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Programme Switching, Control, and Monitoring in Sound Broadcasting

by

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and

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BRITISH BROADCASTING CORPORATION

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FOREWORD

THIS is one of a series of Engineering Monographs published by the British Broadcasting Corporation. About six are produced every year, each dealing with a technical subject within the field of television and sound broadcasting. Each Monograph describes work that has been done by the Engineering Division of the BBC and includes, where appropriate, a survey of earlier work on the same subject. From time to time the series may include selected reprints of articles by BBC authors that have appeared in technical journals. Papers dealing with general engineering developments in broadcasting may also be included occasionally.

This series should be of interest and value to engineers engaged in the fields of broadcasting and of telecommunications generally.

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PROGRAMME SWITCHING, CONTROL, AND MONITORING IN SOUND BROADCASTING

SUMMARY

This paper discusses the factors which influence the choice of efficient and economical switching systems, and presents the development of designs suitable for the various densities and types of traffic which occur in the sound broadcasting system of the British Broadcasting Corporation. Details of inter-regional land line or radio link connections are not discussed.

1. Introduction

1.1. *Broadcast Programme Switching Methods*

1.1.1. *Simple Systems*

The methods of collecting sources of programme and routing them to their destinations are probably as diverse as the number of broadcasting organizations.

Most organizations have grown and some are still growing from small beginnings, at which stage the simplest switching arrangement suffices, and the familiar plug and jack (patch cord) finds almost universal acceptance. It is an economical system for the condition where selection must be made from a large number of inputs to one output under the control of a single operator, as a jackfield accommodating as many as 100 sources is small enough for every part of it to be within reach. It also provides an economical method of preselection which enables seldom-used sources to be connected into a more comprehensive switching system for the period they are required.

A patch cord system, however, is unattractive if a considerable number of simultaneous programme commitments are involved. In such a case the absence of a clearly readable display of the connections is a serious disadvantage, as exemplified by the photograph of Fig. 1, which shows some of the jackfields at Broadcasting House, London, under exceptional peak programme conditions.

An alternative to the use of patch cords is the use of sockets arranged at the cross-over points of a cross-hatch of programme circuits (Fig. 2). A multiple plug with the

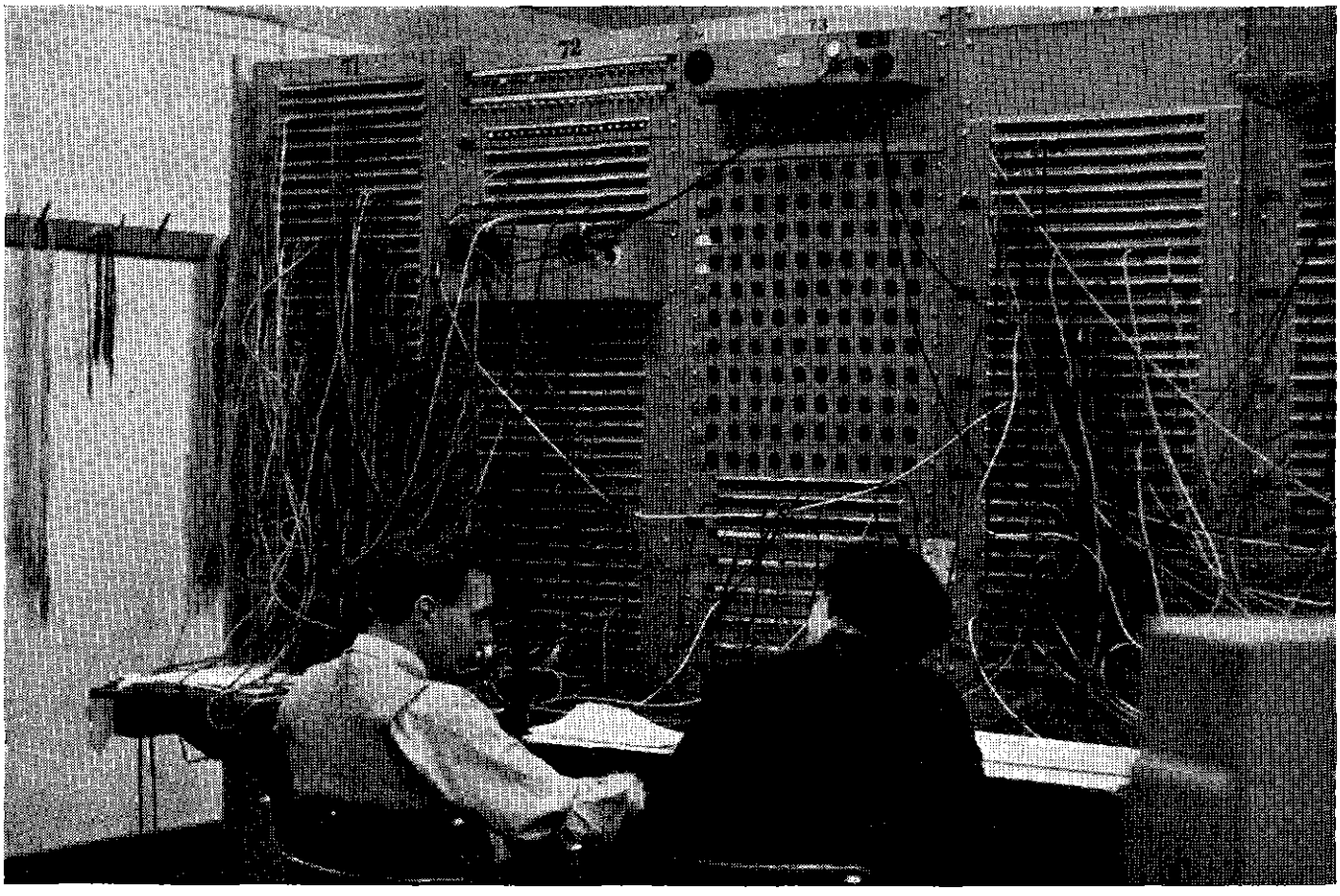

Fig. 1 — London Control Room under peak programme conditions

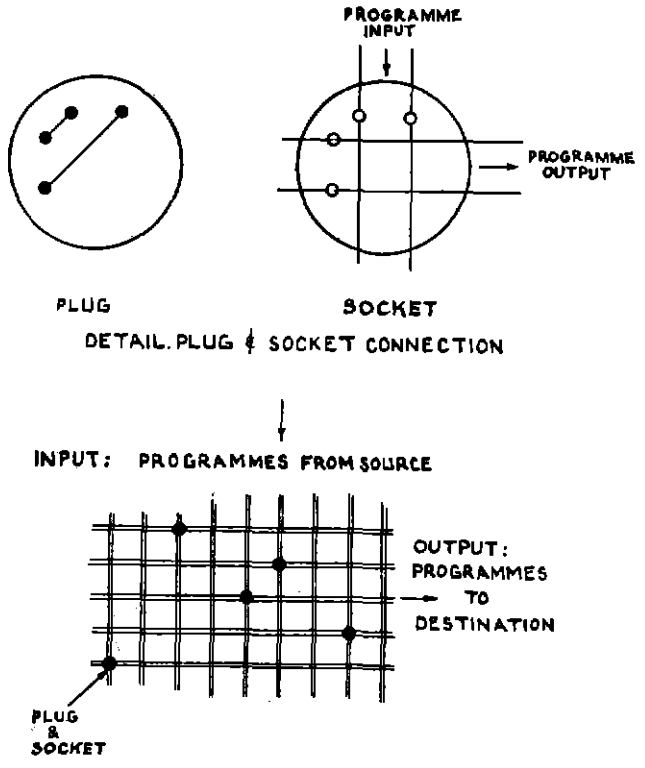

Fig. 2 — Plug and socket cross-hatch

relevant pins strapped is then inserted at each cross-over point at which a junction is required. The physical arrangement is such that the connections in use are clearly displayed against a background mimic diagram.

Should the same programme source need to be connected to two separate outputs during the same period of time the patch cord system must be augmented by using a number of parallel jack connections. The cross-hatch socket field, however, needs no augmentation.

As a telephone connection between source and destination is frequently required simultaneously with the programme connection, it is convenient if both these connections can be made at the same time. With a patch cord system this can be arranged by using two Post Office type plugs mounted together in a manner which enables them to be simultaneously inserted into a programme and into a telephone jack. This simplifies operation and also provides, via the sleeve connections, two additional wires which can be used for auxiliary switching purposes. With the cross-hatch socket field system this telephone connection can be obtained by increasing the number of contacts of the plugs and sockets to accommodate the telephone cross-hatch.

Where continuity of programme must be maintained and a pause between programme items cannot be tolerated, it is necessary to ensure that the next source required is instantly available. This may be done by the provision of an alternative output connection to which a second input (source) may be connected before the time it is required. The second output can then be selected at the appropriate instant by means of a fader or switch (Fig. 3). This arrangement, using a patch cord system, calls for only an extra jack for the additional output. To give the same facility the size of a cross-hatch socket field must be doubled.

Where programmes consist of a series of items each of reasonable length these arrangements serve very well. If, however, there are a large number of programme items of short length which follow in sequence, such as news and topical contributions, then even with two sources available there may be insufficient time between the items to allow time for replugging the sources. The number of programme items preselected to the output switches therefore must be further increased to provide longer periods during

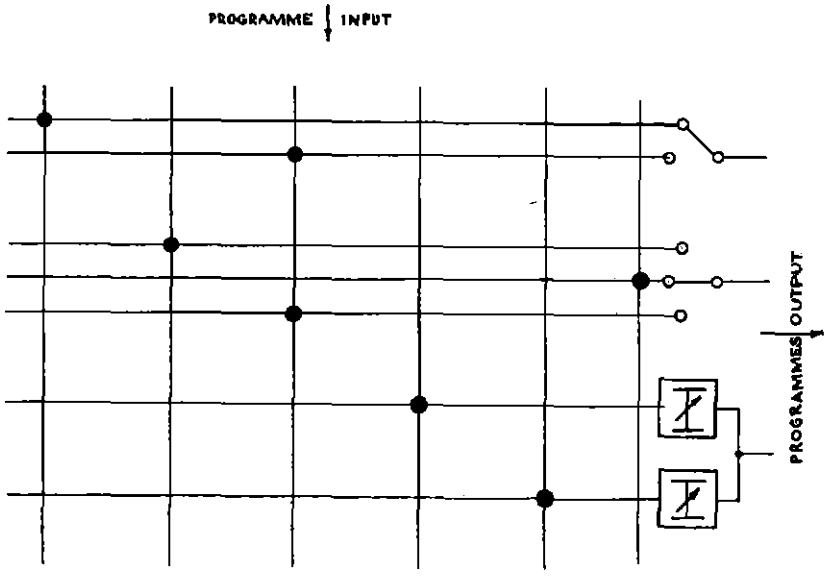

Fig. 3 — Plug and socket cross-hatch. Alternative source selection

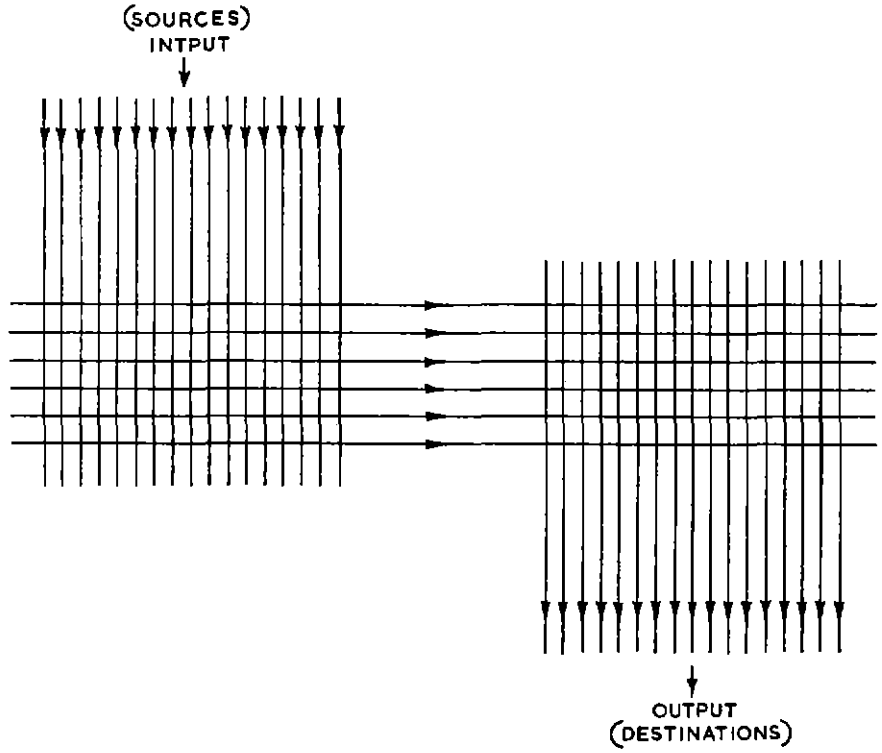

Fig. 4 — Divided cross-hatch

which replugging may be done, and also the output switch be made larger to accommodate the additional preselected connections. Again, the patch cord system needs only one additional jack for each additional preselected connection. For the same unit of increase, however, the cross-hatch socket field must be increased in size by an amount equal to the size of the original single output field, until eventually a point is reached when the physical size of the socket field becomes prohibitive.

1.1.2. *Relay Switching*

To increase the number of circuits which may be simultaneously switched, multiple contact relays may replace the plugs and sockets at the junction of cross-hatch arrangements, and this system of relay switching deservedly finds favour with a number of broadcasting organizations. The relays may be sited away from the operational area, and their operational push buttons or keys arranged in a relatively small space together with a corresponding clear lamp display of the connections in use. Relays such as the British Post Office 3000 type, which accommodate two spring sets with up to nine springs each, permit a larger number of auxiliary circuits to be switched simultaneously with the programme than has so far been attempted using a plug and socket system: noble metals provide reliable contact materials, platinum having been found very satisfactory for programme circuits. Except on the score of cost, relay switching would appear to be the most attractive method of those so far considered.

The size of a cross-hatch relay system can be reduced by dividing the cross-hatch into two groups whereby input to output switching is done via a number of channels common to both groups (Fig. 4).

This system is economical for the circumstance where a large number of inputs and outputs must be accommodated, and the through connections required simultaneously are few.

1.1.3. *Motor Uniselector Switching*

Rotary switches of the motor uniselector[1] type used in telephone practice provide an alternative to relays for the simultaneous switching of a number of circuits.

At one time the use of uniselectors for programme switching found little support because of the faults experienced due to variation of contact resistance. Some improvement can be expected in this respect by paralleling pairs of switch contacts for use in programme circuits, at the expense, of course, of a reduction in the number of contacts remaining for switching auxiliary circuits.

A better solution to the contact resistance problem has been found in the adoption of rhodium plating for the contacts and wiper arms which carry programme.

2. Advantages of Uniselectors

2.1. *On a Basis of Economy*

Motor uniselectors are normally available with fifty outlets (ways) and either eight or sixteen levels (poles). The effective number of outlets per switch can be increased in multiples of fifty at the expense of a reduction in the number of levels which can be simultaneously connected.

An example of this is given later where a 50-outlet, 16-level uniselector is operated as a 150-outlet, 5-level switch, and provides monitoring circuits at about a third of the cost of that of the equivalent relay system. Even a single uniselector may be used in this fashion with resulting economy compared with relays.

