AUTO TO AUTO RELAY SETS

CONTENTS

INTRODUCTION

Within certain limits loop-disconnect pulsing junctions are used to carry the major portion of the directly dialled traffic between one non-director automatic exchange and another, also between a tandem exchange and a director automatic exchange. The junctions are trunked from the levels of group selectors and are terminated on group selectors at the distant exchange.

The circuits of the subscriber's calling equipment and group selector are such that they require an independent holding earth applied to the private (P) wire when they have switched to the next stage of equipment. During the setting up of a connexion the earth is applied by the selector which is at that time directly under the control of the calling subscriber's telephone loop, hence when the connexion is established the holding earth is applied to the P-wire by the final selector circuit. Thus if 3-wire, i.e. positive, negative and private, junctions were provided directly between the levels of the group selectors at the originating exchange and the group selectors at the distant exchange, the setting up and holding of a directly dialled connexion between the two exchanges would be similar to that for a local call. In a connexion between subscribers on the same exchange, the transmission bridge which supplies the direct current for the transmitters in the calling and called subscribers telephones is in the circuit of the final selector. The transmission performance of the subscriber's circuits is, therefore dependent in part on the resistance of the lines and the current feed arrangements in the bridge. The design and construction of a modern telephone

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instrument and the transmission bridge, however, often allow for a line resistance which exceeds that permitted by the operating characteristics of the A relays in the group selectors and the A and D relays in the final selector.

For economic reasons the lines connected to an exchange should be allowed to have the maximum possible resistance, and, from the previous paragraph, it may be stated that the value of this resistance is limited by

(i) the minimum permissible transmission performance, or

(ii) the operating characteristics of the signalling relays in the exchange equipment.

If direct 3-wire junctions are used between exchanges the transmission bridge for a subscriber to subscriber connexion is in the final selector at the distant exchange. The transmission performance and the performance of the A relays in the equipment at the distant exchange are then governed in part by the combined resistances of the junction and the calling subscriber's line. Hence, if direct dialling over direct 3-wire junctions is to be introduced, the maximum resistance of a subscriber's line must also be governed by the resistance of the junctions to the exchanges concerned.

In addition to the limits imposed on the subscribers line resistance the following points must also be considered.

(i) The effect of the resistance, and capacitance to earth of the junction P-wire on the performance of the switching relays in the selectors at the originating and distant exchanges.

(ii) The adjustment of the pulsing relays in the selectors at the distant exchange to give a satisfactory performance when subjected to loop-disconnect pulses over circuits, i.e. junctions plus calling subscribers' lines, of widely differing electrical characteristics.

(iii) The cost of the additional line plant required to provide the P-wire in each junction circuit; the importance of this point will depend largely upon the relative cost of line plant provision and the provision of alternative exchange equipment at the particular time.

The transmission and signalling, i.e. relay operating, problems associated with the use of direct 3-wire junctions can be resolved by the introduction of a transmission bridge and signal repeating arrangement in the junction at the originating exchange. Also the circuit arrangement can be developed to allow for the use of 2-wire junctions. The basic requirements of such a circuit are that it should provide

(a) a holding and guarding earth for the selectors in the originating exchange when the circuit is seized by the calling subscriber,

(b) a current supply for the calling subscriber's transmitter, it should be noted that current for the called subscriber's transmitter is supplied by the transmission bridge in the distant final selector,

(c) a seizing and holding loop for the distant selectors,

(d) a means for repeating the calling subscriber's dialled pulses to the distant selectors,

(e) a means for extending the 'called subscriber answer' signal back for supervisory purposes should the call have originated at a manual-board.

The circuit arrangement which embodies the foregoing basic requirements is known as an auto to auto junction relay-set. The operation of the elementary circuit will now be considered.

ELEMENTARY CIRCUIT OPERATION

The elements of the connexions concerned in the setting up of a directly dialled call over an auto to auto junction circuit between two subscribers is shown in Fig. 1. The relay-set is seized in the inter-digital pause between the last digit of the appropriate dialling code and the 1st digit of the called subscriber's number.

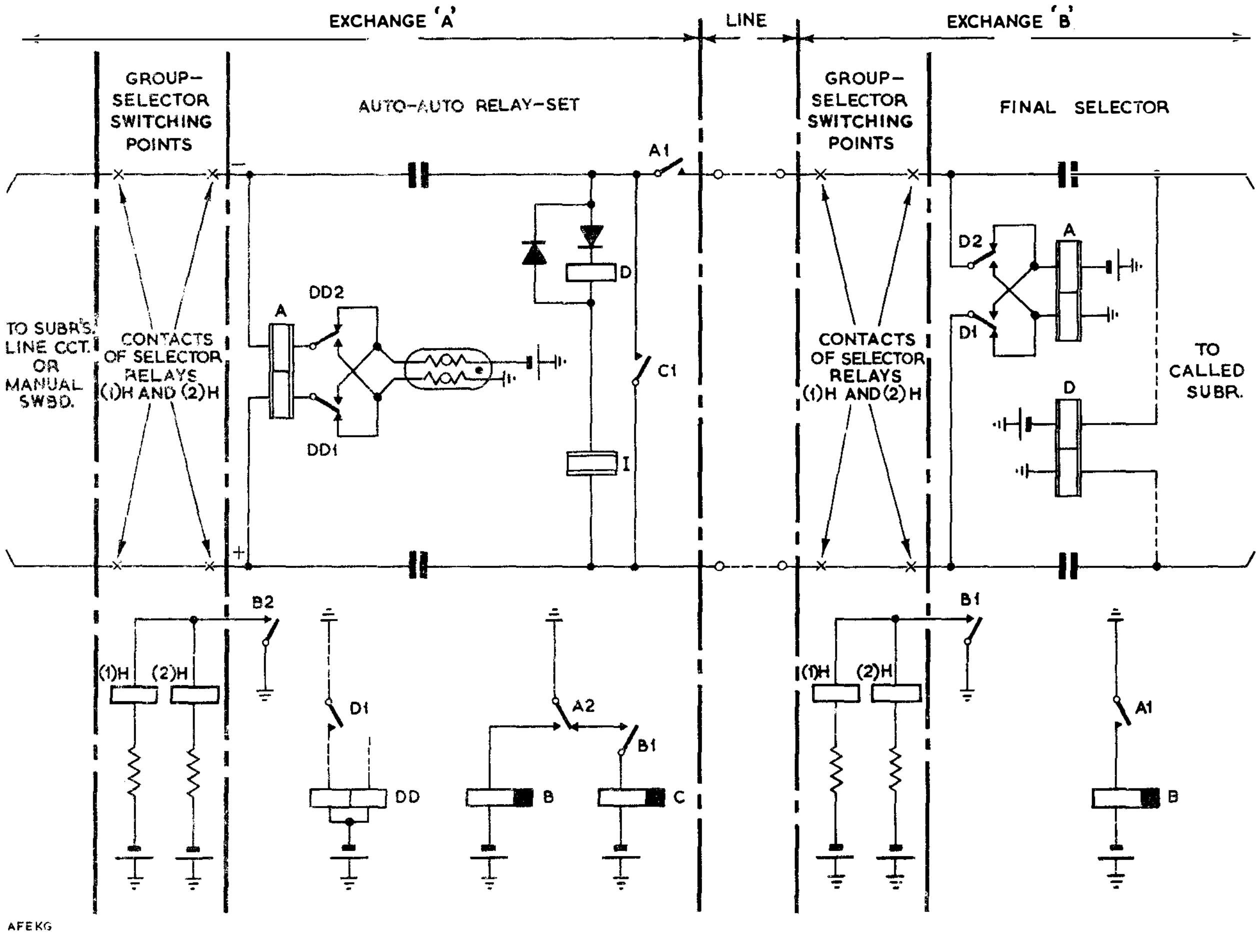

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Fig. 1

The loop from the caller's dial completes an operate circuit for relay A. Contact A1 completes an operate circuit for the A relay in the selector on which the junction terminates. The rectifiers associated with relay D are connected such that with normal line conditions only relay I operates in series with relay A in the distant equipment. Contact A2 operates relay B. Contact B2 applies earth to the P-wire to hold the switching relays in the preceding selectors and also to guard the relay-set against intrusion by another caller. The holding and guarding earth is required to be continuous, consequently relay B is designed to hold during the pulsing of contact A2.

Relay A responds to the trains of pulses appropriate to the called subscriber's number, and at contact A1 repeats them to the selectors in the distant exchange. The first break of contact A2 completes an operate circuit for relay C which at contact C1 short circuits relays D and I to provide a non-inductive pulsing loop of minimum resistance. Relay C releases at the end of each pulse train and thereby leaves the forward equipment held by the D and I relay loop during each inter-digital pause.

When the called subscriber answers, relay D in the final selector operates and at contacts D1 and D2 reverses the line wire potentials. The change of bias potential on the rectifiers allows relay D in the auto to auto relay-set to operate. Contact D1 completes an operate circuit for relay DD which at contacts DD1 and DD2 changes over the potentials on the lines incoming to the relay-set, thereby repeating the called subscriber answer signal. On calls originated at a manual switchboard the reversal is used to extinguish the cord-circuit calling cord supervisory lamp.

Practical Considerations

In practice means must be provided to register an effective call on the calling subscriber's meter, and also to ensure that, on the release of a connexion, the junction is not seized for another call before the equipment in the distant exchange has been given sufficient time to restore. Thus a practical auto to auto relay-set must also provide

(f) a means whereby the 'called subscriber answer' signal causes the operation of the calling subscriber's meter, and

(g) an arrangement such that on the release of the connexion the junction is guarded for a period sufficient to allow the distant equipment to restore.

Originally directly dialled calls from a particular exchange were restricted to the 1-unit fee charge area; i.e. calls which required only one operation of the calling subscriber's meter. Circuit arrangements were subsequently introduced which allowed for calls to exchanges within the 4-unit fee charge area, i.e. calls which required up to 4 operations of the meter; this facility was termed 'multi-metering'. The introduction of the group charging scheme, however, reduced the charge of nearly all the directly dialled calls to the 1-unit fee and dispensed with the 2- and 3-unit charges. In a large number of relay-sets in service the single operation of the subscriber's meter is controlled by a circuit designed for multi-metering purposes, consequently this circuit will be dealt with in some detail. Periodic metering will not be considered in this pamphlet.

Trunking arrangements

In Fig. 1 the relay-set is shown connected between the 2nd selector level and the junction. If all the working levels of a particular 2nd selector are routed to automatic exchanges having the same call charge, the number of relay-sets required for the junctions can be reduced by connecting the relay-sets in the trunks between the 1st and 2nd selectors. A detailed account of the economics of the two trunking schemes, Figs. 2(a) and 2(b) is given in E.P. TELEPHONES 3/11.

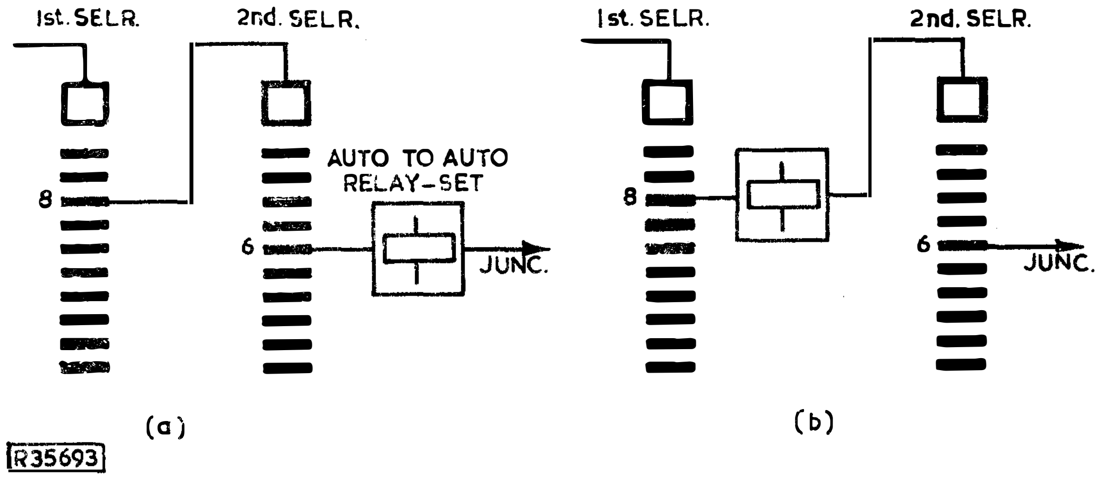


Fig. 2

DETAILED CIRCUIT OPERATION

The diagram of a circuit which provides facilities common to the majority of the auto to auto junction relay-sets with multi-metering facilities is appended to this pamphlet. In the following circuit description the relay-set is considered as connected in the trunking scheme shown in Fig. 2(a).

