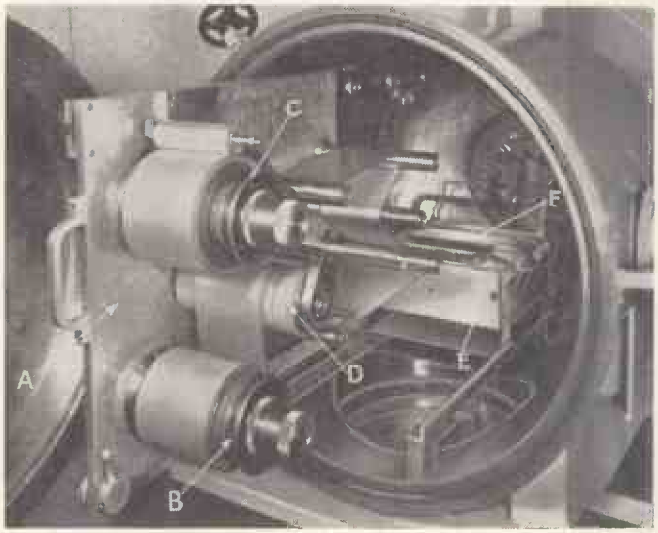

Fig. 4. Close-up of metallizing chamber, showing details of winding mechanism and sources

Metallizing Plant

Pumping Equipment

It has already been explained that metals such as aluminium must be evaporated at greatly reduced gas pressure (less than 5×10^{-4}mm Hg) to prevent oxide contamination of the deposit, whereas highly conducting zinc films can be deposited on to nucleating films at gas pressures as high as 0·5mmHg. It is thus not essential to use a diffusion pump on a zinc metallizing plant to obtain low gas pressures as is the practice with routine vacuum evaporation plant.

However, there has been a great deal of uncertainty regarding the upper limit of gas pressure at which zinc can be satisfactorily condensed and the early models of the continuous coating equipment, described below, were evacuated, via a high vacuum valve, by a 9in diameter

Pre-Drying and Degasing Capacitor Paper

An important preliminary operation to the zinc metallization of the paper is the removal of a sufficient quantity of the absorbed volatile content to ensure both reasonable pressure conditions during the coating process and that the zinc is not deposited on to wet paper which would hasten its oxidation during storage. In the case of capacitor paper the absorbed volatile content is mainly water, which is held in equilibrium with the atmosphere. Murphy[19] has investigated the drying of papers and their rates of decomposition at various temperatures. Measurements made in the authors' laboratory on rolls of capacitor tissue show that absorbed water content averages 7·5 to 8·5 per cent.

The mechanism occurring in drying a porous solid which is initially in a wet state can be broken down into the following stages:

(1) Direct evaporation from a wet surface, the desorption rate being proportional to the vapour pressure of water at the surface temperature.

(2) A falling rate period during which evaporation takes place from a partly saturated surface.

(3) A final falling rate period, in which desorption completely depends on the rate at which liquid diffuses from the interior of the solid to the evaporating surfaces. If, as is usually the case, the internal resistance to diffusion is much greater than the resistance to evaporation, then moisture concentration at the surface will fall to a negligible value.

A drying mechanism of this type has been fully investigated by Sherwood[20]. The first two stages are completed fairly quickly during the drying process, and the last is found to follow Fick's law (see Barrer[21]) in the form:

$$\partial C/\partial t = D(\partial^2 C/\partial x^2)$$

where:

D is the diffusion constant in cm²sec^{-1}

C is the moisture concentration in g.cm^{-3} at a distance $x$cm from the origin.

A particular solution of this equation for the case of a rigid rectangular solid drying from two opposite faces can be put into the approximate form:

$$Q_t = Q_0 \, . \, A \, . \exp\left(\frac{-KDt}{L^2}\right)$$

where:

Q_t = amount of volatile material remaining after time t.

Q_0 = amount of volatile material initially (i.e. at $t=0$)

L = distance between drying faces.

A and K are numerical constants.

D is the diffusion coefficient whose value depends on the absolute temperature of the solid and increases exponentially with it.

Firstly, it can be seen from this equation that complete drying implies an infinite drying time, so that from a practical standpoint the material can only be dried to a finite volatile concentration. Secondly, from Fick's law, the rate of drying depends on the concentration gradient for a fixed temperature, and the higher this gradient can be maintained, the more rapid is the drying process.

Relating these considerations to the problem of drying rolls of capacitor tissue (since it is reasonable to assume that this material, although not strictly rigid, follows similar laws), the most efficient and rapid drying will occur in vacuo when:

(1) the external gas plus vapour in contact with the paper is maintained at the lowest possible pressure,

(2) the drying temperature is the maximum possible without physical deterioration of the paper.

(3) the maximum surface area of the paper is exposed.

Pumping Systems for Degasing

In order to comply with condition (1) above, the drying chamber must be pumped by a system having sufficient speed to lower continuously the drying chamber pressure with time.

(i) *Refrigerated Systems.* This is one of the methods employed in the vacuum drying of substances containing copious amounts of water. These normally consist of a heated vacuum chamber pumped by a mechanical oil pump via a cold trap maintained at temperatures less than −50°C. Here an ultimate pressure of 0·01mm Hg can be attained, the residual gases at this pressure being almost entirely permanent ones, since the cold trap has a very fast pumping speed for condensible vapours.

(ii) *Non-Refrigerated Systems.* For the drying of paper it is possible to remove a great deal of the absorbed water content by pumping the drying chamber with an ordinary rotary mechanical pump. Unfortunately, without a moisture trap in the pumping line the water vapour enters the rotary pump and is condensed in the compression stage. The condensed water vapour mixing with the oil is circulated in the pump and reliberated as vapour into the vacuum system. The contamination is accumulative and results in a steady deterioration in the ultimate pressure, which seriously limits the degree of dryness obtainable.

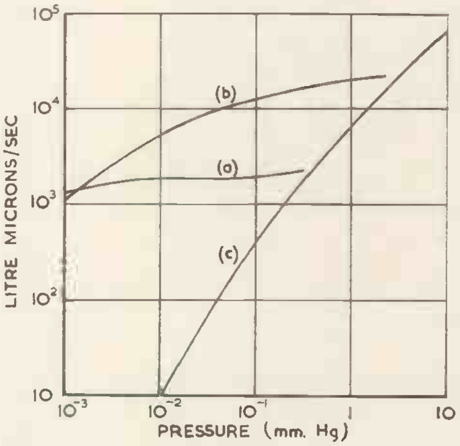

Fig. 2. Pumping characteristics of:—
(a) Edwards-type 903B oil diffusion pump.
(b) Edwards-type 9B3 "Booster" pump.
(c) Speedivac 1S450A rotary pump.

By modifying the mechanical pump to operate on the "gas ballast" principle, whereby water vapour is prevented from condensing inside the pump, a lower ultimate pressure (approximately 0·01mm Hg) can be attained. Experiments with these pumps showed that paper dried in the rolled state for a reasonable time, even at this order of ultimate pressure, still contained an undesirable percentage of absorbed water.

In order to achieve an ultimate pressure of $\leqslant$ 0·01mm Hg and at the same time increase the pumping speed over the range 1mm to 0·01mm Hg, it became necessary to consider the use of special oil vapour pumps or "booster" pumps in conjunction with the mechanical pump. The specially developed vacuum pumps forming the exhaust system on the degasing unit will be described in a separate communication by the authors' colleagues responsible for their design.

silicone oil diffusion pump (Edwards 903B) having a baffled speed of a 1 000lit/sec at 0·0001mm Hg (see the speed curve in Fig. 2). The rotary oil pump for "roughing" the chamber and backing the diffusion pump operated on the "gas ballast" principle, in order to avoid contamination of the oil by any small quantities of water vapour which continued to be evolved by the paper during the coating operation. The latter pump had a free air displacement of 450lit/min. A manually operated by-pass valve was incorporated to enable the diffusion pump to be isolated from the rotary oil pump while the latter was "roughing" the chamber.

With the above pumping system a roll of capacitor paper could be coated at gas pressures of the order 2 to 3 microns Hg providing the paper had been very thoroughly pre-dried.

Further experiments have shown that high quality zinc films can be deposited at gas pressures of the order of 0·1mm Hg. In this pressure region a diffusion pump is inoperative and the 9in silicone oil diffusion pump has been replaced by a booster diffusion pump (Edwards Type 9B1) similar to that used on the degasing unit described above.

It may be considered that because of the higher operating pressure permissible the paper need not be extensively pre-dried. However, thorough drying is still essential, because firstly the zinc coating more rapidly deteriorates when stored if the moisture content of the paper is high and secondly there is an improvement in the performance of the processed capacitor.

Winding Mechanism

The paper winding mechanism is mounted inside a cylindrical chamber some 2ft in diameter and approximately the same in length, having a hinged door at the front.

The pre-dried roll of paper to be metallized is centred between the lower pair of cones B shown in Fig. 4, and the paper fed over the system of rollers to a similar take-up spool located at C. The large roller D is covered with a bonded layer of rubber and provides the driving force necessary to wind the paper. At the back of the plate (not shown) the shaft of roller D is connected to that of the take-up spool C via a friction disk clutch. The latter serves only to keep the paper taut between the two. By this method, with careful adjustments of the tension, if the drive roller is rotated with constant speed, the linear speed of the paper over the sources will remain constant, irrespective of the relative roll diameters.

The winding mechanism is coupled to a motor, mounted externally to the vacuum chamber, by a shaft rotating in a modified "Wilson" type vacuum seal. The motor has a series A.C. winding and reduction gear attachment and is speed controlled by a variable auto-transformer.

Zinc Sources

Two steel crucibles, fabricated into cylindrical form with closed ends and long jet forming apertures, hold the zinc charge which is introduced in the form of powder or wire through the apertures. The crucibles are electrically heated by means of high resistance carbon rods connected to an external low tension current supply. Each of the carbon rods dissipates above 1kW during working conditions. In order to prevent the paper from being exposed to heat radiation from the crucible walls when it passes over the vapour jets, the crucibles are shielded and enclosed in a water-cooled box E, from which only the tops of the jets protrude. (One of these can be seen at F in Fig. 4.) The water cooling system is arranged so that the inlet and outlet piping also forms the electrical connexions to the sources.

The silver source used for pre-sensitizing the paper is constructed in the form of a long carbon rod, which contains a series of pockets. Into these pockets are placed grains of silver, which, when the carbon rod is electrically heated to about 900°C, melt and form a series of evaporation sources. By this arrangement, the formation of a continuous electrically conducting channel of molten silver with the consequent shorting of the heater is prevented. This silver source is located on top of the water-cooled box E preceding the zinc vapour jets.

A sliding shutter (removed in photograph), operated externally, is arranged above the zinc vapour jets, so that the crucibles may be initially heated to the required temperature while the paper is stationary. The shutter can be moved to expose the vapour jets.

Instruments and Gauges

A thermocouple and meter is incorporated to observe the working temperature of the zinc vapour jets. There are also current meters fitted to both the independent power supplies controlling the two sources.

Provision is made to observe continuously the electrical resistance of the zinc film being deposited during the coating process. This is accomplished by passing the metallized surface over two separated metal rollers, which are electrically isolated from the base plate but connected to an external meter circuit. Since the resistance is a function of the film thickness, an indirect indication of the latter is afforded by observation of the ohmmeter deflexion.

The vacuum gauges fitted to the plant are a low pressure type Pirani gauge connected to the chamber and a normal Pirani gauge connected in the backing line.

Performance of the Plant

The capacity of the plant is limited to coating rolls of capacitor tissue not greater than 5in wide and 6in outside diameter. Using 9 micron thick tissue, this represents a length of 5 000ft and can be satisfactorily metallized in a complete cycle of about 35 minutes, including pumping and loading time. The plant is capable, using sufficiently pre-dried tissue, of depositing a bright metallic and uniform layer of zinc having a resistance of 1-2 ohms per square. Assuming the zinc deposits to have the specific resistance of bulk material, the above values of film resistance would correspond to thickness of 0·06 to 0·03 microns respectively. Owing to the higher specific resistivity of zinc in thin film form, the thickness values will be somewhat greater.

A satisfactory coating on lacquered and unlacquered paper could be achieved using only one of the zinc crucibles, having a jet temperature of 350°C, and running the paper at a speed of 200ft/min. Speeds of the order of 500ft/min or greater are quite practical with the two crucibles in operation.

Acknowledgments

Acknowledgments are made to Mr. A. S. D. Barrett, Technical Director of W. Edwards & Co. (London) Ltd, for kind permission to publish this account.

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More about

Circuits and Logic

By T. L. Craven*, B.Sc., A.M.I.E.E.

This article pursues the theme, introduced in these columns a short while ago, of the present day impact of pure logic on the fields of technology.

IN a recent article[1] it was shown that the Boolean algebra now being used in the design of switching circuits was not by any means restricted to that field alone, but was the work of a pure logician and concerned with the analysis of processes of reasoning. Examples were given of the way in which Boolean equations used in switching circuit design could, by virtue of their generality, be interpreted in terms of statements that used everyday concepts. The object of that article was to allow circuit engineers to see Boolean algebra in its natural setting, in the belief that this would prove of interest to them and increase the facility with which they could handle its somewhat unfamiliar equations.

We shall here pursue the same theme further, examining some of George Boole's original work and seeing how he used his algebra in the symbolic enunciation of arguments. This will then raise the question as to whether, since switching circuits can be expressed in Boolean symbolism, they also can be used to exhibit the premises and conclusions of arguments. We shall find that they can indeed be so used.

The author has no particular practical application of this investigation in mind, but he believes that, with the increasing use by engineers of the concepts of formal logic, it is important to advertise these concepts and to stress their generality. There is a danger that one may come to think of Boolean algebra as a mere shorthand notation specially developed for technological applications and bearing little relationship to the world of everyday reality. Nothing could be further from the case.

The Generality of Logic

The true state of affairs may be stated as follows:—

(1) Formal logic exhibits complete generality, so that its theorems are as apt when applied to everyday things like shillings and pence as when applied to the world of fancy which treats of fairies and goblins.

(2) The same generality allows the theorems of formal logic to be applied to switching circuits.

(3) Boolean algebra is a symbolic treatment of formal logic.

(4) Boolean algebra may therefore be applied to switching circuits—and, as we now know, its application is proving to be useful.

An illustration of the first two assertions, (1) and (2), of the preceding paragraph will perhaps be welcome at this stage. Formal logic makes the common-sense assertion, for example, that a statement of the form

All A's are B's

does not of itself imply

All B's are A's

but only

Some B's are A's.

The reader will agree that *All pennies are coins* complies *Some coins are pennies*, but not *All coins are pennies.* Similarly *All fairies are immortals* implies *Some immortals are fairies* but not *All immortals are fairies.* The generality of the reasoning is exhibited by the fact that it can be enunciated in terms of abstract letters A and B. Now it is equally easy to apply it to a switching circuit. *All A's are B's* can be interpreted as *All occasions on which relay A is operated are occasions on which relay B is operated,* which suggests various circuits of which Fig. 1 is typical. (The dotted branch admits the possibility of there being some other operating circuit for relay *B*. We must show it, for otherwise we should be exceeding the original evidence and exemplifying not *All A's are B's* but *All and only A's are B's*). This circuit, constructed on the assertion *All A's are B's*, clearly implies *Some B's are A's*, that is, *Some occasions on which relay B is operated are also occasions on which relay A is operated*, but it does not imply *All B's are A's.*

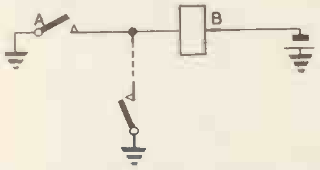

Fig. 1. Circuit representation of "All A's are B's"

George Boole and His Algebra

George Boole was an English mathematician and logician who held the Chair of mathematics at Queen's College, Cork, from 1849 to 1864. In "The Mathematical Analysis of Logic" (1847), and "An Investigation of the Laws of Thought" (1854), he introduced methods for handling the processes of formal logic in a mathematical way.

Boole starts with the concept, familiar in logic, of a "class". A class is simply a collection of all the things having some common characteristic by which the class is defined. A class is to be symbolized by a letter; thus, the class *black things* could be represented by X and the class *horses* by Y.

Next he laid down the convention that if, from any class Y, there be selected all things belonging also to some other class X, the resultant is denoted as the product class XY. In our particular case the class XY is the class *black horses.*

A further convention is that, if two classes are combined, the resultant class is denoted, appropriately enough, by addition. Thus if the class *horses* is denoted by Y, as before, and the class *cows* by Z, then the class *horses and cows* is denoted by $Y + Z$.

The basic symbolism is complete when three more conventions are added. The symbol "0" is used to denote a class which is devoid of members (such as the product class *carnivorous horses*). The class consisting of all things in the universe is represented by "1". And a negative class, like that of *non-horses,* is represented by $(1 - Y)$ where Y represents the class *horses;* this is a readily accept-

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* *Automatic Telephone & Electric Co. Ltd.*

able convention, for clearly the class *non-horses* is obtained by subtracting the class *horses* from that of all things in the universe.

The manipulation of these symbols is extremely simple; no operations are used other than those of multiplication and addition, and normal arithmetical rules apply in general. Evidently $X(Y + Z) = XY + XZ$ for a selection, (left-hand side), from the combined classes Y and Z of all things belonging also to the class X yields the same result, (right-hand side), as a selection from the class Y of all things belonging also to the class X combined with a similar selection from the class Z. Exceptions to normal arithmetic rules are the equations $XX = X$, $X + X = X$ and $1 + X = 1$.

$XX = X$ expresses the fact that if, (left-hand side), the class X be taken, and from it there be selected all things belonging to the class X, the resultant is still, (right-hand side), the class X.

The latter two call for more detailed comment. In the original example on the combination of two classes, we took the case of *horses* and *cows*. These are mutually exclusive, and the number of things in the class *horses and cows* is equal to the sum of the number of things in the class *horses* and the number of things in the class *cows*. But that need not always be the case and we must clear our minds of the idea of physical addition; the two classes may overlap as in the case of *vegetarians* and *quadrupeds*, where the resultant combined class *vegetarians and quadrupeds* will contain vegetarian bipeds and carnivorous quadrupeds, each of which belonged to only one of the original classes, but it will also contain vegetarian quadrupeds, which belonged to both of the original classes. $X + X = X$, then, is merely a statement of what happens in the extreme case when two identical classes are combined, while $1 + X = 1$ points out that any class X is entirely contained in the universal class "1".

The Algebra in Use by Boole

A simple example of the use of Boole's algebra, which introduces one to confidence in its reliability, may be given as follows. If the four classes,

things which are both black and horses,
things which are black but not horses,
things which are horses but not black,
and things which are neither black nor horses,

be combined, the entire universe is obtained. We shall therefore expect to find that their sum, when they are symbolically expressed, is "1"; we shall not be disappointed, for $XY+X(1-Y) + (1-X)Y+ (1-X)(1-Y)$ does indeed equal "1", as the reader may verify for himself by applying normal algebraic technique.

Of greater interest is the use of the algebra in the development of arguments. An argument familiar to all logicians, and which the reader will readily admit to be valid, is of the form

$$\left.\begin{array}{l}\text{All y's are z's}\\ \text{All x's are y's}\end{array}\right\}\ \text{(premises)}$$

$$\therefore\ \text{All x's are z's (conclusion).}$$

It is to be noted that the two premises must have a term in common (y's in this case) if they are to be capable of leading to a conclusion. Without such a common term they would be totally unrelated and no conclusion could arise from their combination; the combination of *All men are fools* with *All geese are bipeds* leads one nowhere, but *All bipeds are fools* and *All geese are bipeds* jointly yield the conclusion *All geese are fools*. Secondly, one must note that the common term y is eliminated in the conclusion, as otherwise the conclusion would be embodying mere restatements of the premises. These facts will guide us as to our procedure in developing the argument algebraically. Let us now do that.

The premise *All y's are z's* means that no y is a non-z, so that the product class of things which are both y and non-z is devoid of members. That is, using capital letters Y and Z for the classes composed respectively of things that are y's and z's,

$$Y(1 - Z) = 0.$$

Similarly *All x's are y's* becomes

$$X(1 - Y) = 0.$$

Since Y is not to appear in the conclusion, the next step is to eliminate Y from these two equations which are simultaneously true. Normal mathematical technique is used, and the result is

$$X(1 - Z) = 0$$

which is the algebraic statement of the conclusion *All x's are z's*.