For programme switching, however, the economic advantages of using uniselectors are not fully realized unless they are used in units large enough to enable the benefits of a factory-wired ribbon multiple to be obtained.

A manufacturers' standard cabinet* accommodating six uniselectors and their associated relays represents about the smallest economical switching unit, and may be considered equivalent to a cross-hatch field of fifty inputs and six outputs.

The relative cost of various sizes of switching systems using either uniselectors with six levels of rhodium-plated contacts or British Post Office type relays are plotted on Fig. 5. This shows that except for very small switching systems of less than 120 cross-hatch points the motor uniselector is cheaper than relays.

To take a practical example which would apply to a BBC Regional Studio Centre or indeed to a number of European Studio Centres: point Q on Fig. 5 indicates the cost of uniselector switches for fifty sources serving twenty-four destinations. Point P shows that the cost of a straight cross-hatch of relays for the same service is more than twice that of selectors. As already mentioned, the size of the relay system and therefore its cost can be reduced by dividing the cross-hatch into two sections and linking them with a limited number of channels.

Applying this division to the example quoted, for the relay system to have approximate parity of cost with uniselectors (Point P', Fig. 5), twenty-four destinations could have access via a maximum of only seven linking channels to the fifty sources.

2.2. *Other Considerations*

The uniselector has other and less obvious advantages over relays which are mainly reflected in operational security, but which nevertheless also bring some economies. For instance, a holding circuit necessary with relays is not required for uniselectors. Further, the uniselector is powered only during the fraction of a second it is driven and should its power supply fail it will remain stationary, still indicating its position. A similar failure using relays could cause complete chaos due to random re-selection when power is restored.

With a relay cross-hatch it is necessary to take precautions against more than one relay in the same row being operated, a consideration unnecessary when using uniselectors, which can rest on only one outlet at a time.

3. Motor Uniselectors

3.1. *Marking and Triggering*

Uniselectors may be controlled either by individual or by common marking controls.

In the individual marking system a set of selector controls is allocated for each switch or switch group associated with a single channel. This enables an operator concerned with only a single output fed from a small number of channels to preselect sources to those channels and then trigger and fade the appropriate one into circuit at the correct instant.

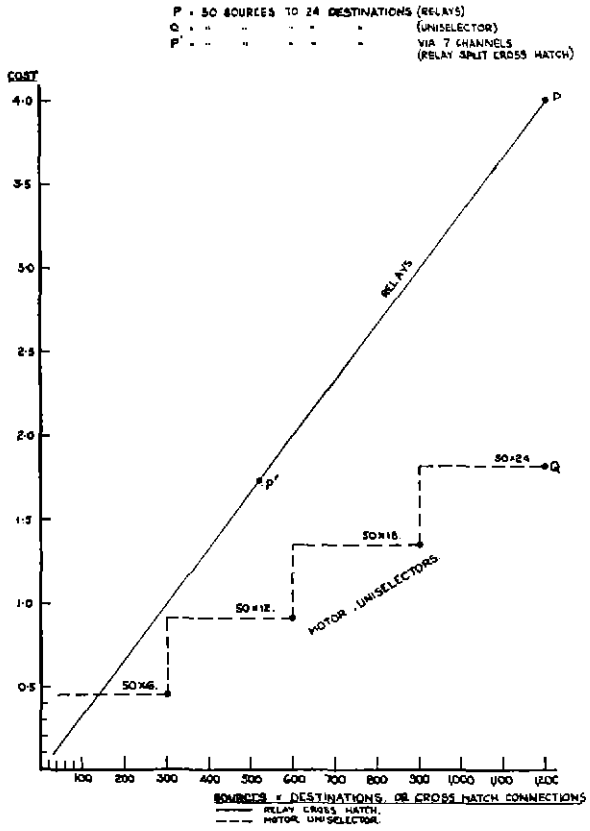

Fig. 5 — Cost of relays compared with uniselectors for switching

At studio centres situated at the crossroads of a national line network it is often necessary to reroute a number of lines simultaneously. This operation can be easily carried out using individual marking by arranging the individual trigger key circuits to be completed via a single master trigger key.

For a programme switching system having a large number of channels the provision of individual marking controls would occupy too much space. Common marking therefore, by means of which one set of marking controls may be used in turn to direct switches, combined with individual triggering, which requires only one key per channel, is more practicable.

Although the operations of marking and triggering uniselectors are more usually carried out manually, there are circumstances which permit the marking to be preset for weeks at a time, and the triggering to be done automatically under the control of an accurate clock. Before describing the application of these methods of control of uniselectors in the BBC service, it might be helpful to present a brief picture of the nature, technical scope, and territorial extent of some of the sound broadcasting services of the BBC.

* Messrs A.E.I. (Woolwich).

4. BBC Programme Control

4.1. *General*

The methods of programme control have developed gradually in response to the ideas and requirements of programme planning and production. The design of equipment, however, influences their effectiveness and in part their shape. As new equipment is brought into service ideas are stimulated, leading again to fresh demands on ingenuity of design.

The two main programme services of the BBC are the Domestic Services, which consist of the Home, Light, and Third Programmes, and the External Services, which consist of the European and Overseas Services.

Techniques of programme building, as may be expected, are very similar in the Domestic and External Services, and even though much of the switching equipment is similar a greater degree of automatic operation may be employed in the External Services. This is because there can be no continuity of presentation for a sequence of programmes in different languages. Very accurate time switching, however, must be adopted, and clock control may supplant manual control.

4.2. *Domestic Broadcasting Services*

The principal studio centre of the BBC's Home, Light, and Third Programme broadcasting services is at Broadcasting House, London, and it is connected to the network of regional studio centres as shown in Fig. 6.

The Light and Third Programmes are common to the whole country, but in addition to the London Home Service there are six variants of the Home Service, which are those of the Midlands, North and West Regions, Wales, Northern Ireland, and Scotland. Each region has a main studio centre at its headquarters, which is situated in the Broadcasting House of Birmingham, Manchester, Bristol, Cardiff, Belfast, and Glasgow respectively.

All these studio centres have a central control room, part of the area being equipped with racks of apparatus and part with control and supervisory desks. The centres accommodate a number of studios furnished with equipment according to the needs of talks, drama, features, music, and variety production.

Each region has complete control of the programme content of its own Regional Home Service, and may also direct items of local interest to specific areas only of the region. It exercises technical control of its own programme feeds to its regional transmitters, and to national transmitters sited in its region. Further, each region is responsible for maintaining programme feeds which may pass through it to other regional centres and their transmitters.

4.3. *External Broadcasting Services*

The headquarters and studio centre of the BBC's External Broadcasting Services, which include the European and Overseas Services, is at Bush House, London. In addition to programmes originating in these studios, contributions may be received from the BBC Receiving Station at Tatsfield, from Broadcasting House, London, or from any of the other studio centres of the BBC.

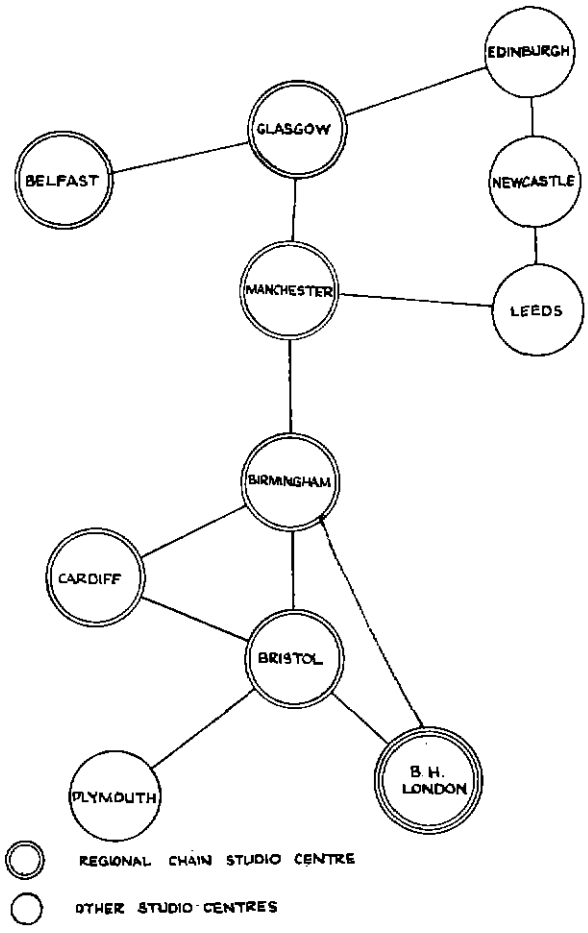

Fig. 6 — Network of studio centres

Compared with the domestic broadcasting services, the external service distribution is simpler in that all transmitting stations are fed directly from the studio centre and more complex in that more programme networks are distributed (sixteen compared with three), which are changed at more frequent intervals. These differences are reflected in the different manner in which outgoing programmes are switched in the two services.

The broadcasts from a number of these networks are picked up at receiving sites in many parts of the world, and re-radiated by local transmitters. As only a few seconds are allocated for programme switching to lines, and lines to transmitters, the speed and accuracy of switching needed in the external services needs no further emphasis.

4.4. *Sources of Programme*

Contributions to the programmes of the BBC come from many varied sources. Apart from programmes produced at each of the studio centres, local programme contributions are accepted from studios and concert halls connected to these centres, and also from a large number of outside broadcast points.

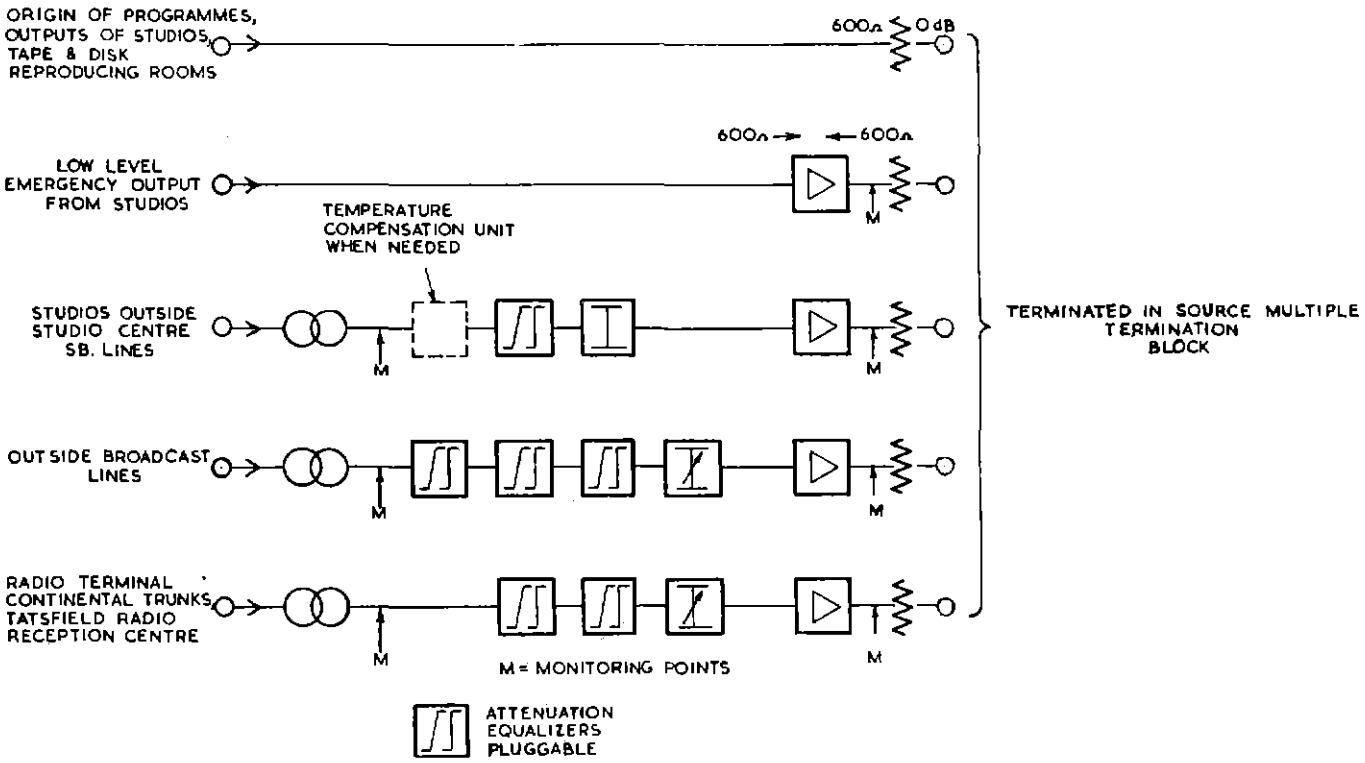

Fig. 7 — Circuits previous to source multiple

Contributions to London are also received via the new transatlantic cable, and continental trunk lines, whilst the BBC radio receiving station at Tatsfield collects contributions from all over the world. Radio receivers at studio centres are used as emergency sources of programme.

Programmes which have been recorded, as well as interval signals, can also be considered as sources of programme.

From these sources of programme, which approach fifty at regional centres and total some hundreds at Broadcasting House, London, a selection is made for distribution in a predetermined order for the Domestic as well as the External Services. In addition to the programme contributions made to the main services, each regional service can contribute to any of the other regions via Post Office lines.

According to their point of origin, these sources of programme terminate in the nearest studio centre control room. Here permanent lines with known characteristics are equalized by specific equalizers, whilst O.B. and temporary lines are equalized by units having variable control of their characteristics.

All sources are adjusted by the use of amplifiers, equalizers, and attenuators as necessary to have the same level of 0 dB (ref. 1 mW into 600 ohms), and generally have an output impedance of 600 ohms. Schematic diagram, Fig. 7, shows a number of typical sources and their chain of connections as far as their termination which is designated a source multiple.

4.5. *Destinations of Programmes*

The number of destinations to which programmes must be fed varies from about sixty at regional studio centres to some hundreds at a London studio headquarters. All are not of equal importance. Those of major concern are the feeds to the land line distribution system, and also to recording rooms and other technical operating areas. The remainder are return feeds to studios, reproducing rooms, and other sources of programme, and additionally to a large number of offices concerned in the planning, production, or technical direction of the programmes.

Every destination is fed from a low-gain amplifier having a high input impedance.

Some groups of these destinations are concerned solely with the distribution of a common programme or programme network. In these cases the high-impedance inputs of the destination amplifiers are connected together, and the common feed to this junction is termed a route.

Each destination amplifier is followed by a correction network which assists in maintaining the sending impedance close to 600 ohms over the frequency band of interest. This is followed by an attenuator of a value which sets the correct level to line.

Where the destinations are listening points in studio centre offices, the amplifier is followed by a step-down transformer which presents a low output impedance across which a considerable number of office lines may be connected. Examples of destination groups and single destination circuits are shown schematically in Fig. 11.

4.6. *Selection of Sources*

Of the total sources of programme available, a number are required on a seasonal basis, e.g. cricket and football grounds, and need be connected to the switching system only for the appropriate period. One or two sources, such as Big Ben and Greenwich time signal, are required so frequently that they may be made permanently available at control positions as sources without the necessity of passing through a source selection system.

Most of the remaining sources, however, must be available for connection to destinations and routes in a manner which enables the ever-changing pattern of programme distribution throughout the country to be accomplished without undue delay.

These switching changes may be carried out at various switching positions, designated Continuity, Control, Control/Monitor, and Miscellaneous Switching Positions respectively.

