# MESSAGE SWITCHING SYSTEMS



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## 1. INTRODUCTION.

1.1 This note provides an introduction to Message Switching Systems, and discusses the requirements and operating principles of the various types. The note is based on information from the Telecom. Journal of Australia, Vol. 16 No. 2.

1.2 Telegraph Message Switching Systems are classified into system types according to their operating mode, method of storage or controlling logic. The operating features and relative advantages of each type of system are discussed and a survey of both the application of these systems in Australia and of the current development trends is made.

2. GENERAL.

2.1 For many years Telegraph Message Switching Systems in Australia have been quite simple in equipment provision, relaying almost entirely on the ability of human operators to achieve as satisfactory service.

With the rapid expansion that has occurred in business and industrial circles in the last decade has come the need for fast, reliable, and flexible communications, and this has been reflected into the message switching field. Increasing labour costs have placed the emphasis on automatic operation in preference to manual working.

Message switching systems have found their applications initially in the Post Office for handling the Public Telegram traffic, and subsequently in the Defence Departments, newspaper, airline and financial organisations, manufacturing industries and retail trading firms. Each organisation established an independent network, based on a central switching office with access to all outstations or branch offices. The outstations were equipped with a standard teleprinter and connected via Post Office land-lines or telegraph trunk channels to the switching centre.

Such systems provide rapid and safe transmission of operational, administrative or accounting information, with the advantage of reception in the form most suitable for business needs, that is, paper tape or page copy.

The alternatives to such systems are:-

(i) The Postal System; generally too slow for the transfer of operational information (airline bookings, for example).

(ii) The Public Telephone Network; generally too expensive in view of the volume of traffic and distance to be covered.

(iii) The Public Telex Network; this network is quite satisfactory and is widely used where the traffic volumes are small, but becomes far too expensive for heavy traffic users. Further, the operating and message handling problems become difficult with heavy traffic densities and with priority and multi-address messages in this system.

3. THE REQUIREMENTS OF MESSAGE SWITCHING SYSTEMS.

3.1 In order to appreciate the relative advantages of the message switching systems to be discussed, it is first necessary to define the facilities which are required of message switching systems. While the principal facilities are listed below, it should be borne in mind that all of these are not required with every installation, and many successful systems have been operated with quite a limited number.

The requirements of Message Switching Systems are to:-

(i) Reliably handle traffic on a continuous on-line basis.

(ii) Operate with minimum cross office switching delay.

(iii) Incorporate facilities for checking the incoming message sequence number to detect lost message.

(iv) Insert a sequence number on outgoing messages.

(v) Cross reference the incoming message sequency number against the outgoing message sequency number for message tracing purposes. This is commonly known as first line monitoring.

(vi) Generate check messages to be transmitted to line in low traffic periods in order to check the continuity of the line.

(vii) Handle multi-address messages.

(viii) Handle priority messages.

(ix) Interrupt the passage of a low priority message to an outgoing line when an extremely urgent message is required to be transmitted.

(x) Store or file a history record of the messages as they pass through the system, so that they can be retrieved and re-sent and re-sent in the event of a lost or mutilated message.

(xi) Handle different transmission speeds on different lines.

(xii) Handle a number of message formats.

(xiii) Perform message format or code conversion.

4. MESSAGE FORMAT.

4.1 Since a message is to be transmitted from an outstation into the system, without any communication or confirmation with the receiving position at the switching centre or the destination station, it is necessary for the originating station to clearly state the message address and other instructions, and to sequentially number messages to avoid lost messages. In order to achieve these aims operating formats have been laid down. These formats vary from a very loose convention of start and end of message for manual tape relay, up to extremely complicated procedures requiring letter perfect transmission over approximately 20 characters. In general, it can be said that the more complex the switching system, the greater the complexity of message format required, the greater the responsibility placed on originating operators, and the greater the chance of equipment interruption disrupting the transit of the message.

Typically a message format is as follows:-

(i) Start of address indicator – from one to four characters (typically ZCZC).