It is both gratifying and rather exciting to find that one can develop an argument in this mathematical way. A second example the reader will doubtless be able to follow with less explanation:

$$\begin{array}{r|l|l}
\text{All z's are y's} \rightarrow & Z(1-Y) = 0 & \\
\text{No x's are y's} \rightarrow & \quad XY \quad = 0 & \\
\hline
 & \text{Eliminate Y} & \\
 & \text{for} & \\
 & \quad XZ \quad = 0 & \rightarrow \therefore \text{No x's are z's}
\end{array}$$

Lastly, it is interesting to see how the algebra behaves if asked to deal with two premises which, despite the presence of a common term, are incapable of yielding a conclusion. The reader will see on reflexion that nothing can be elicited from, for example,

All z's are y's
All x's are y's.

Algebraically, these are

$$Z(1 - Y) = 0$$
$$X(1 - Y) = 0$$

and the elimination of Y leads only to

$$XZ = XZ$$

which is no conclusion but only a tautology. So not only will the algebra find the right conclusion where one exists, but it will in no uncertain way call a halt where no conclusion is to be found.

The foregoing is sufficient for our present purpose, but in deference to Boole it must be pointed out that it is but the beginning of his work.

The Illustration of Arguments in Terms of Switching Circuits

It is here necessary, in the interests of those readers who have not the earlier issue to hand, to recapitulate a small part of the June, 1953, article.

Switching circuits can be expressed in terms of Boolean algebra by making use of such conventions as those shown in Fig. 2; these, supported by the example shown, should be self-explanatory.

The value of such a procedure lies in the fact that it is possible to arrive at a circuit to meet specified conditions, and to effect any available simplifications of complicated circuits, by operations upon the algebra, often with considerable saving of labour.

This has been extensively discussed elsewhere, but our concern here is to interest ourselves with the question that was posed in the opening paragraphs: since switching circuits can be expressed in terms of Boolean algebra, and Boolean algebra can be used in the development of arguments, can switching circuits be used as illustrations of arguments? The answer to the question will prove to be in the affirmative.

The first of the arguments examined was of the form *All y's are z's, All x's are y's, ∴ All x's are z's*, expressed algebraically as

$$
\begin{gathered}
Y(1 - Z) = 0 \\
X(1 - Y) = 0 \\
\therefore \text{ (on eliminating } Y) \\
X(1 - Z) = 0.
\end{gathered}
$$

Let us first ask ourselves just what we mean by asserting that such an entirely abstract argument is valid. We mean that values may be assigned to the letters x, y and z whereupon, if conditions are such that the premises are true, then the conclusion must necessarily be true. If it is true that *All dogs* (*y*) *are quadrupeds* (*z*) and that *All spaniels* (*x*) *are dogs* (*y*), then it is true that *All spaniels* (*x*) *are quadrupeds* (*z*).

Now expressed as a circuit equivalent to the algebraic form, the first premise asserts that a circuit consisting of a normally-open contact of relay Y in series with a normally-closed contact of relay Z is always open. Fig. 3 (a) depicts this, and the similar treatment of the second premise and the conclusion. Applying the line of thought of the previous paragraph, then, we should hope to find that if conditions are such that the two "premise-stating circuits" are always true, then the "conclusion-stating circuit" is also always true. In other words, that any control arrangements designed solely to ensure that the two premise circuits can never provide closed paths between their terminals should be found to perform the same function also for the conclusion circuit.

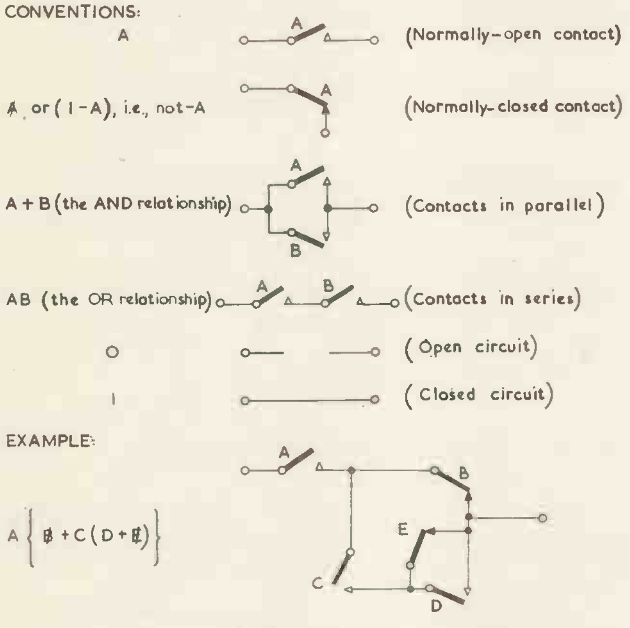


Fig. 2. Boolean algebra applied to switching circuits

Regarding the premise circuits only, then, and resolutely ignoring for the time being the conclusion circuit, we must arrange a control circuit of relays X, Y and Z such that

if Y is operated, so is Z
(for the first premise)

and also

if X is operated, so is Y
(for the second premise).

This is easily done, as is shown in the figure, and one is immediately gratified, on looking to see if the final control circuit enables one to make any deductions about a possible relatedness of X and Z, to find that it ensures the very condition necessary for the conclusion circuit, namely that

if X is operated, so is Z.

A word of comment is necessary about those control leads that are shown dotted. These leads may seem unnecessary, but not so; they are provided for exactly the same reason as was the dotted branch in Fig. 1. Considering the control circuit for the first premise, the reader will see that, in the absence of the dotted lead, the circuit would be asserting

if *and only if* Y is operated, so is Z.

This would be to exceed the available evidence, which was

if Y is operated, (but also possibly otherwise), so is Z.

To so exceed the evidence is, in logic, a grievous offence, always likely to lead one to an unjustified conclusion; this matter will be pursued further shortly.

The second argument, shown in Fig. 3(b), should present no difficulty; once again the control circuit, which has been designed solely with the premises in mind, is found to ensure also the truth of the conclusion. But it will be of some interest to see if a circuit is as perspicacious as was the algebra in the case of premises which are incapable of yielding a conclusion.

The reader will recall that the pair of premises shown in Fig. 3(c) have been shown to fall in this last category. To maintain their truth, we must have a control circuit which ensures that

if Z is operated, so is Y
(for the first premise)

and also

if X is operated, so is Y
(for the second premise).

This is soon done and then, on looking for some relationship between X and Z, we find that there is none. The circuit is, rightly, at a loss for any deduction.

Suppose, however, that in Fig. 3(c) we were to exceed the evidence by omitting the dotted leads. The first premise control circuit would now preclude the possibility of Y being operated while Z remained normal, and the second would preclude the possibility of Y being operated while X remained normal; a new final control circuit would therefore be needed. In our search for a method of combining the two premise control circuits, then, we might be tempted to proceed as shown in Fig. 3(d): that is, to reverse the order of Z and Y in the first premise control circuit, (since this makes no difference once we have omitted the dotted lead), or to resort to parallel connexion of the relays.

In either case the final control circuit implies that X and Z are always simultaneously in the same condition, operated or released, whence there would be drawn the entirely unjustified conclusion that *All x's are z's and all z's are x's*, alternatively expressed as *All and only x's are z's*.

Conclusion

It is possible that, at this stage, the reader may comment that it was quite unnecessary, in the development of arguments by means of relay controlling circuits, to have brought in Boolean algebra and its circuit equivalents. He may contend that one could equally well have derived the control circuits directly from the *verbal* premises by interpreting, for example, *All y's are z's* as *All occasions on which Y is operated are also occasions on which Z is operated* and that one could equally well have inferred the verbal conclusion in the same direct manner.

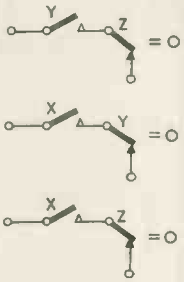
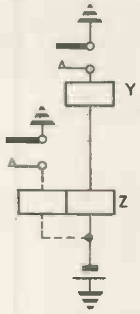
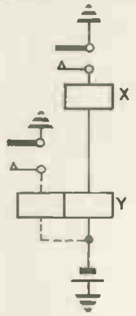
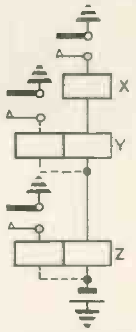
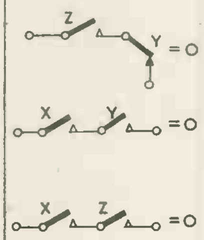
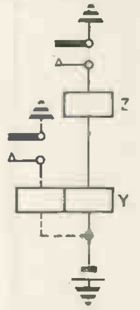
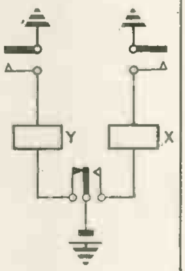
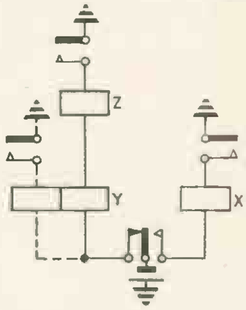
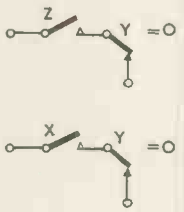
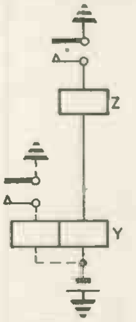
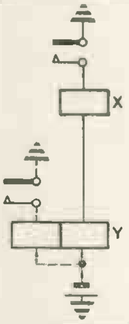
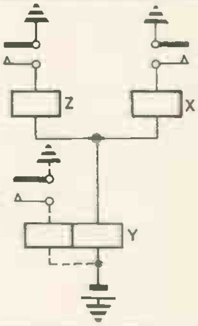
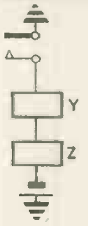
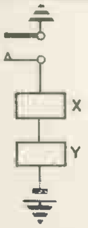
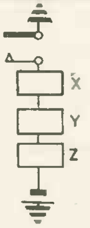
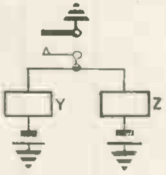
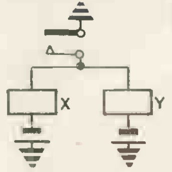
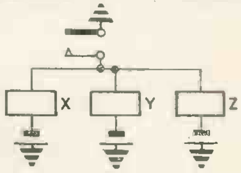
	THE ARGUMENT			CONTROL CIRCUITS		
	EXPRESSED IN WORDS	EXPRESSED IN ALGEBRA	EXPRESSED IN CIRCUITS EQUIVALENT TO THE ALGEBRA	FOR THE FIRST PREMISE	FOR THE SECOND PREMISE	FOR BOTH TOGETHER
(a)	All y's are z's All x's are y's ∴ All x's are z's	$Y(1-Z)=0$ $X(1-Y)=0$ $\therefore X(1-Z)=0$				
(b)	All z's are y's No x's are y's ∴ No x's are z's	$Z(1-Y)=0$ $XY=0$ $\therefore XZ=0$				
(c)	All z's are y's All x's are y's	$Z(1-Y)=0$ $X(1-Y)=0$				
(d)			In the above column, '= 0' means 'is always to be an open circuit'.			
						

Fig. 3. The illustration of arguments in terms of switching circuits

That is perfectly true, but no one who has reached this point of view should feel any disappointment. It is just that the wheel has come full circle, so that there has emerged a clearer realization of the fact, mentioned at the outset of this exploratory article, that formal logic, switching circuits, and Boolean algebra as a tool useful to either, all form a harmonious whole.

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Q as a Mathematical Parameter

By David Morris*, B.Sc., A.M.I.E.E.

This article illustrates a definition of Q that can be applied to RC networks and other systems having lumped parameters. The definition provides the basis upon which conventional conceptions of Q can be extended to systems having very low Q values.

THE concept of the Q of a circuit was developed at a time when interest was mainly in high-Q circuits. For such circuits, it is possible to define Q in terms of ratio of reactance to resistance, relative frequencies at "half-power" points, or ratio of energy transfer to energy dissipation. The slight discrepancies which can occur between such definitions are of little practical importance for high-Q circuits. If Q is small however, the conventional approximations are no longer valid, and the concept of Q has to be more rigidly defined if inconsistencies are to be avoided. The problem arises particularly in the fields of *RC* oscillators and of automatic control, where one may be concerned with values of Q of the order of ½ or less. The least ambiguous concept of Q is obtained by defining it as a mathematical parameter, as in the treatment that follows.

In Fig. 1(a),

$$\frac{V_2}{V_1} = \frac{R}{1/pC + R + pL} \quad \ldots\ldots\ldots (1)$$

where $R = R_1 + R_2$ is the total resistance, and p represents the d/dt of the corresponding differential equation. Write the denominator in ascending powers of (pT), making the first term unity. Choose the time-constant T so that the coefficient of $(pT)^2$ is unity. The reciprocal of the coefficient of (pT) is then defined as Q.

Thus:

$$\frac{V_2}{V_1} = \frac{pT/Q}{1 + pT/Q + p^2T^2} \quad \ldots\ldots\ldots (2)$$

where for this circuit: $T = \sqrt{(LC)}$ and $Q = \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$

Q has here been defined as a parameter in a second order denominator, and this is taken as the fundamental definition. However, the denominator is strongly characteristic of the physical system with which it is associated, and as a secondary usage one may, therefore, speak of the Q of a physical system. For example, a variety of outputs may be taken from the circuit of Fig. 1(a), with responses as follow:

$$\frac{V_3}{V_1} = \frac{1}{1 + pT/Q + p^2T^2} \quad \ldots\ldots\ldots (3)$$

$$\frac{V_4}{V_1} = \frac{p^2T^2}{1 + pT/Q + p^2T^2} \quad \ldots\ldots\ldots (4)$$

$$\frac{V_5}{V_1} = \frac{k\,.\,pT/Q}{1 + pT/Q + p^2T^2} \text{ where } k = \frac{R_1}{R_1 + R_2} \quad \ldots (5)$$

$$\frac{V_6}{V_1} = \frac{1 + (1-k)pT/Q + p^2T^2}{1 + pT/Q + p^2T^2} \quad \ldots\ldots\ldots (6)$$

It is seen that although the numerators vary markedly, the denominator is characteristic of all the responses. Defined in this way therefore, Q is characteristic of a given assembly of components, rather than of a particular output that is taken from the components. Furthermore, the definition of Q can be extended to uses for which the conventional definitions are inapplicable. Thus for the circuit of Fig. 2(a):—

$$\frac{V_3}{V_1} = \frac{1 + p(R_1C_1 + R_1C_2) + p^2R_1C_1R_2C_2}{1 + p(R_1C_1 + R_2C_2 + R_1C_2) + p^2R_1C_1R_2C_2} \,.\quad (7)$$

and the denominator can be rewritten in terms of $T = \sqrt{(R_1C_1R_2C_2)}$

$$\text{and } 1/Q = \sqrt{\left(\frac{R_1C_1}{R_2C_2}\right)} + \sqrt{\left(\frac{R_2C_2}{R_1C_1}\right)} + \sqrt{\left(\frac{R_1C_2}{R_2C_1}\right)}$$

Thus Q can be specified for this system, even though not one of the three conventional definitions of Q applies. The response may be rewritten:—

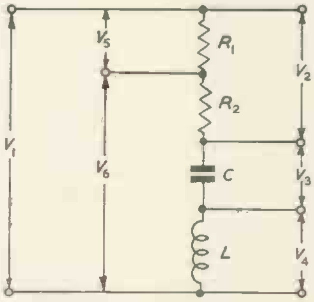

Fig. 1(a). An LRC circuit

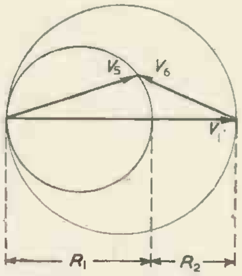

Fig. 1(b). Vector loci for Fig. 1(a)

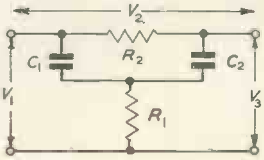

Fig. 2(a). An RC circuit for which Q cannot be defined on the " half-power " basis

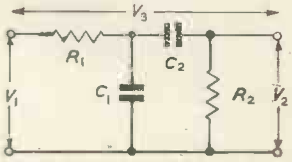

Fig. 2(b). The same circuit used in such a way that Q can be defined on the " half-power " basis

$$\frac{V_3}{V_1} = 1 - \frac{k\,.\,pT/Q}{1 + pT/Q + p^2T^2}$$

$$\text{where } k = \frac{R_2C_2}{R_1C_1 + R_2C_2 + R_1C_2} \quad \ldots\ldots\ldots (8)$$

If the same circuit is used in a different way, as shown in Fig. 2(b), the response is

$$\frac{V_2}{V_1} = 1 - \frac{V_3}{V_1} = \frac{k\,.\,pT/Q}{1 + pT/Q + p^2T^2} \quad \ldots (9)$$

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If f_0, f_1 and f_2 are respectively the frequencies for maximum response and the two frequencies that give 70·7 per cent of maximum response, $Q = f_0/(f_2 - f_1)$, precisely in accordance with the conventional "half-power" definition.

Fig. 3 summarizes the properties of a variety of networks having responses as given by equation (2), while Fig. 4 shows how the same networks may be used in a different way to provide a response of the form given by equation (8). The circuits of Figs. 3(a) and 3(b) are used for feedback in servo-mechanisms, the *RC* section being to filter out commutator ripple while the *CR* section is to transientize the feedback. The circuits of Figs. 3(c) and 3(d) could be used for the same purpose. The circuit shown in Fig. 4(c) is used as a derivative-proportional-integral network in control systems; 4(a) and 4(b) could be used for the same purpose. Circuit 4(d) is used as a null network, and circuit 3(d) is derived from this by interchanging *R* and *C* in the output branch, and setting $m = n$. Circuits 3(d) and 4(d) have been used in combined form to provide the output and the negative feedback in *RC* wave-analysers[1]. Circuit 4(d) is frequently used in symmetrical form ($m = n = 1$), and in this case $Q = \frac{1}{4}$. By tapering the impedance level however (m and n small), it is seen that Q can be made to approach $\frac{1}{2}$. In the author's experience, Q as defined in the foregoing manner is never greater than $\frac{1}{2}$ for *RC* networks. There are also many non-electrical systems whose responses can be expressed in the forms given above.

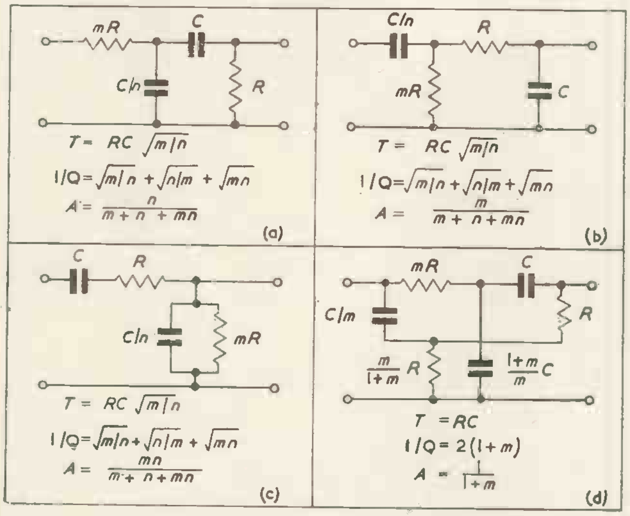

Fig. 3. Circuits of response $V_2/V_1 = A\dfrac{pT/Q}{1 + pT/Q + p^2T^2}$

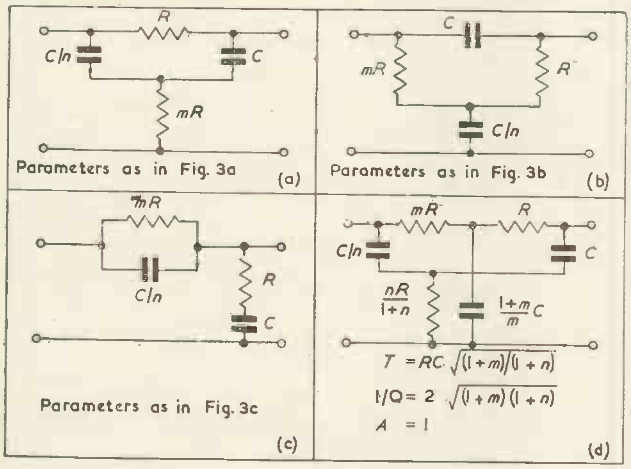

Fig. 4. Circuits of response $V/V_1 = 1 - A\dfrac{pT/Q}{1 + pT/Q + p^2T^2}$

If the circuit of Fig. 4(d) is used in the negative feedback path round a D.C. amplifier in the well-known manner (see Fig. 5(a)) the overall response is:—

$$\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{\alpha}{1 + \alpha\beta}\left\{1 + \frac{\alpha\beta pT/Q'}{1 + pT/Q' + p^2T^2}\right\} \ldots\ldots (10)$$

where $\alpha\beta$ is the loop gain at zero frequency and $Q' = Q.(1 + \alpha\beta)$. It is not possible to define Q both simply and precisely for the complete system if any of the conventional definitions of Q is used[2]. If Q is defined as a mathematical parameter however, it can be stated that the Q of the complete system is precisely $(1 + \alpha\beta)$ times the Q of the feedback network. Properties of more practical interest can always be derived, once the form of response has been precisely defined in the above manner. For example, Fig. 5(b) illustrates the vector locus corresponding to the bracketed portion of equation (10). If the rate of change of phase with frequency is considered for the vectors AD and BD, particular interest attaches to the in-phase condition at C. For the vector AC it is apparent that the rate of change of phase is $\alpha\beta/(1 + \alpha\beta)$ times that for the vector BC. For the in-phase condition therefore, the rate of change of phase for the feedback amplifier is $\alpha\beta$ times the rate of change of phase for the feedback network.