4.6.1. *Continuity Position Source Selection*

'Continuity working'[2, 3] creates a focal point between selection and distribution, at which point the complete responsibility for the selection of all sources for one specific programme network is shared by an announcer and a technical operator. This relieves operational activity in the control room, although at regional centres during off-peak periods and when that region is not providing its own programme material, control may revert to its control room.

The sources required immediately for the programme network are selected at a control desk known as the Continuity Control Position. At this point, which in London is continuously manned during programme hours, the engineering operator can select a number of sources on to fader controls and fade them in and out in turn. Some degree of mixing may be done here, such as a local announcement of a musical item being superimposed over the music as this is faded in. The programme volume is also controlled at this point, and checked for quality via a high-grade loudspeaker.

A Continuity Studio, adjacent to and permanently associated with the continuity room, is occupied during all broadcasting hours by an announcer who is responsible for the artistic presentation and direction of the network programme. He may at his discretion transfer main control of the programme from the continuity engineer's desk to his own in order to insert linking announcements and to broadcast a fill-up programme until normal programme can be resumed.

Apart from its connections to a large number of destinations, the continuity output also appears as a source in the switching system and it may, therefore, be selected by any of the other control positions.

One Continuity Suite is needed for each Domestic programme network, and for each regional studio centre. For the Overseas Services most continuity positions are used without an associated studio, for as mentioned earlier the overseas networks carry a disconnected sequence of foreign language programmes.

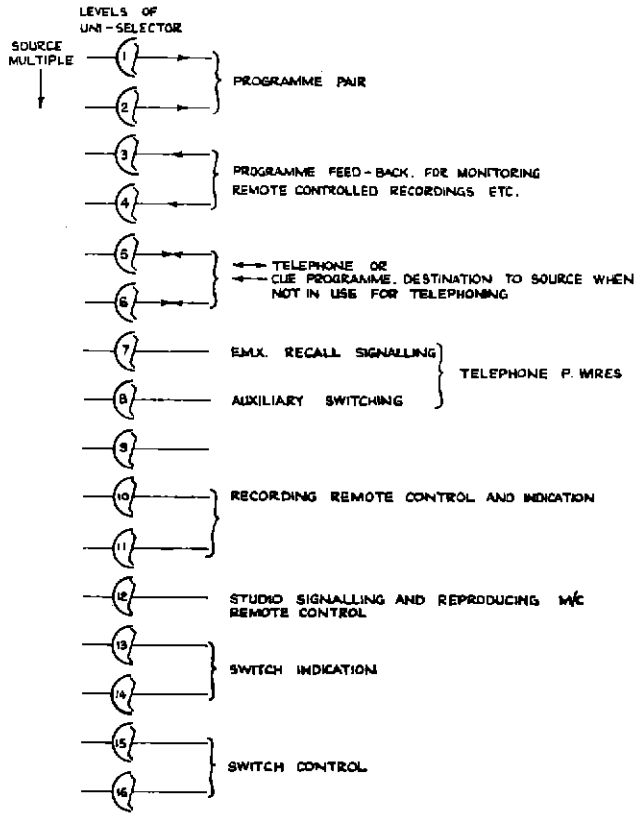

Fig. 8 — Allocation of levels of motor uniselector

4.6.2. *Control Position Source Selection*

Some sources of programme, because of their remoteness or difficult site conditions, may be subject to variations in level and quality. These sources may be intercepted and precontrolled at a control position desk which has technical facilities similar to those of a continuity desk, except that it has no permanently associated studio. Two faders of this desk may be used to control an important programme source which may be received via two separate paths. The operator at the desk fades up that source path which at any instant provides the better signal.

At this desk control may be exercised over programmes which originate at one studio centre for transmission from another centre.

4.7. *Miscellaneous Switching*

4.7.1. *Miscellaneous Switching Position*

A number of programme commitments require the selection of single sources which are already controlled for level and monitored for quality at their point of origin. They are selected and switched to their routes at a Miscellaneous Switching Position Desk in the main control room. The outputs from the various source selection positions are also directed to their routes at this desk.

4.7.2. *Control/Monitor Positions*

Although the majority of single source-to-route links do not normally need continuous monitoring or control, there are occasions, particularly in the London Studio

Centre control rooms, when potentially difficult programme commitments may make it necessary to bridge these links for monitoring or intercept them for control. A Control/Monitor Position Desk, as it is designated, has been designed for this purpose which enables a variable degree of control to be exercised. Initially unattended, monitoring and control may be assumed if necessary without interruption of the programme.

Each desk can accommodate two through-source-to-route links.

5. Application of Selector Switching in the BBC

5.1. *Basic Arrangements of Uniselectors*

From the previous section it may be appreciated that programme switching falls into two broad categories. One is that concerned with all source-selection control positions, and the other that carried out as miscellaneous switching.

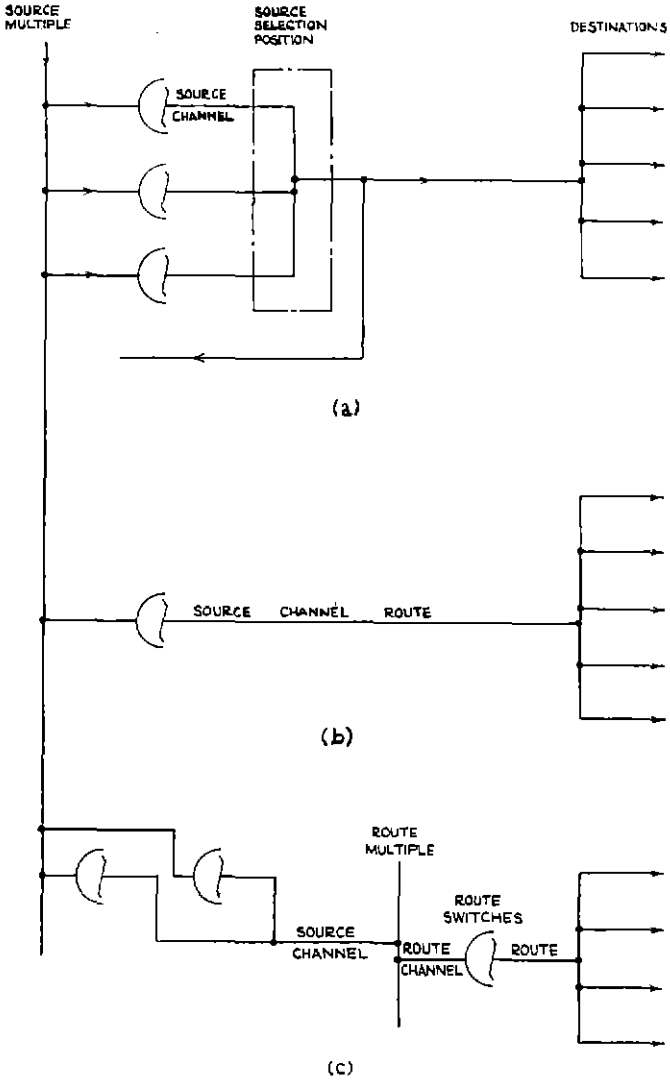

Fig. 9 — Basic switching arrangements

5.1.1. *Source Switching*

For the source-selection positions the basic circuit of Fig. 9a has been adopted. The number of source channels necessary is decided by the maximum number of sources which must be held at any instant ready for fading into circuit, whilst the number of switches per source channel is dependent upon the maximum number of sources to which access is needed. Specific designs are presented later.

5.1.2. *Miscellaneous Switching*

For the miscellaneous switching each source channel requires a sufficient number of switches to provide access to all the sources.

When the number of sources are such that a single switch is adequate to accommodate them, then direct source-to-route switching, shown in Fig. 9b, is the simplest and most economical method. It is easy to expand in terms of routes, and there is no restriction of peak traffic within the limits of the maximum number of sources.

When, however, the number of sources requires two or more switches per channel, the maximum number of channels which may be simultaneously engaged becomes an important factor in deciding the selection system. If this number is small in relation to the total number of routes, then by adopting a double selection system (Fig. 9c), whereby a source is selected to a channel and the channel to a route, a considerable reduction in the number of uniselectors is possible compared with direct source-to-route selection.

Neglecting the artifice of dividing the levels of switches and for simplicity considering only the use of 50-outlet, 16-level uniselectors, the graph of Fig. 10 shows a comparison between the number of selectors required for direct source-to-route switching and the number required for double selection systems for some typical cases.

As a basis for estimating the number of channels necessary to link the source and route switches of a double selection system, programme schedules of past years may be consulted and analysed. In this analysis the designer must be sensitively aware of even small but definite trends in programme production which, of little significance at the time, might grow to be of considerable significance by the time the design is in service.

For instance, an increase in the interchange of programmes between regions, and an increase in the popularity and number of topical programmes, such as sports reports, which carry many short items from outside sources, can considerably increase the load on the source-to-route channels.

These considerations, taken together with the simpler operation and indication associated with direct source-to-route single selection system, lead to the conclusion that the cost of a single selection system would have to exceed by a considerable margin that of a double selection system before a decision would be made in favour of the latter.

5.2. *Single Selection Switching System*

5.2.1. *Basic Switching Arrangement*

From an analysis of programme traffic at regional centres it was considered that initially not more than fifty

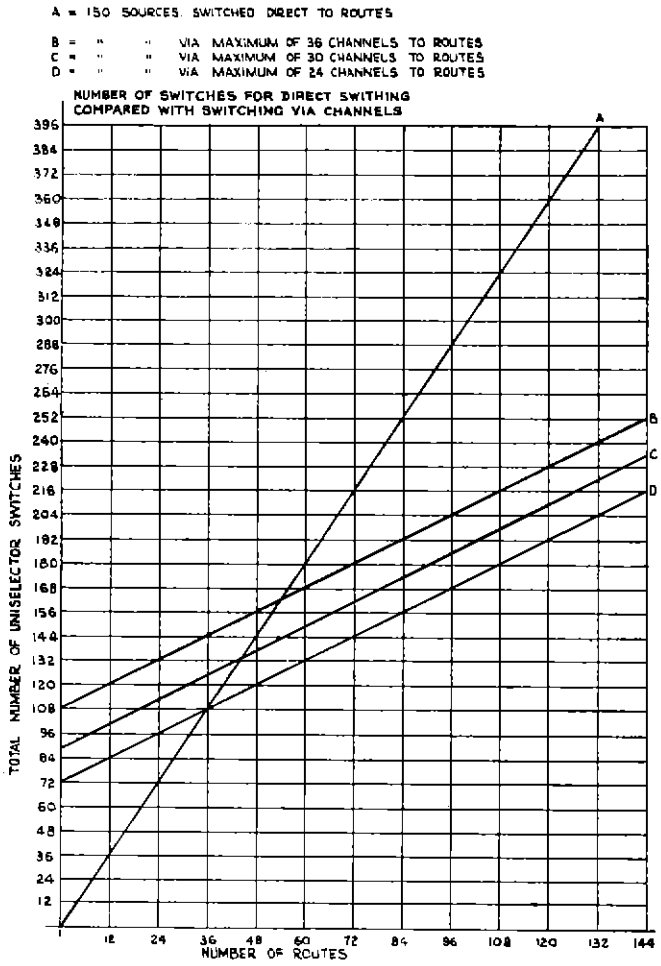

Fig. 10 — Number of switches for direct switching compared with switching via channels

sources need appear in the source multiple and that 16-level switches would be essential to deal with the switching of auxiliary circuits.

Careful consideration was given to the allocation of switches so that the total number should not just exceed nor fall far short of multiples of 12, the unit of expansion. It was decided, therefore, to limit the maximum number to twenty-four, and as fifteen were needed for permanent routes this left nine to be shared between one continuity and two control positions. This arrangement would equip each position with three switchable source channels, but would leave no switches spare for occasional additional routes.

However, as one of the programme inputs to these positions consists for long periods at a time of Basic Home Programme, switch selection of this input was considered unjustified and the connection was made a semi-permanent one. Thus three switches, one from each position, were released for occasional additional routes.

Fig. 11 shows an arrangement which is typical of those now going into service.

During the period that Basic Home Programme is being distributed at a regional studio centre the continuity suite need not be staffed and the technical control of continuity operation may be transferred to a control position which is part of the main control desk in the control room, a photograph of which is shown in Fig. 12.

Also, during the time the continuity suite is not being used for its normal purpose, it may be employed as a control for the control of local programme contributions to other studio centres of the BBC.

The second control position is needed for the occasions when a region, distributing its own home programme via the continuity suite, is also simultaneously making two further contributions to other BBC programmes. During any programme period that three control positions are not in use the programme load may always be arranged to permit any one of them to be withdrawn for test and maintenance.

This interchangeability feature of the design contributes to economy in both equipment and staff.

5.2.2. *Direct Source/Route Selection. Circuit and Operation*

The circuit used for direction and control of the uniselector in the source-to-route switching system at regional studio centres is shown in Fig. 13. It is unorthodox in that the control relays are unoperated except during the transit of the switch to a fresh outlet, and there is no homing circuit in the normal sense, the switch being marked and directed to the home outlet as to any other. Thus it is simple and suitable for use either with common or individual presetting and triggering controls. It has the advantage too that a failure of the control circuit such as, for example, might be caused by disruption of a fuse will not result in a failure of programme passing through the switch.

The marking of each uniselector is preset by means of two rotary switches, one of which marks the tens and the other the unit contacts of the uniselector. The circular dials of the two rotary switches are arranged in juxtaposition and the tens and unit figures of the source appear illuminated in digital display at the point where the dials meet.

Above the presetting dials an indicator illuminates the figure of the source already selected. Thus the operator can see at a glance the pattern of current and preset selection.

A key for triggering the uniselector drive may be operated in one direction fleetingly, when the uniselector immediately drives to the marked outlet; alternatively, operated in the reverse direction and locked, the key connects the trigger circuit to a master trigger key, which can trigger simultaneously all uniselectors so connected. In this condition an indicating lamp above each relevant trigger key is illuminated until the master trigger key has been operated. The uniselectors which have been triggered in this way cannot be redirected until after restoration of the channel key.

The switching circuits for control positions and miscellaneous switching are very similar except that instead of being connected to the master trigger key, each control position trigger key is connected via the back contact of its associated channel fader as a precaution against accidental operation whilst a channel is faded up.