(ii) Channel identification code and message sequence number.

(iii) Start of address indicator – one or two characters.

(iv) Message priority indicator – a two letter code.

(v) Message address or addresses – each address being a two to seven letter code.

(vi) End of address indicator – one or two characters.

(vii) Message text, i.e. the main body of the message.

(viii) End of message indicator – from one to four characters, (typically NNNN).

## 5. MANUAL SYSTEMS.

5.1 Fully Manual Torn Tape Relay. While it may not be strictly valid to refer to these systems as switching systems, they do perform the function of message transfer and are worthy of analysis in view of their simplicity and of the number installed. The principles of these systems are shown in Fig. 1.

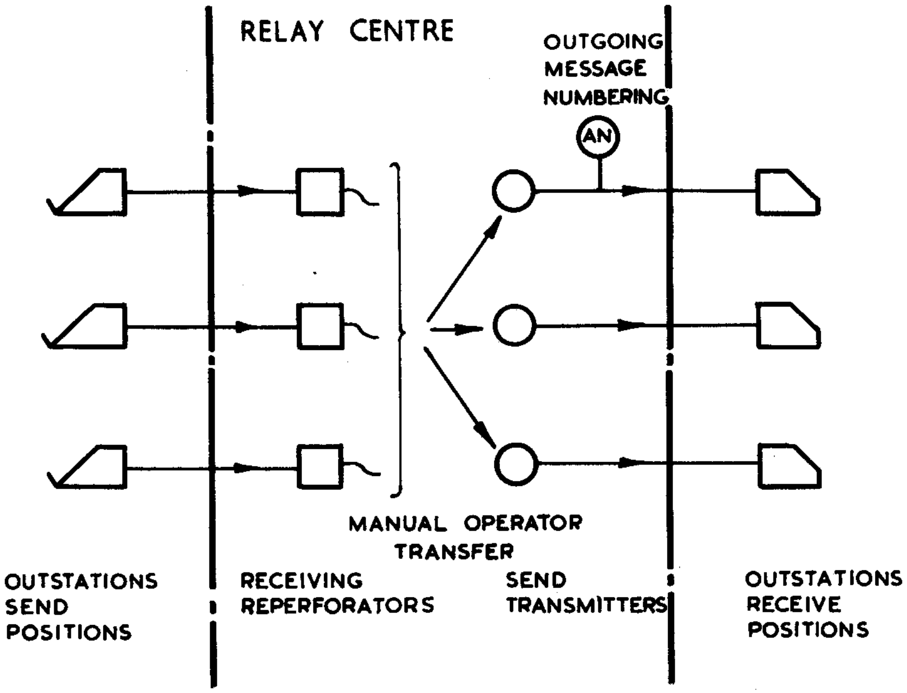


FIG. 1. OPERATING PRINCIPLES OF A MANUAL RELAY CENTER.

The receive lines from the out-stations are terminated on tape reperforators. An operator tears off each message, sorts it in regard to priority and address, and inserts it at the first opportunity into a tape transmitter fixed to the outgoing line. For multi-addressed messages, the operator must retrieve the tape from the first transmitter and re-insert it into subsequent transmission.

A log of message numbering is achieved by manually checking each incoming message sequence number against a check sheet. Numbering on the outgoing side is achieved by tab, (short sequentially numbered tapes inserted before each tape) or alternatively by automatic equipment. As an additional safeguard against lost messages, a first line monitor can be connected to the transmitter so that incoming and outgoing number sequences are cross-referenced.

Systems of the type shown in Fig. 1 have been quite popular in the past, undoubtedly because they can, so long as sufficient efficient operators are provided, satisfy all the requirements for switching systems as set out in Section 3. However, the physical problems of sorting, storing and transmitting become difficult as the number of lines in the systems increase beyond 20 lines, particularly if those lines are heavily loaded. In quite small systems of up to ten lines an operator could be expected to handle up to 200 messages an hour, depending on the amount of message logging required. In large systems this figure falls considerably due to the physical distance to be covered, and because each message must be handled by two operators, one removing the tapes from the incoming machine, sorting and storing them in an intermediate rack, and a sending operator who removes the tape from the rack and inserts them into the transmitter.