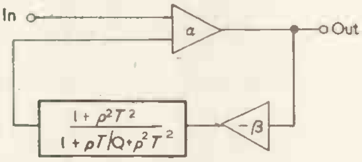

Fig. 5(a) Feedback amplifier

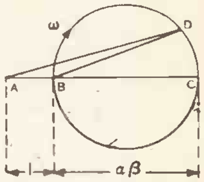

Fig. 5(b). Vector locus for Fig. 5(a)

It has in fact been proposed[2] that the rate of change of phase with frequency should be taken as a measure of Q. This type of definition has advantages in certain applications, but suffers from the disadvantage that Q is then a function of the method of using a circuit, rather than of the circuit itself. With reference to the circuit of Fig. 1(a) for example, if V_5 is the output, $Q_5 = (1/R)\sqrt{(L/C)}$ on the phase-shift definition. If V_6 is taken as the output, inspection of Fig. 1(b) shows that the Q value would be $Q_6 = Q_5R_1/R_2$, which tends to infinity as R_2 tends to zero. It will be observed that Q as defined in this way is not limited to values of less than $\frac{1}{2}$ for *RC* circuits.

The term Q has already too many uses[3], and it might be thought that an additional type of definition as proposed in this article merely aggravates the situation. However, the definition of Q as a mathematical parameter embraces most of the previous definitions, and also extends to certain aperiodic systems for which Q has been used without precise definition. The definition as proposed in this article confines the concept of Q to second order systems. It remains possible, however, to speak of the Q of each second order mode of a higher order system. If other definitions are employed, Q can certainly be "determined" for higher order systems, but has little meaning except in conjunction with a complete specification of the conditions of calculation or measurement.

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Multi-Channel Counter Batching

P. Huggins*, A.M.Brit.I.R.E.

A description of a technique for totalizing information from several random inputs, so that mechanical batching action may be initiated at a pre-selected total. After dealing with the general theory, a specific problem and its practical solution is described.

IN this article, counter batching is treated as an electronic technique comprising a photo-electric transducer, a multi-stage Dekatron counter, an electronic storage and an electro-mechanical batching device. This is for convenient presentation only, and is not intended as a limitation. The system outlined applies to any perception transducer, counter, storage device and batcher. In fact, the principles apply equally to an entirely mechanical counter batcher, or to any combination of physical techniques.

A multi-channel input system has two main advantages over a single channel system.

1. From a production point of view it is possible to feed into the counter batcher from several machines simultaneously, and have single line continuity of batched parts as output, thus leading to increased production.
2. From a computational point of view, it is possible to collate random information from several independent sources (and of several different kinds) and act upon a total.

Practical Considerations

Generally speaking the practical applications fall into one of two categories

(a) The information arrives randomly in every channel.

(b) The information fed into each channel arrives at approximately the same rate, but there is no correlation between channels. While in case (a) there may be an occasional coincidence of information in different channels, in case (b) there may be long periods where two or more channels simultaneously get "in-phase" information from the perception devices.

Hence, it is impractical to feed the information directly from transducer to counter. Nor is it a solution to aportion fixed time delays to each channel. To cope with the exigency of simultaneous objects some form of marshalling the information must be employed before presenting the pulses to the counter. This is conveniently carried out by memory storage methods.

In the method here described, each perception channel has its own storage unit (Fig. 1) which "remembers" the information (if any). An electronic switching device releases the information from each storage unit in rotation. Only one storage unit is "opened" at a time; all others being quiescent. It is convenient that when the storage is opened it contains either one pulse, or no pulse (i.e., an on-off mechanism). This state of affairs is guaranteed by making the frequency of the sequential switching greater than the maximum arrival rate in any channel.

General Description

The action of the apparatus may be summarized as follows:

Perception heads feed into their respective amplifiers, which in turn put the information pulses into storage.

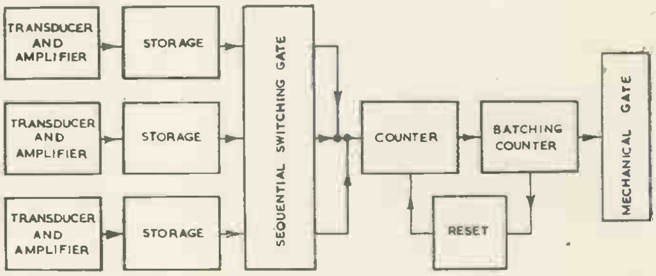

Fig. 1. The multi-channel batching counter

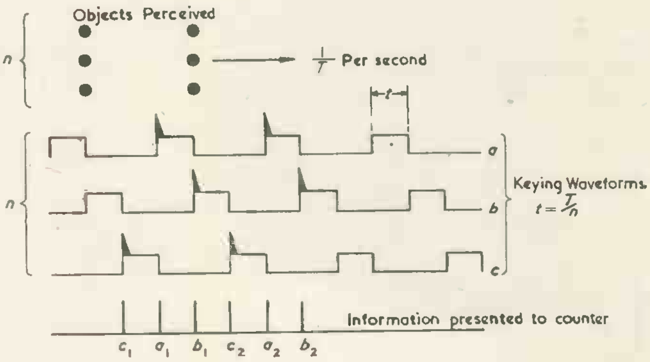

Fig. 2. Theoretical maximum information packing

A gating switch sequentially views each storage unit in rotation, abstracting the information pulse (if any) and passing it to the counter. The counter totalizes the number of impulses received and actuates the batching mechanisms on completion of the preselected batch total.

Storage Theory

The crux of the design lies in the information storage problem. Although the objects arrive randomly and discreetly, they have a mean velocity. This factor will decide the methods of mechanical handling and also the amplifier characteristics. The number of arrive channels (n) is usually predetermined by the user's site requirements. The other important parameter (T) is the minimum arrival

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* *Sargrove Electronics Ltd.*

time interval between two consecutive objects (as distinct from their mean rate of arrival).

Fig. 2 shows a diagrammatic representation indicating the conditions prevailing when $t = T/n$ (where t is the operation time of the gating arrangement). This shows the saturation conditions that exist when the gate frequency is the reciprocal of the minimum distance between consecutive objects. In practice, this is, of course, not emulated and an empirical optimum of $t = T/2n$ has proved a satisfactory solution. However, this diagram illustrates the treatment of the coincident pulse. It will be observed that all three perception heads are energized simultaneously at a frequency equal to $1/T$ per second. Channel c is the first one opened after this moment of time so pulse c_1 is the first admitted to the counter. Pulses a_1 and b_1 are stored and released subsequently—the order of their going being determined by the phase relationship of the gating waveforms. The behaviour pattern is repeated T seconds later, when the three transducers are once again simultaneously excited.

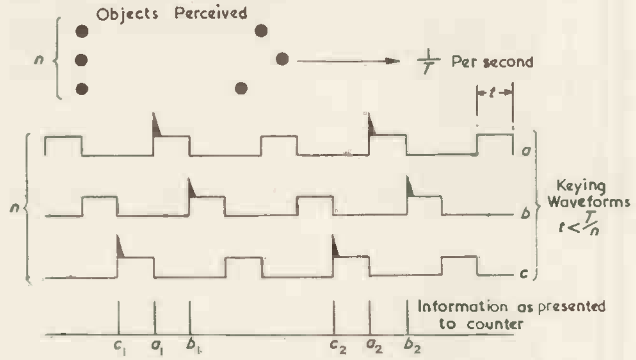

Fig. 3. Typical practical information storage waveforms

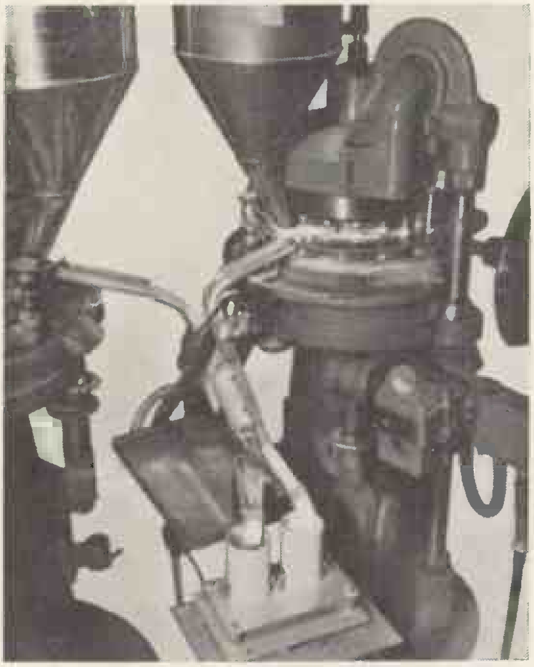

Fig. 4. Two Manesty type DB3 tablet making machines with twin batching mechanism

A more practical case is given in Fig. 3—this corresponds to the design condition: $t = T/2n$.

Twin Channel Tablet Counting

A specific industrial problem solved on these lines will now be described.

Two tablet making machines (Fig. 4) each manufacture 300 pills per minute. It is required to count and batch these into pre-selected totals of up to 999. The minimum distance between consecutive tablets was judged to be 20 per cent of the average figure. Hence, at 300 pills per minute $T = 40$msec.

The empirical formula thus yields $t = 40/2\times2 = 10$ msec for a two-channel system. Since this corresponds to a half cycle at mains frequency the design can be simplified by using the mains as a time-base.

The resolution time of the counter must be better than 10msec (t) and in this application indicates the use of Dekatron valves for counting and batching.

The mechanical aspect of the tablet handling problem is best seen in Fig. 5. The pills feed down independent chutes and pass under two photo-electric transducers. From these, they pass over the ganged twin batching gates and flow into the right-hand carton. On completion of the batch number (say, 500) the batching gates flap open in the vertical plane and consequently the tablet flow is then via the lower exit chute, and thence to the left-hand carton. In this particular application the cartons are removed manually, the operator lidding and labelling the full carton, and then putting an empty one in its place while the other carton is being filled. These cartons stand on a vibrator table which assists in packing the tablets down into their containers. A further feature of the design is a suction system to extract tablet powder from the chutes, thus preventing any clogging of the mechanisms.

Fig. 5. Dual batching mechanism consisting of twin optical system and ganged high speed batching gates for alternate filling of cartons

As a matter of interest, the potential handling power of this two-channel system (with one operator) is five times greater than the older method of single channel, single operator system without electronic batching.

Acknowledgments

The author would like to thank the directors of Messrs. Sargrove Electronics Ltd., Hounslow, for permission to publish this article, and Messrs. Wm. R. Warner Ltd., of Chiswick, Middlesex, for permission to use photographs of equipment supplied to them.

A.C. Voltage Stabilizers

By W. M. Dalton, A.M.Brit.I.R.E.

The operation of the output stage of the valve operated A.C. *mains stabilizer is analysed with the aid of load lines and the relative advantages of various modes of operation are briefly discussed.*

THE majority of voltage stabilizers are considered to operate as servo-mechanisms in which a fixed reference voltage is provided from which an error detector gives an input to be amplified and passed to a power source which bucks or boosts the supply (Fig. 1).

The difficulty of providing a reference voltage is considerably increased with an A.C. unit, for not only must the amplitude be stable, but its phase must be locked to the supply. Various types of reference-detector units have been described by Patchett and others and if merely a reference voltage is required those of Martin and Maddock[1] and Attree[2] slightly modified, will provide the stable low power supply.

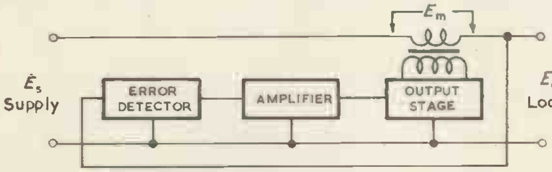

Fig. 1. Voltage stabilizer closed circuit system

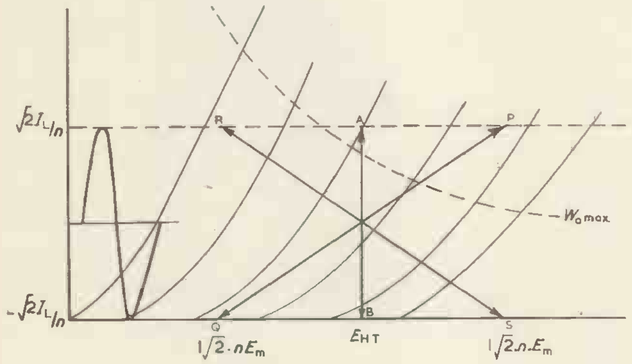

Fig. 2. Load lines on triode curves

Perhaps the only standard part of the stabilizer is the amplifier. Patchett has shown[3] that the output stage differs from a power amplifier in that, subject to the transformer ratio, the full load current flows in the valve(s) at all times. The valves provide power when boosting and absorb power when bucking. This is shown by the load lines RS and PQ respectively in Fig. 2. A single class-A stage is used for convenience, but the argument is equally applicable to the push-pull class-B stage.

It should be noted that when drawn on pentode curves (Fig. 3), the same grid swing is demanded for all load lines or the degree of buck and boost cannot be controlled by amplifying the error voltage. The triode curves are more satisfactory, but two difficulties arise at balance: firstly, with no anode voltage change the full current flows, i.e. the valve has zero resistance, and secondly a definite input is required to provide this current. At balance there should be no error to amplify and therefore no grid input.

First, however, consider another aspect. When absorbing power, the load line PQ passes beyond the maximum dissipation of the valve. It must also be remembered that the H.T. for the valves is obtained from the (unstabilized) supply and when bucking (absorbing power) the H.T. is also higher. To keep the output sinusoidal, the grid bias must also change, and with automatic bias the centres of the load lines will change as shown in Fig. 4, making the overheating worse. The same thing will happen in the push-pull stage. This can produce severe distortion on a step input change.

The improved operation from the lower r_a triode makes the cathode-follower the next logical approach. Here again, although an improvement is obtained as $1/g_m$ becomes less, similar results are obtained and one comes to the conclusion that the equipment ought not to work. Another method of stabilization has been suggested[4] using the controller in parallel with the load (Fig. 5). In this case the load voltage must always be equal to the supply voltage and it is even more obvious that the system cannot work.

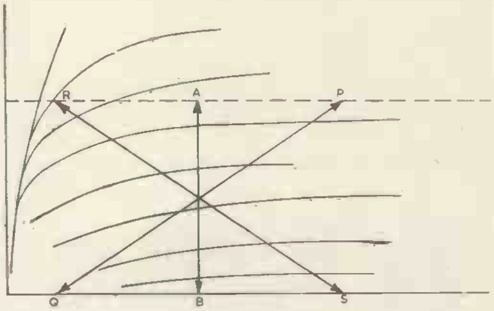

Fig. 3. Load lines on pentode

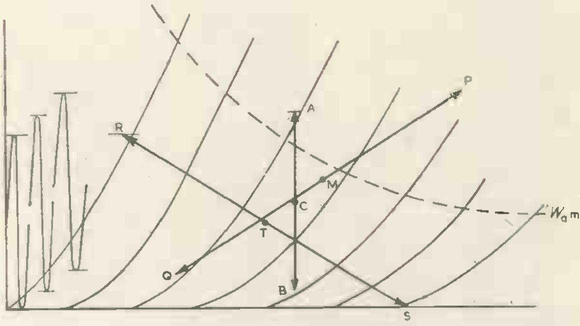

Fig. 4. Effect of changes of H.T.

The parallel system could work if the input was transformed to a higher voltage (ratio 1 : *p*) and a series resistor (*R*) used to drop the voltage to that required. This circuit is shown in Fig. 6 and using the notation given in the Appendix it can be shown that:

$$R = R_o(p - 1) \quad \ldots\ldots\ldots\ldots \quad (1)$$

$$E_a = n \,.\, E_o \quad \ldots\ldots\ldots\ldots \quad (2)$$

$$\pm I_a = \pm I_o \,.\, d \,.\, p/n(p - 1) \quad \ldots\ldots\ldots \quad (3)$$

$$\pm W_a = \pm W_o \,.\, d \,.\, p/(p - 1) \quad \ldots\ldots\ldots \quad (4)$$

$$W_r = W_o(p \pm d \,.\, p - 1)^2/(p - 1) \quad \ldots\ldots \quad (5)$$

$$= [p - 1 \pm 2d \,.\, p + d^2 \,.\, p^2/(p - 1)]W_o \quad \ldots \quad (6)$$

These figures for $d = 10$ per cent input variation and for

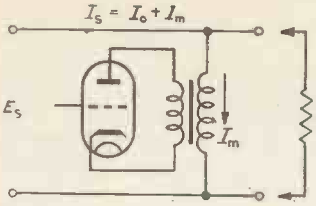

Fig. 5 (left). Shunt control

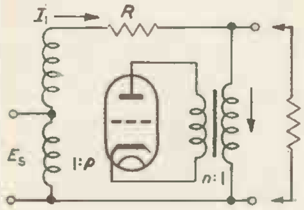

Fig. 6 (below left). Modified shunt

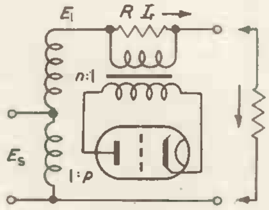

Fig. 7 (below right). Modified series

various values of p are given in Table 1. Here the H.T. supply at minimum supply voltage must be greater than $\sqrt{2} \cdot n . E_o$, but it will be seen that for value of $p = 1{\cdot}4$ the power in the valves, when absorbing or providing power is only a third of that in the load.

Similarly values can be calculated for the series circuit, where the values of R/R_o, $n . I_a/I_o$ and W_r are the same as for the parallel circuit. The important difference with this circuit is that the value of both I_a and E_a change with p. E_a varying by

$$E_a = n . E_o(p - 1 \pm d . p) \quad \ldots\ldots\ldots\ldots \quad (7)$$

This makes the power provided by the valve vary:

$$\pm W_a = \pm d . p . W_o + d^2p^2W_o/(p - 1) \quad \ldots. \quad (9)$$

and the watts dissipated by the resistor are:

$$W_r = W_o(p - 1 \pm d . p)^2/(p - 1) \quad \ldots.. \quad (10)$$

These figures for $d = 10$ per cent input variation and for various values of p are given in Table 2. It will be seen that a marked improvement in the valve dissipation is obtained. When using a step-up of $p = 1{\cdot}4:1$, the valve power at maximum buck is only 0·189 of the output power.

This valve power is actually a minimum when $p = 1 \pm \sqrt{(d/(d + 1))}$.

When operating in this manner it will be seen that when bucking, the valve provides power to increase the drop in the resistor for all values of p. When boosting, however, the valve operates differently according to the value of p. When p is less than $1/(1 - d)$, the valve carries the load current and also provides power to give a reversed voltage drop across the resistor. When $p = 1/(1 - d)$ the valve carries the full load current only at maximum boost, when the anode voltage is zero. For larger values of p, the valve absorbs power, but carries less and less of the load current as p increases, giving a minimum power in the valve when $p = 1 \pm \sqrt{(d/(d - 1))}$. The load lines for $p = 1{\cdot}4$ and $d = 10$ per cent are shown in Fig. 8, where the curves show clearly that the best type of valve is a pentode in which the anode current need not change, while the voltage is swinging. It might also be noticed that the largest anode swing is required when bucking, or when the H.T. is greatest.