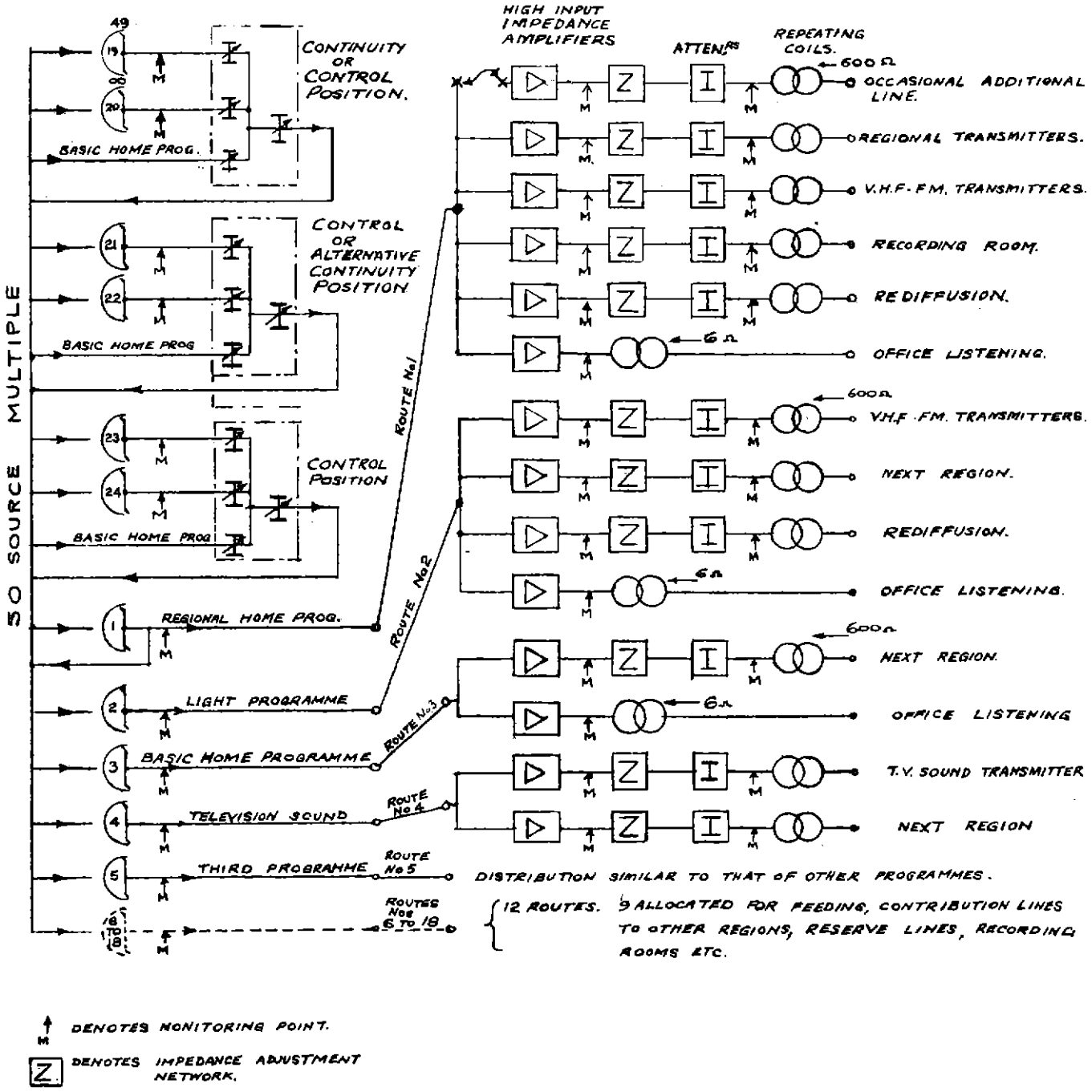

Fig. 11 — Basic schematic of direct source/route switching

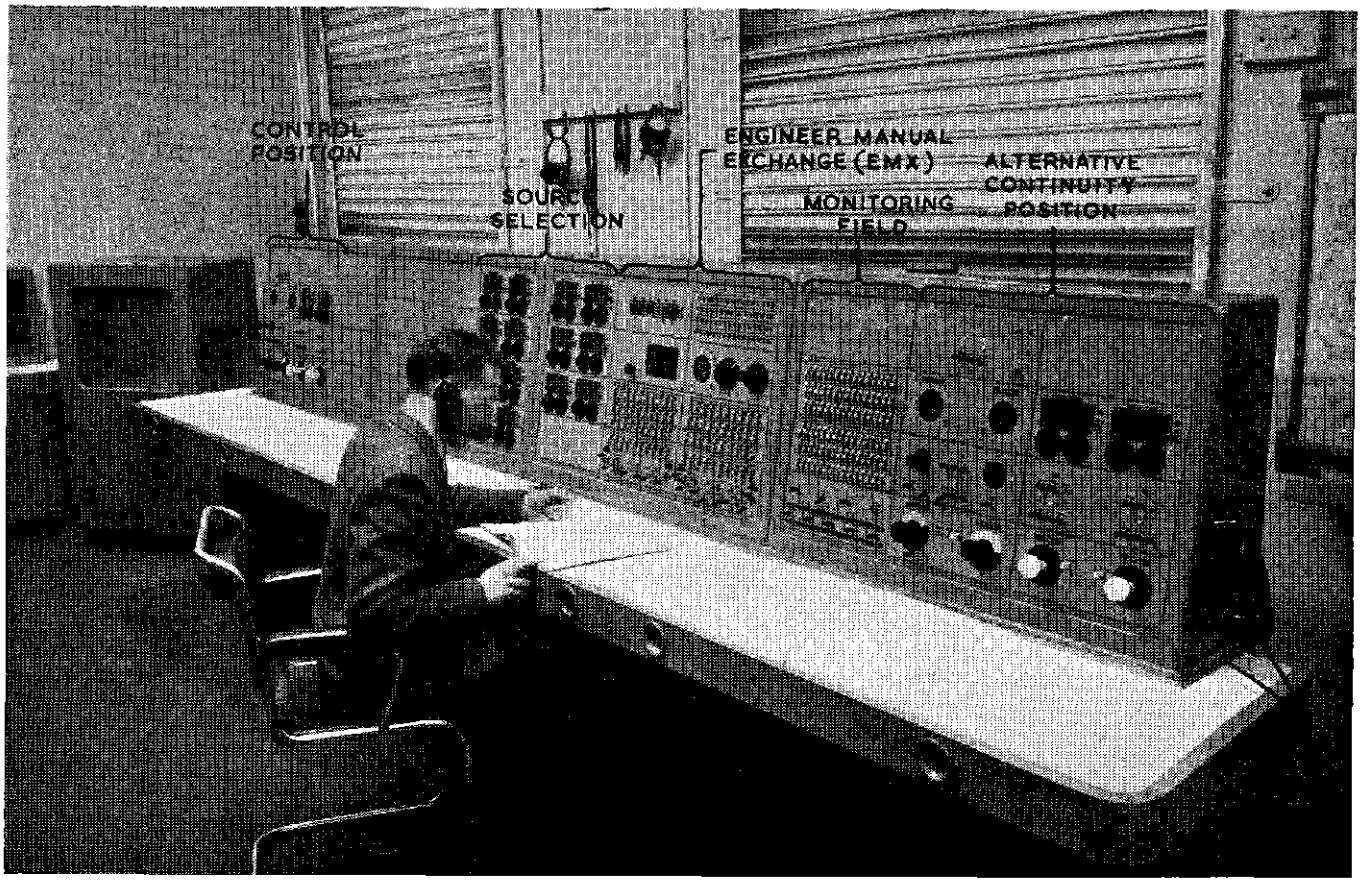

Fig. 12 — Main Control Desk, Glasgow Studio Centre

5.3. *Double Selection Switching System*

5.3.1. *Basic Switching Arrangements*

The largest and most diverse switching installation so far completed by the BBC is that for the central direction of all programmes of the Overseas and European Broadcasting Services.[4]

An estimate of programme traffic indicated that initially 150 sources and 156 routes would have to be catered for and that the maximum number of simultaneous programmes would not exceed fifty. This meant that the economy deriving from a double selection system could be obtained. Three switches with levels allocated as in Fig. 8 were assigned to each source channel and a single switch to each route. Control and continuity positions numbered thirteen, whilst six control/monitor positions were considered necessary for the control room. Twenty-four of the route switches were segregated from the rest for the specific purpose of switching network programmes which, being planned on an inflexible time basis of multiples of a quarter of an hour, were arranged to be switched automatically by clock-operated apparatus. The basic programme switching circuit is shown in Fig. 14.

The corresponding switching of lines to senders is also carried out by clock-controlled apparatus at transmitting stations in Cumberland[5] and Dorset, and this automation will also be extended to other transmitting stations of these Services.

5.3.2. *Source Selection Circuit and Operation*

The circuit for the direction and control of the selectors used for source selection is shown in Fig. 15.

The three switches for each source channel are designated A, B, and C, to which are connected the first, second, and third group respectively of fifty of the 150 sources. The letters form the first and the figures the second and third digits of a three-digit source-selection code, which is A.00–A.49, B.00–B.49, C.00–C.49. Expansion to 200 sources would necessitate the addition of a fourth switch per channel which would be designated D. The circuit is similar in principle to that already given in Fig. 13 and described in para. 5.2.2. Individual marking is provided for control positions and common marking for miscellaneous switching.

Rotary switches cannot be conveniently used for the display of three digits, and three rows of push-button switches are used instead. The top row chooses the selector A, B, or C, and the rows below tens and units contacts of the selectors. An additional push button on the top row enables a previously used uniselector to be preselected for triggering to its off position on its home outlet.

When a source code is preset on the push buttons and the trigger key is pressed, the circuit first ensures that all three uniselectors 'home' and then the chosen one drives to the marked source according to the preset code.