## 6. SEMI-AUTOMATIC LINE SELECTION SYSTEMS.

6.1 In an endeavour to overcome the physical problems of handling a large number of torn tapes, and to minimise the number of operators required, systems of the type shown in Fig. 2 were devised.

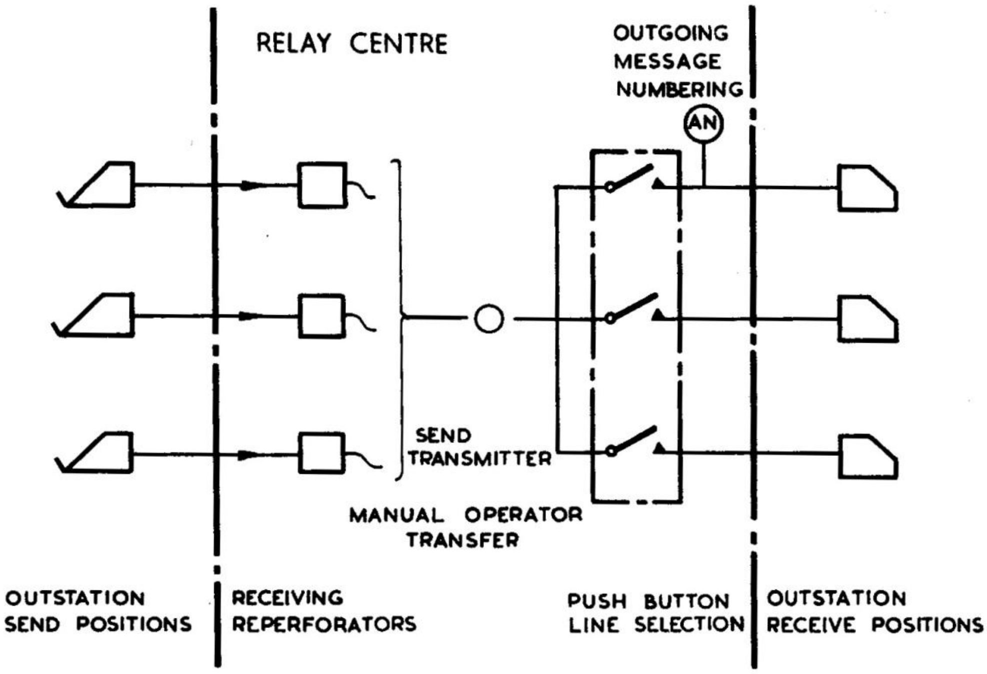


FIG. 2. OPERATION PRICIPLES OF A SEMI-AUTOMATIC SYSTEM.

Instead of individual transmitters being fixed to each line, a transmitter position is associated with a push button panel and is able to select any of the outgoing lines. By arranging the receiving reperforators in tiers within reach of the operator, who is seated in front of the transmitter, it is possible for one operator to handle from six to ten incoming lines, depending on traffic loading, together with three transmitters. In this way, provided the system is designed with the correct grouping of reperforators and transmitters to facilitate traffic flow, it is possible for the operator to handle up to 300 messages per hour, thus achieving the best use of operating labour.

A distinct advantage of this system is that the time required to transmit multi-addressed messages is greatly reduced, as the operator can select a combination of outgoing lines by pressing a number of push buttons, and simultaneous transmission can be made to each line from the one transmitter. The limitations on this type of system are physical, occurring when the operators can no longer reach the number of incoming reperforators, or due to a reduction of operator efficiency as the transmitters encounter switching delays because of increased outgoing traffic loading.

This type of system achieves the most efficient use of manual operators and has been successfully operated up to 30 lines, although this would appear to be approaching the maximum efficient size.