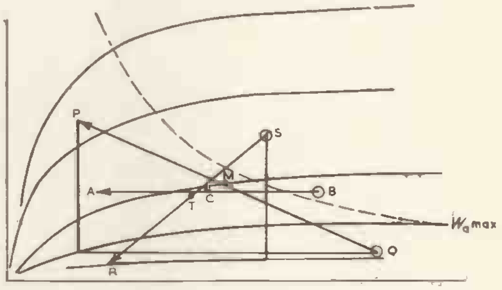

Fig. 8. Load lines

At first sight it might be thought that using the transformer will lower the efficiency of the unit. It must, however, be remembered that the control valve is operated from the supply and even in class-B, the overall efficiency —including filament power—is below 50 per cent. Assuming such an efficiency, the figures of Table 3 show that the overall efficiency is improved by using a transformer and is highest when the valve barely supplies power at maximum boost.

TABLE 1

Parallel Control ± 10 per cent input variation

p	R_d/R_o	$\pm n. I_a T_o$	W_a/W_o	W_r High	W_r Low	W_s/W_o High	W_s/W_o Low
1·0	0	00	00	00	00	00	– 00
1·025	0·025	4·1	4·1	0·65	0·024	5·75	– 2·86
1·05	0·05	2·1	2·1	0·48	0·055	3·58	– 1·04
1·1	0·1	1·1	1·1	0·44	0·001	2·54	– 0·099
1·2	0·2	0·6	0·6	0·51	0·032	2·11	+ 0·43
1·4	0·4	0·35	0·35	0·73	0·17	2·07	+ 0·82
1·8	0·8	0·225	0·225	1·2	0·48	2·42	+ 1·256

– W_s/W_o means that the valve supplies power to the input.

TABLE 2

Series Control ± 10 per cent input variation

p	High Input W_s/W_o	High Input W_a/W_o	High Input W_r/W_o	Low Input W_s/W_o	Low Input W_a/W_o	Low Input W_r/W_o
1·0	1·1	00	00	0·9	00	00
1·025	1·128	0·523	0·65	0·923	– 0·3175	0·024
1·05	1·155	0·33	0·48	0·945	– 0·1155	0·055
1·1	1·21	0·231	0·44	0·99	– 0·011	0·001
1·2	1·32	0·192	0·51	1·08	+ 0·048	0·032
1·4	1·54	0·189	0·73	1·26	+ 0·09	0·169
1·8	1·98	0·222	1·2	1·62	+ 0·14	0·48

$W_s = W_r\ W_o - W_a$ *high* or $W_s = W_r + W_o + W_a$ low.

The effect of varying the load must be considered. It can be shown that this will cause no change of E_a, but if the load current varies to $a . I_o$, where a can be less or greater than unity, the anode current I_a will vary to absorb this change of current:

$$I_a = I_o(a - 1) \pm p . d . I_o/(p - 1)$$

This will give a greater or less dissipation in the valve but the change of current is merely in the resistor (at E_a) and the power required is considerably less than that dissipated by any attempt to maintain constant load on the unit.

TABLE 3

Operating Efficiencies
(*Efficiency* = $W_o/W_s + 2W_a$)

p	AT BALANCE (per cent)	PARALLEL HIGH (per cent)	PARALLEL LOW (per cent)	SERIES HIGH (per cent)	SERIES LOW (per cent)
1·0	100	zero	zero	zero	zero
1·05	96	7·2	21	47	65
1·025	91	13	31	46	85
1·1	83	21	50	60	99
1·2	70	30	62	59	85
1·4	51	40	66	52	70
1·8	31	35	59	41	53

Assuming Valves to be 50 *per cent efficient.*

The circuit of Fig. 7 thus provides an output stage operating in the manner originally specified. The next problem is its control.

In general there are two methods of controlling a stabilizer; the closed circuit method, shown in Fig. 1 and the open circuit control of Fig. 9, where the control is effected from the supply side. Each of these methods requires a reference voltage and an error detector, although these may be combined in the one unit.

Considering the reference voltage, this can be A.C., or D.C. An A.C. reference voltage is difficult to obtain and this must be locked to the supply frequency for supply voltage changes are usually accompanied by changes of frequency —or progressive change of phase if preferred. A D.C. reference is easily obtained, but there follows a time delay in the smoothing system and the trouble of reconverting the D.C. to A.C. Lamp bridges, saturated diodes and other devices operating on thermal effects also suffer from similar delays.

Open circuit control was abandoned by Patchett because it did not compensate for changes of load and because improved regulation and less distortion was obtained by the "feedback" of the closed circuit. The use of the series resistor, which must be adjusted to suit the load, makes the first reason invalid and one must be careful of definitions when referring to the closed circuit as a feedback system.

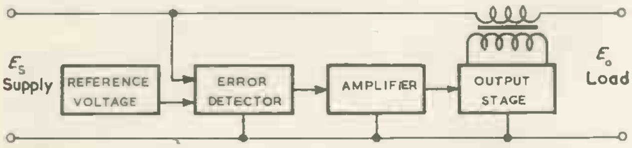

Fig. 9. Open circuit system

In the closed circuit, the voltage fed back is not a portion of the output of the amplifier, but is a portion of the error that the amplifier plus the supply voltages make with the reference voltage. As the amplifier provides only one-seventh of the power in the load even at maximum buck, it is obvious that one is feeding back from the supply rather than from the amplifier.

With the closed circuit control, except at balance, there must always be an error which can be amplified to provide the control. The gain of the amplifier has to be large in order that this fixed error shall be small. Distortion in the amplifier: 7 per cent distortion means only 1 per cent in the load and this, being wholely error, is fed back for re-amplification in a direction to buck the supply. Any harmonic distortion in the amplifier may thus be increased, being out of phase with the supply. The harmonics in the supply will provide an error in the same way, but these will be reduced by the amplifier gain. Distortion in the reference source will be faithfully reproduced.

The open-circuit control has no fixed error and the amplifier gain has only to be unity. Thus with this method a large amount of feedback can be used in the amplifier—as distinct from overall—to achieve zero gain. Distortion in this amplifier is not corrected, but is small compared with the supply and is not fed back. Distortion in the supply is reduced or suppressed provided that the reference source has a sinusoidal output. The purity of an A.C. reference source must be emphasized.

From the above it will be seen that there is little to choose between the two systems on the score of distortion. Changes of amplifier gain are usually downwards, and this gives increased stability, but a larger fixed error to the closed circuit system. This error, however, is smaller than that produced for the same change of gain when using the open circuit system. It should, however, be easier to maintain a gain of unity than one of 99 or 999 times.

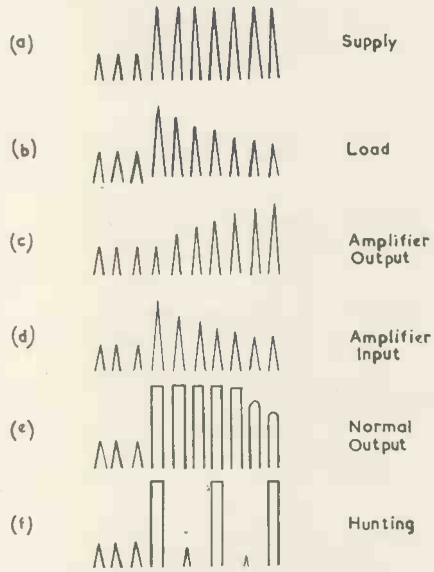

Fig. 10. Effect of step-function with closed circuit control

The effect of changes of temperature is confined to the reference source and the error detector and provided that the amplifier is reasonably flat the effects of change of frequency should also be confined to these sources. The time of response can be a function of the source-error detector, but it can also be a function of the method of control.

Consider the action of a step rise of input to the closed circuit control. The load voltage will tend to rise to follow the step, thereby providing a large error which falls as the output bucks the supply. This is shown in Fig. 10, where (a) shows the change of supply voltage and (b) is the load voltage. The output from the amplifier must then be as in (c), while the input to the amplifier is as in (d). Obviously both (c) and (d) cannot be correct and in practice the large initial error overloads the amplifier (requiring Metrosil or other protective devices), bucking the output down to balance where a "capture" effect takes place. If the amplifier gain is excessive, and there is a delay in the error detector-convertor circuits, the output can be bucked below balance to be followed by a boost, buck, boost in which the output varies more than the supply.

This tendency to hunt is an accepted part of the theory of servo-mechanisms where it would be due to the inertia of the load. In this case the cause is the time delay in the "differential". The absence of any tendency to hunt when using the open circuit control is perhaps a feature which outweighs the disadvantage of changes with output load.

It is possible to combine both methods, using the open circuit for supply changes and the closed circuit for load changes. As the load changes are small and infrequent, the open circuit can be made instantaneously acting while the closed circuit can have a small loop gain and an integrating circuit incorporated to delay its action and so prevent hunting.

APPENDIX

SYMBOLS:

E_s, W_s = voltage and watts from supply
$d \,.\, E_s$ = variation of supply voltage
E_o, I_o, W_o = volts, amperes and watts in load
E_r, I_r, W_r = volts, amperes and watts in resistor
E_a, I_a, W_a = volts, amperes and watts in valve
p = supply transformer step-up ratio
n = output transformer step-down ratio
a = fraction change of load

PARALLEL CIRCUIT (Fig. 6)

At Balance:

$$E_a/n = E_o = E_s; \;\; I_r = I_o; \;\; I_a = I_r - I_o = \text{zero}$$

$$E_r = I_o \,.\, R = E_o(p-1) \text{ Thus } R = R_o(p-1) \quad \dots \quad (1)$$

Off Balance:

$$E_a = n \,.\, E_o \quad \dots\dots\dots\dots \quad (2)$$

$$p \,.\, E_o(1 \pm d) = E_o + R(I_o \pm n \,.\, I_a) = E_o + E_o(p-1) \pm n \,.\, R \,.\, I_a$$

or $\pm\, n \,.\, R \,.\, I_a = \pm\, d \,.\, p \,.\, E_o$ Substituting for R in (1) gives

$$I_a = d \,.\, p \,.\, I_o/n(p-1) \quad \dots\dots\dots\dots \quad (3)$$

$$W_a = n \,.\, E_o \,.\, d \,.\, p \,.\, I_o/n(p-1) = d \,.\, p \,.\, W_o/(p-1) \quad \dots \quad (4)$$

$$\begin{aligned} W_r &= (p \,.\, E_o \pm d \,.\, p \,.\, E_o - E_o)(I_o \pm n \,.\, I_a) \\ &= E_o \,.\, I_o(p \pm d \,.\, p - 1)[1 \pm d \,.\, p/(p-1)] \\ &= W_o(p \pm d \,.\, p - 1)(p - 1 \pm d \,.\, p)/p - 1) \\ &= W_o(p - 1 \pm d \,.\, p)^2/(p-1) \quad \dots\dots\dots\dots \quad (5) \end{aligned}$$

SERIES CIRCUIT (Fig. 7)

At Balance:

$$E_a/n = E_o(p-1); \; I_a = \text{zero}; \; R = R_o(p-1) \quad \dots \quad (6)$$

Off Balance:

$$\begin{aligned} E_a/n = E_r &= p \,.\, E_o(1 \pm d) - E_o \\ &= E_o(p - 1 \pm d \,.\, p) \quad \dots\dots\dots\dots \quad (7) \end{aligned}$$

$n \,.\, I_a = I_o - E_r/R$ and substituting for R in (6) gives

$$I_o - E_o(p \pm d \,.\, p - 1)/R_o(p-1) = I_o[1 - 1 \pm d \,.\, p/(p-1)]$$

or

$$I_a = \pm I_o \,.\, d \,.\, p/n(p-1) \quad \dots\dots\dots\dots \quad (8)$$

$$W_a = Ea \,.\, Ia = \pm p \,.\, d \,.\, W_o + p^2 \,.\, d^2 \,.\, W_o/(p-1) \quad \dots \quad (9)$$

$$\begin{aligned} W_r = E_r(I_o \pm n \,.\, I_a) &= E_o \,.\, I_o(p - 1 \pm d \,.\, p)[1 \pm d \,.\, p/(p-1)] \\ &= W_o(p - 1 \pm d \,.\, p)^2/(p-1) \quad \dots\dots\dots\dots \quad (10) \end{aligned}$$

W_a is zero when $-d \,.\, p = d^2 \,.\, p^2/(\mathrm{p}-1)$

or when

$$p = 1/(1-d) \quad \dots\dots\dots\dots \quad (11)$$

W_a is minimum when $\delta \,.\, W_a/\delta \,.\, p = 0$

$$\begin{aligned} 0 &= \frac{(p-1)(2d^2 \,.\, p + 2d \,.\, p - d) - d^2 \,.\, p^2 - d \,.\, p^2 + d \,.\, p}{(p-1)^2} \\ &= d^2 \,.\, p^2 + d \,.\, p^2 - 2d^2 \,.\, p - 2d \,.\, p + d \end{aligned}$$

or when

$$p = 1 \pm \frac{\surd(d^2 + d)}{(d+1)} = 1 \pm \surd(d/(d+1)) \quad \dots\dots \quad (12)$$

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The Measurement of Transistor Characteristics

J. Ewels* Ph.D., A.Inst.P.

SINCE transistors can be permanently damaged very easily by an accidental overload, and considerable changes in their characteristics can occur through overheating or by faulty insertion in live circuits, it is essential that their performance can be rapidly checked under standard conditions. An apparatus is described with which certain network parameters, the gain and the noise factor can be rapidly measured; these parameters are defined.

Definition of Parameters

The application of four pole network theory[1] to transistors shows that the small signal properties can be uniquely determined by four independent quantities relating the instantaneous input and output voltages and currents shown in Fig. 1. The particular set of parameters used depends on the type of transistor and the method of measurement. Thus, for point contact transistors, four impedances are found to be most convenient. These are defined by the equations:

$$\begin{aligned} v_1 &= R_{11}\, i_1 + R_{12}\, i_2 \\ v_2 &= R_{21}\, i_1 + R_{22}\, i_2 \end{aligned}$$

In these equations v_1, v_2, i_1 and i_2 are variables and R_{11}, R_{12}, R_{21} and R_{22} are constants. The measurement of these impedances requires the collector and emitter to be open-circuit to alternating currents and for different measurements, i.e. either i_1 or i_2 to be zero.

For junction transistors, which have high collector impedances, these conditions are impracticable and the "hybrid parameters" are more convenient. These are defined by the equations:

$$\begin{aligned} v_1 &= h_{11}\, i_1 + h_{12}\, v_2 \\ i_2 &= h_{21}\, i_1 + h_{22}\, v_2 \end{aligned}$$

It should be noted that h_{11} is an impedance, h_{22} is an admittance and h_{12} and h_{21} are ratios. Measurement of the hybrid parameters requires the emitter to be open-circuit, i.e., i_1 to be zero and the collector to be short-circuit, i.e., v_2 to be zero. Further, it is important to understand that the two sets of parameters are measured,

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* *E.M.I. Engineering Development Ltd.*

under different conditions, so that R_{11} is not equal to h_{11}, and R_{22} is not $1/h_{22}$.

For design purposes these parameters are not useful and it is more convenient to use the *T*-equivalent circuit shown inside the dotted lines of Fig. 1, since the resistances of this circuit are associated with the physical construction of the transistor. The relationships between these resistances and the impedances and hybrid parameters are:

$$\begin{aligned} r_e &= R_{11} - R_{12} &&= h_{11} - h_{12}/h_{22}\ (1+h_{21}) \\ r_b &= R_{12} &&= h_{12}/h_{22} \\ r_c &= R_{22} - R_{12} &&= 1/h_{22}\ (1-h_{12}) \\ r_m &= R_{21} - R_{12} &&= 1/h_{22}\ (h_{21}-h_{12}) \end{aligned}$$

These dynamic measurements are most easily made by adding a small alternating current to the D.C. bias and measuring the resultant alternating voltages and currents.

Noise Factor

A further property which it is often desired to measure is the noise factor. For this purpose an appropriate load resistor and a voltage input from a source of known impedance are required.

The noise factor[2] is given by

$$F = \frac{v_n^2}{4kTR_1\ (f_2 - f_1)\ A_v^2}$$

where v_n is the mean noise voltage measured over a bandwidth of $(f_2 - f_1)$, A_v is the voltage gain of the transistor under the same conditions, R_1 is the source impedance, *T* is the absolute temperature and *k* is Boltzmann's constant.

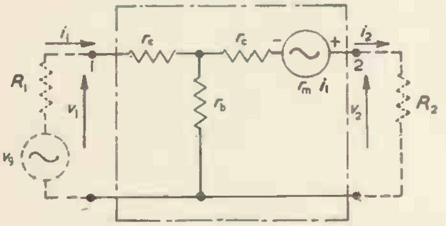


Fig. 1. Equivalent circuit of transistor

Apparatus

The circuit diagram of the apparatus is shown in Fig. 2. In this apparatus, the bias currents are supplied from H.T. batteries through a resistor and choke; these prevent excessive leakage of alternating current to the batteries.

For D.C. measurements, the A.C. supply is disconnected by S_{1a}; for A.C. measurements $S_{1b,c}$ disconnect the D.C. voltmeters.

Switch S_2 permits a choice of input; either:

(a) a constant current can be passed through the emitter or collector or

(b) a low impedance voltage generator, in series with a predetermined source impedance R_1, can be connected to the emitter.

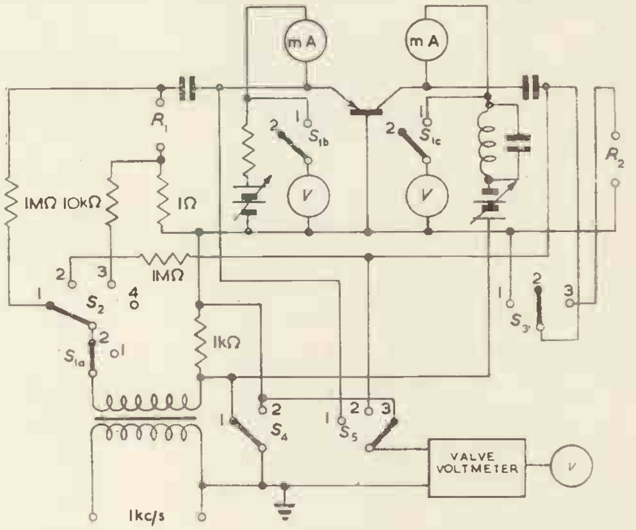
By manipulation of S_3 the load in the collector circuit can be made zero, or a nominal open-circuit (i.e., 200kΩ —the D.C. circuit impedance) or resistor R_2. The voltage at the emitter or collector, or the current flowing in the circuit selected can be measured on a valve-voltmeter by selection of the appropriate positions of switches S_4 and S_5.

Parameter Measurements

The procedure for the measurement of the impedances and hybrid parameters is shown in the table given with Fig. 2. A convenient value for the input current, when normal bias is applied, is 50μA. This is considerably larger than any noise levels likely to be encountered, but is small enough to avoid transgressing the non-linear portions of the characteristics. Impedance parameter measurements can be made to an accuracy of 3 per cent on point contact transistors whose collector impedance is less than 20kΩ.

Gain and Noise Measurements

For noise measurements a selective filter which has a bandwidth of 60c/s and a mid-frequency of 1kc/s is provided in the valve-voltmeter. Suitable values of R_1 and R_2 are 500Ω and 10kΩ for point contact transistors and 500Ω and 100kΩ for junction transistors; low noise components (wire-wound) should be used in these positions. With S_2 in position 3 the voltage gain (A_v) of the transistor may be measured by comparison of readings with S_5 in position 3 (when the reading is 1 000 × input volts) and position 2 (when the reading is the output volts). If the A.C. input is then disconnected by switching S_2 to position 4, the mean noise voltage can be read; noise factors of more than 30db may be measured in this way.



IN EACH CASE SET UP D.C. CONDITIONS WITH S_1 IN POSITION 1, THEN SWITCH S_1 TO POSITION 2 FOR A.C. MEASUREMENTS	
To measure— $R_{21}\left(=\frac{v_{21}}{i_1}\right)$ and $R_{11}\left(=\frac{v_1}{i_1}\right)$ 1. S_2 to position 1 2. S_3 to position 2 3. S_4 to position 1 4. S_5 to position 3 $\left(\text{Note } i_1=\frac{v}{1000}\right)$ 5. S_4 to position 2 6. S_5 to position 2 (Note v_2) 7. S_5 to position 1 (Note v_1)	To measure— $R_{22}\left(=\frac{v_2}{i_1}\right)$ and $R_{12}\left(=\frac{v_1}{i_2}\right)$ 1. S_2 to position 2 2. S_3 to position 2 3. S_4 to position 1 4. S_5 to position 3 $\left(\text{Note } i_2=\frac{v}{1000}\right)$ 5. S_4 to position 2 6. S_5 to position 2 (Note v_2) 7. S_5 to position 1 (Note v_1)
To measure— $h_{21}\left(=\frac{i_2}{i_1}\right)$ and $h_{11}\left(=\frac{v_1}{i_1}\right)$ 1. S_2 to position 1 2. S_3 to position 3 (R_2=1000Ω) 3. S_4 to position 1 4. S_5 to position 3 $\left(\text{Note } i_1=\frac{v}{1000}\right)$ 5. S_4 to position 2 6. S_5 to position 2 $\left(\text{Note } i_2=\frac{v}{1000}\right)$ 7. S_5 to position 1 (Note v_1)	To measure— $h_{22}\left(=\frac{i_2}{v_2}\right)$ and $h_{12}\left(=\frac{v_1}{v_2}\right)$ 1. S_2 to position 2 2. S_3 to position 2 3. S_4 to position 1 4. S_5 to position 3 $\left(\text{Note } i_2=\frac{v}{1000}\right)$ 5. S_4 to position 2 6. S_5 to position 2 (Note v_2) 7. S_5 to position 1 (Note v_1)

Fig. 2. The circuit used and the procedure for measuring parameters

Acknowledgments

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The Driven Clamp in the Presence of Noise

By P. B. Helsdon*, A.M.Brit.I.R.E.