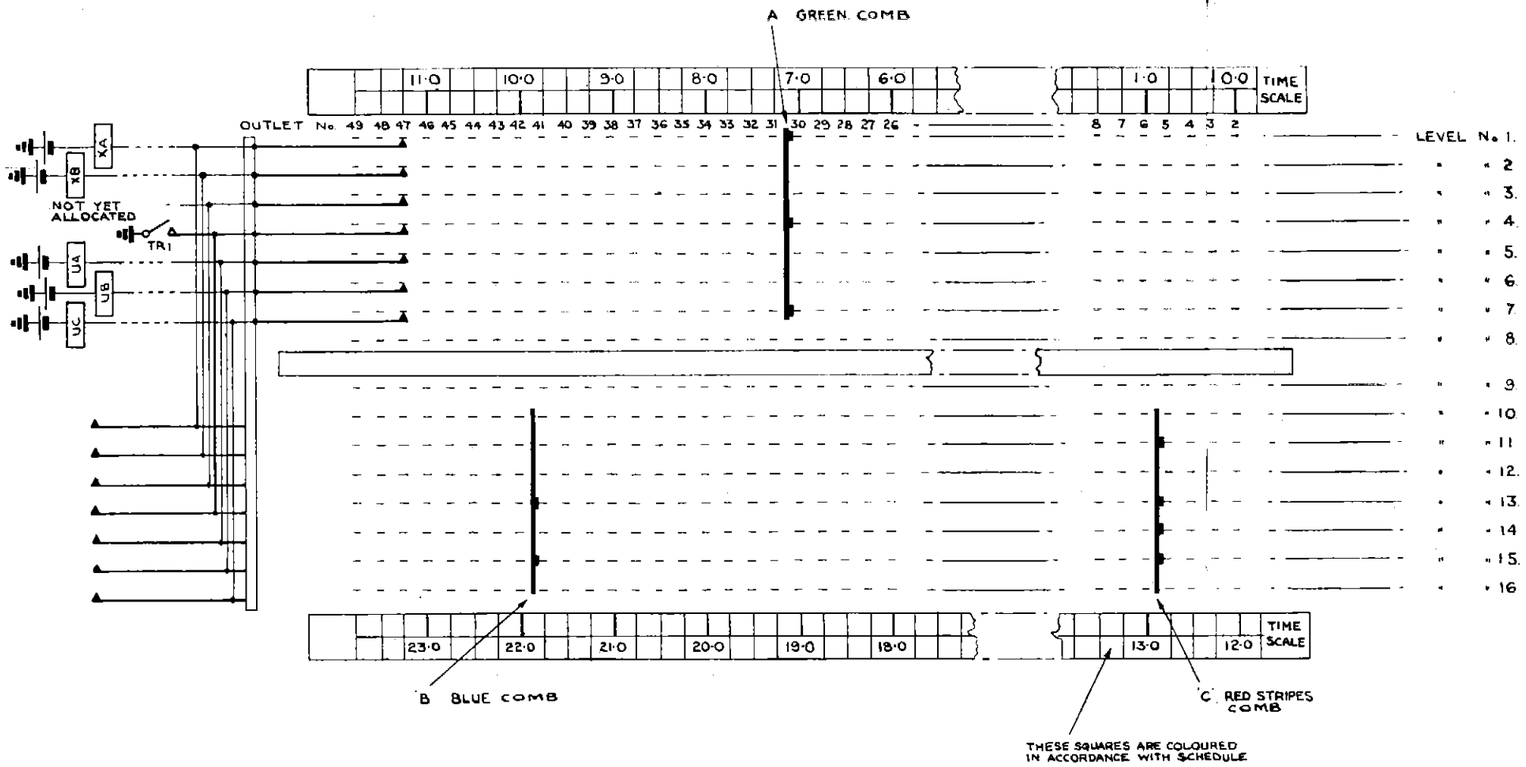

Fig. 16b — Marking of uniselector contacts by combs

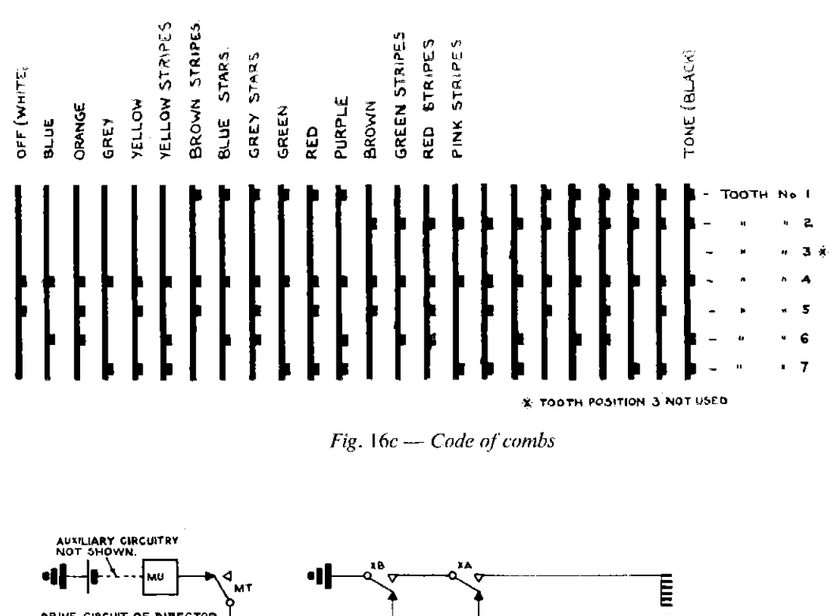

Fig. 16c — Code of combs

Fig. 16 — Programme selector marking

Fig. 16a — Marking code selector. Arrangement and circuit

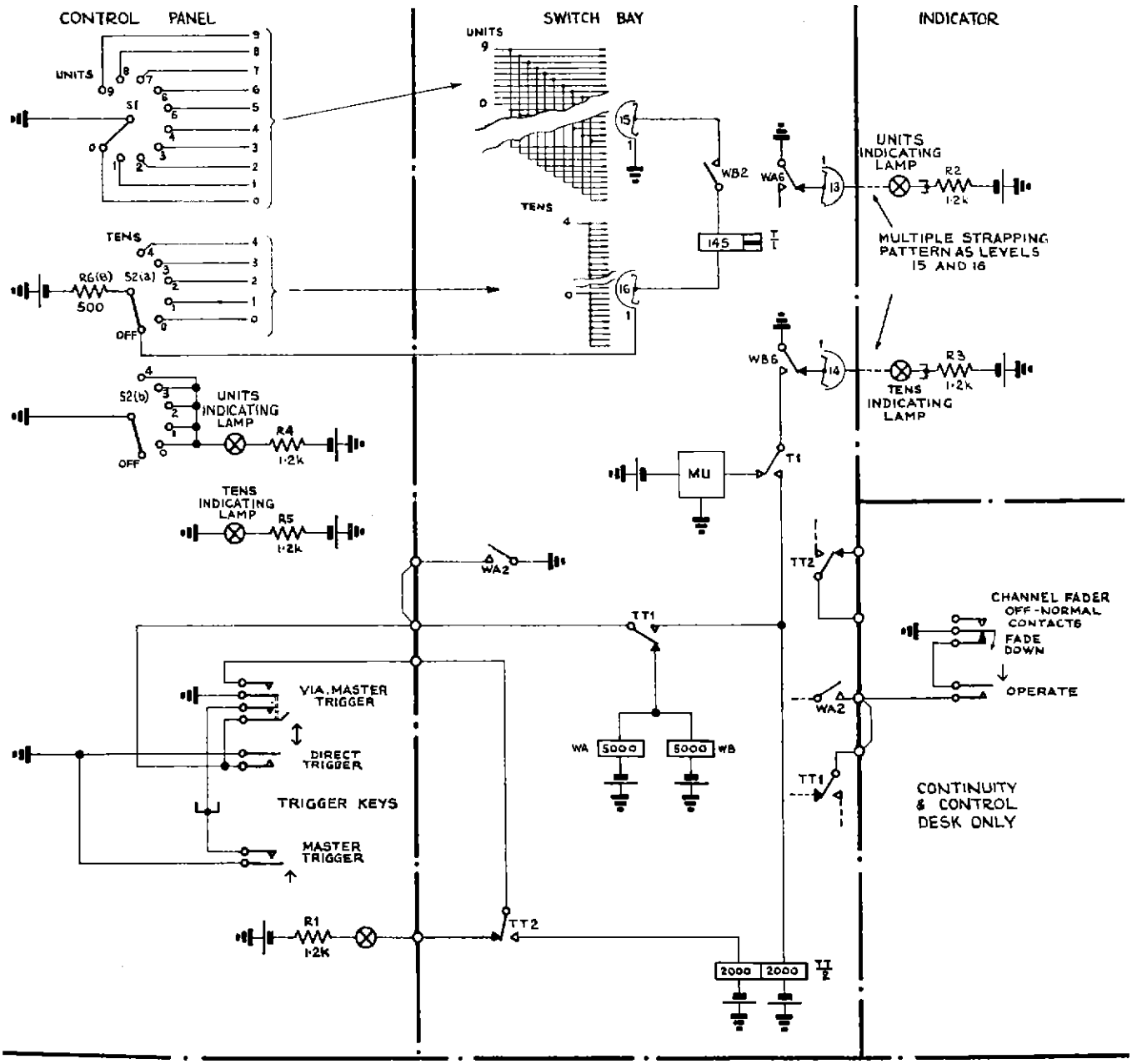

Fig. 13 — Individual marking and triggering of uniselectors

5.3.3. *Route Selection Circuit and Operation*

The circuits for miscellaneous route switching are similar to those already given for direct source/route selection. Common marking, however, controlled by push-button keys is employed instead of the individual marking by rotary switches.

5.3.4. *Clock-Controlled Automatic Route Selection*

The route switching equipment for those routes which carry the network programmes is capable of connecting a maximum of twenty-four channels each to any of twenty-four routes. These connections are either maintained, cancelled, or changed at quarter-hour intervals in accordance with information preset in a switching director. The director has an information capacity of 24 hours (i.e. 96 quarter-hours) repeated automatically. This preset information can be overridden by the manual operation of presetting controls associated with each route.

The whole apparatus is normally unattended and timing is under the control of a master pendulum clock, itself automatically corrected for any error by Greenwich time signals.

(1) *Network Route Switching*

The basic network route switching control circuit is similar to that for direct source/route switching. The net-

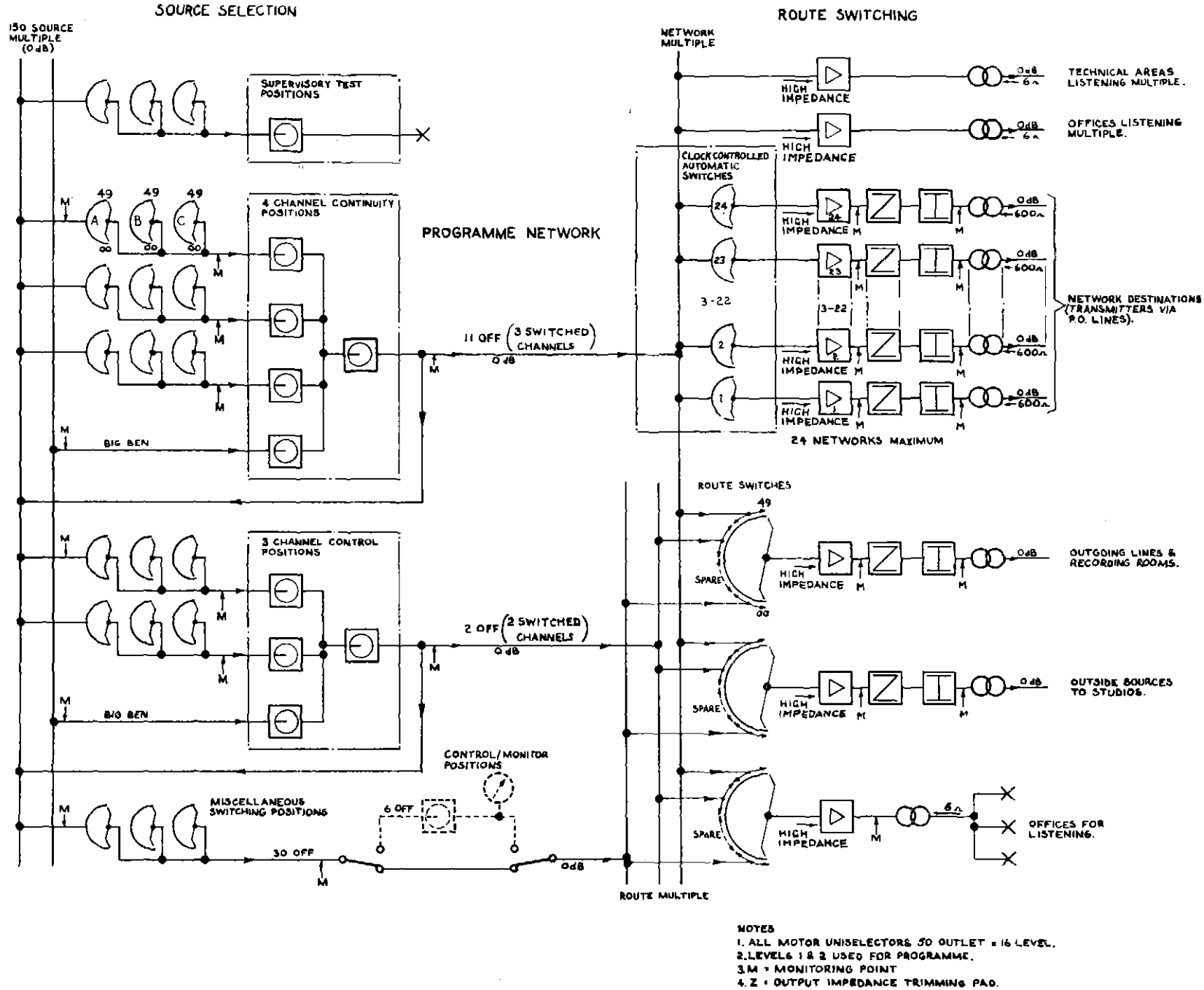

Fig. 14 — Basic switching circuit. Double selection system, Bush House

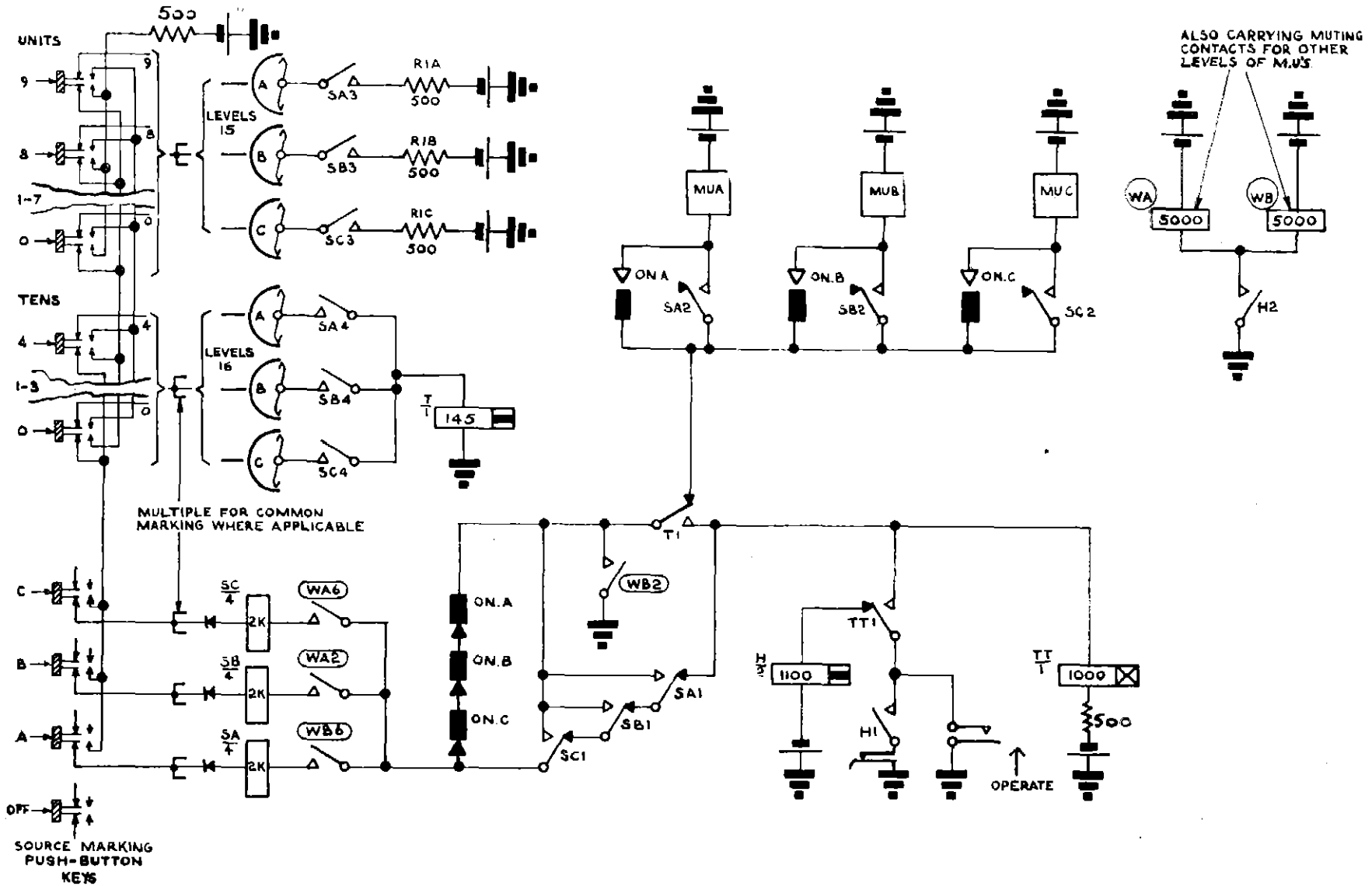

Fig. 15 — Source switching control circuit

work route selectors are, however, automatically marked by a director which is in turn controlled by timing apparatus.

(2) *Direction*

The director consists of twenty-four specially modified motor uniselectors, one associated with each route, which together with a group of relays stores and transmits marking information to the network route switches.

A tree of contacts of five relays, as shown in Fig. 16a, marks twenty-four contacts of the network route selectors. The relays in turn are preselected in different patterns via the contacts of a modified motor uniselector designated a Marking Code Selector.*

Each director motor uniselector is fitted with wipers staggered at 180°. Seven wipers scan levels Nos. 1 to 7, and the opposite seven wipers scan levels 10 to 16.

Level 8 and contacts numbered 1 and 50 of all levels are not used. Level 9 is used in the circuit of the uniselector (Appendix 1) which drives the wipers round one step every 15 min.

Thus seven wipers connect to a row of seven different bank contacts each quarter of an hour; one half of the selector being scanned the first 12 hours and the other half the second 12 hours of a day.

Five of the seven wiper contacts are connected to the marking relay windings as shown in Fig. 16b, which also shows the arc of contacts of a modified uniselector bank in linear form. Wipers Nos. 4 and 13 are returned to earth via the contact of a trigger relay.

By providing means of strapping the contact of level No. 4 or 13 to other contacts in the same vertical row, then according to the combination of contacts chosen, the marking relays are preselected so that when the trigger key is operated the route switch is marked.

The strapping of the required combination of contacts is done by a number of metal combs plugged directly into the uniselector bank. Each metal comb is secured between a plastic moulding and a thin laminate of insulating material through which the bowed teeth of the comb protrude as Fig. 17 shows.

A segment of phenolic resin sheet inserted between levels 8 and 9 partitions the selector bank and acts as a guide for the metal combs, as shown in Fig. 18.

According to whether a comb is inserted above or below the partition, the bank contacts corresponding to the teeth of the comb are connected to either level No. 4 or 13, and so prepare the marking relays for preselection, which occurs as the switch wipers rest on each vertical row of contacts.

Each pattern of the arrangement of the teeth of a comb is designated by that colour which also identifies a particular programme network. Fig. 16c shows the range of combs available and three combs are shown in position in Fig. 16b, which also shows the time scales in quarter-hours, above and below the bank.

The spaces representing quarter-hour periods on the time scale are coloured to indicate the colour of the programme network to be switched at the beginning of that period. It is only necessary to ensure that the colour of the comb corresponds with that in line with it on the time scale to check that the correct directing information has been preset. Fig. 18 shows a typical arrangement.

The time scales are cut from the printed and coloured chart which schedules the transmission periods of the programme networks. By this means errors in the transfer of this information from one medium to another are avoided.

The marking code selectors step at 15 min zero, which is at 18 sec after the previous triggering instant. They are therefore preset 15 min in advance of clock time, ready for the next programme change.

(3) *Timing*

A battery-powered master pendulum clock controls slave clocks throughout a building by transmitting 2 sec and $\frac{1}{2}$-min-interval pulses of 1 sec and 100 msec duration respectively. These pulses are used for the time integrating circuits, and their relationship with the swing of the pendulum is shown in Fig. 19b.

The pendulum is adjusted to a slowing rate of approximately 4 sec per day. Greenwich Time Signals are applied hourly to a correction device which compares the signals against the pulse-integrating mechanism.

A platform is fixed to the pendulum above its centre of gravity. A small weight actuated by solenoids is automatically placed on or removed from the platform according to whether the comparison senses the pendulum as slow or fast. The circuit is shown in Fig. 19a.

These correction devices, developed by the clock manufacturers† for the BBC, maintain accuracy of timekeeping to within $\pm 0{\cdot}5$ sec.

Two time units running in synchrony provide two time-integrating circuits independent of each other except for their common connections to the clock system. Either unit can be set to be the 'duty time unit' for control and triggering, while the other stands by. Each time unit comprises two motor uniselectors with associated relays. One uniselector integrates the time pulses from the clock, and directs the other, which registers the 15-min intervals.

The timing sequence of operations controlled by the integrating uniselector is tabulated in Appendix 2.

The single-stepping circuit which drives both time unit uniselectors is the same as that used for the marking code selectors.