A feature of manual systems, which should be borne in mind when comparing them to automatic systems, is the relative inability of the manual operator to cope with traffic peaks. While an operator can sustain a rate of 300 messages per hour, that is, 12 seconds per message, they are not capable of greatly reducing this handling time if a peak of traffic arrives, and the system then goes into delay, and cannot be cleared until a considerable time after the peak is passed. As will be shown later, the switching time of the common equipment of an automatic system, even with the slowest systems, is around one second. Thus while traffic peaks may put the system into delay, clearance is effected much quicker than with manual working.

7. AUTOMATIC SYSTEMS.

7.1 The obvious advantages to be gained by automatic systems are the elimination of human operators, which affords considerable savings in running costs particularly in large systems, a reduction in lost and mis-routed messages and a greatly decreased message switching delay. Further, the physical limitations of system size and the congestion which occurs with heavy traffic peaks are eliminated. Since the human operator has been removed, intelligence of the switching control must be placed in common control equipment, which is by necessity complicated. The reliability of the system is therefore largely a function of the reliability of the common control equipment. Whereas with manual systems a circuit fault puts one line out of service, a fault in the common equipment of an automatic system can prevent operation of the entire system.

It is therefore essential, in order to achieve system reliability, to duplicate common equipment. This considerably increases the cost involved, particularly for the more complex systems.

With manual systems, the message format can be quite unrestricted, relying on the intelligence of the operator to interpret the address. With automatic systems, however, the start and end of message and start and end of address indicators, together with the address and priority coding, must adhere to a strict procedure. This places considerable responsibility on the originating teleprinter operator in order to ensure the transit of messages through the system. As a result more highly skilled operators must be employed at the outstations, otherwise the advantages to be gained in automatic working are jeopardized by an excessive number of message re-runs.

Alternatively, where skilled operators cannot be justified, format generating equipment can be associated with the outstation teleprinter so as to insert the start and end of message sequence on each message. The operator is therefore only required to type the message text. Such equipment is not cheap and could rarely be justified at all outstations.

7.2 Automatic systems fall into three basic types, classified by the method of message storage and logic control:-

(i) Sequential access storage.
(ii) Random access storage using fixed circuit logic.
(iii) Random access storage using programmed logic.

7.3 Sequential Access Storage. The storage medium in this type of system is either paper tape or magnetic tape or core storage of small capacity. The basic mode of operation of these systems is shown in Fig. 3.

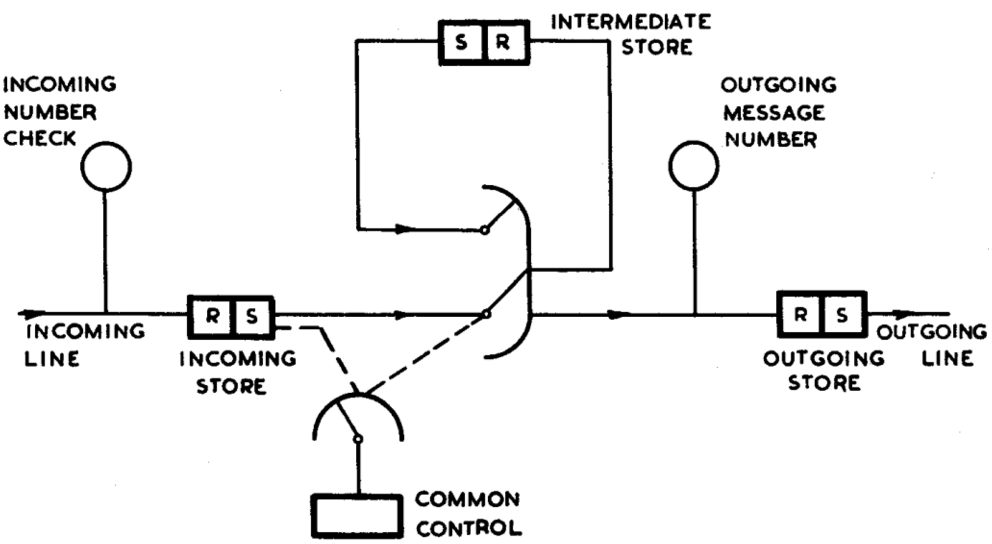


FIG. 3. OPERATING PRINCIPLE OF SEQUENTIAL ACCESS SYSTEM.