Establishing a Connexion

Subscriber seizes the circuit

When the group selector switches to the relay-set the subscriber's telephone loop is extended over the negative and positive wires and completes an operate circuit for relay A, Fig. 3.

Relay A operates and at contact A1 completes an operate circuit for relay B. Contact A2 prepares a circuit for seizing relay A in the distant 1st selector.

Relay B operates and at contact B2 extends earth to the P-wire to guard the circuit and also to hold the switching relays in the preceding selector circuits as outlined in Fig. 3. Contact B3 completes an operate circuit for relay BA. Contact B4 earths the P-wire forward to hold any equipment between the relay-set and the junction, e.g. the group selector in Fig. 2(b).

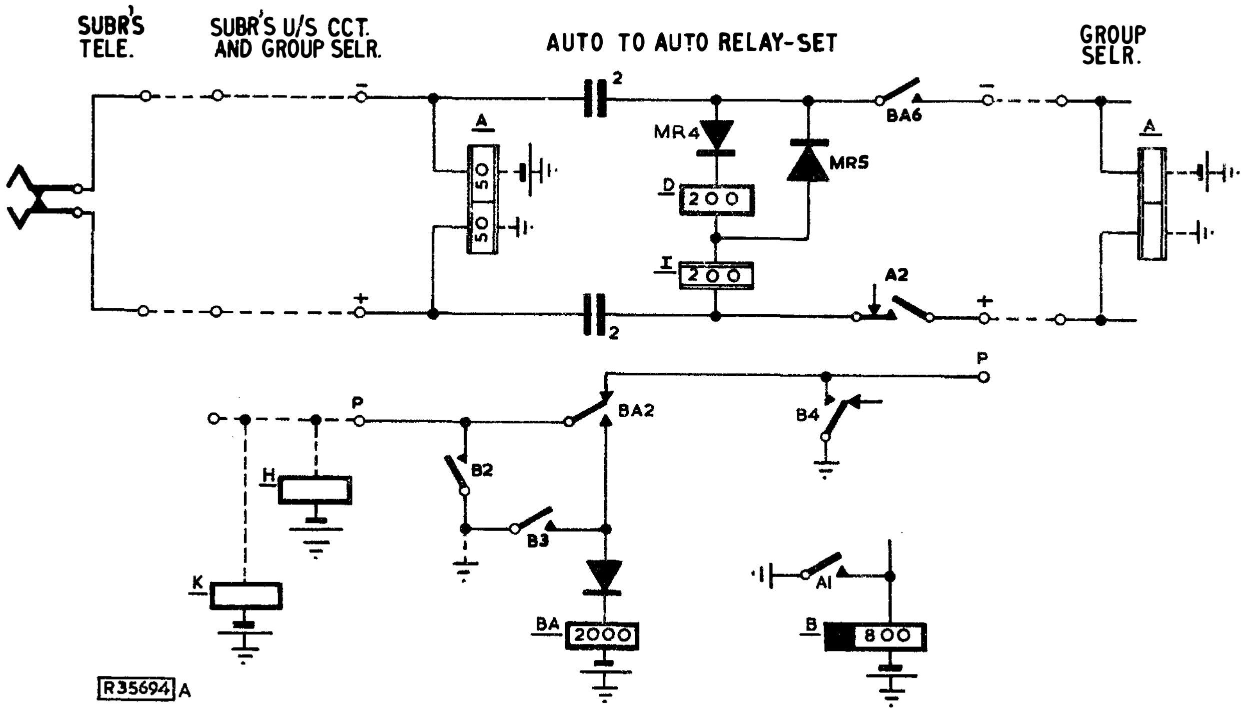


Fig. 3

Relay BA operates and at contact BA6 completes the 'D and I relay loop' which completes the operate circuit for relay A in the distant 1st selector. The metal rectifier MR4 is so connected that with normal line conditions, as shown in Fig. 3, it offers a very high resistance to the flow of current through relays D and I, but MR5 is connected such that it acts as a low resistance shunt to relay D and MR4. Thus relay I operates in series with relay A but relay D remains normal. The operation of relay I is ineffective at this stage. Contact BA2 dissociates the incoming and outgoing P-wires and provides an alternative hold circuit for relay BA.

The calling subscriber's transmitter current is fed via the coils of relay A which in conjunction with relays D and I, and the two 2 μF capacitors forms a capacitor type transmission bridge. In practice there is a ballast type resistor, i.e. a barrettor, in the earth and battery leads to the A relay.

Dialling

When the subscriber dials, relay A, Fig. 3, responds to the loop-disconnect pulses, the relay releasing during each break of the dial pulse springs. The release of relay A during the break period of the first pulse causes circuit changes which provide for a non-inductive pulsing loop, under the control of contact A2, for the remainder of that pulse train.

At the first release of relay A, contact A1 disconnects relay B and completes an operate circuit for relay CD, Fig. 4. The release lag of relay B is designed to be not less than 250 ms, therefore that relay does not release during the $66\frac{2}{3}$ ms break periods of relay A. Relay CD operates and at contact CD2 completes, with contact BA5, the short circuit on relays D and I, thereby providing the non-inductive pulsing loop during the subsequent make periods of contact A2. It should be noted that contact A2 is a make-before-break unit so arranged that it completes a short circuit on relays D and I immediately at the first break period, thereby reducing to a minimum any surges of current over the transmission bridge caused by the energy stored in those relays. Contact CD3 completes an operate circuit for relay CA, which operates and at contact CA2 completes a circuit feature which is effective at the end of the pulse train.

During the pulse train the loop-disconnexions from the subscriber's dial are repeated to the A relay in the forward equipment by contact A2. The release lag of relay CD is some 120 ms and aids in maintaining that relay operated, and consequently relay CA operated, during the $33\frac{1}{3}$ ms make periods of contact A1.

At the end of the pulse train the non-inductive pulsing loop is replaced by the D and I relay loop for supervisory purposes. If, however, the change occurred in a single step, the inductance of the D and I relays would cause the current in the distant A relay to momentarily fall to zero and then gradually rise to the steady state value. The A relay in the distant selector will, therefore, tend to momentarily release, thus imparting a false pulse to the associated stepping circuit. The foregoing effect is known as 'Subsequent pick-up' (S.P.U.) and is dealt with fully in E.P. TELEPHONES 5/3. In modern relay-sets the effect of S.P.U. is mitigated by the use of the rectifier shunt on relay D and the use of a circuit arrangement often known as 'two-stage dropback'. The circuit operation is as follows:-

At the end of the pulse train, relay A remains held operated and relay CD, Fig. 4, releases at the end of its lag period. Contact CD3 disconnects the slow to release relay CA, and contact CD2 disconnects the non-inductive pulsing loop.

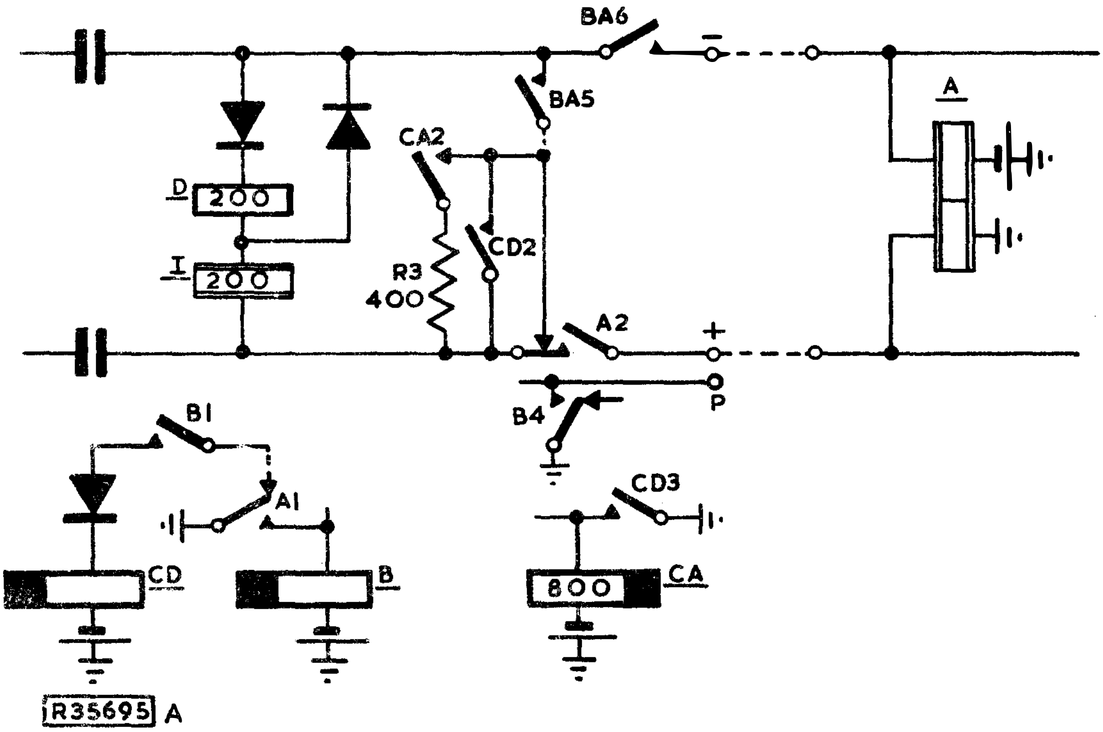


Fig. 4

Therefore, for the duration of the release lag of relay CA the distant A relay hold circuit is the 400 ohm resistor R3 in parallel with the D and I relays. The release lag of relay CA is such that when the relay releases and at contact CA2 disconnects R3, the current in the D and I relay circuit is sufficient to hold the distant A relay.

During the first train of pulses relays BB and MD, not shown in Figs. 3 and 4, are also operated and prepare features which are effective in subsequent stages of the circuit operation.

Successive trains of pulses are received and repeated to the forward equipment with a two-stage drop back at the end of each train as described in the foregoing.

Called subscriber answer (C.S.A.) and metering

At the end of dialling and before the called subscriber answers relays A, B, BA, BB, MD, and I are operated.

When the called subscriber answers, the battery and earth potentials on the outgoing negative and positive wires are reversed at the forward equipment. The rectifier in shunt with relay D is now biassed such that it has a very high resistance to the flow of current, and consequently relay D operates. The operation of relay D initiates the registration of the call on the calling subscriber's meter and a reversal of incoming line conditions for switchboard supervisory purposes.

When relay D operates, contact D1, Fig. 5 (appended), disconnects relay MD which releases after a lag period of some 150 ms. The lag period is necessary to guard against the momentary releases of relay D which may occur because of line surges during the setting up of the call. On the release of relay MD, contacts D1 and MD2 complete an operate circuit for relay DD. Relay DD operates and at contacts DD2 and DD3 reverse the potentials on the incoming positive and negative wires, thereby passing the called subscriber answer signal back to provide supervisory conditions should the call have originated from a manual-board.

Before describing the operation of the metering circuit element the meter pulse arrangements will be considered. A chart of the machine generated battery pulses which control the metering circuit is shown in Fig. 5. The 2- and 3-units pulses are no longer used, and the 4-units pulse used only in a few cases. Thus in the majority of relay-sets the 1-unit pulse is connected to the terminal labelled 'battery meter pulses' in Fig. 5. The first S pulse to occur after the operation of relay DD starts the operation of the metering circuit, and the subscriber's meter is operated during the period of the Z pulse which follows the S pulse. The circuit operation will now be considered.

Contact DD5 operated extends one coil of relay DA to the S pulse supply, and on receipt of the pulse the relay operates. Contact DA1 completes the circuit for relay MC to the meter pulse supply. Contact DA2 disconnects relay DA from the S pulse and completes a hold circuit for that relay to the earth at contact BA4. Contact DA3 completes a circuit for relay DB in series with relay DA to the Z pulse supply. The Z pulse begins 150 ms before the meter pulses, consequently relay DB operates before relay MC. Relay DB operates and relay DA holds to the Z pulse. Contact DB3 disconnects the original operate and hold circuit for relay DA and completes a hold circuit, which is dependent on contact BA4, for relay DB. Contact DB1 extends positive battery to contact MC1 in preparation for metering.