(4) *Auxiliary Controls*

Any failure of switching functions will not affect programme unless it occurs at the moment of programme triggering or so shortly before as to give inadequate time for corrective action. Fault conditions are indicated by both visual and audible alarms.

In the control room the settings of the marking code selectors may be previewed and the network route programmes monitored. Also, the marking code selectors may be overridden by manually operated controls, and the associated network route selectors either triggered at

* Direct Marker for Pre-Selection for Uniselector. British Patent No. 798.831.

† Gent & Co. Ltd, Leicester.

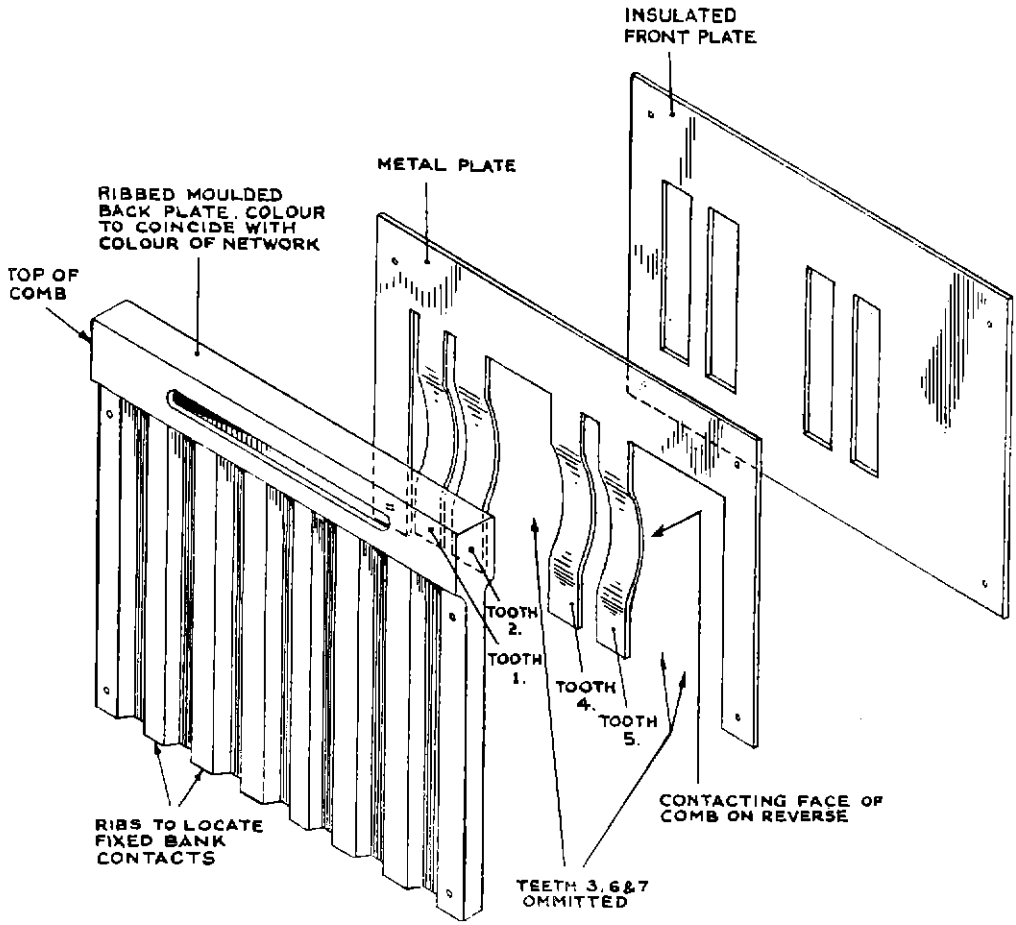

Fig. 17 — Details of combs for marking code selector

any time by hand, or at the next quarter-hour by the clock.

Override settings may be cancelled before being triggered. After cancelling or triggering, control is restored automatically to the marking code selectors.

5.4. *Engineering Manual Telephone Exchange*

5.4.1. *General*

A considerable engineering communications system quite distinct from the general administrative telephone system links the regions with each other and with the local technical areas inside and outside the studio centres.

The operational position of this engineering telephone network is the Engineering Manual Exchange (E.M.X.), which has a cordless switchboard. It is invariably situated adjacent to the operational desks concerned with programme switching and monitoring, which together form the major operational control centre at all studio centres.

A large part of the traffic of this exchange consists of communication between the control room and the 'subscriber' rather than of calls between one subscriber and another. There are two main reasons for this:

1. A substantial part of subscriber-to-subscriber traffic is diverted from the E.M.X. by the automatic extension of source-to-destination telephone lines whenever an associated programme source-to-route selection is made.

2. The E.M.X. is staffed by a technical operator who is also concerned with programme switching and routing.

5.4.2. *Special Features*

The following facilities additional to those normally required for the engineering telephone exchange are designed to meet the special needs of programme operational techniques:

1. If a subscriber selected into the E.M.X. has not been disconnected on conclusion of a call, then a further call will be indicated by the subscriber's calling lamp and also by the supervisory lamp of the tie circuit to which the subscriber is still connected. This prevents isolation of a subscriber who has only one line into the exchange. The E.M.X. operator may also retain selection of a subscriber who is for a period in frequent demand, thus obviating frequent supervision, selection, and disconnection.

2. When source-to-destination control telephone lines are diverted from E.M.X., supplementary switching still enables the local source-and-destination subscribers to call E.M.X. The E.M.X. operator may always bridge a line to originate a common call to both subscribers.

3. If a source-to-destination connection has been established as in (1) and the destination is unmanned or does not respond to a call originated by the source, then after

a delay of approximately ½ min the extension to the destination is automatically disconnected and calling from the source into E.M.X. is restored. This condition will prevail until, by eventual cancellation of the original calling signal at the destination, the extension is restored. Outside Broadcast callers having only one line of communication value this arrangement.

5.4.3. *Design and Circuit*

In the E.M.X. design presented the functional equivalents of the 'Call' and 'Answer' cords of a manual exchange are the wiper arms of 'Call' and 'Answer' selectors. The selector bank outlets accommodate the multiple of subscriber lines, which are the equivalent of the subscriber jacks of a corded-type exchange.

By arranging that staggered wipers scan in sequence two halves of 8-level motor uniselectors, a bay of twelve provides a basic E.M.X. unit of accommodation for 100 subscribers and six cordless tie circuits. The circuit and the schematic of associated external apparatus are shown in Fig. 20. The substitution of 16-level uniselectors increases the maximum number of subscribers to 200, whilst duplication of the latter unit doubles the available tie circuits, which two operators may share equally during peak periods of telephone traffic.

Expansion in this fashion enables a common design to meet varying requirements. For example: the 100-subscriber unit is adequate for regional studio centres, and the 200 for the new London Television Centre, whilst for the new London Broadcasting House Control Room a 200-subscriber, twelve-tie-circuit, installation, supplemented by two 100-subscriber, six-tie-circuit, units is planned. One of the latter will be shared by two operators, each using three-tie circuits.

5.5. *Auxiliary Facilities*

5.5.1. *Cue Programme*

Cue programme here means programme passed from the destination to a source so that the latter receives a cue to enter the programme.

A destination can connect cue programme to the source/destination control lines. When the telephone is in use, the cue is automatically cut off and restored at the conclusion of the call.

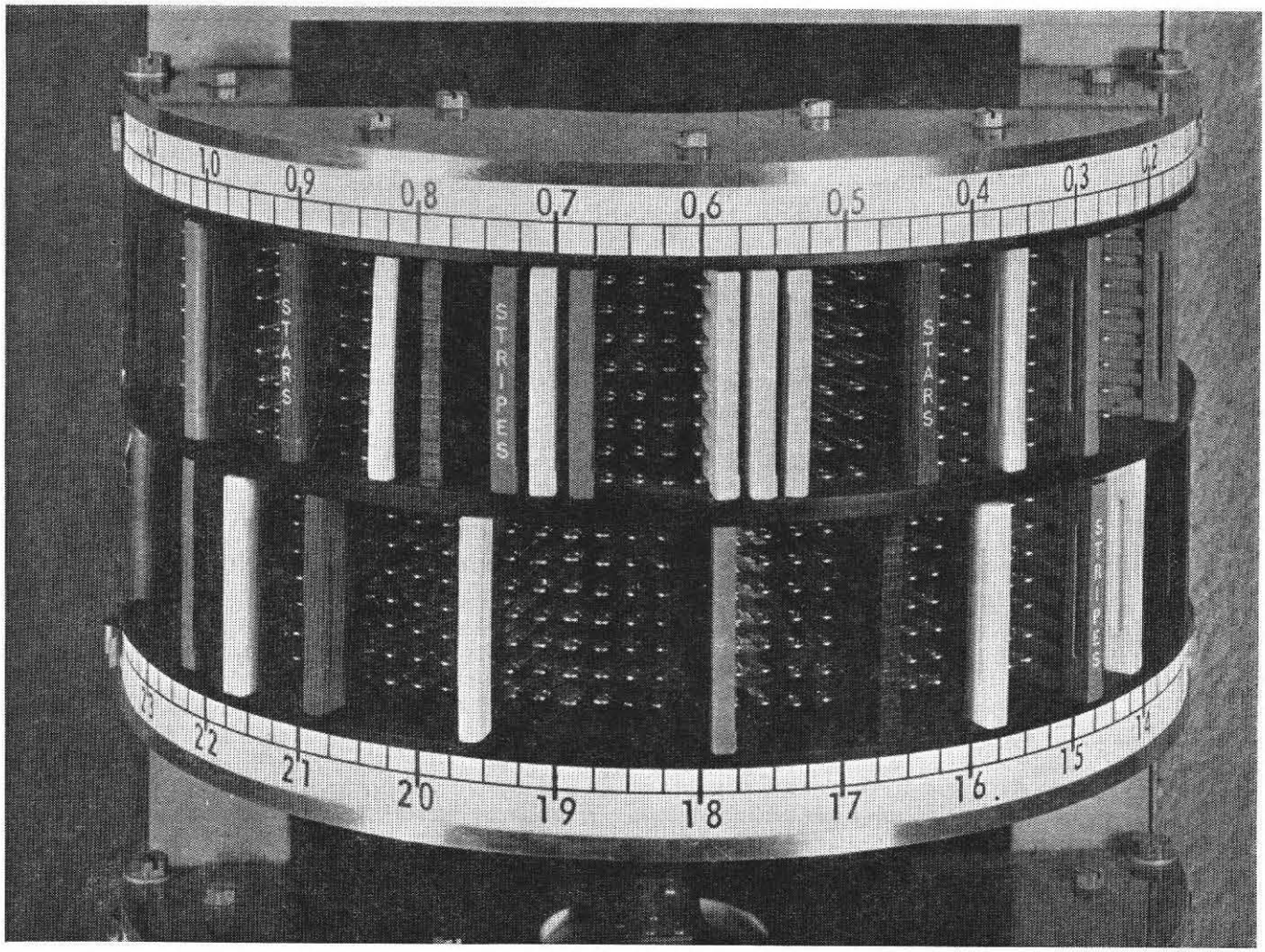

Fig. 18 — Marking code selector with combs inserted

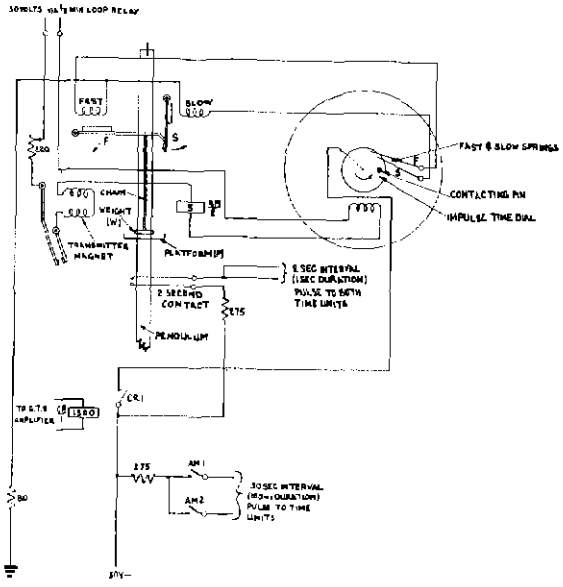

Fig. 19a — Master pendulum clock and correction circuit

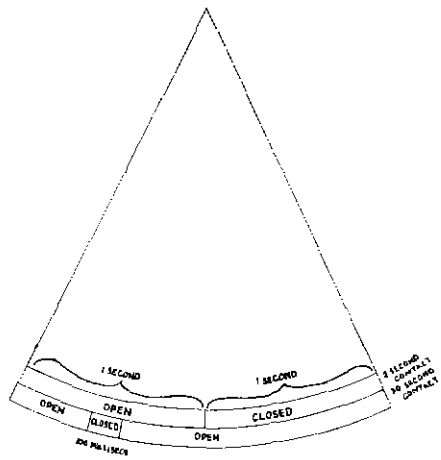

Fig. 19b — Time relationship between clock pulses and pendulum swing

5.5.2. *Studio Signalling*

Two-way signalling between studios (and other local programme sources) and control positions is carried by a single level (No. 12) of the programme uniselectors. The signalling indicates visually and audibly:

readiness to start a programme (signal from control end); acknowledgment of readiness (signal from source end); 'on the air' warning at source (signal from control end); end of programme (signal from source end); and acknowledgment of end of programme (signal from control end).

5.5.3. *Remote Control of Sound Recording and Reproducing Apparatus*

Levels Nos. 10 and 11 of the programme uniselectors are reserved for the remote control circuits for starting and stopping recording machines and for indicating by lamps at both ends of the circuit when a machine is prepared for, and when actually recording. Level 10 and Studio Signalling Level (12) provide similar facilities for the remote start of a reproducing machine.

6. Monitoring

6.1. *General*

The technical quality of the programme is determined at its source by the acoustics of the studio, by the relative disposition of artists and instruments, and by control of the relative level of the outputs from a number of microphones. Subsequent monitoring is to check that this quality is maintained. Over many of the links in the broadcasting chain this is done automatically by methods which have been described elsewhere.[6]

At some points, however, it is necessary, and at others economical and convenient, to employ manual monitoring methods, as, for instance, where a number of points can be grouped for sampling by a single operator.

6.2. *Continuous Monitoring*

Between the points where a programme enters a studio centre control room as a source and leaves it as a destination, continuous manual monitoring is usual only when such programme forms part of a programme network, or, for the reasons given earlier, it is passed through an intervening manned control position.

For domestic programme networks continuous monitoring is maintained at the continuity position by sequential sampling of the local A.M. and V.H.F. F.M. transmissions for $\frac{1}{2}$-min periods. These are compared with the continuity position output only when a fault is suspected.

Thus transmission faults are quickly detected at the studio centre, where the effect of interference which may not be detectable at the transmitter can be assessed.

6.3. *Pre-fade Monitoring*

A further requirement in continuity rooms is the ability to monitor a programme channel before it is faded up, either to identify incoming programme or to choose a moment suitable for a smooth 'fade-in'. Monitoring amplifiers and meters are duplicated to enable the sound volume of the incoming item to be regulated relative to that already being broadcast. In the studio the continuity announcer uses similar pre-fade monitoring equipment to assist him in timing his linking announcements.