As the message is received from the outstation and taken into the incoming store, incoming equipment scans the message for the incoming channel code and message sequence number to ensure that no messages have been lost. The output side of the store scans the message looking for the start of address indicator, then pauses for the common control equipment to be connected. This feature is particularly necessary when the cross office transmission speed is greater than line speed, to ensure that the cross office connection is not held unnecessarily due to the read-out of the store catching up to the read-in.

When the common equipment is connected, the address of the message is read from the store into the common equipment where analysis and selection of the outgoing line takes place, and also into a small capacity store so that it will be available for re-transmission to the outgoing line.

Once connection has been made to the outgoing line, the common equipment is released and a test is made to determine whether the outgoing line is busy or free. If busy, the transmitter must "camp-on" the outgoing line, and continue to retest until the line becomes free. When free, the automatic numbering equipment associated with that line inserts the heading line of the message including an outgoing channel number. The address is sent from the address store, followed by transmission of the message text from the incoming store. On the end of message indicator, the cross office connection is released.

Transmission of the message from the outgoing store to line can commence immediately the message starts to arrive at the input side, as speed changing is usually from a higher speed of cross office to the lower line speed.

The sequential nature of the incoming store imposes the limitation that messages can only be taken from the store in the order of their arrival. Thus if a message at the head of the queue is waiting to switch, all other messages behind it in the store are in delay. This delay can be avoided if a pool of intermediate stores are provided. Instead of a message "camping-on" a busy line, it is diverted into an intermediate store, thus allowing the next message in the queue to be switched. The provision of these intermediate stores is quite expensive and they are provided only with the more complex systems.

Systems of this type can efficiently handle large volumes of traffic with cross office delays of less than one or two times the message length, and can readily switch up to 3000 messages per hour.

In general, sequential access storage systems do not lend themselves to handling priority or multi-address traffic. Again because of the limitations of sequential accesses, a priority message arriving behind a number of low priority messages cannot receive attention until all the other messages ahead of it have been switched. Obviously, this results in considerable delay to the priority message. However, once the priority message has reached the head of the incoming queue, it is relatively easy to arrange for it to be given preference in gaining access to the outgoing line. Alternatively, it can be switched via a special outlet, which bypasses the outgoing store, and be sent directly to line.

With multi-addressed traffic the limitation is imposed by the capacity of the address store to hold a number of addresses, and for reasons of economy this is usually limited. This limitation can be avoided if reversible transmitters are employed. Such transmitters read the message header into the common control, and then reverse back to the start of address of the message, so that the address can subsequently be sent to line.

Further, as a multi-addressed message has to switch to a number of lines, complications arise if on testing these lines not all are free. The message must wait until all are free simultaneously, or alternatively if intermediate stores are provided the messages can be sent to the idle lines as well as being held in the intermediate store until such time as the busy lines become free. While the first approach results in the most simple and economical solution, it is from a traffic handling standpoint far inferior to the second. With intermediate stores both the common control and the address store must be capable of recognising the lines to which the message was sent on the initial attempt, and deduct these from subsequent transmissions of that message. The equipment required to perform this operation is quite complicated and expensive.

First line monitoring equipment for logging the incoming message sequence number against the outgoing sequence number is possible with these systems, though is not always provided when tape stores are used, as these stores present a ready checking point for lost messages.

As sequential access magnetic stores are usually of rather limited capacity, 2000 characters being typical, it is not possible to keep a permanent record of one day's traffic as it is with tape storage, thus first line monitoring facilities are more applicable to these systems. This contributes to magnetic storage systems being generally higher in cost than tape systems.