The line by line black level clamp, as used in television systems, is discussed as an error sampling and subtraction process. The best value of the clamp time-constant is also considered.

An error free non-composite television signal conveys information only during the picture period. There is no information conveyed during the blanking period, since it is known that it represents the black level which is a constant. If, however, the television signal is mixed with an error signal, which is low in frequency compared with the line blanking frequency, the error signal can be detected by sampling the level during the blanking period. The difference between the sampled level and the known black level is a measure of the error at that instant. This error can be stored and subtracted from the next line leaving only a residue of error, which is the change of error during that line. The lower the frequency of the error signal, the lower is its rate of change for a given waveform. Consequently this error sampling, storing and subtraction system works best for low frequency error signals.

The operation of error detection, storage and subtraction is combined in the "driven clamp" circuit shown in Fig. 1. An idealized form of the clamp is shown in Fig. 2 where the diodes are represented by a switch and a single resistor represents the previous anode load and the diode impedances, etc.

Consider first the operation of the circuit (Fig. 2) under error free conditions. The input consists of a noise- and error-free television signal. During the blanking period the signal level at the input is zero. When the switch is closed for the sampling period (within the blanking period) there is, therefore, no potential to charge the capacitor. During the picture period, the switch is open and the clamp time-constant becomes very large so that picture signals at the input pass through the capacitor to the output unchanged. A constant D.C. potential added to the input causes the capacitor to charge through the resistor during the sampling periods, to a potential equal to the added D.C. When steady state conditions prevail the equal potentials cancel at the output and so the added constant D.C. may be neglected.

When a low frequency error signal is added to the noise-free television signal, the level at the input is no longer zero during the sampling period. Consequently the capacitor charges through the resistor during this period. If the time-constant of the circuit is small compared with the sampling period, the capacitor charges to a potential equal to the error signal at that time. This charge is stored throughout the picture period. The signal at the output then consists of the sum of the television signal, the error signal and the potential due to the stored charge on the capacitor. This stored potential is in opposition to the error signal, so these cancel, leaving only the television signal and the change of the error signal during the picture period. With the clamp time-constant equal to the sampling period though, the capacitor is charged to only 62 per cent of the error potential, leaving 38 per cent to be corrected. A relatively constant error signal is therefore corrected in steps, the steps becoming negligible more rapidly for a shorter clamp time-constant. When the clamp time-constant is one third of the sampling period an error is reduced to 5 per cent at each sample.

If the television signal contains noise the black level established by the clamp becomes subject to a noise error due to the non-zero value of the noise during the sampling period[1]. This noise error is also stored in the capacitor during the picture period. Should the signal-to-noise ratio in the television signal be low, this noise error can be greater than the error signal, thus defeating the object of the clamp. The magnitude of the noise error for a given signal-to-noise ratio is dependent upon the relative values of the clamp time-constant, the sampling period and the reciprocal of the noise bandwidth. When the sampling period is not long compared with the reciprocal of the noise bandwidth, involved statistical laws come into play. In practical clamps the sampling period is long, so that the noise bandwidth can be neglected and the analysis simplified. The maximum initial noise error for a given noise pulse develops when the noise pulse occurs at the end of the sampling period. The same noise pulse occurring earlier in the sampling period causes less noise error. For example, if the noise pulse is assumed to be rectangular with a duration equal to the clamp time-constant and the sampling period is three times this, the noise error will be 62 per cent of the noise pulse amplitude when the noise pulse occurs in the last third of the sampling period, but when the same noise pulse occurs in the first third the noise error is only about 10 per cent.

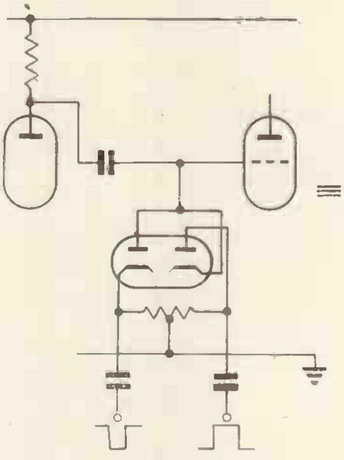

Fig. 1. The "driven clamp"

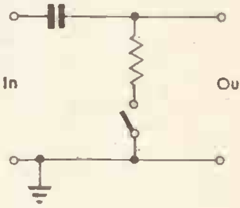

Fig. 2. An idealized clamp

Now with wideband random noise of uniform spectrum, a noise pulse of given amplitude and duration has equal probability of occurrence at any time. Therefore for a given clamp time-constant the initial noise error is independent of the sampling period, although as seen above, the number of steps required to reduce the initial noise error to a given fraction is dependent upon the ratio of the sampling period to the clamp time-constant. The initial noise error is less for a longer clamp time-constant, but for a given sampling period, a greater number of steps are required to reduce it to a given fraction.

The sampling period is limited to the duration of the blanking interval, or it may be less depending upon other considerations. The value of the clamp time-constant must therefore be a compromise between the number of steps required to reduce a relatively constant error signal to negligible proportions and the noise error introduced through sampling the noise in the signal. The best compromise value depends upon the visibility of the various error signals in the displayed picture and is a subjective consideration.

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* *Marconi's Wireless Telegraph Co., Ltd.*

A Simplified Circuit and Conductimetric Tube for Chemical Analysis at Low-Frequency

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

This article describes a circuit in which transformers are replaced by a single iron-cored choke and capacitors. Protection to operation is provided by limiting resistances. A formula for dipper calibration is given and a new and more accurate method of solution measurement and delivery "Dipper draining" is described.

A new type of "Conductimetric tube" displaces the usual "conductivity cell"; this can be immersed in any quantity of solution. An adjustable resistor standard is described, also a tubular solution container which, making use of liquid displacement, requires only 10cm³ of solution for titrations, etc.

THE circuit arrangements described are designed for A.C. operation. While equally effective as other A.C. methods in obviating the cumulative action of polarization and for accuracy in general use, they provide an inexpensive and simplified method for conducting electro-chemical analysis and titration.

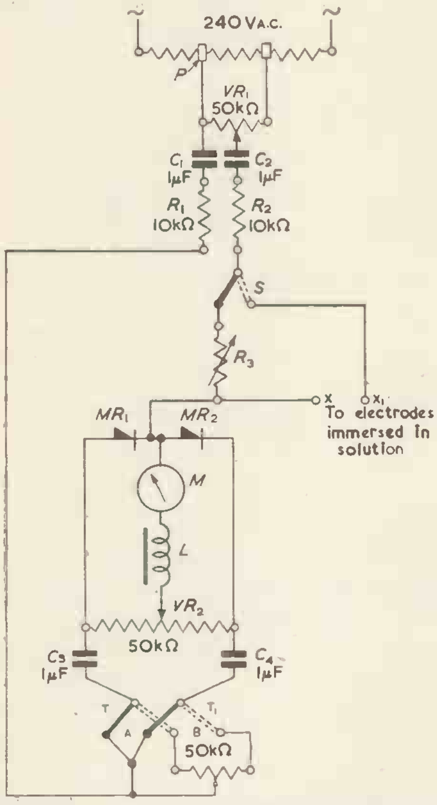

Fig. 1. Simplified A.C. circuits for chemical analysis, titration, measurements of concentration, etc.

When operated by the B *circuit the opposing currents from* MR_1 *and* MR_2 *are slightly unbalanced to provide the required micro-amperage.*

A potential divider displaces the usual step-down transformer and a single iron-cored choke and capacitors take the place of a transformer specially wound to match the microammeter.

The circuit shown in Fig. 1 can be employed for the measurement and comparison of solution concentrations, for titration and to observe delayed chemical reactions, etc. The author has employed it recently to compute the cubic delivery capacity of dippers and microdippers[1,2] and afterwards to compare their calibrations with those obtained by rectified radio-frequency[2]. The circuit presents several new features. The mains voltage after suitable reduction by a potential divider P is finely regulated by means of a potentiometer VR_1. C_1 and C_2 are two 1μF capacitors. R_1 and R_2 are two 10kΩ resistors; these are provided to limit the current and ensure the safety of the operator.

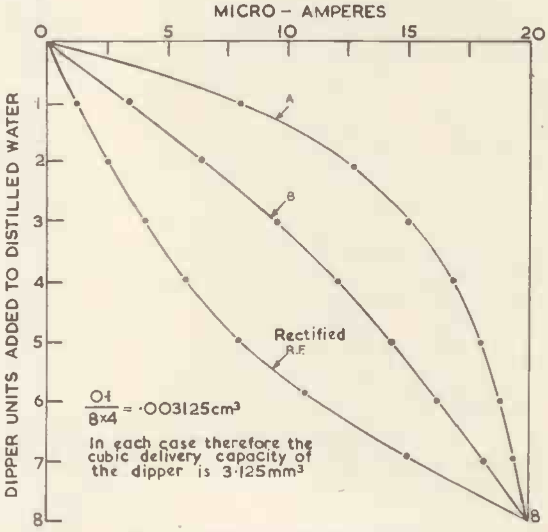

Fig. 2. Dipper calibration curves

R.R.F. *was plotted by rectified radio-frequency, and* A *and* B *by low frequency methods. In all three cases it took 8 units of N/1 HCl to make up a 0·25 per cent mol solution.*

S is a switch by means of which either the terminals X and X_1 may be connected to the electrodes (of a standard conductivity cell or conductimetric tube) or alternatively to a variable resistor R_3. MR_1 and MR_2 are two small metal rectifiers. M is a microammeter reading 30-0-30. An iron-cored choke L prevents A.C. from passing through the meter. The D.C. from the rectifiers (which are connected in opposition) is balanced as required by means of a potentiometer VR_2. C_3 and C_4 are 1μF capacitors; A and B are alternative circuits, the purpose of which becomes clear by comparing curves A and B, Fig. 2.

Dipper Calibration

A simple formula for dipper calibration has been given[1] and from this the following method has evolved.

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* *University of Sydney. Dept. of Chemistry.*

(1) A meter deflexion is first obtained for a 0·25 per cent mol solution of HCl (this may be given any value desired—say 20μA).

(2) The HCl solution is then replaced by 10cm^3 of distilled water to which (one by one) dipper units of N/I HCl are added until the meter deflexion is 20μA, i.e. the same as that for the 0·25 per cent mol solution.

(3) Where a is the number of dipper units which were added to 10cm^3 of water $0{\cdot}1/42 =$ the delivery capacity in cubic centimetres.

Fig. 2 reproduces calibration graphs for the same dipper plotted by circuits A and B, Fig. 1. Both discover the same number of units, i.e. 8 for 0·25 per cent mol solution of HCl. The straighter of the two curves gives a more evenly distributed spacing, particularly at the 20μA end of the curve and is therefore preferable for dipper calibration.

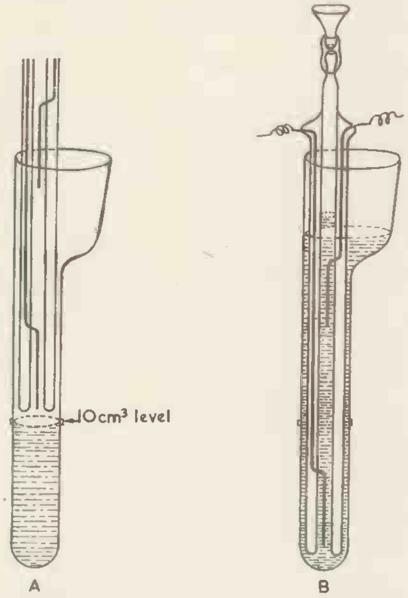

Fig. 3. A low-frequency conductimetric tube with internal electrodes as used when calibrating the dippers.

Note how the liquid rises in the tube as it is introduced into the container.

As the circuits shown in Fig. 1 entirely avoid the cumulative effect of polarization at the electrodes there is no longer a necessity to employ a standard conductivity cell having platinized platinum electrodes. For most purposes tungsten electrodes may now be used.

Instead of using a cell the conductimetric tube shown in Fig. 3 may be employed, designed on the lines (except that its electrodes contact the solution) of that described in Ref. 2, whereby the electrolytic resistance of only a column of the solution is measured. This general purpose A.C. conductimetric tube was employed to plot the dipper calibration curves here reproduced.

When the tube is inserted into a test-tube containing 10cm^3 of distilled water the latter rises well above the upper electrode and both electrodes are submerged.

It was found convenient to enlarge the mouth of the test-tube sufficiently to allow for insertion of the dipper, and the addition of a funnel at the top of the conductimetric tube to facilitate the washing out of the tube from time to time during operations.

The conductimetric tube can be used, of course, with a solution container of any size given sufficient depth to cover its upper electrode. The same dipper was then calibrated by the rectified radio-frequency method. In this case the conductimetric tube was fitted with external electrodes[2]. As seen from Fig. 2, complete agreement was obtained. This result is important as it demonstrates that for all practical purposes in both R.R.F. and A.C. methods we are measuring the same thing, i.e. the electrolytic resistance of the solution. It is evident that the small changes in dielectric constant which must occur in the former case are too small to detect. This is confirmed also by the titration graphs in Fig. 4, plotted respectively by the A and B A.C. circuits (Fig. 1) and by the R.F. method[2]. All three methods discover the same end point, viz. 6 dipper units. In this case the dipper had a delivery capacity of 4·18mm^3. From these graphs it is seen that the A circuit is better suited for titration than the B.

The Use of the Adjustable Resistor R_3 (Fig. 1)

Having selected a meter deflexion for any particular solution concentration it is useful to substitute an equivalent resistor R_3 for reference instead of the standard solution. In this way time and trouble is saved.

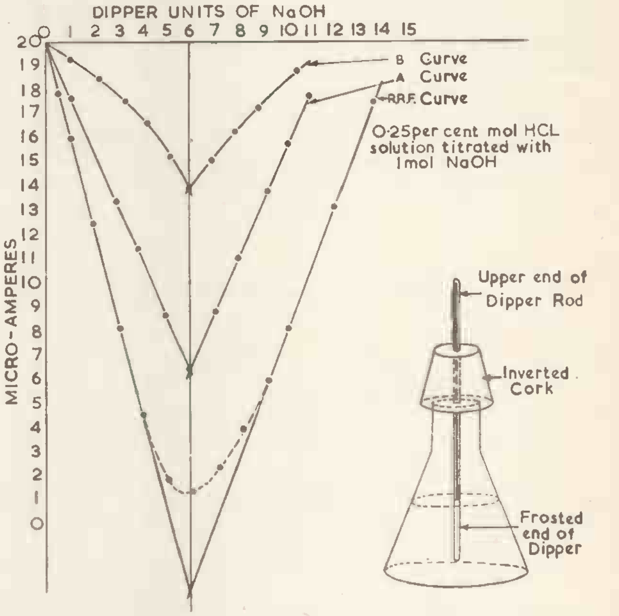

Fig. 4. The titration of a 0·25 per cent mol HCl solution by N/I NaOH.

Note that the RRF. and A and B A.C. graphs all discover the same end point.

Inset. Showing a frosted glass dipper rod inserted through an inverted cork

This ensures the same depth of immersion upon replacement after each withdrawal.

Dipper Transfer

There are two procedures which may be followed when transferring quantities of a liquid by dippers.

(1) For rapid work, provided that care is taken, the dipper can be immersed in N/I solution and the whole amount of the liquid which it picks up transferred directly to the solution under test. Or

(2) After the dipper has been immersed in the N/I solution it can be drained by touching its lower end against the surface of a sheet of filter or blotting-paper before it is introduced into the solution.

Although the amount transferred by this method is smaller, greater accuracy is obtainable. Drained dippers were used for all the curves reproduced in this paper. Fig. 4 is a sketch of a frosted glass dipper when immersed to the correct depth in a bottle of 1 mol HCl.

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Oscillator Feedback Networks

of Minimum Attenuation

By P. W. Ward*, B.Sc., A.M.I.E.E.

A single valve RC oscillator with feedback network consisting of three equal resistors and three equal capacitors requires an amplifying stage with gain exceeding 29. It is known that this gain may be reduced if unequal component values are used. In this article a method of determining optimum values is proposed.

THE networks discussed in this article are of the two basic types involving three phase-shifting stages which are generally used with a single valve for fixed frequency operation.

Oscillators involving those networks were first proposed by Nichols some thirty years ago, and have since been the subject of much literature and controversy. While therefore some preliminary remarks are considered necessary to clarify the situation, it is not intended that the subsequent discussion should be related to past controversies.

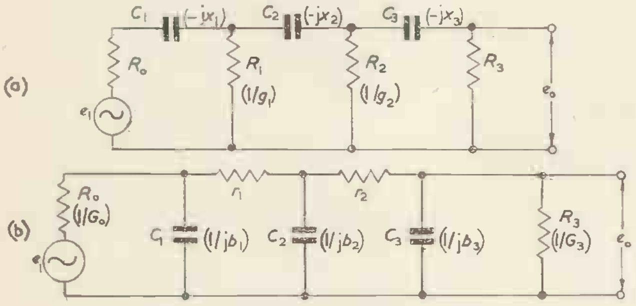

Fig. 1. Three-stage feedback networks

These oscillators have applications in modern equipment as very light and compact sources of audio frequency signals. A practical disadvantage is that while a certain value of gain is required to maintain oscillations, excessive gain causes distortion. Stability of gain is therefore an important design consideration if the oscillator is to function without attention for the normal life of the valve. Such stability is most readily obtained in conjunction with minimum attenuation in the phase shifting network.

It is proposed to consider the networks of Figs. 1(a) and 1(b), to show that at any one frequency duality exists between these networks, and to deduce expressions which will allow component values to be chosen for either network to give minimum attenuation.

With the first network it is usual to consider $R_1 = R_2 = R_3$ and $C_1 = C_2 = C_3$. Many designers neglect the output resistance R_0 of the valve. The resistance R_0 of the second network usually consists of a resistance equal to r_1 and r_2 in series with the amplifier output resistance, while $C_1 = C_2 = C_3$. The input resistance R_3 of the valve with its grid leak is almost invariably ignored. The attenuation factor, $-e_1/e_0$, of either these networks with equal resistors and equal capacitors must be greater than 29.

Several references exist to a system of staggering to reduce the attenuation. This reduction is based on the principle that if each phase shifting stage could be made of so much higher impedance than the preceding stage that it would impose negligible loading, the attenuation factor would approach 8. Extensions of this arrangement applicable to finite values of the ratio $R_3 : R_0$ have been analysed in some detail with the aim of designing networks of reduced, but not minimum, attenuation.

Determination of Optimum Values

A satisfactory design requires the determination of values for the components of the networks of Figs. 1(a) and 1(b) which give minimum attenuation with the conditions that R_0 and R_3 have predetermined finite values and that the phase shift of the respective networks should be $\pm\pi$ at a selected frequency.

The notation of impedance and admittance shown in Fig. 1. has been chosen to avoid unduly cumbersome algebraic expressions. Small letters are used for quantities considered variable in the mathematical sense. In order that the calculation may be presented reasonably briefly, it will be assumed that at least one set of conditions giving minimum attention can exist. Justification of the assumption that an expression has finite value will be omitted where this is fairly obvious; also those stages which involve only manipulation of the elementary trigonometrical identities will be omitted.