It should be noted that contact DB3 in completing a hold circuit for relay DB which is effective until the connexion is released, ensures that relay DA cannot operate to subsequent S pulses. The circuit arrangement is such, therefore, that metering can only occur once during an effective call.

Relay MC operates a number of times appropriate to the meter pulse supply, i.e. once or 4 times, and contact MC1 extends a similar number of positive battery pulses to the P-wire to operate the calling subscriber's meter. During the transit time of contact MC1, the P-wire is maintained at earth potential to negative connected relays by the earth connected through the metal rectifier MR2.

At the cessation of the Z pulse relay DA releases but relay DB remains held operated as previously described. Contact DA1 disconnects relay MC from the meter pulse supply. Contact DA2 reconnects relay DA to the S pulse supply but contact DB3 operated prevents the reoperation of that relay. Contact DB2 operated ensures that the battery through the resistor R2 is not connected to the S pulse supply, which is common to all the relay-sets, during the bunching of contact DA2.

When the connexion has been established and metering has taken place the following relays are held operated,

A, B, BA, BB, D, I, DD and DB.

Release of a Connexion

Calling subscriber clears first

Disconnexion of the calling subscriber's telephone loop causes the release of relay A. Contact A2 disconnects the D and I relay loop, thereby causing the release of the forward equipment. The release of contact A1 initiates the operation of a circuit arrangement which allows a time period sufficient for the forward equipment to fully restore before the relay-set is released, thus preventing the partially released equipment being seized by another call. It would be wasteful of equipment, however, to hold the preceding group selectors and subscriber's calling equipment for the whole of the delay period. Provision is made, therefore, to disconnect momentarily the incoming P-wire early in the period and thereby allow the preceding selectors to release.

Contact A1 disconnects relay B and operates relay CD, Fig. 6 (appended). Contact CD3 operates relay CA. Contact CA4 provides an alternative holding circuit for relay BB to guard against the release of contact I1 when that relay releases (contact A2). Contact CA3 connects a guarding earth to the outgoing P-wire independent of relay B, contact B4 Fig. 6.

The release of relays D and I at contact I1 leaves relay BB dependent on contacts CA4 and BA7, and at contact D1 releases relay DD and prepares an operate circuit for relay MD. The release of relay DD at contact DD4 completes an operate circuit for relay MD, i.e. earth, contacts BA3, D1, BB2, DD4, relay MD to battery. Contacts DD2 and DD3 restore the normal potentials to the positive and negative incoming wires for supervisory purposes. Relay MD operates and at contact MD6 prepares a holding circuit for relay CA to guard against the subsequent release of contact CD3.

Relay B releases at the end of its 250 ms lag period and at contact B1 disconnects relay CD. Contacts B2 and B3 disconnect the guarding earth from the incoming P-wire and disconnect relay BA. The incoming P-wire is now disconnected from earth; the preceding equipment, therefore, commences to release. Relay BA is designed to have a release lag of some 40 ms so that when it releases and, at contact BA2, extends the incoming P-wire to the earth at contact CA3, the preceding H and K relays will have had sufficient time to release. Contact BA7 disconnects relay BB and provides an alternative hold circuit for relay CA.

Relay CD releases at the end of its 120 ms lag period, and at contact CD1 disconnects the hold circuit for relay MD.

Relay MD releases at the end of a 150 ms lag period and at contact MD6 disconnects relay CA, which is the last relay in the circuit to release.

Relay CA releases at the end of its 250 ms lag period and at contact CA3 disconnects the guarding earth from the P-wire. The relay-set is now free to handle other calls.

The foregoing release arrangements, often termed the 'junction guard' feature, may be summarized as follows:-

Trunking as shown in Fig. 2(a). When the calling subscriber releases the connexion relay A releases and disconnects the loop holding the equipment in the distant exchange. Some 250 ms after the release of relay A, the incoming P-wire is 'opened' for a period of approximately 40 ms in order to allow the group selectors and subscriber's calling equipment to release. The earth is then reconnected to the P-wire for a further period of approximately 500 ms, thus preventing the relay-set, and consequently the junction, from being seized for another call before the equipment in the distant exchange has had sufficient time to fully restore.

Trunking as shown in Fig. 2(b). When the calling subscriber releases the connexion relay A releases and disconnects the loop which is holding the equipment in the distant exchange. It should be noted that all the group selectors in the originating exchange are being held by the P-wire earth. Approximately 250 ms after the release of relay A the earth is removed for some 40 ms from that section of the P-wire which is holding the subscriber's calling equipment and 1st selector, thus allowing that equipment to release. The 2nd group selector remains held during the 40 ms period, this must be so, of course, to maintain a guard on the junction. The earth is then reconnected to the P-wire for a further period of 500 ms for reasons already given. At the end of the period the 2nd group selector releases, thereby releasing the junction for further calls via the same or other relay-sets.

It should be noted that there is a possibility of double connexions, i.e. overswitching, occurring during the 40 ms open period. In practice, however, the traffic conditions are such that overswitching during the open period rarely occurs.

A chart showing the earth condition on the P-wire and the conditions of the relays concerned during the junction guard circuit operation is shown at the bottom of Fig. 6 (Appended).

Called subscriber clears first

As previously stated, relays A, B, BA, BB, D, DB, I, and DD are held operated during the call.

If the called subscriber clears first, relay D releases and relay I releases momentarily when the line potential conditions return to normal on the release of relay D in the distant final selector.

The momentary release of relay I is ineffective but the release of relay D at contact D1, Fig. 5, disconnects relay DD. The release of relay DD at contact DD4 completes an operate circuit for relay MD, Fig. 6. Contacts DD2 and DD3 restore the normal potential conditions to the incoming positive and negative wires. The remaining contacts of the relay are ineffective at this stage.

Contact MD6, Fig. 6, prepares a holding circuit for relay CA pending the subsequent release of relay BA when the calling subscriber clears.

Relay A releases and relays CD and CA operate when the calling subscriber subsequently clears, and the release of the circuit is then as previously described. It should be noted that irrespective of the trunking arrangement used, the junction is marked busy until the calling subscriber clears the connexion.

Calling subscriber clears before called subscriber answers

The relays held operated under these conditions are A, B, BA, BB, I and MD.

When the calling subscriber clears relays A and I release and relays CD and CA operate, Fig. 6, as previously described. Relay MD is already held operated because relay D has not operated, therefore the circuit operation after the operation of relay CA is very similar to that for the normal release, i.e. calling subscriber clears first.

Manual hold

The 10 000 ohm coil of relay MC, Fig. 6, is used for manual hold purposes when a call is routed through a U.A.X. to a manual exchange. The battery is maintained on the +ve wire, and therefore relay MC remains operated, until the distant operator withdraws the answering plug from the jack. If relay MC remains operated, relays MD and CA do not release, consequently the connexion is guarded until the distant operator has cleared the incoming equipment.

JUNCTION LIMITS

The limits of the junction associated with the auto to auto relay-set are governed primarily by two considerations:

(i) Pulsing

(ii) Signalling.

The signalling limits are governed by the operating and holding currents of the A, D and I relays, and the pulsing limits by the degree of pulse distortion which is introduced by the line, junction and pulse-repetition equipment. The distortion introduced must not be more than that which will reduce a standard pulse of rectangular waveform to one which only just meets the operating requirements of a final selector.

The pulse-repetition arrangements in the relay-set already described are such that the A relay contact, A2, directly generates the pulses which operate the forward equipment. Thus any distortion in the pulses which operate relay A or which is introduced by that relay, is repeated in the pulses to the forward equipment. In practice the cumulative action of the pulse distortion restricts to three the number of auto to auto junctions which can be employed in a subscriber or operator directly dialled connexion.

The characteristics of the D and I relays in early type equipment are such that the signalling requirements limit the resistance of a single junction not used for tandem working to 1200 ohms. If, however, the equipment is fitted with a ballast type transmission bridge the resistance limit is 1500 ohms. The circuit arrangement of an early type 800 ohm D and I relay loop arrangement is shown in Fig. 7, this particular circuit has the two-stage drop back feature. The contact shown as C1 would be labelled in a modern relay-set as CD1. Relay D is a polarized relay of the shunt field type and operates only when the pole faces of the two cores exhibit similar polarities. The connexions to the windings are arranged so that similar polarities exist only when the normal line conditions are reversed, i.e. on called subscriber answer.

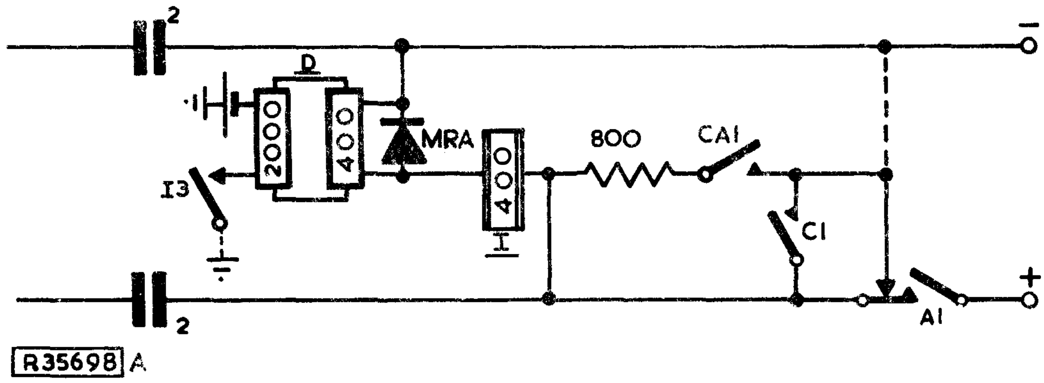


Fig. 7

The maximum resistance of a junction equipped with a relay-set which has a circuit similar to that appended to this pamphlet is 2000 ohms. When junctions are worked in tandem there is a specified resistance limit for each link and also an overall resistance limit which is less than the sum of the maximums for each link. When three junctions are worked in tandem an overall limit is usually given for the first two junctions.

Examples of the resistance limits for various combinations of equipment is given in Appendix 1 of this pamphlet.

RELAY-SET WITH PULSE REGENERATOR

General

The number of junctions worked in tandem can be increased by the use of a mechanical pulse regenerator in the auto to auto relay-set. The function of the pulse regenerator is to receive and store successive trains of pulses and then to transmit the pulses correct in both speed and ratio. Theoretically, with the use of regenerators, the number of junctions which may be worked in tandem is unlimited, but the resistance limit for each junction is determined by the characteristics of the A, D and I relays. The use of successive regenerators in a series of links, however, causes delay in the setting-up of a connexion because of the pulse storage feature at each regenerator. In practice it is desirable to use only one regenerator in a series of junction links.

When a pulse regenerator is used in the relay-set at the originating exchange, and the objective, or terminal, exchange has 2000- or 4000-type equipment four junctions may be worked in tandem. The individual junction resistance limits are as follows:-

EXCHANGE EQUIPMENT					JUNCTION RESIS. LIMITS IN OHMS			
Exch. 1	Exch. 2	Exch. 3	Exch. 4	Term. Exch.	Junc. 1	Junc. 2	Junc. 3	Junc. 4
R/S with Regen.	BC	BC	BC	C	800	800	800	1500

B = Relay-set with 3000-type relays.
C = Relay-set with 2000-type or 4000-type circuit arrangements.

When exchanges 2, 3 and 4 are not equipped with ballast type transmission bridges, the overall resistance of junctions 1, 2 and 3 must not exceed 1800 ohms.

Normally, when the terminal exchange has pre 2000-type equipment only three junctions may be worked in tandem. If, however, the resistance of the first junction does not exceed 500 ohms, the originating exchange may be considered to be a subscriber and the first junction as the subscriber's line. The second exchange is then considered as the first for the purpose of tandem working. Reference to the table in the Appendix 1 shows that within the resistance limits specified three junctions may be worked in tandem to a pre 2000-type exchange. Hence, under the foregoing conditions the use of a regenerator allows the use of four junctions in tandem to a pre 2000-type exchange.

Another advantage of the pulse regenerator is that the output inter-digital pause can be regulated to any required length, independent of the number of pulses in the train and the speed of manipulation of the dial. Such a facility is important because in certain circuit arrangements the normal inter-digital pause period provided by a dial is scarcely adequate for the circuit changes which have to occur during the pause period.