7.4 Random Access With Fixed Circuit Logic. Random access is the term applied to storage devices which permit a message to be removed from the store at any time after its arrival, irrespective of its time of arrival or of other messages already in store.

This facility represents a considerable advance on the techniques of message handling, and removes the limitations on priority and multi-address which were inherent in the previous systems. Random access storage gives in effect the same flexibility possible with the purely manual relay system, but with vastly improved handling speeds and reliability.

A common method of providing the large capacity random access storage is with a rotating magnetic drum. Typically a drum 5 feet high with a 12 inch diameter and rotating at 1500 r.p.m. is capable of storing 250,000 telegraph characters and can be used at a speed of 50 kilobauds.

Fig. 4 shows a typical trunking diagram of the system.

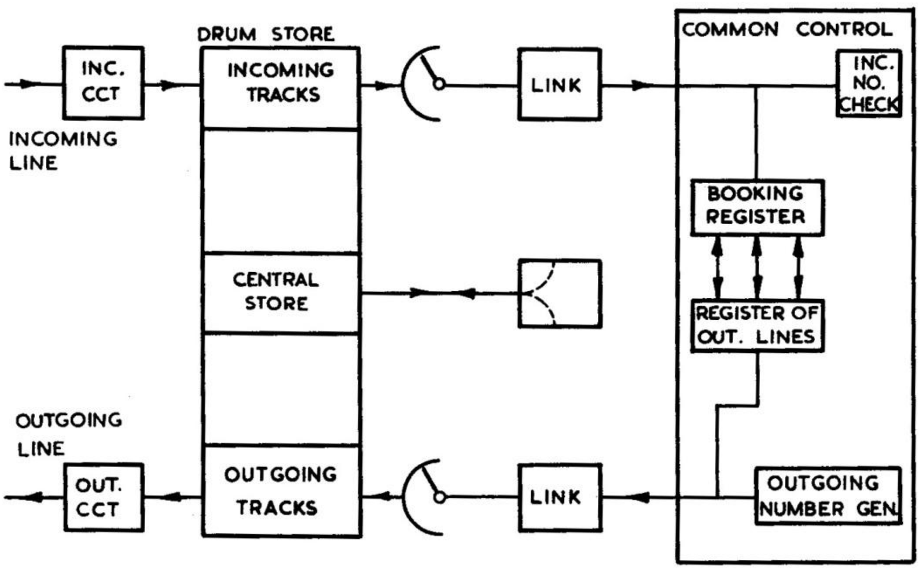


FIG. 4. OPERATING PRINCIPLES OF RANDOM ACCESS FIXED CIRCUIT LOGIC SYSTEMS.

Since the message is received at the incoming circuit at speeds of between 50 and 200 bauds, a scan is made to detect the start of message signal. Once detected each character is taken into a one character line store and at the end of that character is transferred at 50 kilobauds to an incoming track on the rotating drum. The incoming line circuit meanwhile has been scanning for the end of message signal, and when received, the message is transferred from the incoming track to the central store, via a group and link circuit. As it passes through the link circuit the message header is taken into the common control.

From the message header the incoming message number is checked and the priority and address analysed. This information is placed in a booking register.

The booking register is continually scanned and compared to a register of outgoing lines. Once it has been recognised that a message is waiting and that the outgoing line is free, the highest priority message is read from the store via the outgoing link track, an outgoing number being inserted in the message on the way.

From the outgoing track the message is transferred character by character at 50 kilobauds to a store in the outgoing line circuit, and from there to line at the desired telegraph operating speed.

For multi-address messages, a mark is placed in the booking register for each of the required outgoing lines and thereafter the message is treated as a number of individual messages. This is possible because the read out of a message from the central store is non-destructive and the message is available there until it is replaced by another message being read-in, which is not allowed until the message has been cleared to all addresses.

Over-flow magnetic tape stores are provided in the event of the common store approaching its maximum capacity (due to failure of outgoing lines for example). Messages can be transferred from the common store to these tapes and retrieved later when the line is available.