Application of Kirchhoff's laws to the network of Fig. 1(a) gives the following results:

$$R_3 \mathscr{R}\, e_1/e_0 = R_0(1 + g_2 R_3) + R_3(1 + g_1 R_0) - x_1 x_3 (g_1 + g_2) - x_2 [g_1 x_1 (1 + g_2 R_3) + g_2 x_3 (1 + g_1 R_0)]$$
$$= \mu_1 - \mu_2 x_2, \text{ say, } \ldots\ldots\ldots\ldots \quad (1)$$

$$R_3 \mathscr{I}\, e_1/e_0 = -x_1(1 + g_2 R_3) - x_3(1 + g_1 R_0) - g_1 x_1 R_3 - g_2 x_3 R_0 + x_2 [g_1 g_2 x_1 x_3 - (1 + g_1 R_0)(1 + g_2 R_3)]$$
$$= \mu_3 + \mu_4 x_2, \text{ say, } \ldots\ldots\ldots\ldots \quad (2)$$

Hence for a phase advance of π, $R_3 \dfrac{e_1}{e_0} = \mu_1 - \dfrac{\mu_2 \mu_3}{\mu_4}$ (3)

Similar analysis of the second network shows:

$$G_0 \mathscr{R}\, e_1/e_0 = G_3(1 + r_1 G_0) + G_0(1 + r_2 G_3) - b_3 b_1 (r_2 + r_1) - b_2 [r_2 b_3 (1 + r_1 G_0) + r_1 b_1 (1 + r_2 G_3)] \ldots\ldots\ldots \quad (4)$$

and

$$G_0 \mathscr{I}\, e_1/e_0 = b_3(1 + r_1 G_0) + b_1(1 + r_2 G_3) + r_2 b_3 G_0 + r_1 b_1 G_3 - b_2 [r_2 r_1 b_3 b_1 - (1 + r_2 G_3)(1 + r_1 G_0)] \ldots \quad (5)$$

The duality of the two networks is now evident, the difference of sign of the imaginary parts signifying difference of sense of phase-shifts. The first network only will be considered, and the duality will be used to obtain corresponding results for the second network.

Partial differentiation of the expression $\mu_1 - \dfrac{\mu_2 \mu_3}{\mu_4}$ with respect to g_1, g_2, x_1 and x_3 would yield four equations whose solutions would give the optimum values of the four variables. Although such a method would not be practicable, it is convenient to consider here the results of partial differentiation of the expression with respect to g_1 and g_2. It follows that for the required conditions:

$$\mu_4^2 \frac{\partial \mu_1}{\partial g_1} - \mu_2 \mu_4 \frac{\partial \mu_3}{\partial g_1} - \mu_3 \mu_4 \frac{\partial \mu_2}{\partial g_1} + \mu_2 \mu_3 \frac{\partial \mu_4}{\partial g_1} = 0$$

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* *The General Electric Co., Ltd., England.*

and

$$\mu^2_4 \frac{\partial\mu_1}{\partial g_2} - \mu_2\mu_4 \frac{\partial\mu_3}{\partial g_2} - \mu_3\mu_4 \frac{\partial\mu_2}{\partial g_2} + \mu_2\mu_3 \frac{\partial\mu_4}{\partial g_2} = 0$$

But $$\frac{\partial\mu_1}{\partial g_1} = \frac{\partial\mu_1}{\partial g_2} \text{ and } \frac{\partial\mu_3}{\partial g_1} = \frac{\partial\mu_3}{\partial g_2}$$

$$\therefore \mu_4 \left(\frac{\partial\mu_2}{\partial g_1} - \frac{\partial\mu_2}{\partial g_2}\right) = \mu_2 \left(\frac{\partial\mu_4}{\partial g_1} - \frac{\partial\mu_4}{\partial g_2}\right)$$

$$\therefore \mu_4 [x_1 (1+g_2R_3) - x_3 (1+g_1R_0) - g_1x_1R_3 + g_2x_3R_0] = \mu_2 [R_3 (1+g_1R_0) - R_0 (1+g_2R_3) - x_1x_3 (g_1-g_2)] \quad (6)$$

Referring now to equations (1) and (2), let $g_1R_0 = a\cos\alpha - 1$, $g_2R_3 = b\cos\beta - 1$, $g_1x_1 = a\sin\alpha$, $g_2x_3 = b\sin\beta$. The corresponding substitutions for equations (4) and (5) are

$r_2G_3 = a\cos\alpha - 1$, $r_1G_0 = b\cos\beta - 1$, $r_2b_3 = a\sin\alpha$, $r_1b_1 = b\sin\beta$.

Since now $\mu_2 = ab\sin(\alpha+\beta)$ and $\mu_4 = -ab\cos(\alpha+\beta)$, it follows from equation (3) that:

$$R_3\, e_1/e_0 = \mu_1 + \mu_3 \tan(\alpha+\beta)$$
$$= \sec(\alpha+\beta)\left(bR_0 \frac{a-\cos\alpha}{a\cos\alpha-1} + aR_3 \frac{b-\cos\beta}{b\cos\beta-1}\right) \quad (7)$$

For minimum attenuation, $\partial/\partial a\,(R_3\, e_1/e_0) = 0$

$$\therefore bR_0 \frac{\sin^2\alpha}{(a\cos\alpha-1)^2} = R_3 \frac{b-\cos\beta}{b\cos\beta-1} \quad (8)$$

Similarly $$aR_3 \frac{\sin^2\beta}{(b\cos\beta-1)^2} = R_0 \frac{a-\cos\alpha}{a\cos\alpha-1} \quad (9)$$

Also for minimum attenuation $\partial/\partial\alpha\,(R_3\, e_1/e_0) = 0$

It follows from equation (7) that

$$R_3\, e_1/e_0 \sin(\alpha+\beta) + bR_0 \frac{(a^2-1)\sin\alpha}{(a\cos\alpha-1)^2} = 0 \quad (10)$$

By symmetry, considering the condition that

$$\partial/\partial\beta\,(R_3\, e_1/e_0) = 0$$

$$bR_0 \frac{(a^2-1)\sin\alpha}{(a\cos\alpha-1)^2} = aR_3 \frac{(b^2-1)\sin\beta}{(b\cos\beta-1)^2} \quad (11)$$

Equations (8) to (11) contain sufficient information for the evaluation of a, b, α and β in terms of R_0 and R_3, but are not readily solved directly. Equation (6) however has a "catalytic" effect. By substitution and simplification, equation (6) may be reduced to

$$bR_0 \frac{\sin\alpha}{a\cos\alpha-1} = aR_3 \frac{\sin\beta}{b\cos\beta-1} \quad (12)$$

Elimination of b from equations (8), (9) and (12) yields

$$(a^2+1)\sin(\beta-\alpha) - 2a\cos\alpha\sin(\beta-\alpha) = 0$$

Hence either $\beta = \alpha$ or $a = e^{\pm j\alpha}$. The complex solutions are not admissible, especially since real variables were assumed in differentiation. The only solution consistent with real finite values of the components of the networks is then $\beta = \alpha$. Equations (8) to (11) now show redundancy, and may be reduced to:

$$\alpha = \beta = \cos^{-1}\frac{a+b}{ab+1},\quad b(b^2-1)\,R_0 = a(a^2-1)\,R_3$$

$$\text{and for } ab(a+b)^2 = (ab+1)^3 \quad (13)$$

In terms of R_3, the component values of the network of Fig. 1(a) are then:

$$R_0 = \frac{a\,(a^2-1)}{b\,(b^2-1)}R_3 \quad R_2 = \frac{ab+1}{b^2-1}R_3 \quad R_1 = \frac{a}{b}\, R_2$$

$$C_3 = \frac{1}{b\omega R_3}\sqrt{\left(\frac{b^2-1}{a^2-1}\right)} \quad C_2 = \frac{b^2}{ab-1}C_3 \quad C_1 = \frac{b^2}{a^2}C_3$$

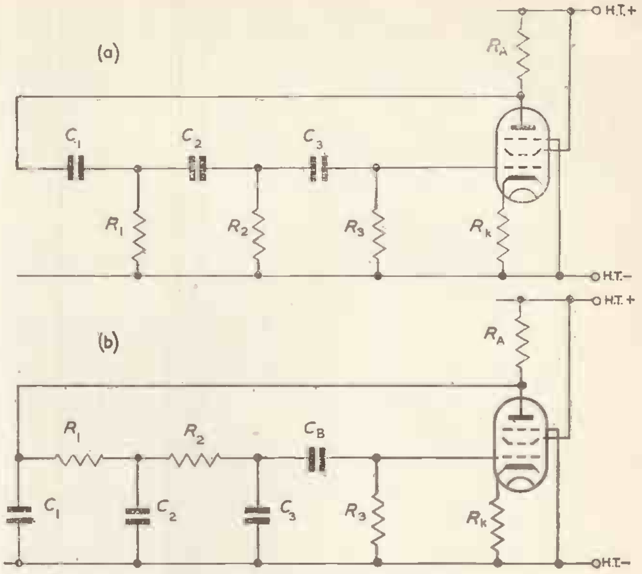


Fig. 2. Basic oscillator circuits

The component values of the network of Fig. 1(b) are:

$$R_0 = \frac{a\,(a^2-1)}{b\,(b^2-1)}R_3 \quad r_2 = \frac{a^2-1}{ab+1}R_3 \quad r_1 = \frac{a}{b}\, r_2$$

$$C_3 = \frac{a}{\omega R_3}\sqrt{\left(\frac{b^2-1}{a^2-1}\right)} \quad C_2 = \frac{ab-1}{a^2}\, C_3 \quad C_1 = \frac{b^2}{a^2}\, C_3$$

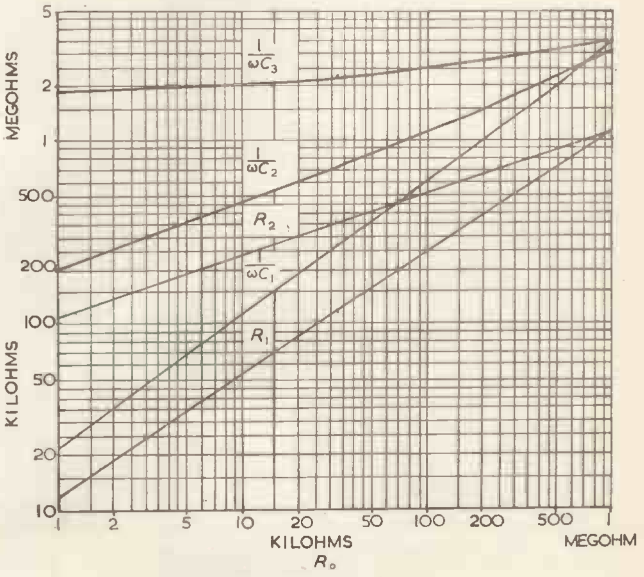
For both networks the attenuation factor, $-e_1/e_0$, is $\frac{2\,a^2b\,(a+b)}{b^2-1}$, from substitution in equation (7).

In all these expressions, a and b are related according to equation (13).

Application of the Results

Basic circuits involving the two networks are shown in Figs. 2(a) and 2(b). The use of pentodes is recommended since the frequency is more dependent upon the output impedance of the amplifying stage with this arrangement than with networks using conventional values. The

Fig. 3. Component values for the network of Fig. 1(a) for minimum attenuation with $R_3 = 1\text{M}\Omega$



cathode decoupling capacitors which are usually shown in these circuits have been omitted. This is quite practicable because relatively little gain is required. While it is agreed that the negative feedback does not reduce distortion, it does reduce the variation of gain with ageing of the valve. It also reduces the dependence of output impedance on valve characteristics; and for low frequencies a bulky component is eliminated.

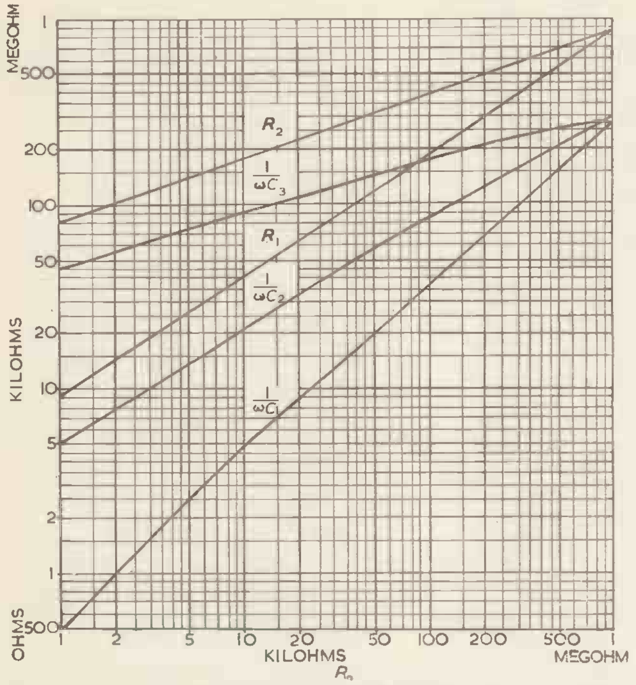


Fig. 4. Component values for the network of Fig. 1(b) for minimum attenuation with $R_3 = 1\text{M}\Omega$

Referring to Fig. 2(b), the blocking capacitor C_B should be located as shown, and not at the anode of the valve. The customary resistor between the anode and C_1 may be included if desired. This forms part of R_o, and increases the attenuation of the networks; for low frequencies it may save a bulky capacitor C_1.

At the risk of reviving old arguments, it is suggested that the first circuit is preferable for very low frequencies and the second for relatively high frequencies. The capacitors of Fig. 2(a) are of much smaller capacitance, while the valve capacitances of the second circuit are relatively unimportant.

Component values for minimum attenuation are plotted in Figs. 3 and 4. These curves are based on $R_3 = 1\text{M}\Omega$.

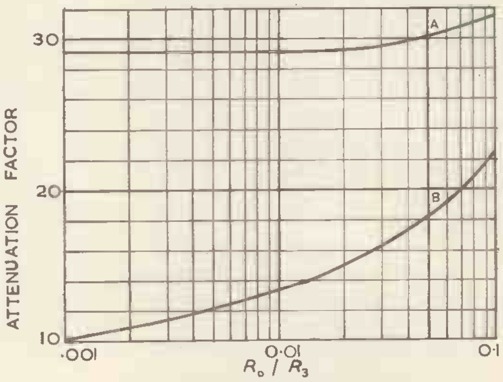


Fig. 5. Attenuation factor

Curve A. Network of Fig. 1(a) when $R_1 = R_2 = R_3$ and $C_1 = C_2 = C_3$.
Curve B. Either network of Fig. 1 with optimum component values.

For $R_3 = n$ MΩ, the figures of both scales should be multiplied by n. It was noted while compiling these curves that for all conditions $58{\cdot}7° < \alpha < 60°$. In Fig. 5, curve A is derived from the network of Fig. 1(a), and shows the attenuation which occurs when $R_1 = R_2 = R_3$ and $C_1 = C_2 = C_3$. Curve B shows the attenuation of either network when optimum values are used.

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COLOUR TELEVISION

At a recent demonstration by Marconi's Wireless Telegraph Co. Ltd, two systems of colour television adapted to present British standards were demonstrated. Both methods are fully electronic in operation and are compatible, though in varying degrees.

The first system is a straightforward adaptation of the American N.T.S.C. system, the complete signal being transmitted in the 3Mc/s bandwidth. In this system the full bandwidth of 3Mc/s is used to convey the luminance information, and the two colour difference signals are modulated on quadrature subcarriers of 2·6578125Mc/s within the luminance band. The existing BBC television signal waveform has not been altered except for the addition of the subcarrier and a sync burst of 9 cycles of subcarrier frequency at the back porch of the sync pulse, which is used to synchronize the colour detectors in this receiver; the peak white/sync ratio is reduced from 70/30 to 60/30 to partially accommodate the subcarrier overswing.

In the second system, known as the wideband system, the chrominance information is transmitted outside the 3Mc/s luminance channel; the chrominance signal occupying approximately 1·5Mc/s. Although this necessitates an increase of some 50 per cent in the total bandwidth required it results in better colour pictures and a very considerable improvement in compatibility. In the demonstration each of the three components was allocated a separate channel, i.e. a width 3Mc/s for the luminance information and 1Mc/s and 0·4Mc/s for the two colour difference signals, but in practice the two chrominance signals could be modulated on quadrature carriers or each have its own separate carrier.

Since the Television Advisory Committee has already proposed channel widths of 7·5Mc/s in Band IV and V the wideband system could be used without any difficulty, but in Bands I and III the necessary overlapping between adjacent channels would almost certainly produce objectionable crosstalk in fringe areas.

The experimental two-tube camera used takes advantage of the fact that human vision cannot discriminate colour in fine detail; an assumption common to both the systems of transmission described. One camera tube produces a high definition monochrome signal of 3Mc/s bandwidth and the other tube is arranged to give two low definition colour signals by means of a colour filter of alternate red and blue strips at right angles to the scanning lines. This type of camera has economic advantages over the more normal three-tube types, which in any case produce more colour information than is required by the transmitting system. It also has a number of technical advantages over the current type of single tube camera in which a very fine colour grid of red, green and blue strips is used. With this system the colour grid must have a resolving power of two to three times that of the equivalent monochrome picture; a requirement which is contrary to the principle, employed in the transmitting systems, of restricting the definition of the colour information.

The pictures were presented on both RCA tri-colour tubes and on a modified triple-tube Philips-Schmidt projector unit.

Short News Items

The Radio Industry Council announces that Sir Miles Thomas, chairman of the British Overseas Airways Corporation, is to open the National Radio Show at Earls Court, London, on 25 August. The exhibition remains open until 4 September and there will be a preview for overseas visitors and other social guests on 24 August. Mr. Clive Rawes has been appointed as programme officer for the Radio Show and Mr. A. E. Lloyd Williams as stage manager/producer, both being seconded by the BBC for the period of their special duties.

The City and Guilds of London Institute, Department of Technology, has prepared a five-year part-time course in Instrument Making which will come into operation for the College session 1954/55. This course has been arranged in response to requests from a number of member organizations of the Scientific Instrument Manufacturers' Association of Great Britain Ltd. Particulars of the course are given in a pamphlet, price 6d., which may be obtained from the City and Guilds of London Institute, Department of Technology, 31 Brechin Place, South Kensington, London, S.W.7.

The Department of Scientific and Industrial Research announce that the Lord President of the Council has appointed Sir Hugh Beaver to be Chairman of the Advisory Council for Scientific and Industrial Research in succession to Professor Sir Ian Heilbron, who retires on 30 September on completion of his term of office. The Advisory Council for Scientific and Industrial Research is composed of persons eminent in industry and science. Its task is to advise the Lord President of the Council on the policy and activities of the Department of Scientific and Industrial Research.

Marconi's Wireless Telegraph Company Ltd, and International Aeradio Ltd have together secured a substantial contract for radio communication and direction-finding equipment from the Ministry of Defence of the Republic of Syria. This contract entails the planning and engineering of a complete radio communications network, which is to include automatic and manual V.H.F. direction-finding stations (both mobile and static), with associated V.H.F. ground-air communications facilities. A training school for personnel of the Syrian Air Force is also to be provided. the two companies being responsible for every phase of this.

Cinema-Television, the Rank Organization associate company, announce that a Cintel large screen television was recently installed in the Palais de Chaillot, Paris, by the Compagnie Francaise Thomson-Houston, for the first large screen television demonstration in France. The Thomson-Houston Company in France believe that there is a big future for large screen television there and will fulfil initial orders by buying large screen projectors from Cinema-Television Ltd.

The Technical College, Bradford, Department of Electrical Engineering, announce that a course of eight lectures on The Principles and Applications of Transistors will be given by Dr. G. N. Patchett, the head of the department. The lectures will be held on Wednesdays at 7 p.m. commencing on Wednesday, 29 September. The fee for the course will be £1 10s., and students should possess a degree, a higher National Certificate in Electrical Engineering, or other suitable qualification. Application forms may be obtained from the Principal, Technical College, Bradford, 7.

British Insulated Callender's Cables Ltd announce that Mr. W. H. McFadzean has become chairman of the company on the retirement of Sir Alexander Roger.

The Royal Society, under the terms of the scheme to commemorate the late Lord Rutherford of Nelson, announce the appointment of Dr. E. Marsden of New Zealand, as the Rutherford Memorial Lecturer for 1954 and Mr. D. M. Brink, a graduate of the University of Tasmania, as a Rutherford Scholar for three years to carry out research in nuclear physics at the Clarendon Laboratory, Oxford.

Aluminium Laboratories Ltd, the research, engineering and geological exploration unit of Aluminium Ltd, have announced the completion of the new extensions to their research laboratories at Banbury, Oxon. The buildings were designed by Sir Percy Thomas & Son of Cardiff and incorporate many of the latest developments in laboratory design.