An outline of the operation of a mechanical pulse regenerator is given in Appendix 2 to this pamphlet.

Pulse Repetition with Regenerator

The circuit elements of the pulse repetition arrangements in an auto to auto relay-set which is equipped with a pulse regenerator are shown in Fig. 8 (appended). The circuit of the complete relay-set is appended to this pamphlet.

Prior to receiving the first train of pulses relays A, B, BA and BC are held operated.

(a) Receipt of Pulses

Relay A responds to the received loop-disconnect pulses. On the first release of relay A, contact A1 removes the short circuit from relay CD, short circuits relay B, and completes an operate circuit for the regenerator receive magnet RM.

Relay CD operates to the battery at R7 and contact CD1 completes an operate circuit for the regenerator marking magnet MM. Contact CD3 completes an operate circuit for relay IP to the earth at contact ON7.

Relay IP operates and contact IP2 completes with contact CD4 a low resistance pulsing path on the outgoing side of the transmission bridge. Contact IP1 completes an operate circuit for relay IS which performs no function at this stage.

When relay A reoperates to the first make pulse contact A1 disconnects the receive magnet, removes the short circuit from relay B, and reconnects the short circuit to relay CD. A slow release feature is thereby imported to relay CD which remains held operated during the pulse train. The release of the receive magnet moves the receive element off-normal and so causes the regenerator N springs to operate. Contact N1 prepares an operate circuit for relay ON.

Relay A responds to the remaining pulses in the first train and at contact A1 repeats the pulses to the receive magnet. At the end of the pulse train relay A remains operated and at contact A1 short circuits relay CD and disconnects the receive magnet. The final release of the receive magnet positions the marking arm in the regenerator to a position corresponding to the received digit. The release of relay CD at the end of its release lag, disconnects the marking magnet at contact CD1. The release of the marking magnet depresses a code pin in the regenerator and so registers the received digit.

The first digit is now registered in the regenerator.

(b) Transmission of pulses

The release of relay CD and the marking magnet at contacts CD2 and MM dm completes the operate circuit for relay ON.

Contact ON3 guards its relay against any subsequent operation of contacts CD2 and MM dm which will occur as further pulse trains are received. Contact ON2 prepares an operate circuit for relay ST which at this stage is short circuited by the earth at contact TM dm. Contact ON7 prepares an operate circuit for the transmit magnet TM. Contacts ON5 and ON6 disconnect the D and I relay loop from the forward equipment and connect the regenerator 67% break pulsing springs in the forward holding loop in preparation for pulsing out. During the changeover of the ON contacts the forward loop is maintained by the circuit - R9, contact IP2 and 67% break pulse springs. Contact ON5 is arranged to short circuit the D and I relays to stabilize the transmission bridge during pulsing.

The release of contact CD3 disconnects the slow to release relay IP. When relay IP releases contact IP1 disconnects the slow to release relay IS. The subsequent release of contact IS1 completes the operate circuit for the transmit magnet, TM.

The operation of the transmit magnet depresses the resetting plunger which restores a displaced code pin to normal. It should be noted that this particular code pin is the one which was displaced at the end of the pulse train preceding the one just stored; in this particular description the pin will have been displaced at the end of the last train associated with the previous call handled by the relay-set. The springs TM dm also operate and disconnect the short circuit on relay ST which then operates after its operate lag.

Contact ST1 operated completes an operate circuit for relay IP to the earth at contact ON7. Contact IP1 completes an operate circuit for relay IS which disconnects the transmit magnet at contact IS1.

The release of the transmit magnet allows the regenerator driving wheel to rotate until the resetting plunger engages the code pin which was displaced at the end of the first pulse train. During the movement of the wheel the number of pulses appropriate to the first pulse train received are generated by the two sets of pulsing springs. The 67% break spring-set transmits loop-disconnect pulses to the forward equipment, and the 50% make spring-set extends earth pulses to the 600 ohm winding of relay ST.

The release of the transmit magnet also remakes the TM dm springs, thereby short circuiting the original operate coil of relay ST and giving that relay a slow to release feature. Relay ST remains held, however, during the pulsing by the earth pulses via the 50% make spring-set. At the end of the pulse train the 67% break spring-set remains made to maintain a forward holding loop, and the 50% make spring-set contacts remain open, thus allowing relay ST to release slowly.

When relay ST releases, the slow release relay IP is disconnected at contact ST1. The subsequent release of contact IP1 disconnects relay IS. When relay IS releases at the end of its release lag period contact IS1 completes an operate circuit for the transmit magnet to the earth at contact ON7 if further pulse trains have been received from the calling subscriber. The next and subsequent trains of pulses are transmitted as previously described. The commencement of transmission is the operation of the transmit magnet, hence there is a pause between each train equal to the sum of the lags of relays ST, IP and IS, i.e. 800 ms.

When the last pulse train stored in the regenerator has been transmitted, the N spring-set contacts open and disconnect relay ON. The subsequent release of relay ON disconnects at contact ON5 the short circuit from relays D and I and connects those relays to the outgoing positive wire. Contact ON6 disconnects the 67% break pulsing springs from, and completes the connexion of the D and I relays to, the forward equipment. Contact ON7 disconnects relay IP and disconnects the operate circuit for the transmitting magnet.

At this point in the operation, relay IP is operated, therefore R9 is in parallel with the D and I relays and so forms the first stage of the two stage drop-back feature.

Relay IP releases at the end of its lag period and disconnects relay IS at contact IP1. Contact IP2 disconnects R9 from across the positive and negative wires thereby completing the drop-back feature. The forward equipment is now held in the normal way by the D and I relay loop. The subsequent release of relay IS is ineffective at this particular stage of the circuit operation.

(c) Subscriber clears during pulsing out

If the calling subscriber replaces the telephone handset during the time that the regenerator is sending pulses, the following occurs:-

(i) the holding earth is momentarily disconnected from the P-wire to allow the equipment preceding the relay-set to release,

(ii) the forward loop is disconnected to allow the equipment in the distant exchange to release,

(iii) the relay-set is guarded until the regenerator has pulsed out all the stored digits, and

(iv) the junction guard feature is applied.

At the instant when the calling subscriber clears, relays A, B, BA, BC, GD and ON are operated and the state of relays ST, IP and IS is dependent on the condition of the regenerator. At this instant it is possible for there to be pulse trains to be stored in the generator, the transmit section of which is either pulsing out or stationary for an inter-digital pause period.

When the calling subscriber clears relay A releases. Contact A1 releases and short circuits relay B, completes an operate circuit for the receive magnet RM, and disconnects the short-circuit from relay CD, see complete circuit diagram appended to this pamphlet.

Relay B releases at the end of its release period and at contacts B1 and B2 disconnects earth from the incoming P-wire and relay BA. The switching relays in the preceding equipment release and initiate the release of the selectors. Contact B3 releases the receive magnet and thereby stores a pulse train of one digit in the regenerator. Contact B4 completes a hold or operate circuit for relay IP via contact MD3. Relay IS will, therefore, operate or remain held.

Relay BA releases and at contacts BA5 and BA6 disconnects the forward loop to allow the equipment at the distant exchange, if seized, to release. If there is a group selector between the relay-set and the junction it remains held by the P-wire earth at contacts MD6 and IS2. Contact BA2 reconnects earth to the incoming P-wire to guard the relay-set during the clear down. Contact BA4 disconnects relays MD and BC.

The conditions on the incoming and outgoing P-wires will now be considered separately.

The outgoing P-wire. When relay BC releases, relay IP is left dependent for holding on the contact MD3. Relay MD releases at the end of its lag period and at contact MD3 disconnects relay IP. The release of relay IP at the end of its lag period disconnects relay IS at contact IP1. Relay IS releases at the end of its lag period and at contact IS2 disconnects the guarding earth from the P-wire and disconnects relay GD. Thus when access to the junction is obtained via a group selector connected to the relay set, Fig. 2(b), the junction is guarded, and therefore the selector held, for a period equal to the release lags of relays MD, IP and IS.

The incoming P-wire. Relay ON is held operated until all the pulse trains stored in the regenerator have been pulsed out and the N1 contacts have opened. The outgoing pulse trains are, of course, made ineffective by contacts BA5 and BA6. Contact ON4, therefore, maintains a guarding earth on the incoming P-wire until the regenerator is normal. If the relay GD has not released when the regenerator returns to normal, contact GD1 maintains the guarding earth until that relay releases.

It should be noted that when relay BC is released, contact BC4 effectively short circuits the 800 ms inter-digital pause period. At the end of a pulse train relay ST releases and at contact ST1 the earth from contact ON7 is extended via contact BC4 normal to operate the transmit magnet TM. The TM dm contacts open and disconnect the short-circuit from relay ST. The consequent operation of relay ST disconnects TM at contact ST1 and so allows the regenerator to pulse out the next train of pulses.

Thus when the relay-set is connected directly in the junction, Fig. 2(a), the junction is guarded until the regenerator is normal or relay GD releases, i.e. the relay-set is normal, and this period is at least equal to the release lags of relays MD, IP, IS and GD.

FIXED SINGLE-FEE METERING

Some types of auto to auto relay-set are designed to provide only a single meter pulse when the called subscriber answers. The duration of the pulse is governed by the release period of a relay usually labelled J, in the relay-set, thereby dispensing with the need for a separate pulse machine. Circuit arrangements are also provided to guard against false metering.

The circuit elements concerned with metering in an earlier type relay-set are shown in Fig. 9(a).

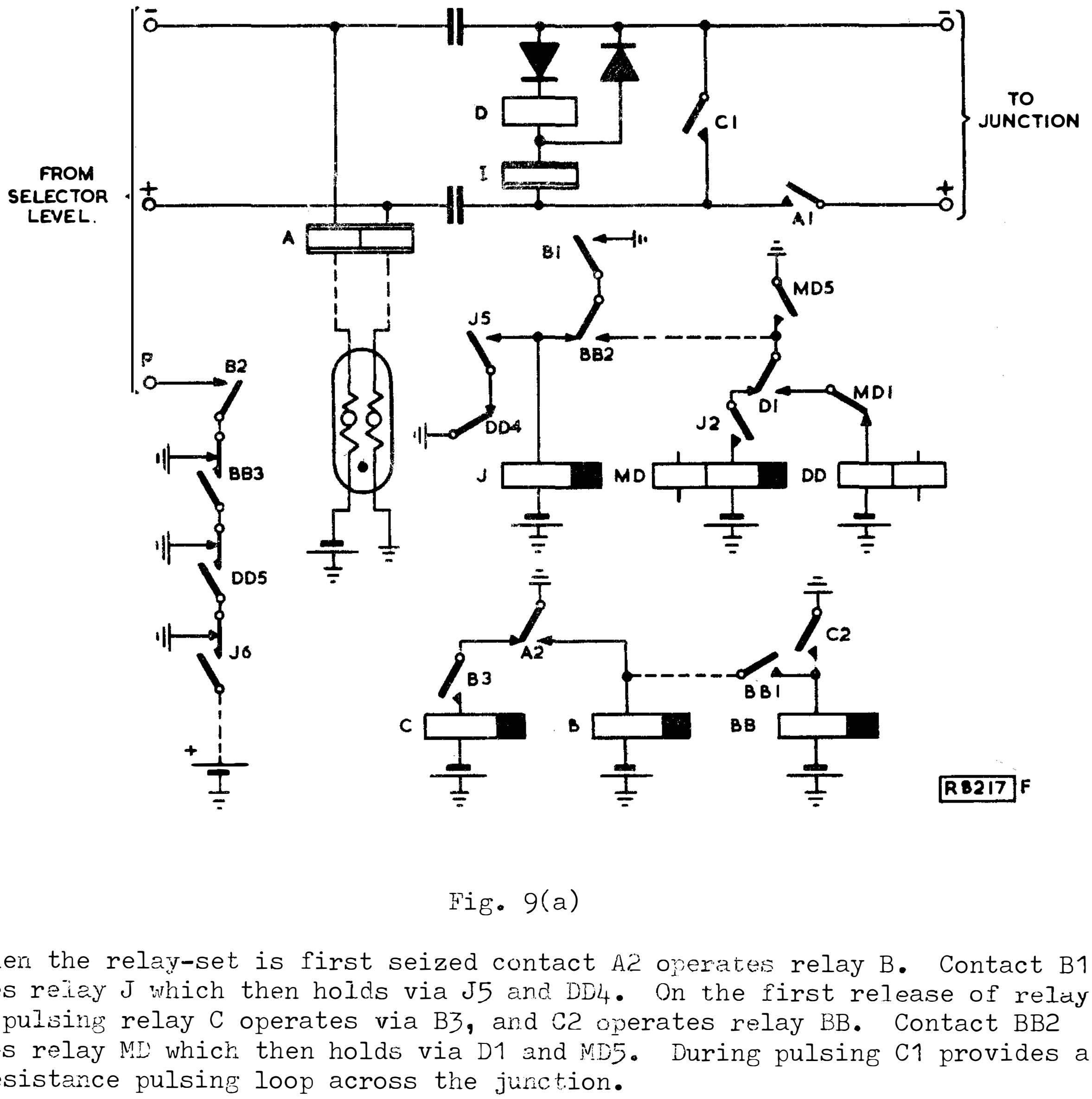


Fig. 9(a)

When the relay-set is first seized contact A2 operates relay B. Contact B1 operates relay J which then holds via J5 and DD4. On the first release of relay A during pulsing relay C operates via B3, and C2 operates relay BB. Contact BB2 operates relay MD which then holds via D1 and MD5. During pulsing C1 provides a zero resistance pulsing loop across the junction.