The individual line circuits are extremely simple, containing virtually only a one character store. As the remainder of the system operates on a common basis, the need for circuit reliability is greatly increased. A failure in the common control or drum storage equipment will not only prevent switching, but will result in messages being lost, as there are no individual line stores for holding the incoming traffic. This traffic will continue to arrive until such time as all outstations are contacted and asked to stop sending. This is in contrast to systems having individual line stores where a common control failure will stop switching but will not result in lost messages. It is therefore necessary to duplicate virtually the entire system to achieve reliability, and this of course greatly increases the cost of these systems.

7.5 <u>Random Access with Programmed Logic</u>. The distinguishing feature of this method of working is the use of a standard electronic computer programmed for message switching, and working via "interface" equipment to telegraph lines or data lines. Interface equipment is designed to convert the incoming signals to a form suitable for application to the computer, and to convert the computer output to a form appropriate to the telegraph line or data link. The basic principles are shown in Fig. 5.

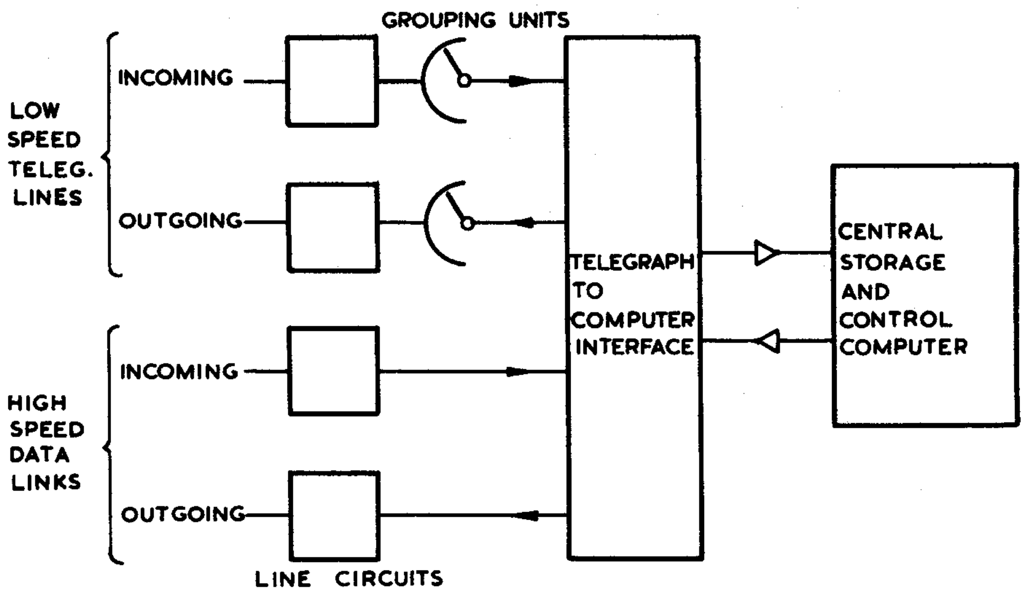


FIG. 5. OPERATING PRINCIPLES OF A RANDOM ACCESS PROGRAMMED LOGIC SYSTEM.

As a message switching system it can provide all the required features, at extremely high cross office speeds and with the utmost flexibility in address decoding and multi-access working and system trunking.

Since the message interpreting and address decoding equipment is not tied to fixed logic circuits, it is possible to accommodate a wide range of telegraph operating speeds, and to handle messages with different message formats or even with different code alphabets, as code translation can be readily handled in the programmed control.

Further, since the control logic of the system is dictated by programme, it is possible by changing the control programme (or portions of it) to quickly alter operating conditions such as the trunking or the operating speed of any line. This enables the size and operating conditions of the network to be altered as the traffic varies with daily or seasonal requirements, or when additional lines are added.

Many systems have the ability to perform error detecting and correcting functions on each received character. In the event of a mutilated message, the computer can generate a request to the outstation to rerun such messages.