6.4. *Comprehensive Check Monitoring*

6.4.1. *General*

Comprehensive switching systems have been designed for the fleeting monitoring of programmes at their point of entry to and exit from a studio centre and also at points

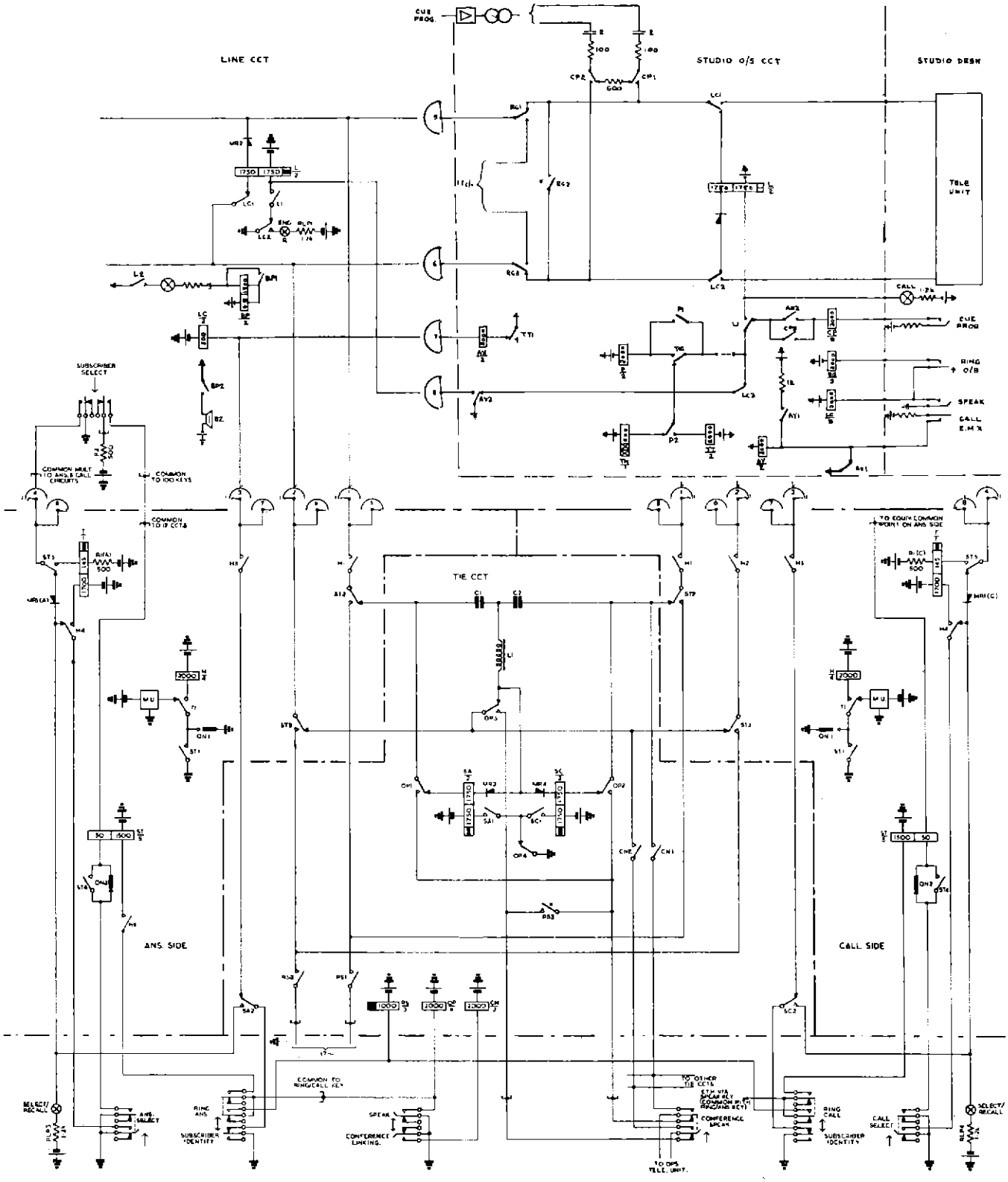

Fig. 20 — Engineering manual exchange. Circuit

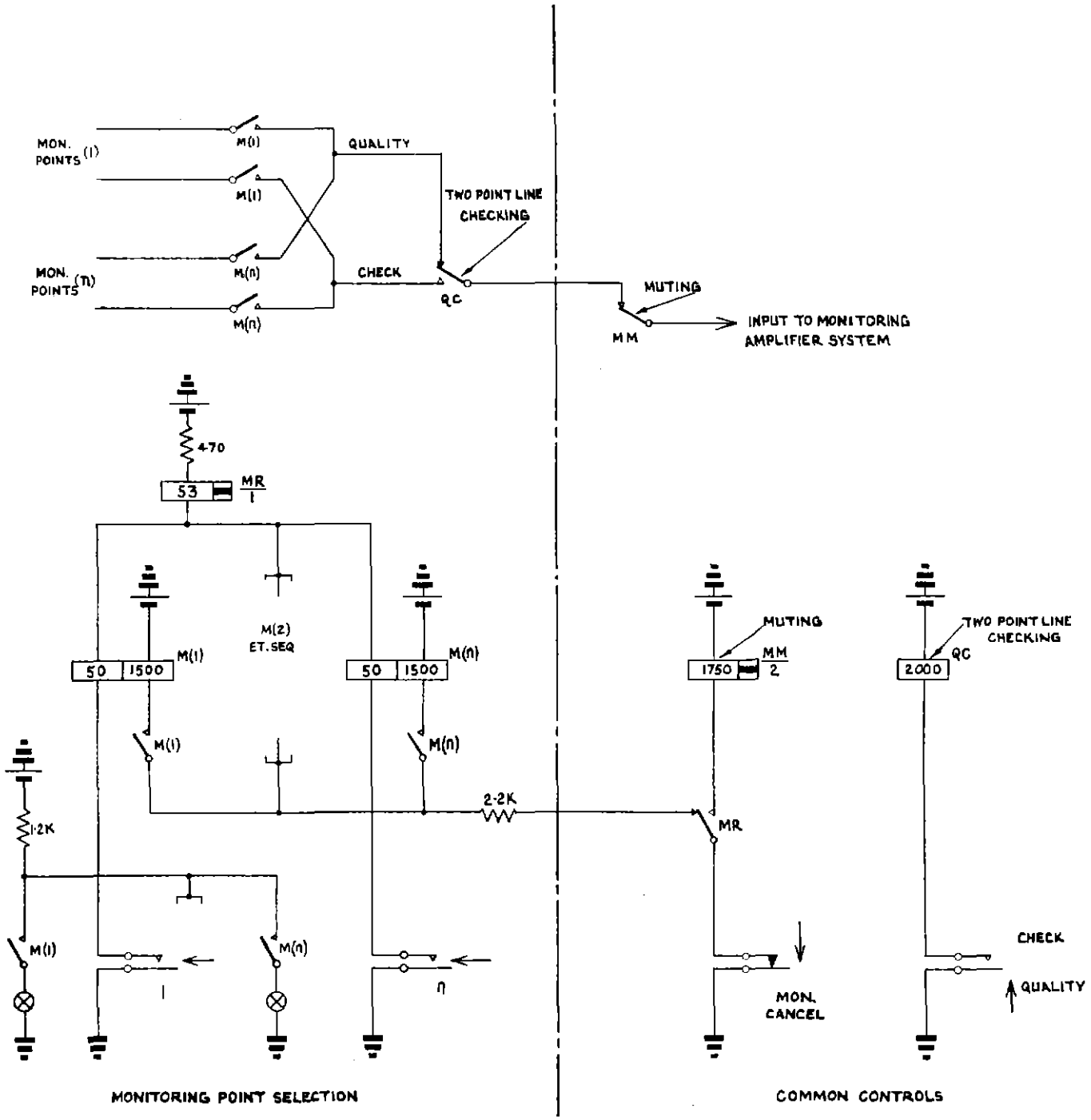

Fig. 21 — Monitoring circuit using relays

between. This monitoring assists in establishing that the links of a programme chain are correctly connected, and also ensures that a fault in a chain is quickly located. The monitoring points of typical programme chains are indicated by arrowheads (M) on the schematic diagrams of Figs. 7, 11, and 14.

A large proportion of the comprehensive monitoring selection controls is disposed within reach of the Engineering Manual Exchange, at which reports of faults are normally received.

Programme quality cannot be satisfactorily monitored at points where lines enter or leave a studio centre because of the effect of line characteristics. Nevertheless, it is necessary to know whether the correct programme is entering and leaving the centre. Monitoring systems have therefore been designed to select simultaneously two monitoring points of a line to opposite sides of a changeover switch. The two monitoring points for incoming lines are the line and its equalized, amplified output. The corresponding monitoring points on outgoing lines are the outgoing line

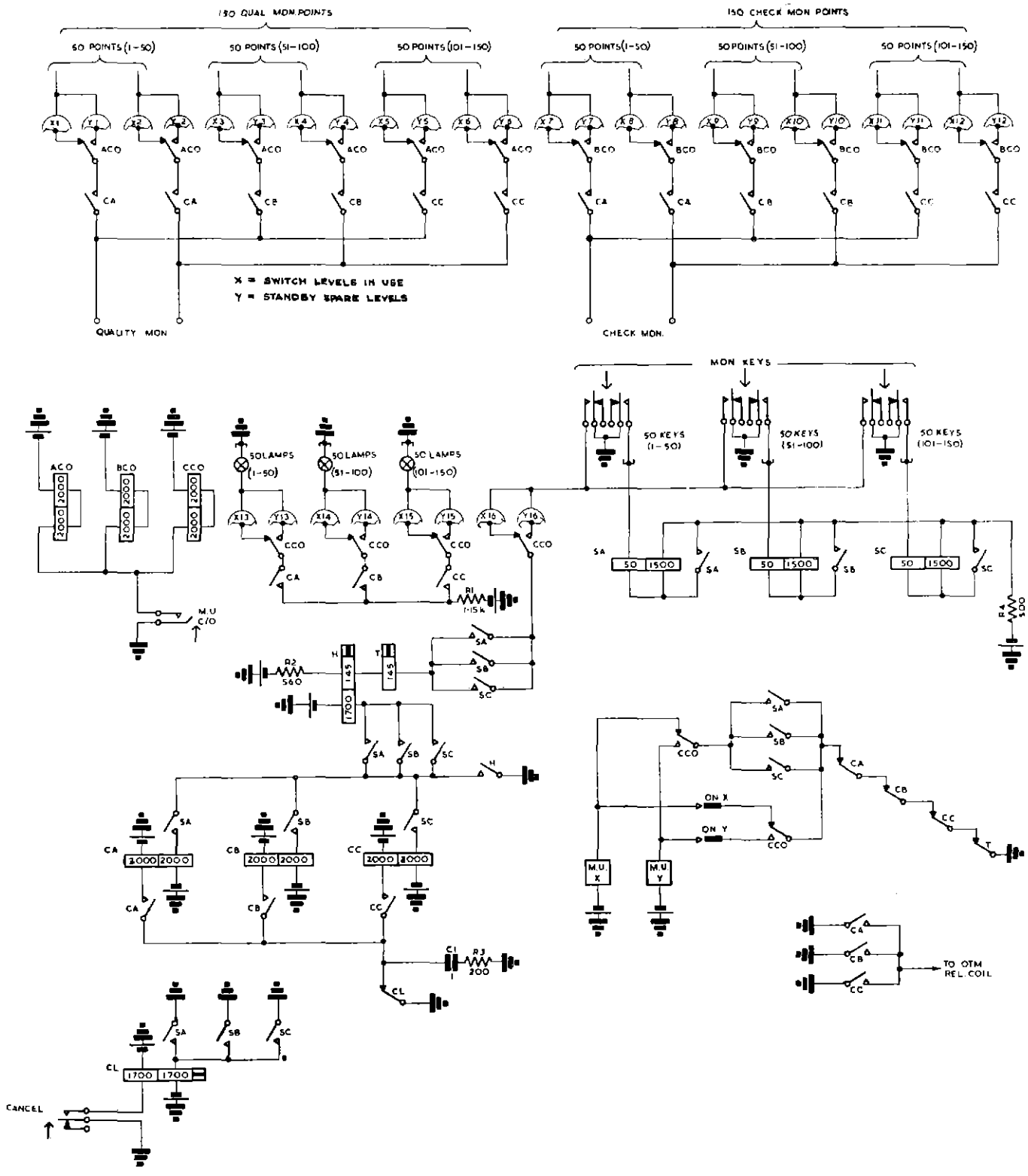

Fig. 22 — Monitoring circuit using motor uniselectors

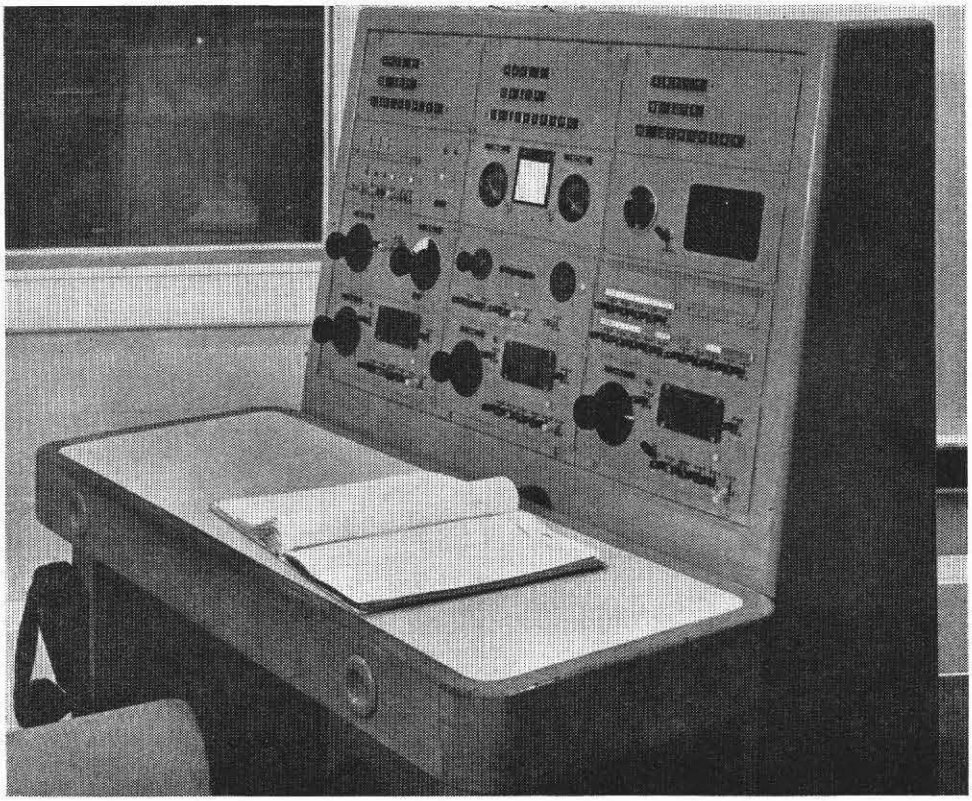

Fig. 23 — Typical console desk

and the output of the amplifier feeding this line. Once these twin monitoring points have been selected, operation of the changeover switch enables either programme quality or continuity of programme to line to be checked.

For monitoring a few points a relay switching system is adequate, but when the number exceeds, say, forty, a more recently designed uniselector switching system is considerably more economical.