On the release of relay C at the end of pulsing, the D and I relay loop is replaced across the junction. Relay D does not operate at this stage as it is shunted by a rectifier. When the called subscriber answers the connexions of relay A in the distant final selector are reversed by the operation of relay D, thus causing the operation of relay D in the relay-set. Contact D1 disconnects relay MD which, after its slow release completes the circuit for relay DD at MD1. Contact DD4 disconnects J which releases slowly. During the slow release of relay J positive battery is connected to the P-wire via J6 (releasing), DD5 and BB3.

Fleeting operation of relay D due to current surges in the line, before the called subscriber answers, is prevented from affecting the caller's meter by the slow release feature of relay MD.

If the called subscriber fumbles with the switch-hook on answering or deliberately flashes afterwards, thus causing further operation of relay D, the caller's meter does not receive false pulses as relay MD is disconnected at J2. Contact D1 is, therefore, ineffective.

The circuit arrangement of Fig. 9(a) requires that contact J6 is of the make-before-break type so that an earth or positive battery is maintained on the P-wire. A heat coil must, therefore, be connected in the positive battery supply lead to guard against contact J6 bunching for longer than the design period. In later relay-sets an additional relay, JA, and a metal rectifier were provided, and the metering circuit arranged as shown in Fig. 9(b). Relay J at contact J1 operates relay JA, and contact JA6 prepares the positive battery circuit. When the called subscriber answers, relay DD operates after the release lag of relay MD as in the cirucit arrangement Fig. 9(a). Contact DD4 disconnects relay J, Fig. 9(b), and contact DD5 completes the circuit for the application of positive battery to the P-wire.

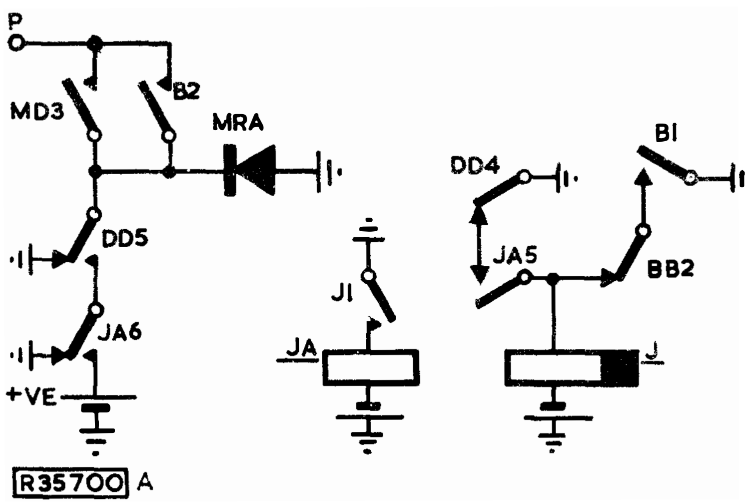


Fig. 9(b)

Relay J releases at the end of its lag period and at contact J1 disconnects relay JA. The subsequent release of relay JA disconnects the positive battery at contact JA6. Thus the positive battery is applied to the P-wire for the duration of the release lags of relays J and JA.

Rectifier MRA provides a holding earth for the negative battery connected switching relays in the preceding selectors during the transit times of contacts DD5 and JA6. The rectifier is so connected, however, that it does not short-circuit the positive battery during metering. Such an arrangement allows the use of changeover contact units instead of the make-before-break units previously used.

The fixed single-fee metering arrangements in the relay-set equipped with a mechanical pulse regenerator are shown in Fig. 10.

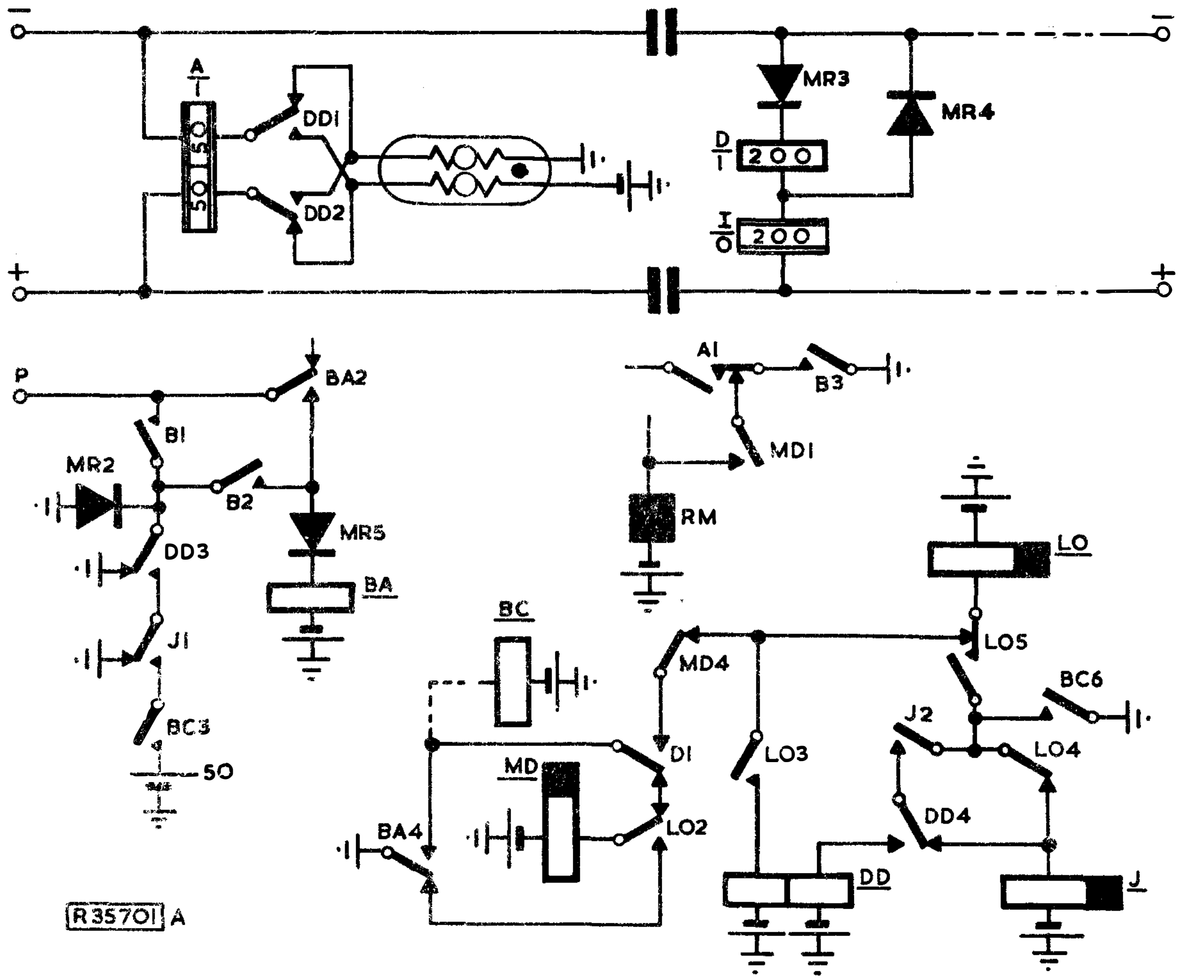


Fig. 10

The relays held operated at the time when the called subscriber answers are A, B, BA, BC, MD, DD and J.

When the called subscriber answers the battery and earth potentials on the outgoing wires are reversed and so cause relay D to operate. Contact D1 disconnects relay MD and extends the earth from contact BA4 to prepare operate circuits for relays LO and DD.

Relay MD releases at the end of its lag period and at contact MD4 completes an operate circuit for relay LO. Contact MD1 disconnects the receive magnet circuit to guard against the possible momentary release of contact A1 when contacts DD1 and DD2 subsequently change over.

When relay LO operates an operate circuit for relay DD is completed at contact LO3. Contact LO2 guards agains the possible reoperation of relay MD if the called subscriber flashes, thereby releasing and reoperating relay D. Contact LO4 leaves relay J under the control of contact DD4.

Relay DD operates and at contact DD3 extends the incoming P-wire to the positive battery. Rectifier MR2 maintains the P-wire at earth potential with respect to negative battery. Contact DD4 disconnects the slow to release relay J. Contacts DD1 and DD2 reverse the potentials on the incoming positive and negative wires.

Relay J releases at the end of its lag period and at contact J1 disconnects the positive battery from the P-wire and short circuits the rectifier MR2. The lag period of relay J is of sufficient duration to produce a pulse adequate to operate the calling subscriber's meter. Contact J2 prevents a reoperate path via DD4 to the earth at BC6 for relay J when the called party clears and relay DD releases.

SUBSCRIBER TRUNK DIALLING

The majority of the junctions which are, or will be, used to connect local automatic exchanges to the group routing and charging equipment at the group switching centres are within the limits of loop-disconnect pulsing. The relay-sets in the junction circuits at the local exchanges will, therefore, contain some of the features of those described in this pamphlet. The periodic metering arrangements of STD, however, require line current reversals on the junction during the conversational period and consequently require special circuit arrangements at both ends of the junctions. The complete circuit arrangements of the relay-sets concerned will be described in other pamphlets in this draft series.

APPENDIX 1

JUNCTION LIMITS

Because of pulse distortion and pick-up effects, the number of junctions which can be worked in tandem is limited to a maximum of three for subscriber-dialled traffic and calls from operators routed via leg/loop pulse conversion relay-sets, and four for all other types of traffic. In all cases junction resistance limits are imposed, and these limits are determined by considering the type of exchange equipment at the beginning and end of each junction link. Some typical junction resistance limits are given in Table 1. Exchange equipment is placed in one of three categories in the table:-

Category A: Equipment employing pre-3000 type relays.

Category B: Equipment employing 3000 type relays and pre-2000 type selector mechanisms.

Category C: Equipment employing 3000 type relays and 2000-type selector mechanisms.

The table shows typical junction resistance limits for subscriber-dilled traffic, and traffic from operators' dials via leg/loop pulse conversion relay sets.

TABLE I

No. of Junctions in Tandem	Exchange Equipment				Junction Resistance in ohms			Total Resistance in ohms
	Exch. 1	Exch. 2	Exch. 3	Terminal Exch.	Junc. 1	Junc. 2	Junc. 3	
1	A	-	-	A	1200	-	-	
1	A	-	-	BC	1500	-	-	
1 (NOTE 1)	BC	-	-	AB	1500	-	-	
1 (NOTE 2)	BC	-	-	C	2000	-	-	
2	ABC	ABC	-	C	800	1500	-	
2 (NOTE 2)	BC	BC	-	B	1200	1500	-	1800
2 (NOTE 2)	BC	BC	-	C	1200	2000	-	2700
3	A	BC	BC	C	800	800	1500	J1 + J2 = 1000
3	BC	BC	BC	B	800	800	1500	(J1 + J2 = 1000 (J1 + J2 + J3 = 1500
3 (NOTE 3)	BC	BC	BC	C	800	800	1500	J1 + J2 = 1000
3 (NOTE 4)	BC	BC	BC	C	800	800	1500	

Note 1: Junction resistance is limited to 1200 ohms if the terminal exchange is pre-3000 type and of G.E.C. manufacture.