The inclusion of large capacity magnetic tape or disc file stores enables history records of all messages to be retained, and on a request for a rerun of a message from an outstation, the computer can retrieve this message and resend it without recourse to a manual operator.

Alternatively the mutilated message can be presented to an operator, on a television screen for example, where it can be corrected or edited by a simple keyboard operation.

Extending beyond the strict telegraph message switching field, this system can also switch data traffic either independently of the low speed telegraph traffic, or by grouping large volumes of telegraph traffic onto a broadband group (1,000 baud or higher) for transmission. This feature can be used for large volume links to other switching centres or into a subsidiary computer for processing. The only computer based system scheduled for installation in Australia to date is for a major airline operator, and incorporates this facility in order to transfer messages from the switching computer into a seat reservation and booking computer. Information as to the seat details are then returned to the switching computer, and sent as a telegraph message to confirm the booking to the outstation.

A further possibility claimed by most manufacturers is to time share the computers capacity which is not fully utilised, particularly in light traffic periods, so as to simultaneously run the switching programme with a routine data processing programme. In this way administrative or clerical data processing can be performed on the same computer without interfering with the message switching, and this is obviously a most attractive feature from the user's viewpoint. The computer can also give regular reports and statistical data on the traffic being carried and on the performance of the system itself. The stringent reliability requirements imposed by real-time continuous on-line operation dictated the installation of a dual system. In order to avoid any interference to the traffic in event of a failure the two computers are operated in parallel, with each message actually being processed by them both, although only one is actively on line at a time. Line patching facilities are also offered which can automatically replace the line circuitry.

Typically a system with a storage capacity from 5 to 500 million bits could switch a 500 line system carrying 50,000 messages per hour, the cross office transmission time for each message being less than 60 milliseconds.

Such systems at this stage appear to offer the ultimate in message and data handling, but the cost is extremely high and a considerable effort must be exerted to organise the executive programmes. However, once installed, the speed and flexibility and supplementary facilities are most attractive.

## 8. EXISTING INSTALLATIONS IN AUSTRALIA.

8.1 A survey of the message handling systems at present in Australia is summarised in Table 1. In total there are approximately 50 systems, representing a capital investment of over two million pounds.

| Type | No. of Installations | Average No. of Lines |
|---|---|---|
| Full Manual Relay | 34 | 10 |
| Semi-Automatic Line Selection | 8 | 16 |
| Automatic Sequential Access Storage | 7 | 90 |
| Automatic Random Access Storage. Fixed Circuit Logic. | 2 | 40 |
| Automatic Random Access Storage. Programmed Logic | 1 (projected) | - |

TABLE 1. EXISTING SYSTEMS (1966).

Of these systems, 31 are owned and maintained by the Post Office but leased to private business, industrial or governmental organisations. All of these are of the manual or semi-automatic types.

Seven integrated automatic tape storage systems are operated by the Post Office to carry the public telegram traffic. Generally these are quite large systems, one being of 350 lines. The seven systems are interconnected in an Australia-wide network and for the last six years have carried approximately 20 million messages annually.

Approximately 12 systems are owned and maintained by operators outside the Post Office, principally by the armed forces.

## 9. FUTURE DEVELOPMENTS.

9.1 Until 1959 only manual systems were operating in Australia. Since then, because of the need for greater efficiency and reduced handling times, the following changes have occurred:-

(i) Eight semi-automatic and nine automatic systems have replaced manual systems.

(ii) A further three semi-automatic systems are being developed.

(iii) One automatic tape storage system is being installed.

(iv) A major Airline company is installing a computer based system (random access programmed logic) which replaces a large manual system. This is the first of the programmed logic systems scheduled for Australia.

9.2 Another branch of development is expected in the data transmission field, as a result of computers being applied in organisations which previously have had no message switching requirements.

This requirement will be high speed traffic between computers, and transmission from data collection points into a central computer for processing. This type of traffic could be accommodated on a common carrier switching network, with a consequent reduction in trunk channel charges.

END.