The BBC is putting in hand arrangements for the provision of a television service to the Channel Islands. A receiving station will be set up at Torteval on the south-west coast of Guernsey. This station will use high gain directive receiving aerials for the reception of the high power television transmitting station at Wenvoe, near Cardiff. An alternative aerial system directed on to the Alexandra Palace television transmitter will also be erected at Torteval. By arrangement with the General Post Office the received picture will then be transmitted by radio link to Les Platons on the north coast of Jersey. At Les Platons a television transmitter operating on a 61·75Mc/s vision and 58·25Mc/s sound with a power of ½kW, will give a service to Jersey, Guernsey and Sark. It is expected that Alderney will also receive a service.

Land, Speight & Company Ltd, of Glasgow, announce the formation of a new company, Elesco Electronics Ltd, to act as the selling organization for the electronic and electrical equipment which they handle.

Group Captain P. Allerston, recently retired from the R.A.F., has been appointed manager of the Equipment Servicing Department of A. C. Cossor Ltd. He will be responsible for the installation and maintenance, both at home and overseas, of the firm's large and small airfield control radar, their Gee ground and airborne equipment and other equipment in the radio and radar fields.

Commander C. M. Jacob, R.N. (Retd.), has been appointed deputy technical manager of the Marconi International Marine Company Ltd.

Mr. A. E. Grimsdale, Special Assistant Sales Management, Metropolitan-Vickers Electrical Co., Ltd., has been appointed a Director of Metropolitan-Vickers Electrical Export Co., Ltd.

Mr. A. Simpson of The General Electric Company was awarded an M.B.E. in the Birthday Honours List. Mr. Simpson has been engaged in the design of radio equipment in the Coventry group of the General Electric Company for the past 19 years. After a short time in the domestic receiver field, he transferred to the Communications Group to complete the development of the receiving station used by the South African Broadcasting Company to relay the BBC programmes. Subsequently, he was a member of the small team which made the initial investigation into V.H.F. radio. This led to the airborne radio telephone and police radio as it is known today. During this period, he developed the first V.H.F. superhet receiver ever to be manufactured commercially. Mr. Simpson has also contributed articles to ELECTRONIC ENGINEERING.

Errata. It is regretted that in the June issue the degrees and qualifications of Mr. W. Morcom of Marconi's Wireless Telegraph Co, Ltd, were omitted from the heading of his article, "A High Power Communication Transmitter," which appeared on page 237. These should read, "W. Morcom, B.Sc.(Eng.), A.C.G.I., Wh.Sch., M.I.E.E."

LETTERS TO THE EDITOR

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

Theoretical Transistor Symbol

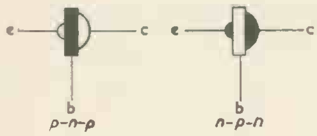
DEAR SIR,—There has been some correspondence regarding the theoretical symbol to be employed for transistors in both *Electronic Engineering* and *Wireless World*.

Mr. L. Molyneux in the April issue suggests a rather curious symbol resembling a bucket and spade on the grounds that, as the collector is shown detached from the base, one can more easily visualize the existence of collector-base potential, the emitter being shown by the usual arrow. This appears illogical to say the least as the basic dissimilarity between the transistor and the thermionic valve is that the transistor is a current operated device with all its elements in physical contact.

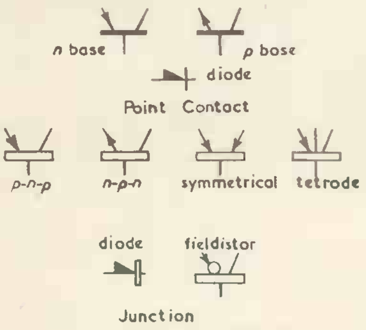
It is not stated whether this symbol is intended to be applied to both point contact and junction transistors. It appears, however, to break down when applied to symmetrical junctions.

(left). Original transistor symbol

(below) Symbols introduced by Mr. H. Morgan



A suggestion was also made by Mr. F. Oakes that the original symbol for the transistor introduced by Shockley was adequate. This, however, was refuted by Mr. H. Morgan who, while considering this symbol adequate for point contact transistors introduced symbols for junctions discriminating emitter and collector on the basis of differently sized segments attached to a rectangular base, p and n germanium being discriminated by shading (*Wireless World*, March and April, 1954).



Suggested symbols for current types of transistors.

This is a reasonable suggestion but hardly fulfils its claim to simplify drawing office work.

I would suggest that the present symbol is adequate and, if distinction between junction and point contact transistors is required, the junction may have the base shown as a box, the direction of the arrow on the emitter indicating the direction of flow of holes in the conducting direction (conventional direction of current flow).

These symbols appear to cover most present day types of transistors, though it appears difficult to fit any symbols to such devices as analogue transistors.

Yours faithfully,
D. NAPPIN,
South Harrow.

The correspondent replies:

DEAR SIR,—Mr. Nappin has been much kinder in his description of my transistor symbol than have some friends from the Department of Psychological Medicine. However, to answer his more serious points—when the transistor is being used as an amplifier of small signals, then the concept of the interconnexion of its electrodes is, of course, sound, and since mathematical relationships and design procedures have been developed it is quite possible to predict its behaviour at any time during the cycle. When transistors are used in switching circuits, where the linear relationships no longer hold, it is necessary to follow in the imagination, or on paper, the behaviour of all electrodes at all times, and in doing this, one inevitably gives some form to a phenomenon which, of itself, has none.

In the literature mechanical movement is frequently implied, and most teachers invent some form of model. At least one eminent professor is known to think in terms of buckets of water fitted with interesting taps. When a form of apparatus is invented, it is represented in a symbolic way which usually follows closely the mechanical form of the original. The symbol for the thermionic valve is almost a plan view of its physical arrangement, and the fact that it has remained almost unchanged since its introduction is perhaps a measure of its emotive power.

A major change, suggested some years ago[1], was founded on draughting convenience, though this approach has never been considered for other branches of engineering drawing. It is, perhaps, unfortunate that the mechanical arrangement of a transistor, on which the generally accepted symbol appears to be founded, does not lend itself readily to acceptable imagery. This has worried one leading authority[2] to the extent of causing him to invent and use throughout a paper, a new symbol which possesses desirable emotive qualities.

Yours faithfully,
L. MOLYNEUX,
Newcastle-upon-Tyne.

REFERENCES

1. KEEN, A. W. *Wireless World 73*, 99 (1947).
2. WILLIAMS, F. C. and CHAPLIN, G. B. B. *Proc. I.E.E. 100*. Part 3 (1953).

Microphony in Voltage Reference Tubes

DEAR SIR,—I should like to comment on the letter by Messrs. Aitchison and Murray in the May, 1954, issue regarding a comparison of the microphonic properties of the reference tubes types 85A1 and QS83/3, when subjected to mechanical shock. It would seem that the 85A1 is being used under conditions for which it was not designed and for which another tube, the 85A2, is more suited.

The 85A1 was designed a number of years ago at a time when the requirement was for a tube which would give extremely good reference voltage performance, both long and short term. The performance of the tube under mechanical shock was considered of minor importance compared with its normal electrical behaviour. For this reason a valve was produced which had no mica supports or spacers present in its structure, since gas liberated from mica is one of the major causes of instability in glow discharge tubes. It was stated in the published data for the 85A1 that the tube should not be subjected to shock or vibration.

Against this background the results quoted for the microphonic output of the 85A1 are not surprising. It should be remembered, however, that very few applications can tolerate absence from microphony if the price to be paid is poor burning voltage stability, either during operation or on shelf. The complete performance of the tube should therefore be considered when comparisons are made.

As the application of reference tubes was extended, particularly for military and industrial equipments, a more rugged tube was required to replace the 85A1; the 85A2 was developed to meet these needs. The 85A2 also dispenses with mica but has multi-supported electrodes which give greatly increased rigidity. This design has led to a tube with a stability equal to that of the 85A1 and a microphony performance which is of the same order as that of the mica supported valve quoted by your correspondent. In addition, a special quality version of the 85A2 has been developed under Government contract to meet the stringent specification laid down by the British Services for reliable valves. I therefore feel that comparison of the microphonic properties of reference tubes should be related to this type of valve.

Yours faithfully,
K. F. Gimson,
Industrial Technical Service
Department,
Mullard Ltd.

High Speed Magnetic Amplifiers

Dear Sir,—Mr. A. E. Maine, in the May issue, gave a very clear picture of recent developments in quick response magnetic amplifiers. We wish to add some notes on our own experiences with some of these devices.

As the author has pointed out, the quick response of the amplifiers is obtained at the expense of power gain. The smallness of this gain usually makes it desirable to approach the maximum theoretically possible power gain for a certain time-constant, as closely as possible. This can be done by careful attention to the circuit design, etc. Three points are particularly important. Firstly, maximum gain condition exists when the load resistance is equal to the internal impedance of the amplifier, as one would expect. Secondly, the power which a reactor is required to dissipate can be limited without reducing the power gain. For instance, if in the Lufcy bridge amplifier, Fig. 6(d), a resistor is included in series with the power supply, the output current can be limited to suit the maximum dissipation of the reactors. The inclusion of this resistor does not affect the current gain because the average output current is proportional to the difference in flux change in the two cores and independent of the supply voltage. This also eliminates the two unfavourable features of the circuit, pointed out by the author for D.C. output. Thirdly, a high permeability core material requires better rectifier performance than that given by the selenium type.

A feature of magnetic amplifiers which is not usually fully realized is the limitation the rectifiers have had on their performance in the past. For instance, the design criteria laid down by Milnes[1] using selenium rectifiers limits the current turn gain of a single half wave unit to about 100, whereas an ideal rectifier could give a current turn gain of the order of 800. In the case of Ramey circuits, the limitation is even more evident due to the form factor of the input current. The introduction of the germanium junction rectifier into this field will greatly improve magnetic amplifier performance in general and make the quick response amplifier a much more promising proposition.

We feel that the half wave circuit of Lufcy has a much more promising field of application than the author has indicated. Except for full wave output applications this circuit can give a performance comparable with any other magnetic amplifier, with fewer components. The phase/frequency response characteristic can be varied from a limit set by the supply frequency by inserting an impedance in series with the input. This also varies the current gain by controlling the circulating current in the input circuit. When a single cycle response is desired together with maximum power gain a resistance equal to the input reactance is included. Under these conditions the current gain of the Lufcy circuit is about one quarter to one eighth of that obtained from the Ramey type of switched input circuit due to the circulating currents in the former and the input current form factor of the latter. However, when used in interstage amplifiers, the input of the Lufcy circuit is automatically switched by the preceding stage and the amplifier has a gain of similar order to the Ramey circuits.

In the case of the input stage, we doubt whether the switched input circuits are warranted since they increase the sensitivity only at the expense of simplicity and possible drift stability.

One point worth mentioning in connexion with these amplifiers is that the core characteristics of certain materials under certain operating conditions can produce instability. It is found that symmetrical dynamic *BH* loops for Permalloy-F cores cannot be observed when sinusoidal flux changes of amplitude less than the saturation value are applied. The loop is triggered into one of its two possible saturated loops depending on the initial conditions. In the Lufcy amplifier with a resistor R_P in series with the power supply to limit the current, instability may occur when R_P is greater than the load resistor R_L. For certain initial conditions the amplifier behaves normally until the input current rises above a specific value. When this point is reached it is impossible to put it back into its original state by varying the input current. The amplifier will now produce its maximum output current in either the positive or negative direction depending on the polarity of the input current. The amplifier can be returned to its original condition by momentarily short-circuiting R_p. In the normal condition both cores are able to saturate during the supply cycle. In the abnormal case the core which the input current drives away from saturation cannot reach saturation. This is due to the small voltage drop across R_L when the other core has fired. Thus as long as both cores saturate no instability will occur. However, when one core remains unsaturated for the whole supply cycle instability is produced by the core characteristics. In order to avoid this effect it is necessary to arrange the operating conditions so that both cores will always saturate over a complete range of firing angles. This can be arranged by supplying the cores during the non-conducting half cycle with a saturating pulse before they are reset.

Yours fathfully,
D. F. Walker and E. T. Angus,
Applications Laboratory,
Ferranti Ltd.

REFERENCE

1. Milnes, A. G. Letters to the Editor. *Electronic Engineering 25*, 443, (1953).

The Author replies:

Dear Sir,—The letter of Messrs. Walker and Angus will be of interest to those concerned with the development of high speed circuits since it underlines important factors of design and also focuses attention on instability effects experienced with Permalloy-F. In this latter connexion we first observed the effect when attempting to display symmetrical hysteresis loops on a C.R.T. visual display unit. It was found that the loop remained at either the upper or lower saturation level, and could be moved from one datum to the other by means of introducing a switching transient into the system. The actual transition was readily observable and occupied a large number of cycles of the excitation supply. The mechanism involved is complicated and results in the starting point of successive loop cycles being displaced progressively in a general upward and downward direction. The effect, which applies to practically all square loop materials has been described by Batdorf and Johnson[1] and the conclusions show that the phenomenon is a property of the material itself. The counter-measures described by Walker and Angus represent a successful circuit technique but one is bound to feel that the elimination of the effect itself is what is really needed.

It is regretted if my recent article suggests that the Lufcy amplifier is unduly limited in application and the writer certainly agrees that this amplifier offers a very high performance for only a small outlay of components. In contrast to schemes laid down in Lufcy's original paper it has been found that the best performance is obtained when using several stages in cascade, all operating with late quiescent firing angles (150° or more). A 4-stage arrangement of this sort can furnish power gains of 10^6 with a response time of only 2 cycles of the supply frequency. In spite of this, the writer still feels that there are many instances where other forms of amplifier suit a given problem rather better, and the original statement should be interpreted in this context.

The importance of the series resistance in the Lufcy bridge amplifier has been stressed, but the writer feels that a more vital function that this performs concerns "firing angle expansion" through a multi-stage arrangement. Without the resistance, a control signal of sufficient amplitude to unblock the main rectifiers would be short-circuited resulting in only a limited flux re-set. With the resistance in circuit, however, the excess voltage may be absorbed, thus permitting the full flux change to be impressed in the core.

The writer hesitates to generalize on the question of switched or non-switched control circuits, since the choice of these is apt to be determined by the particular functions required of the amplifier. It is, however, interesting to note that a recent paper[2] describes Ramey type amplifiers which have no rectifiers in the control circuits and are free from the limitation of current gain, turns ratio, and source impedance which apply to Lufcy and similar couplings.

Yours faithfully,
A. E. Maine.
De Havilland Propellers Ltd.

REFERENCES

1. Batdorf, S. B., Johnson, W. N. Instability of Self-Saturated Magnetic Amplifiers Using Rectangular Loop Core Materials. *Trans. Amer. Inst. Elect. Engrs. 72*, Pt. 1, 223, (1953).
2. Scorgie, – Fast Response with Magnetic Amplifiers. *Trans. Amer. Inst. Elect. Engrs. 72*, Pt. I, 741, (1954).

ELECTRONIC EQUIPMENT

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

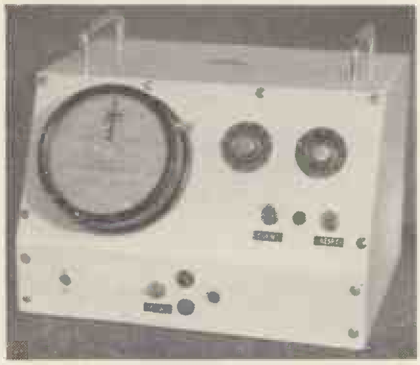
Electronic Counter

(Illustrated below)

THIS is mains operated resettable equipment and is capable of counting electrical pulses up to a rate of 5 000 per second (300 000 per min.).

The unit consists of two Dekatron counter tubes feeding a high speed electro-mechanical register, complete with the necessary power supplies and driver stages, all mounted in one cabinet. Counter tubes indicate "Units" and "Tens" and the High Speed Register indicates "Hundreds" up to a maximum count of one hundred million pulses.

A front panel switch starts and stops the count and a spring loaded switch resets the Dekatron tubes. The High Speed Register is reset by means of knurled knobs. Indicator lights are provided for "Mains on" and "Count" and the protective fuses are accessible from the front panel. The input socket accepts standard $\frac{1}{4}$in coaxial cable which may be of any reasonable length.



Pulse input is 10 volts peak, positive or negative, although this can be varied within fairly wide limits to suit individual requirements.

A range of pick-ups suitable for use with this equipment is also available.

Davis, Wynn & Andrews, Ltd,
Vittoria House,
Cheltenham.

Audio Tester

(Illustrated above right)

THE audio tester TF 894A comprises a portable beat-frequency oscillator and output meter. The oscillator is directly calibrated from 50c/s to 27kc/s in two ranges, has a maximum power output of 2 watts into 600, 15, or 3ohm.

The instrument includes an output meter and constant-resistance 600Ω step attenuator, both of which carry power and voltage calibrations providing an overall output range greater than 60db.

For operation at the alternative impedances of 15Ω and 3Ω the attenuator is switched out of circuit, the output level then being read on the voltage scale of the output meter and adjusted by means of the level control.

Provision is made for the injection of a voltage at the supply frequency when standardizing the frequency scale and, as an added facility, the output meter may be switched to measure external audio frequency voltages in three ranges up to 80 volts, so that the instrument may operate as a self-contained unit for the testing of audio amplifiers.

Marconi Instruments Ltd,
St. Albans,
Hertfordshire.

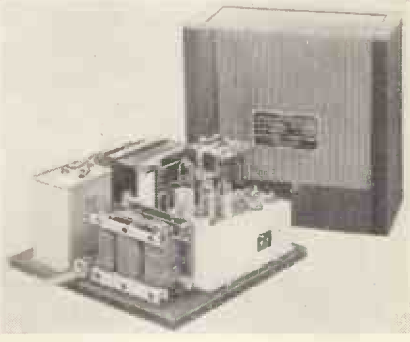
Voltage Stabilizer

(Illustrated below)

THE voltage stabilizer type S53150 is of the saturated transformer type but in addition has an electronic circuit to guard against output voltage variation due to changes in the supply frequency. The output from the saturated transformer is fed to a voltage sensitive detector producing an out-of-balance signal if the output of the stabilizer departs from its correct R.M.S. value (due, for example, to a change of frequency or load power factor). The signal is amplified and fed to the control winding of a saturable reactor. The phasing is such that the effect of the reactor on the saturated transformer is to restore the output voltage to its correct value.

Input voltage may vary between 180-250V and frequency from 47-51·5c/s. The unit has a rating of 150VA and is unaffected by load variations in this range.

Philips Electrical Ltd,
Century House,
Shaftesbury Avenue,
London, W.C.2.

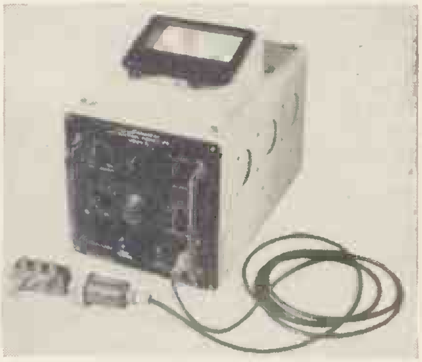


Electro-manometer

(Illustrated below)

THE N.E.P. electro-manometer is intended primarily for the measurement of intracardiac and intravascular pressures but it is equally useful for industrial pressure analysis and a range of pressure heads for this purpose is in hand.

The standard pressure head is of the capacitance type, of low volume displacement and inherent high frequency response. It is temperature compensated and linear within 2 per cent over each of the five ranges up to 400mm Hg pressure or vacuum. Cable lengths up to 10ft do not affect the sensivity.



The detector-amplifier contains a stable radio-frequency oscillator, frequency-modulated by the pressure head. The change of frequency is proportional to pressure, and is converted to an output voltage and current, sufficient to operate the large meter incorporated and also an external mirror-galvanometer, oscilloscope and recorder-amplifier. The power supplies are electronically stabilized and operation is unaffected by X-ray equipment.

New Electronic Products Ltd,
9 New Cavendish Street,
London, W.1.

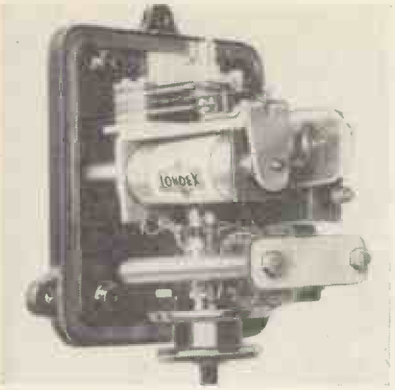
Electronic Relay

(Illustrated above right)

THE electronic relay Type CCR is housed in a dust-proof cast aluminium casing. It consists essentially of a small transformer for isolating from the mains, one gas-filled relay and a Type KR relay fitted with single pole change-over output contacts, switching capacity up to 2A at 250V A.C.