Note 2: In equipment of early design, the resistance of D and I relays (or the equivalent) fitted in relay sets and similar equipment resulted in signalling functions restricting the limits for intermediate and terminal junctions to 800 and 1500 ohms respectively. Relay sets of later design, however, permit an increase of the limits for intermediate and terminal junctions, as governed by signalling requirements, to be 1200 and 2000 ohms, respectively.

Note 3: These limits apply when 2 or 3 exchanges, excepting the terminal exchange, are of non-ballast type.

Note 4: These limits apply when 2 or 3 exchanges, excepting the terminal exchange, are of ballast type.

APPENDIX 2

MECHANICAL PULSE REGENERATOR

General

Two views of the mechanical pulse regenerator which is fitted in certain types of relay-set are shown in Figs. 11 and 12. An explanatory drawing of the regenerator is shown in Fig. 13 (appended). The regenerator may be considered to consist of two elements,

(i) a receiving and marking element, which receives and stores trains of dial pulses, and

(ii) a transmitting element which sends out the received pulse trains in correct sequence and at the standard speed and ratio.

The mechanism is fitted with the following mechanically operated springsets:-

(i) Two pulsing contact units, mounted as a single springset and arranged to provide pulses of $66\frac{2}{3}$ break ratio and $33\frac{1}{3}$ or 50% break ratio at a governor controlled speed of 10 pulses per second.

(ii) An off-normal 'make' contact unit, which makes when the main shaft is rotated from the normal position on receipt of the first digit and breaks when all the stored pulses have been transmitted. One contact of the unit is the body of the mechanism and the other is an insulated flat spiral spring, Fig. 11. Connexion to the insulated spring is by means of a flexible lead, the transmitter magnet armature extension, Fig. 12 and the inner spindle, both of which are insulated from the mechanism.

(iii) A marking magnet springset which consists of a single 'break' contact unit, the contacts of which break at each operation of the magnet armature.

(iv) A transmitting magnet springset identical in make up and style of operation to that associated with the marking magnet. Both magnet springsets are similar in construction to those on a 3000-type relay, and the lever spring is actuated directly by the magnet armature, Fig. 12.

(v) An SP springset in the form of a 'make' contact unit which is arranged to operate when the transmission of a train of pulses is completed. One contact of the unit is insulated from the mechanism and is formed by the resetting plunger, Fig. 13. Connexion to this contact is by means of the centre-contact spring bearing on to the resetting-plunger assembly, Fig. 11, both of which are insulated from the body of the mechanism. The other contact of the unit is formed by the particular marking pin associated with the plunger, the pin is, of course electrically connected to the body of the mechanism. The SP contact has proved to be electrically unreliable because a persistent contact between the resetting plunger and associated marking pin is not a necessary requirement for the satisfactory operation of the regenerator. Consequently, modern circuits are designed, where possible, to dispense with the need for the springset; in the appended diagram of a relay-set with regenerator the springset is included but shown short-circuited.

The operation of the mechanism will now be considered.

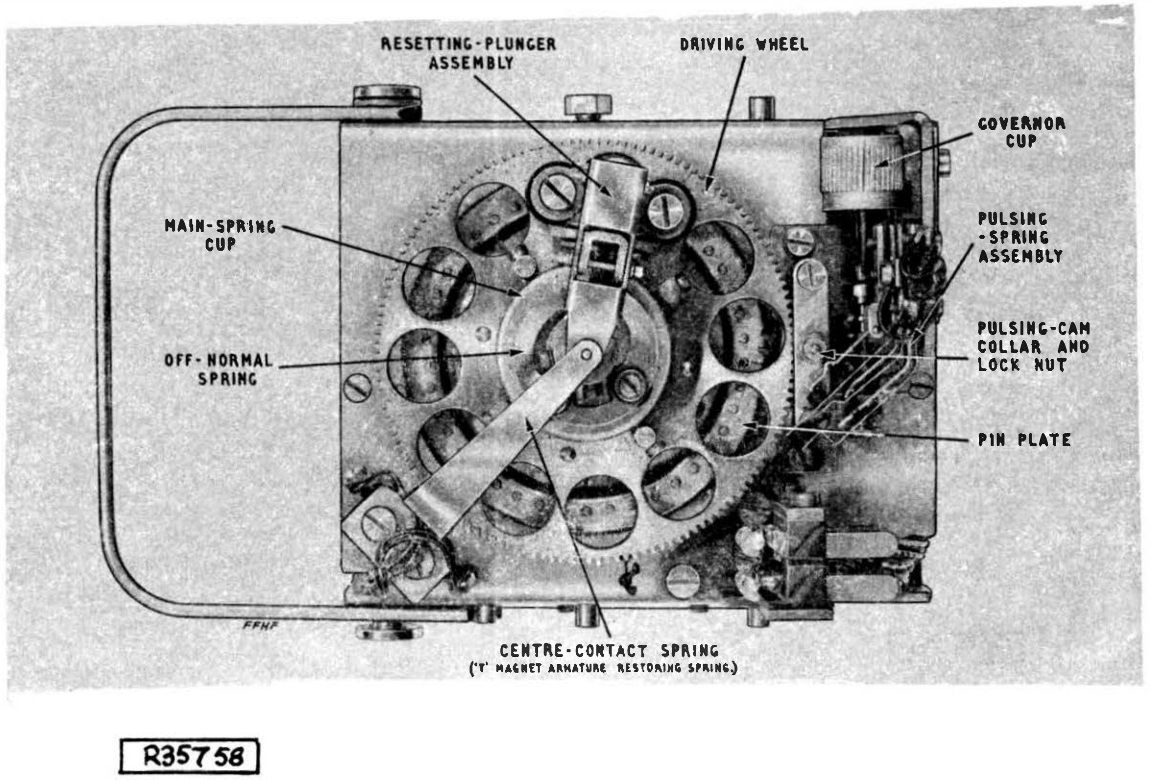
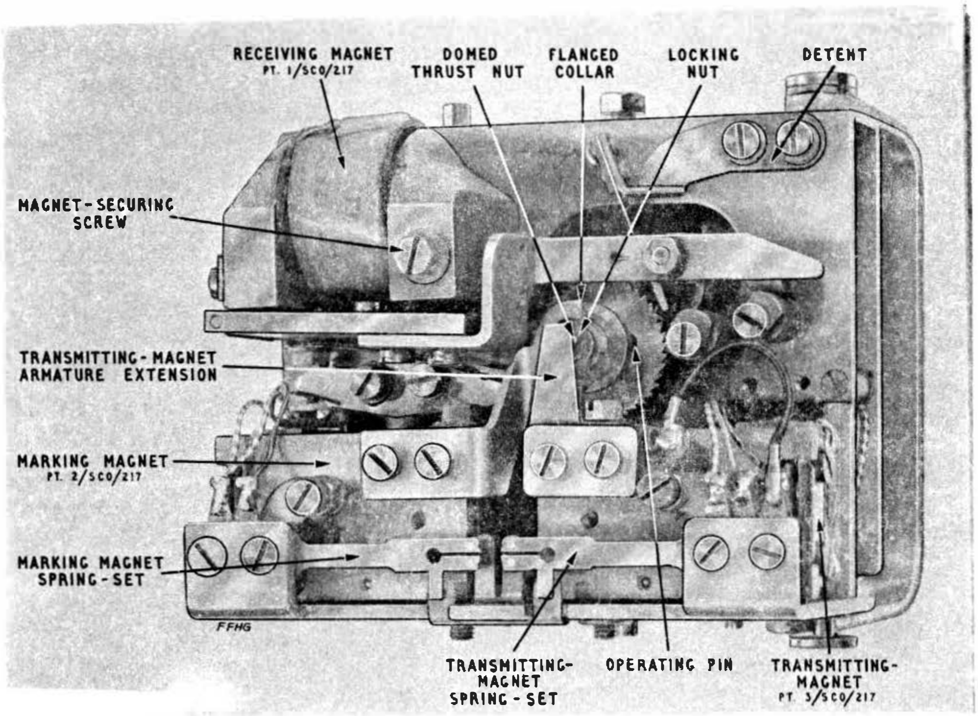


Fig. 11



R35759

Fig. 12

Receiving and marking element

The function of this element is to receive the pulse train, to count the number of pulses, and at the end of the train to mark them off on one of a group of 42 code pins arranged in a ring concentric with the shaft. The marking is done by pushing the selected pin through the plate causing it to be out of alignment with the other pins in their normal position. The pins are held in position by the friction of short cylindrical nickel-silver rollers placed between each pair of code pins, the ring of rollers being retained under pressure by an encircling, endless, helical spring.

Before the counting of a train can proceed it is necessary to operate the marking magnet (MM) and in Fig. 13 this is done by the operation of relay CD during the first break pulse. There is time for this operation before the counting actually starts because the stepping of the ratchet wheel is by reverse action of the receive magnet. The operation of the marking magnet by contact CD1 lifts the marking arm from the pin, which was last selected on previous reception, clear of the ring of pins and holds the arm in this position until the end of the pulse train. During each make period of the pulsing relay the receive magnet (RM) is disconnected, the armature restores and the ratchet wheel is stepped through one tooth space, moving the marking arm from a position centrally over one pin to a similar position over the next pin. The number of pulses received in the train will correspond to the number of pin separating spaces passed over (i.e. one more than the number of intervening pins). On the first movement of the ratchet wheel from its normal position the off-normal springs are operated. At the end of the train the CD relay restores, releasing the marking magnet, which causes the marking arm to depress the code pin over which it has been positioned. Counting and marking of successive trains may continue in this manner up to the limit of the capacity of the 42 code pins, if necessary, before starting the transmission; but in practice it is usual for the circuit to be arranged so that sending of a pulse train commences after the first train has been completely stored.

The stepping of the ratchet wheel in addition to counting the number of pulses received has another important function. It rotates the shaft, winding up the main spring which provides the mechanical energy necessary for the transmission of pulses.

The transmitting element

In the circuit element shown in Fig. 13, when the marking magnet restores at the end of the first train the closing of the MM dm springs permits the operation of relay ON. ON2 prepares for the operation of relay ST. ON3 energizes the transmitting magnet (TM). The transmitting magnet armature causes the inner spindle to move through the shaft, raising the resetting lever against the pressure of its restoring spring. The resetting lever depresses the resetting plunger causing it to reset the code pin against which it was held. The TM dm springs in operating remove the short circuit from the operate coil of relay ST, which operates. ST1 disconnects the transmitting magnet, the armature of which restores, allowing the resetting lever to restore and the resetting plunger to become disengaged from the restored code pin. ST1 also operates relay IP. The main spring now causes the driving wheel to rotate. This wheel is geared to a spindle carrying a cam which operates a pulse spring assembly, the speed of which is controlled by a governor. The assembly carries two sets of pulsing springs which are arranged to generate pulses of $66\frac{2}{3}\%$ and 50% break respectively, at a nominal speed of 10 p.p.s. The springsets are operated by a 3-lobe cam mounted on the shaft which carries the pinion which is meshed with the driving wheel. Three pulses are generated during each revolution of the cam, one third of a revolution of the cam corresponding to $\frac{1}{42}$ of a revolution of the driving wheel. This fraction of a revolution also corresponds to the angular distance between two code pins. When the resetting plunger engages with a pin which has been depressed by the marking arm the driving wheel is stopped and the sending of that train is complete.

ST relay, which was held during pulsing, now releases and at ST1 releases relay IP. Contact IP1 releases relay IS and IS1 completes the circuit for the transmitting magnet. The transmitting magnet armature, working through the mechanism of the inner spindle and the resetting lever, causes the resetting plunger to reset the marked code pin. The TM dm springs, in operating, remove the short circuit from the operate coil of relay ST and this relay re-operates to prepare for the next train to be sent.

When the final pulse train has been sent the off-normal springs release and relay ON releases. Contact ON1 releases relay ST, whilst contacts ON3 and ON4 restore the D and I loop to the pulsing out wires. ST1 releases relay IP which in turn releases relay IS. The relays now held are A, B, BB and I and the call proceeds in the normal manner.