6.4.2. *Relay Switching Circuit*

The basic monitoring circuit using relays is given in Fig. 21. Selection is by means of a field of non-locking push buttons, each of which operates a relay to connect the associated point to the input of a monitoring amplifier. Momentary depression of the button corresponding to the circuit to be monitored cancels any previous selection and operates the relay, which makes the new selection and self-holds until another selection is made, or until the cancel key is operated. Operation of the cancel key also restores the E.M.X. operator's headset to the telephone exchange. Thus in response to a telephoned query quality and continuity of programme may be rapidly checked and the query answered.

6.4.3. *Uniselector Switching Circuit*

A motor uniselector is particularly applicable to the two point monitoring of lines already described, as two switch levels can accommodate the quality monitoring points, and two levels the programme continuity check points. With a fifth level for the indicating lamps circuit, and a sixth for marking the switch, an 8-level selector is adequate for monitoring fifty double points.

A 16-level switch may have its levels allocated in sections such that three groups of four levels are allocated for programme monitoring, three levels (one for each group) for lamp indication, and one common level for marking the switch. With auxiliary relays arranged to transfer from one group of levels to another, 150 double monitoring points may be scanned, and great efficiency and economy obtained. This is the design adopted for the new London Broadcasting House Control Room, where 450 monitoring points are accommodated on three uniselectors. Even with three additional uniselectors, which can be switched into service whilst the normal ones are maintained, the total cost is little more than a third that of equivalent relay switching. Fig. 22 shows the circuit.

The contacts of one side of each monitoring push button key mark an outlet on the selector bank, whilst the other side is connected to a relay SA, SB, or SC according to whether the monitoring point is located in the first, second, or third groups of level in the switch.

When the monitoring key is depressed and held, the uniselector switch is marked, the appropriate S relay operates, the switch drives to the marked outlet, and a circuit is prepared for the appropriate relay (CA, CB, or CC).

When the switch reaches the marked outlet, relay T stops the switch, relay H operates the C relay, which in turn connects the monitoring circuit and also lights the indicator lamp.

The monitoring push button is then released, relays T, H, and CL release, and the C relay self-holds. The maximum period for this cycle of operations is 150 msec.

6.4.4. *Monitor Equipment*

Visual monitoring of programme volume is indicated by peak programme meters which are preceded and operated by high input impedance monitoring amplifiers.[7] The meters have a linear decibel scale over most of their range. By the operation of a key the time constant of the fall-back circuit of the meters may be increased so that the movement of the needle is slow enough to enable the programme volume at different studio centres to be compared by telephonic communication.

Concurrently with visual monitoring, aural monitoring is available via headphones and/or loudspeakers which are fed from the same monitoring amplifier that drives the programme meter.

The E.M.X. telephone headset is used for telephoning and for monitoring. It is therefore a lightweight, sensitive instrument with two earpieces to reduce the masking effect of ambient noise. The quality of sound reproduction is adequate to enable distinct distortions to be detected, although a loudspeaker may be switched in place of the headset for critical listening.

In Studio Headquarters Control Rooms the main E.M.X. position is provided with independent monitoring for each of two operators, who share a high-fidelity loudspeaker for checking sound quality. Either operator can dim this loudspeaker, whether it is in use by himself or by his colleague, should it interfere with communication.

6.5. *Sequential Monitoring*

Programme sampling, or 'sequential monitoring' has, come into increasing use in connection with remote and automatically controlled unattended transmitters. It is also used at the manned multi-sender transmitting stations of the external programme services.

The familiar 'flip-flop' relay circuit is adequate for monitoring two points alternately, but for large transmitting stations a more interesting and complex sequential monitoring system is employed in conjunction with the clock-operated automatic programme switching equipment.

The sequential monitor presents in sequence to the input of the monitoring amplifier firstly an incoming programme line and then in turn the output of each transmitter fed from that line, before presenting in like manner subsequent incoming lines and their associated transmitter outputs.

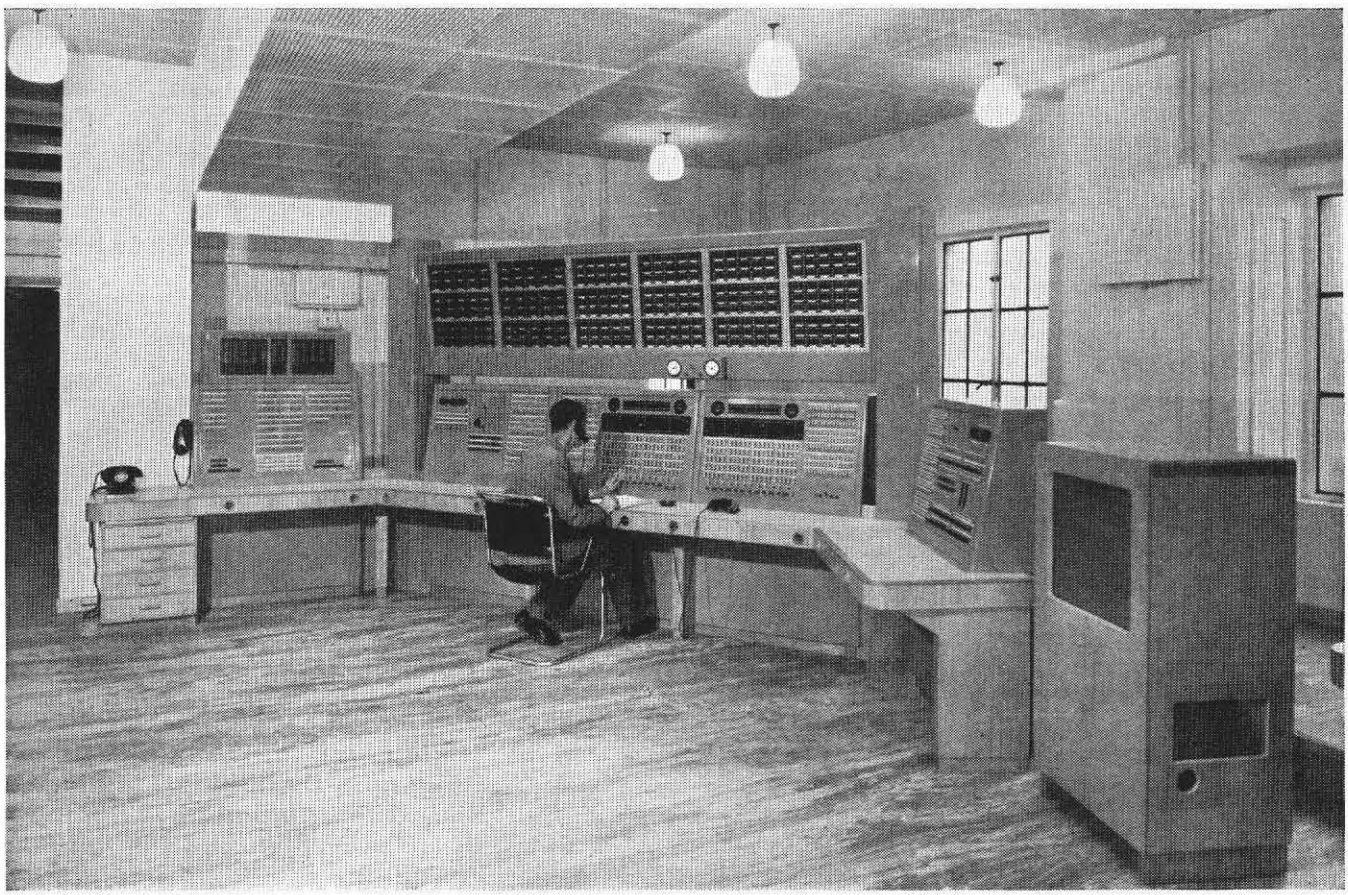

Fig. 24 — Bush House Control Suite

As the pattern of transmitters connected to programme lines is changed every 15 min by automatic programme switching equipment, this is designed also to rearrange the pattern of the monitoring sequence to correspond.

Lines and transmitters not in use are automatically excluded at each rearrangement and the equipment switches itself off when there are no transmissions.

With this equipment a single operator can monitor the continual varying output of a multi-transmitter station with minimum aural fatigue.

For instance, at a station with eighteen transmitters served by six lines, the monitoring system described ensures a maximum of six audible changes of programme per cycle. With 5 sec listening per point, the minimum listening period per programme is 10 sec, and the maximum time of a complete cycle 2 min.

(If an ordinary straight sequential monitoring system were used, the number of audible changes of programme could be twenty-four, and the minimum listening period 5 sec for a 2 min cycle.)

Lamps indicate each monitoring point change, but the operator is only audibly aware of each programme change as another line is selected. He may instantly stop the sequential monitor or override its selection if necessary.

7. Constructional Features

All apparatus and switching bays are limited to a height of 7 ft to enable them to be accommodated in rooms of normal ceiling height.

Rows of apparatus bays sited in large control rooms are equipped on both sides with apparatus panels which are hinged to allow access to the wiring. In small areas such as continuity rooms only one side of the bays is equipped, which enables them to be mounted with their backs close to the wall so that they do not encumber the room.

Amplifiers[7] and equipment carrying components vulnerable to failure are plugged into position and secured by quick-acting fasteners. It might seem a retrograde step to introduce the hazard of additional plug and socket connections instead of soldered joints, as contact faults represent a large proportion of the failures in all communication equipment. Nevertheless, records show no increase in faults due to this change, which enables equipment failures to be dealt with swiftly and effectively, for as soon as the faulty unit has been identified, it is bypassed, a spare unit substituted, and the circuit restored to normal. The faulty unit is then serviced away from the operational area.

Unit construction of bay-mounted units is, of course, in general use, and in the BBC this policy has been extended to the design of consoles for control desks, one of which, a control position desk, is shown in Fig. 23. The desk is 3 ft 4 in. wide and the vertical panel strips each have four large rectangular holes over which the sub-panels are fitted.

This unit construction considerably reduces the overall time between the initiation of a project and its service date, as constructional work can be carried out in advance of final circuit design.

An arrangement of console cabinets which form the main operating position of the BBC External Services Control Room is shown in Fig. 24, with an operator at an E.M.X. position.

8. Conclusions

From the foregoing it may reasonably be deduced that except at extremely small broadcasting studio centres the introduction of some degree of automatic programme switching is worth while on grounds of operational convenience, efficiency, and economy.

It will be appreciated that the degree of automatic switching which may be employed with advantage increases as the frequency of changes in the network distribution pattern increases, and that where a broadcasting programme service conforms to a repetitive and precise time schedule a high degree of automatic switching control may be used successfully.

9. Acknowledgments

The designs which have been presented represent part of projects which involved close co-operation with colleagues of the operational and other specialist engineering departments of the BBC, to whom full acknowledgment is made for bringing the designs to fruition.

Our thanks are due to those colleagues in the Designs Department who shared in these designs and assisted in the preparation of this Monograph.

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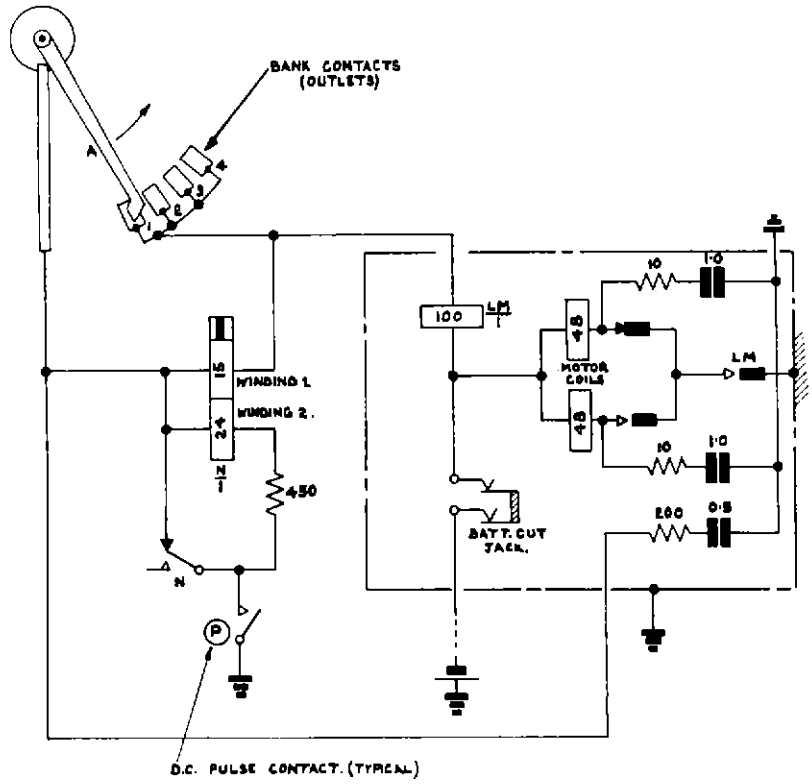
APPENDIX 1

SINGLE STEPPING OF MOTOR UNISELECTORS

The circuit, British Patent No. 660.926, and the principle of its operation are shown and described below.

It will be seen that the circuit requires the use of a level of the selector (non-bridging wiper), the bank contacts of which are strapped together. The marking code selector (5, 3, 4 (2)) for which this circuit is used cannot have this driving level (9) strapped externally because of the marking combs and their centre guide. The strapping has therefore been done internally by means of metal foil inserted during manufacture.



When contact P closes, battery earth is applied to latch magnet (LM/1) via contact N, wiper A, and bank contact 1. LM/1 operates and selector commences to drive. Wiper A moves towards bank contact 2. As soon as it leaves bank contact 1, relay N/1 operates on winding 1 in series with LM/1. This relay will operate to break contact N in approximately 0·3 msec. Contact N breaks, inserting winding 2 of N/1 and 450 ohms in series with winding 1 and LM/1. LM/1 now has insufficient current to keep it operated. It releases therefore, in time to stop the selector as it arrives on bank contact 2. N/1 continues to hold until contact P breaks. A second closure of P will now step the switch to bank contact 3 and so on, one step for each closure of P.

Appendix 2 on following page

APPENDIX 2

TIMING SEQUENCE OF INTEGRATING UNISELECTOR

SWITCH OUTLET NUMBER	TIME RELATIVE TO ZERO. SECS.	TIME MIN	SECS.	OPERATION
1		14	59	
2	ZERO *	00	00	MARKING CODE SELECTORS STEP
3		00	30	
4	ZERO +60	01	00	TONE ON
5		01	30	
6 TO 27		02 TO 12	00 30	
28		13	00	
29		13	30	
30	ZERO -60	14	00	TONE OFF
31		14	30	
32	ZERO -29	14	31	FIRST 2 SEC INTERVAL PULSE.
33		14	33	
34	ZERO -25	14	35	
35		14	37	
36		14	39	
37	ZERO -19	14	41	PROGRAMME TRIGGER RELAYS OPERATE.
	ZERO -18 †	14	42	PROGRAMME TRIGGER RELAYS RELEASE.
38		14	43	
39		14	45	
40	ZERO -13 ‡	14	47	MIDDAY AND MIDNIGHT TRANSFER OF MARKING CODE SELECTORS.
41		14	49	
42		14	51	
43		14	53	
44		14	55	
45		14	57	
46	ZERO -1	14	59	FIRST TIMING SELECTOR ITSELF HOMES (TO OUTLET ONE).

* ZERO TIME OCCURS ON THE HOUR, AND AT 15, 30, AND 45 MINS PAST THE HOUR.
† PROGRAMME SELECTOR CHANGE IS TRIGGERED ON RELEASE OF RELAY.
‡ AT 11.44 47 . AND 23 44 47 HOURS ONLY.

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