When the "trigger" circuit is completed, the cold-cathode valve strikes, energizing the KR relay which is connected in its anode circuit. When the "trigger" circuit is broken the valve extinguishes, de-energizing the relay.

The sensitivity is such that the cold-cathode valve will strike even if the "trigger" circuit is completed through an external resistance up to 2MΩ. The current in this circuit is then only approximately 0·03mA. The circuit is so designed that even when the "trigger"



circuit is completely shorted, the maximum current that can flow is only approximately 0·1mA; so that it can be switched by the most delicate contacts without damage due to arcing or burning.

**Londex Ltd,
Anerley Works,
207 Anerley Road,
London, S.E.20.**

L.R.F. Amplifier

THE Savage L.R.F. amplifier is designed for use with magneto-striction, moving-coil or moving-iron transducers and will find a ready application where high frequency vibration testing or research is to be done. The amplifier has a maximum output of 1kW and there are two models which cover respectively the frequency ranges 1·5kc/s to 30kc/s and 5kc/s to 100kc/s. The output transformer is tapped to provide output voltages of 25, 50, 75 and 100 and full output is obtained for an input of 0·5V at 600Ω.

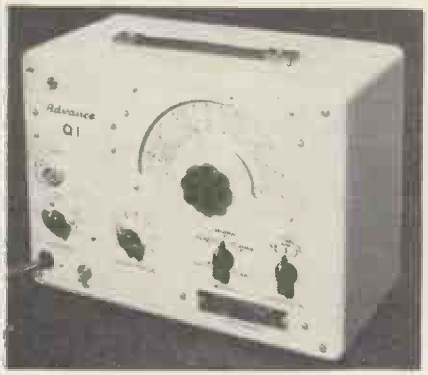
The frequency response of the amplifiers is flat within their respective bands and the application of negative feedback ensures a good waveform at the output terminals. The amplifier is carried on a 6ft 6in rack 21in wide and 14in deep. It is powered by 50c/s supply mains (single phase) and transformer taps mains voltages from 200-250.

**W. Bryan Savage Ltd,
Westmorland Road,
London, N.W.9.**

V.H.F. Signal Generator

(Illustrated below)

THE Advance type Q.1 signal generator has been produced primarily to meet the needs of servicemen dealing with band 3 television.



It provides signals from $1\mu V$ to 100mV into 75Ω over a frequency range of 7·5Mc/s to 250Mc/s. The instrument contains a variable capacitance tuned Colpitts oscillator with switched inductors for five ranges. The frequency is directly calibrated, the calibration being displayed on a large scale of total scale length—37½in. The oscillator may be internally anode modulated to give 30 per cent sine wave modulation at 1 000 c/s, or it may be internally grid pulsed giving 50/50 square pulses at a repetition rate of 1 000 per second.

A termination unit is provided to correctly terminate the R.F. output lead.

**Advance Components Ltd,
Back Road, Shernhall Street,
London, E.17.**

Miniature C.R.T.

(Illustrated above)

THE ICPI is a small cathode-ray tube intended for incorporation into electronic equipment for monitoring purposes. The screen diameter is approximately 1in. and the overall length 4in. It has electrostatic deflexion and fixed electrostatic focus. A voltage of between 500 to 800V is required for anode 3. The sensitivity of the X plates is $90/V_{a3}$mm/V and of the Y plates $110/V_{a3}$mm/V.

**Electronic Tubes Ltd,
Kingsmead Works,
High Wycombe,
Buckinghamshire.**

Soldering Irons

(Illustrated below)

THE Litesold soldering irons are available in a range of sizes having bit diameters between ⅛ and ⅜in. The smallest of these is 6in long and weighs only ½oz without flex; a cover is provided to protect the bit when not in use, and for when it is desired to pack the iron while it is still hot. These irons are available for use on a number of voltages between 6V and 250V.

**Light Soldering Developments Ltd,
30-32 Devonshire Road,
London, S.E.23.**

Electroformed Waveguides

AN electroforming service is provided by the Middlesex Gun Co. This process facilitates the production of intricate internal forms which must be manufactured to close tolerances. By this method a degree of accuracy can be obtained which would be virtually impossible by fabrication. Electroforming, therefore, is particularly suited to the production of waveguides and microwave equipment, i.e., taper sections, stepped waveguides, and resonant cavities.

Copper is the metal most commonly deposited, but electroforms can be produced with an initial deposit of ·003/·005-in. silver or nickel, backed with copper to the required wall thickness.

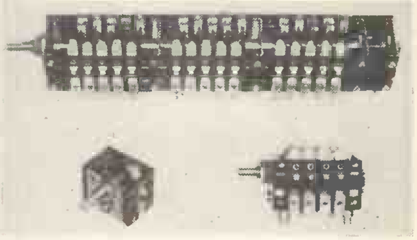
The metal is grown on mandrels of stainless steel, wax or other soluble plastic. When the specified thickness has been obtained, the mandrels are extracted, leaving a bore of the required shape and size, in fact, an exact internal reproduction of the mandrel.

**The Middlesex Gun Co., Ltd,
Hall Con Mill,
Rawtenstall, Rossendale,
Lancashire.**

Multi-Contact Switches

(Illustrated below)

THESE Magnum switches are of the cam and roller type, the contacts being operated by a series of insulated cams which impart a wiping movement to the contacts while pressure is being applied. The cams can be arranged to operate the contacts in an almost unlimited number of combinations. They are available with contacts rated at 5, 10 and 15A. These switches can be supplied in contact combinations to suit requirements.



**Burne-Jones & Co., Ltd,
309-317 Borough High Street,
London, S.E.1.**

Miniature Power Relay

THE new type M power relay incorporates two micro-switches providing two changeover combinations capable of switching 5A at 230V A.C. Each microswitch is enclosed in a separate moulded case. The power consumption of the coil is 0·85W at from 6 to 120V D.C. The operating time at nominal applied voltage is 25 to 40msec. The mounting and terminal arrangement can be varied to suit customers requirements. The overall dimensions of this relay are 1¾in × 1 9/16in × 1⅝in.

**P.A.R. Ltd.,
95 Talbot Street,
Nottingham.**

Heavy Duty Switch

A NEW switch, the Tenamp, has recently been introduced by Austinlite Ltd. It has a two pole four way slow make and break action. Contact pressure is provided by a compression spring which does not carry current. The A.C. rating is 5A at 440V and 10A at 250V and the D.C. rating 5A at 250V.

**Austinlite Ltd,
Lighthouse Works,
Smethwick, Birmingham.**

BOOK REVIEWS

Principles of Transistor Circuits

Edited by Richard F. Shea. 535 pp. 469 figs. Demy 8vo. Chapman & Hall Ltd. 1953. Price 88s.

THE experienced designer of electronic circuits using conventional valves often under-estimates the part played by his own experience in determining his approach to everyday circuit problems.

He will automatically reject circuits depending for their action on those valve parameters which have a wide spread of characteristics (e.g. grid current), even though he may not consciously consider what is happening. Indeed, an approach to the more normal routine of circuit design can become a habit, and if the habit is a good one this need not be a serious disadvantage.

When, however, such a person turns to newer devices, and in particular to the transistor, such habits, acquired unconsciously for use with valves, can become very dangerous.

So far any attempt on the part of the enlightened circuit designer to acquire a new set of techniques for use with transistors has always been difficult. The information has been comparatively scarce and what is available spreads over a wide range of journals and technical publications.

It is with the understanding that the transistor is a quite separate and different device from the radio valve, that the reader should approach the present book. In its 530 pages it covers the beginnings of the new science of transistor circuit design. Starting with a short chapter on semi-conductor physics, it then goes on to introduce both the germanium point-contact and junction triode. Subsequent chapters consider low frequency amplification; methods of stabilizing the D.C. working point of transistors; power amplifiers; direct current amplifiers; narrow-band, tuned amplifiers for radio and intermediate frequencies; wide-band and video amplifiers; oscillators; and finally non-linear large amplitude circuits such as time base saw tooth oscillators, multivibrators and scaling circuits.

Additional chapters deal with matrix methods of circuit analysis, transient phenomena and noise. A large and comprehensive bibliography together with a list of symbols and technical terms completes the book.

While this first published full length work on transistor circuits should find a place on every circuit designer's book shelf, it has three serious limitations.

The first, which of course cannot be overcome, is that the science of transistors is developing so rapidly that even those actively engaged in their manufacture are finding it needs considerable effort to keep up with their own advances. The reader of this book should therefore regard it as a background to the art rather than an exposition of the latest developments.

The second limitation lies in that the American approach to circuitry appears to differ fundamentally from the British. Even as early as page 33 out of over 500 pages, the reader is introduced to the equivalent circuit; from then on the major emphasis is on the "Black Box" rather than on the transistor physics itself. The so-called duality between transistors and valves is emphasized, as are also matrix algebra methods of solution to the equivalent network.

In the reviewer's opinion, equivalent circuits should only be used after the circuit designer has a clear picture of the physical principles in operation in the transistor itself. Answers obtained from the "Black Box" are only as good as the original data fed into it. Only after the designer understands the physical picture and can decide for himself if his particular problem and frequency of operation come within the scope of the transistor parameters and particularly equivalent circuit, should he use this potentially dangerous short cut.

As for "duality," the ability to take portions from the prior art of valve circuits and transform them into transistor equivalents is very useful for the experienced designer, but such possibilities should not be used as an excuse for failing to understand transistors from the basic approach.

Here again, due to the different spreads of characteristics in manufacture, limitations of transistor physics, and the varying circuit requirements between transistors and valves, they are not always duals of each other.

Duality and equivalent circuits might have been better covered at the end of the book rather than near the beginning. Both principles are quite useful servants, but used without discretion very bad masters.

As to the third limitation, while the transistor symbols used in this book are clear and easy to understand, particularly since the actual transistor itself is drawn in a circle, the circuit arrangement is very poor. In many cases, the H.T. positive and negative lines are both drawn at the bottom of the circuit and it is not immediately apparent from which line the supply for a particular collector or emitter is coming.

This arrangement was used when drawing valve circuits in about 1930 but it has since been almost entirely given up in favour of a logical system with the most positive H.T. at the top of the circuit and negative lines at the bottom. In valve circuits, the earth line was usually drawn about three quarters of the way down with negative supplies below it.

There seems to be no reason why this system should not be continued for transistors. For P.N.P. types, the top rail would be earthed and the bottom one merely labelled so many volts negative. Such a system would also logically accept circuits using both P.N.P. and N.P.N. transistors. In this book the system used, where the lower rail is always earthed, will have no logical arrangement at all when both types of transistor are used together.

It is a great help when studying new circuits if the reader is always able to deduce the direction of current flow from the circuit layout.

However, in spite of these criticisms the book is an important contribution to the understanding of transistor circuitry and is well worth attention.

G. GRIMSDELL

Statistical Methods in Electrical Engineering

By D. A. Bell. 176 pp., 35 figs. Demy 8vo. Chapman and Hall Ltd. 1953. Price 25s.

DR. Bell is to be congratulated on producing an interesting book on statistical methods, for students and professional engineers. Reviews of books on statistics normally commence with a scathing account of the author's views on the foundations of the subject, but that is hardly fair in this case. The first chapter is a clear and very concise exposition of the various theories of probability and the rest of the book is written in the same way.

The author utilizes the mathematical equipment of the electrical engineer to concentrate on methods and principles. The concepts and methods are introduced one by one and illustrated by one or two examples, so that the reader can grasp the essential difficulties without being swamped by details. At places where the reader may feel in need of more information there are references to suitable textbooks or original papers.

It is hardly necessary to state that Dr. Bell has drawn in his examples with a very wide network, but the scope of the book is considerable for its size, and it concludes with chapters on fluctuation phenomena—the best examples occur in electrical engineering—and the theory of the transmission of information.

G. J. KYNCH.

Industrial Electronic Engineering

By W. L. Davis and H. R. Weed. 514 pp., 100 figs. Demy 8vo. Sir Isaac Pitman & Sons, Ltd. 1953. Price 55s.

THIS book is more suitable for the advanced student and young development and design engineer, than the industrial user of electronics.

While not covering the whole field of industrial electronics, the text makes a good qualitative approach to rectifier, photoelectric apparatus, timers, motor control, and R.F. heating.

The descriptive work with regard to valves is quite wisely confined to consideration of those of the vapour discharge type, e.g. thyratrons and ignitrons, and a good account is given of the lesser known phenomena in these types of valves.

The chapters covering the theoretical treatment of servomechanisms and regulators will be thought lengthy by many readers, by comparison with the remainder of the book. However, there seems fair justification for detailed treatment of feedback systems since the future of electronic control in industry is most probably tied up with feedback controllers of various kinds. Two minor defects have been noted in the chapter on servomechanisms; one page 328-9) which states that positive *CR* feedback is a satisfactory means of obtaining "proportional plus derivative" control. Few engineers with design experience in this field would agree with this statement. The other defect is mainly an omission and concerns the treatment of an *n* stage regulator, which is analysed, but no statement appears as to how it can be stabilized. The authors have missed a valuable opportunity of applying feedback theory in this more general case.

The cursory treatment of the saturable reactor will be considered misleading by those who have detailed experience with this type of device.

As indicated above the book is essentially a theoretical treatise and gives little application data, and no detail particulars of actual applications of electronic control to industry. However, as a book on quantitative treatment it can be recommended; the series of problems which terminate the major chapters are well chosen and will adequately test the abilities of the graduate student.

A. L. WHITELEY.

Microwave Spectroscopy

By M. W. P. Strandberg. 140 pp., 15 figs. Crown 8vo. Methuen & Co. Ltd. 1954. Price 9s. 6d.

THIS book is one in the series of Methuen's monographs on physical subjects which are intended to supply science students at university level with a compact statement of the modern position in each subject.

The text begins with a calculation of the quantum energy levels of a rotating molecule, and considers the various perturbations which may or must be recognized to interpret precise experimental data. The final sections deal with the instrumentation necessary to measure the frequencies in the microwave region which are characteristic of differences between these energy levels.

Static Electrification

104 pp. Crown 4vo. Supplement No. 2. The Institute of Physics. 1953. Price 25s.

IN the early part of 1951 a proposal was made to The Institute of Physics that a volume on the generation and effects of static electricity should be published in the Institute's series of Physics in Industry monographs.

It was eventually decided by the Board of the Institute that, in the present state of knowledge of the subject, it would be preferable to hold first a conference covering all aspects of static electrification and to publish the proceedings as a supplement to one of the Institute's scientific journals. The conference was held at Bedford College, London, on 25-27 March, 1953, and the papers presented, together with an edited account of the discussion, are contained in this supplement.

BOOK REVIEWS (Continued)

Electrical Earthing and Accident Prevention

Edited by M. G. Say. 248 pp., 116 figs. Demy 8vo. George Newnes Ltd. 1954. Price 25s.

MOST electrical engineers, and still more electronic engineers, would probably consider that the subject of earthing for safety could be covered in one chapter of a book. This book shows how wide of the mark this is, and most engineers can read it with advantage. Being written by 19 contributors there is inevitable overlapping, but the obvious drawback of this is countered by the fact that for some specific points one reference is sufficient, provided that the reader has at least glanced through the book as a whole to know what is present.

The first chapter, on accidents and their prevention, is a fascinating one and worth study by all engineers. The subject of earthing, both single and multiple, and protection by voltage-operated and differential current earth-leakage circuit-breakers, and earth proving systems is well discussed here or in other chapters; the case for all-insulated domestic wiring systems is also well put by an authority on this subject.

In the chapters which may be considered as devoted to "power" those dealing with portable electrical appliances and machine tools will apply to all electronic engineers concerned with manufacture, but the chapters of more obvious electronic interest are those on the earthing of telecommunications systems, industrial electronic equipment, electromedical apparatus and radio frequency instruments.

The vast difference between an earth connexion suitable for D.C. and mains A.C. on the one hand, and a low-impedance connexion for a high frequency circuit is well brought out. As an example H.F. apparatus such as diathermy fed from A.C. mains is liable to feed a H.F. component back into the mains, causing interference, which is commonly filtered out by a system of 1μF from each line to earth. The preferred scheme is shown as 0·1μF from each line to a common point, which is connected via 0·01μF to earth.

The chapter on R.F. instruments is particularly interesting, and has applications to all electronic testing, including the mutual operation of a number of nearby instruments without interaction: screening as well as earthing is involved. Correct earthing for radio frequency measurements is an essential for accuracy of readings, rather than for shock prevention.

The hackneyed subject of earth resistance measurement and maintenance does not seem to admit of much new treatment, but in fact the subject is very well explained and much new material is given, including new nomograms to facilitate calculation of alternative earthing resistance arrangements.

The only point of criticism raised by the present reviewer is that the subject of earth electrodes is not well defined and stressed. Many chapters deal with the various methods, either one or all of them: buried plates, buried earth strips and driven rods and pipes. In some chapters the advantage of driven earth rods is stated, but in others only "earth plates" are mentioned. While this may be intended to cover all systems generally, as is in fact stated in one chapter, it is misleading since many readers will take it that "earth plates" means earth plates literally, whereas it has been published in various quarters over some years that the most efficient and economic method of reaching a given low resistance is by driven earth rods, with few exceptions such as in rocky ground. Code of Practice C.P. 326,101 on *Protection of Structures against Lightning* is mentioned in the book, but the preferred method of using any number of unit rods which can be screwed together is not quoted, although prominently recommended in the Code. Significant extracts from "Explanatory notes on some of the recommendations in the Code" include: "It will be observed that plate electrodes are not mentioned in the recommendations . . . ." "If the use of earth rods is impossible, the next best substitute is buried copper strip." A general reference to earth electrodes instead of earth plates, with details of earth rods, would be preferable to the present method of treatment in these chapters where such reference is made.

The book is well printed on good paper and the many line diagrams are very clear and explanatory. At 25s. the book is good value in these days.

E. H. W. BANNER.

Servo-Mechanisms

By J. C. West. 225 pp., 226 figs. Demy 8vo. Cleaver Hume Press Ltd. 1953. Price 25s.

THIS recent addition to servo literature deserves special consideration if only because it is a book of a new type. Intended for students whose first serious impact with the subject is at undergraduate level, it should particularly appeal to that majority of engineering students who remain unsatisfied with an abstract, theoretical approach to a subject and prefer a more practical treatment which introduces theory as and when required.

The "theme song" of the book, so to speak, is a simple low-power position control system, consisting in its original (and critically stable) state of two potentiometers and an idealized D.C. amplifier and field-fed servo-motor assumed free of time-lags. Variations on the theme occur in later chapters which embellish this electrical analogue of a simple pendulum by considering the effects on transient and steady-state sinusoidal response of friction, the motor field time-constant, velocity feed-back, and various other damping methods. Stripped of one integration the system becomes a velocity control. These "themic" chapters are interspersed with others of a more general theoretical character on such topics as stability, gain-phase criteria, static accuracy, etc.

In view of the wide field covered in a restricted compass, some of the chapters are rather sketchy, notably the one on non-linearities which should either be amplified or omitted in a later edition. Some aspects are entirely omitted; indeed the author concludes by a list of these to which it would be churlish to add. And if some passages are a little aggressively Mancunian who shall deny the author his parochial loyalties?

On the whole a very useful addition to undergraduate teaching of the subject, particularly if used in conjunction with a demonstration model as suggested by the author.

J. M. LAYTON.

Wireless and Electrical Trader Year Book 1954

296 pp. Demy 8vo. Trader Publishing Co., Ltd. Price 10s. 6d.

IN this edition, data of practical use to dealers and general reference and technical information have been carefully selected. A valuable new feature is the complete text of the wages agreement covering radio and television service engineers. The comprehensive list of the I.F. values of commercial radio receivers which have been marketed during the past six years has been revised and extended. Other data include specifications of current radio receivers, legal and licensing information and a directory of trade associations.

One of the principal aims of the Year Book is to assist traders to keep abreast of the constant changes in the names, addresses, telephone numbers and products of the firms engaged in the radio and electrical industries.

Optical Workshop Principles

By Charles Deve, translation by T. L. Tippell. 436 pp., 160 figs. Demy 8vo. 2nd Edition. Hilger & Watts Ltd. 1954. Price 42s.

THIS second English edition is a completely new translation of the French third edition of Colonel Deve's work, "Le Travail des Verres d'Optique."

The author was a pioneer in adducing theoretical bases for the manipulations required to produce optical work of high quality and in this book he very clearly set forth those principles. The work is very informative on workshop methods and recipes and gives useful data on abrasives and tools.

Chapters are devoted to the testing of raw material and work in progress; to cutting, grinding and polishing; to centring, edging and cementing; to engraving and to metallization. The production of aspherical surfaces is treated in some detail and work on glass and on crystals is described.