END

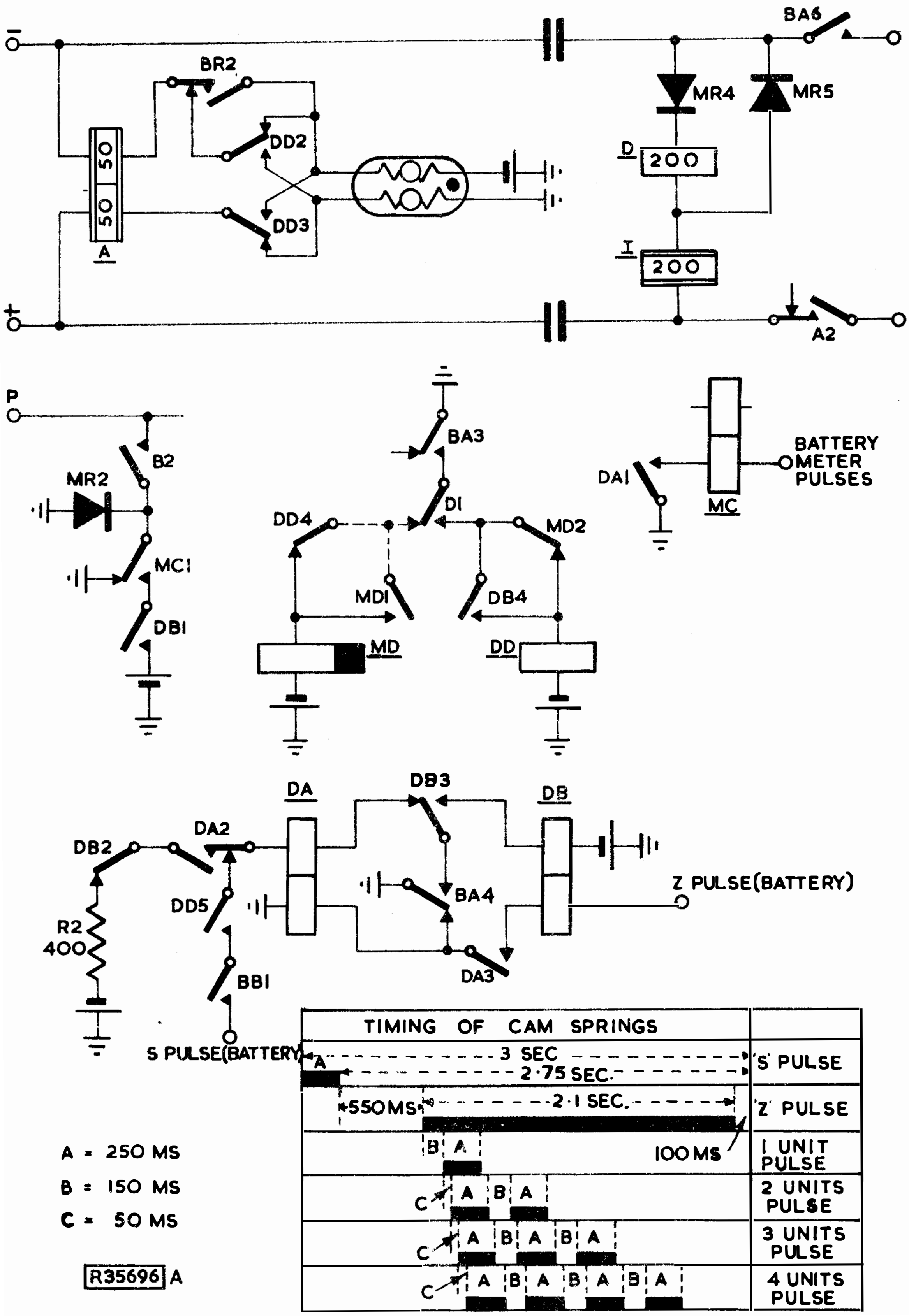
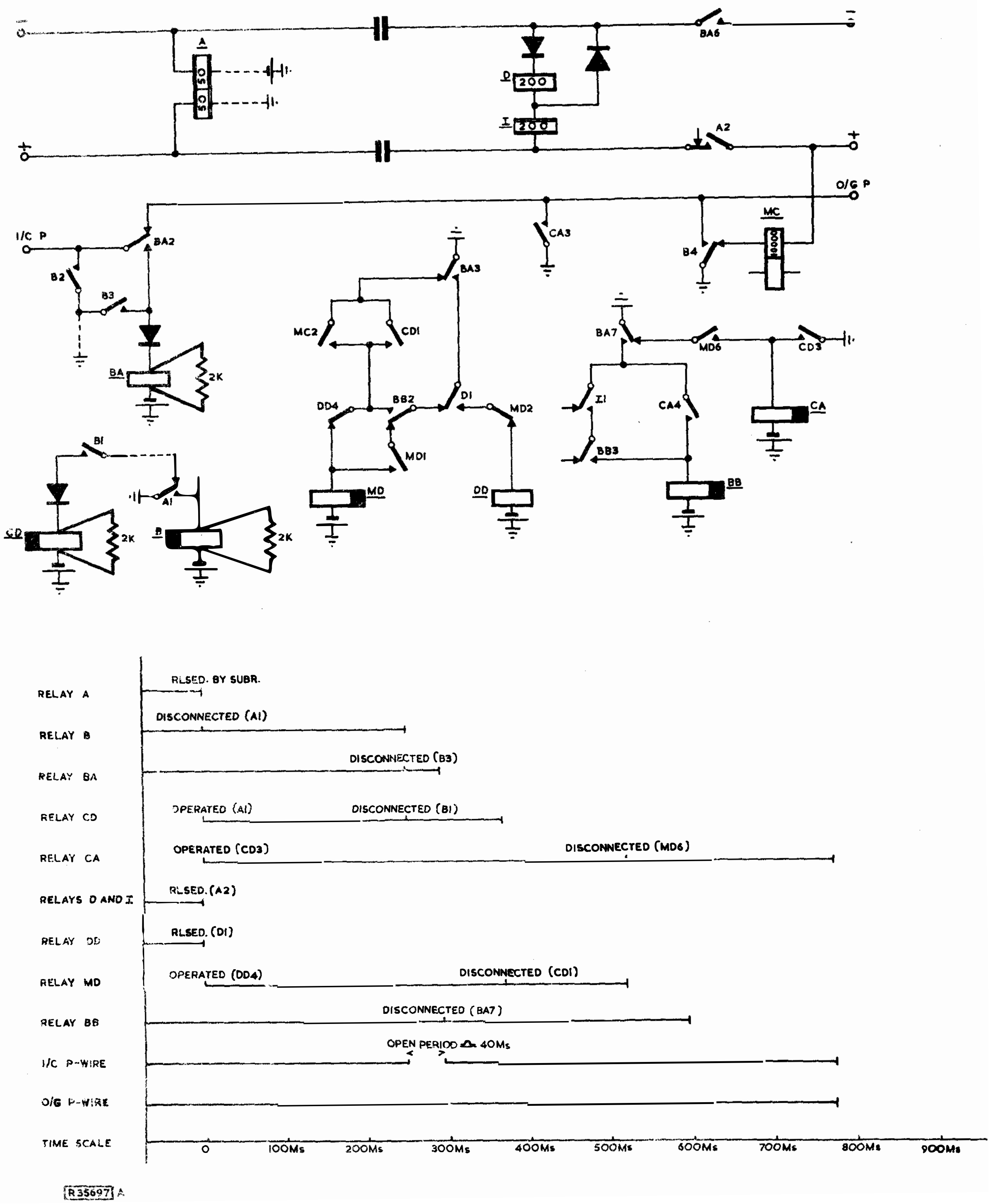
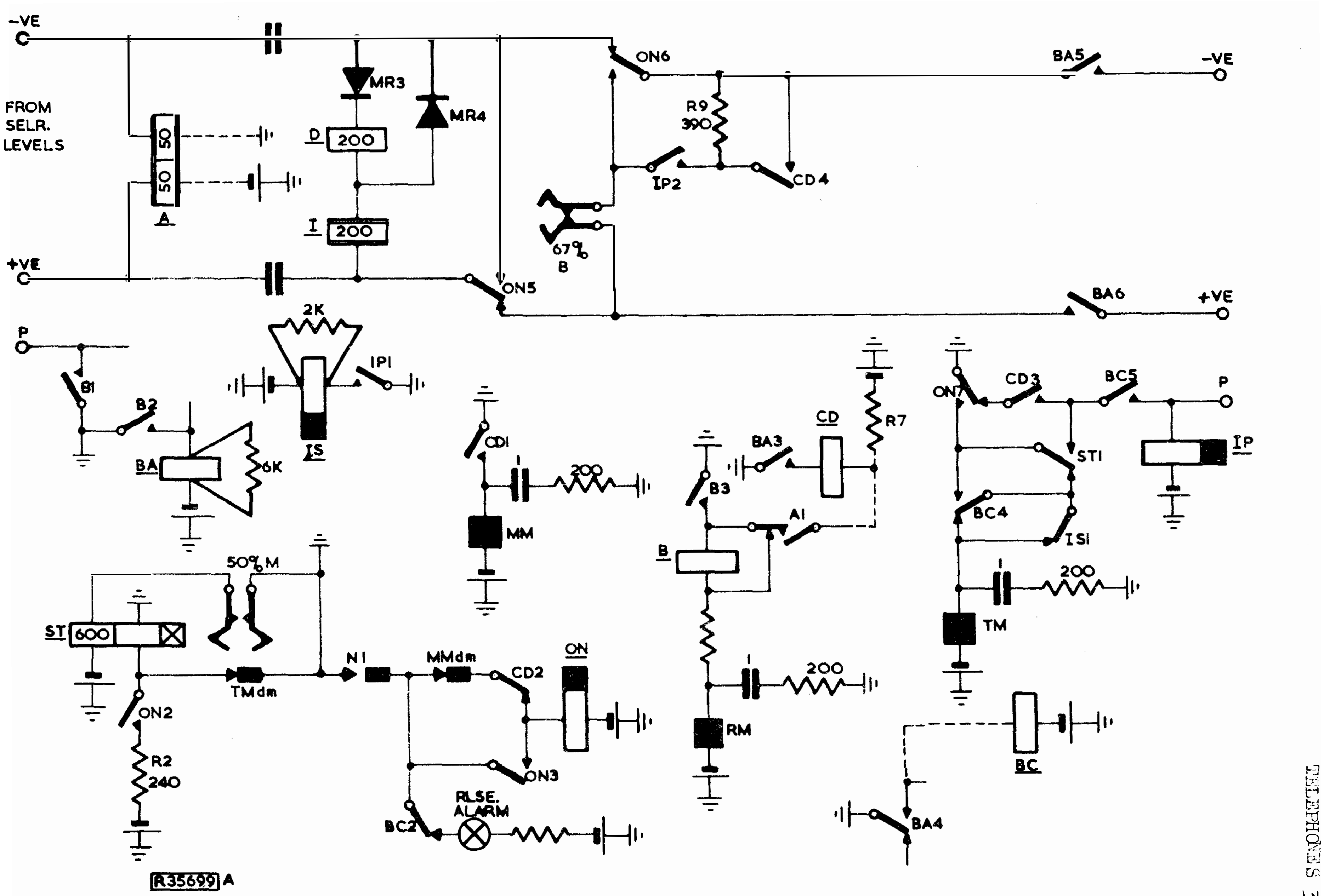

BA6
BR2
MR4
MR5
DD2
DD3
D
200
I
200
50
50
A
A2
P
B2
MR2
MC1
DB1
BA3
D1
DD4
MD2
MD1
DB4
MD
DD
DA1
MC
BATTERY METER PULSES
DA
DB3
DB
DB2
DA2
DD5
R2 400
BB1
BA4
DA3
Z PULSE(BATTERY)
S PULSE(BATTERY)
TIMING OF CAM SPRINGS
3 SEC
2·75 SEC.
'S' PULSE
550 MS
2·1 SEC.
'Z' PULSE
100 MS
1 UNIT PULSE
2 UNITS PULSE
3 UNITS PULSE
4 UNITS PULSE
A = 250 MS
B = 150 MS
C = 50 MS
R35696 A

Fig. 5



RELAY A
RLSED. BY SUBR.
RELAY B
DISCONNECTED (A1)
RELAY BA
DISCONNECTED (B3)
RELAY CD
OPERATED (A1)
DISCONNECTED (B1)
RELAY CA
OPERATED (CD3)
DISCONNECTED (MD6)
RELAYS D AND I
RLSED. (A2)
RELAY DD
RLSED. (D1)
RELAY MD
OPERATED (DD4)
DISCONNECTED (CD1)
RELAY BB
DISCONNECTED (BA7)
I/C P-WIRE
OPEN PERIOD ≏ 40Ms
O/G P-WIRE
TIME SCALE
0
100Ms
200Ms
300Ms
400Ms
500Ms
600Ms
700Ms
800Ms
900Ms
R35697 A

Fig. 6



-VE
FROM
SELR.
LEVELS
50
50
A
MR3
MR4
D
200
I
200
+VE
ON5
ON6
R9
390
IP2
CD4
67%
B
BA5
-VE
BA6
+VE
P
B1
B2
BA
6K
2K
IS
IPI
CDI
200
MM
CD
R7
BA3
B3
AI
B
200
RM
ON7
CD3
BC5
P
IP
STI
BC4
ISi
200
TM
BC
BA4
50% M
ST
600
ON2
R2
240
TMdm
N1
MMdm
CD2
ON
ON3
BC2
RLSE.
ALARM
R35699 A

Fig. 8

MECHANICAL PULSE REGENERATOR.

PRINCIPLES OF MECHANISM & CONTROL CIRCUIT

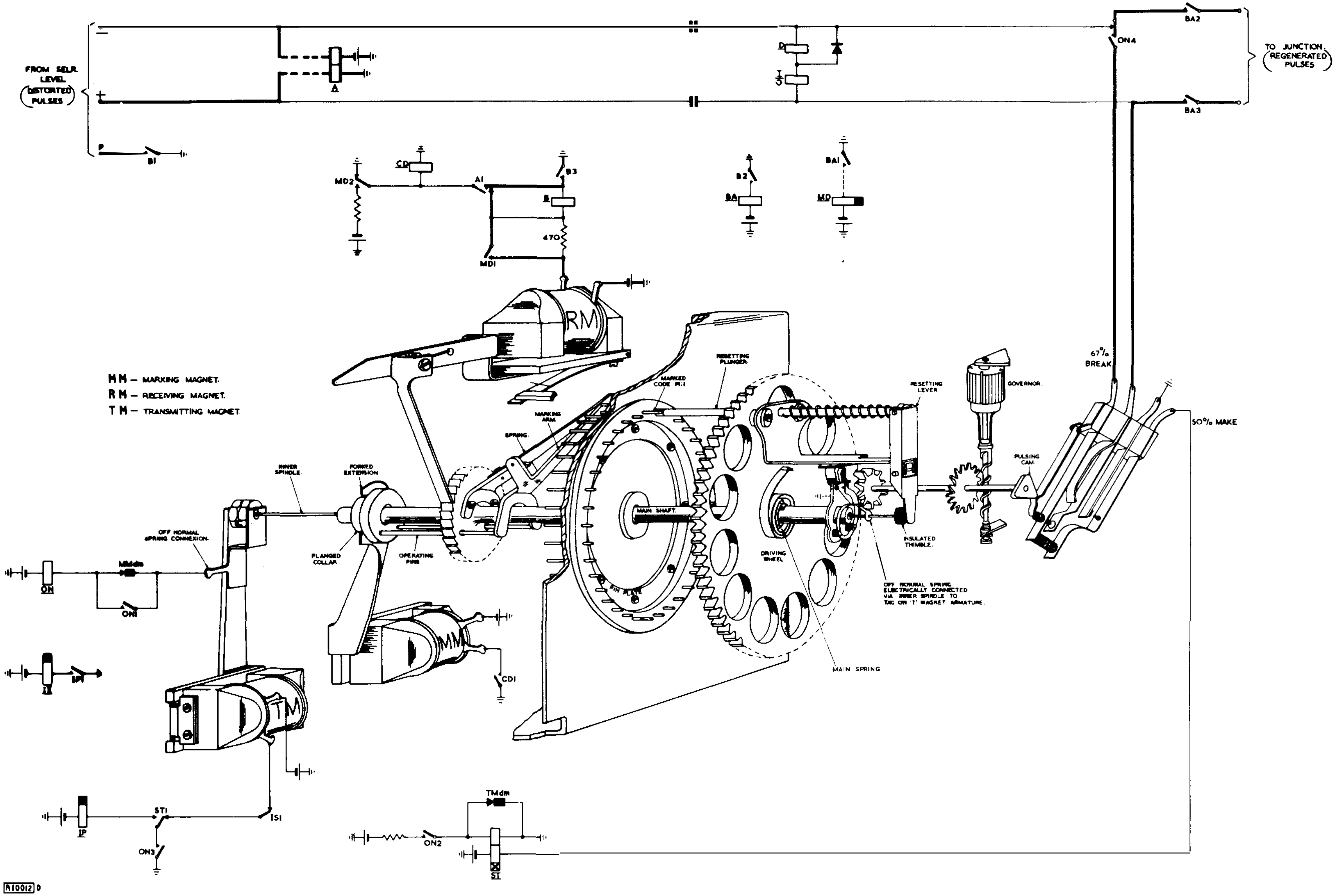
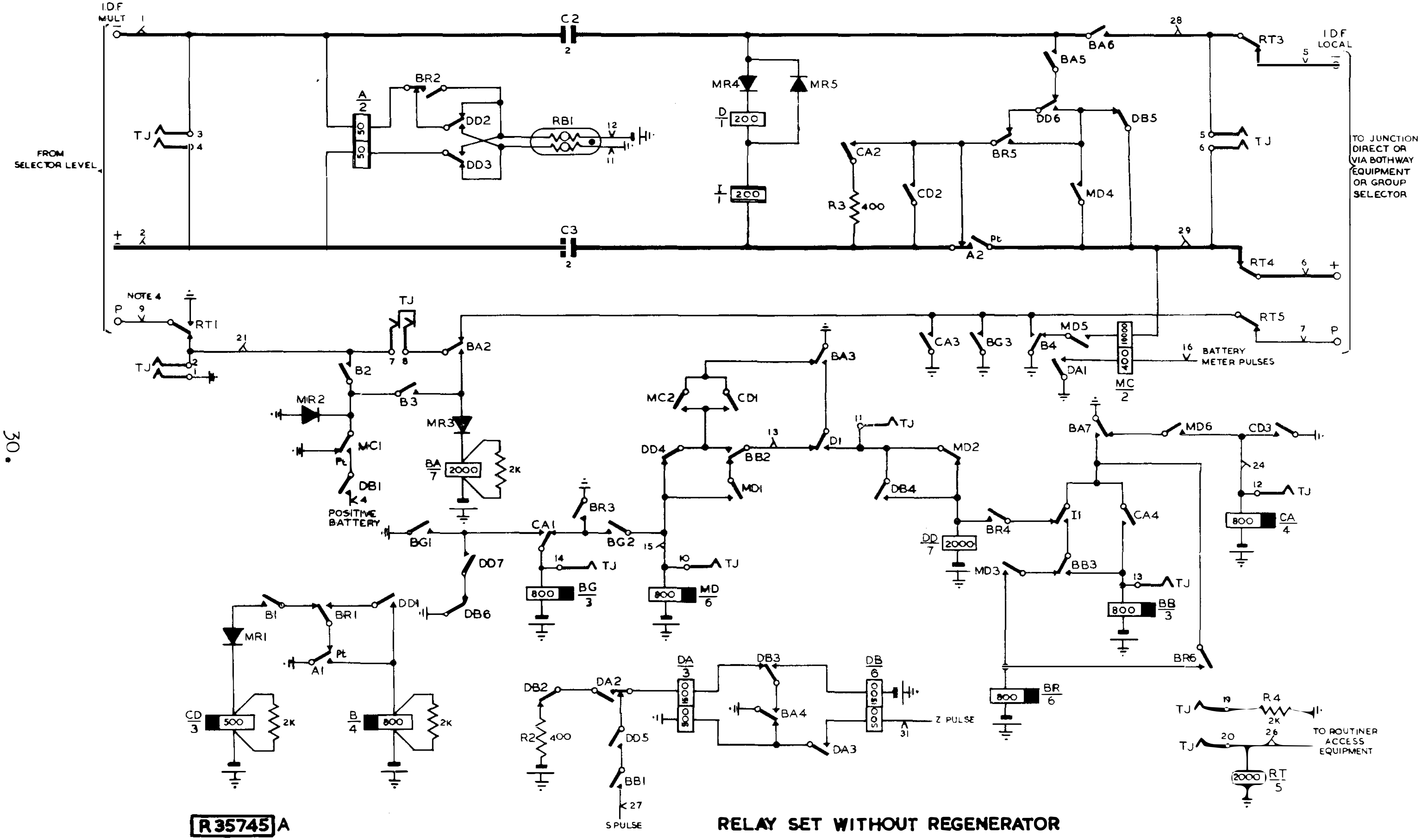


Fig. 13



RELAY SET WITHOUT REGENERATOR

Fig. 14

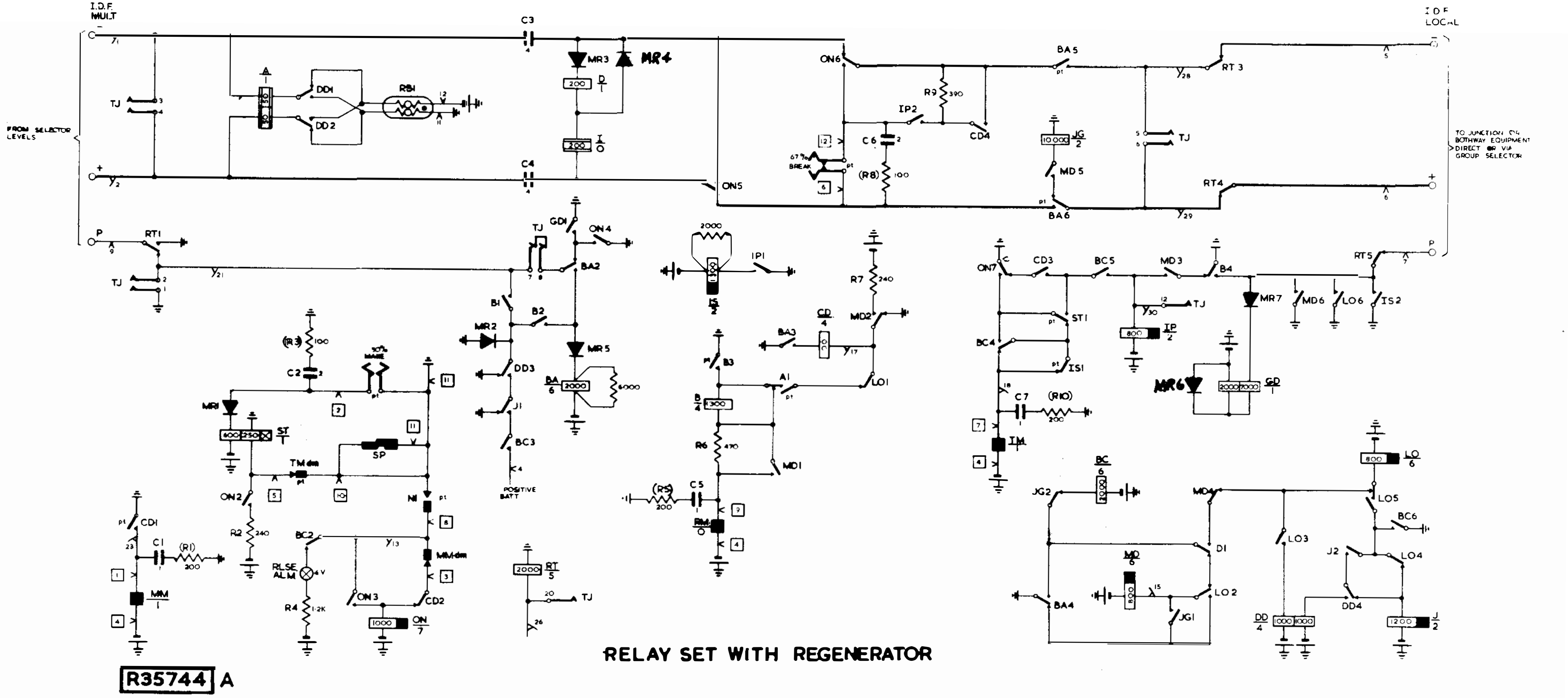

I.D.F. MULT
I.D.F. LOCAL
FROM SELECTOR LEVELS
TO JUNCTION OR BOTHWAY EQUIPMENT DIRECT OR VIA GROUP SELECTOR
RELAY SET WITH REGENERATOR
R35744 A

Fig. 15