repeater station from the exchange are fed into a static modulator, working on the principles already described, and control the output from a source of a.c. at 3825 Hz. The keyed output is fed through a band-pass filter passing a narrow frequency band centred on 3825 Hz. The audio signals are passed through a filter having a pass range of 300–3400 Hz. The outputs of the two filters are paralleled, and the combined output is passed into the multi-channel equipment in the usual way. The sending filters ensure that the speech and the control signals occupy discreet frequency bands within the allocated band of 4 kHz in the main system, and can thus be readily separated at the receiving end. The combined speech and signalling outputs from all the channels are translated by the carrier equipment to suitable frequency bands for transmission over the main carrier circuit as described in Chapter 1.

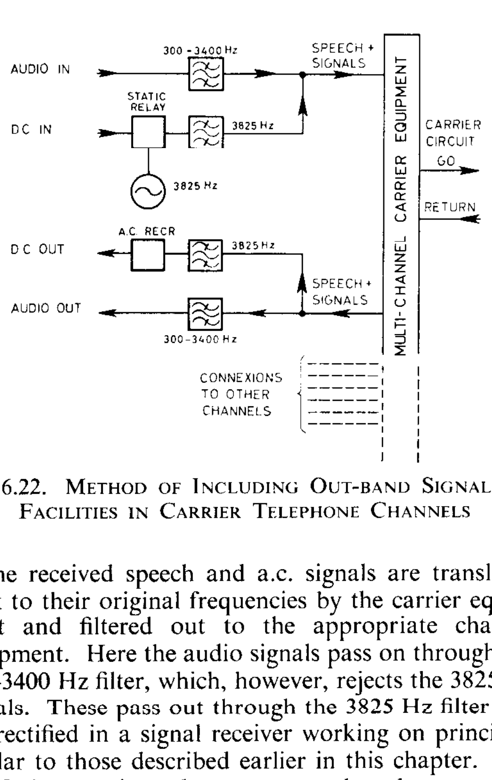

FIG. 6.22. METHOD OF INCLUDING OUT-BAND SIGNALLING FACILITIES IN CARRIER TELEPHONE CHANNELS

The received speech and a.c. signals are translated back to their original frequencies by the carrier equipment and filtered out to the appropriate channel equipment. Here the audio signals pass on through the 300–3400 Hz filter, which, however, rejects the 3825 Hz signals. These pass out through the 3825 Hz filter and are rectified in a signal receiver working on principles similar to those described earlier in this chapter. The rectified output is used to operate a relay whose contacts provide the necessary conditions to control the exchange signalling equipment.

The d.c. signalling arrangements are illustrated in principle in Fig. 6.23. The audio signals are extended from the terminal repeater stations, where the carrier equipment is installed, to the telephone exchanges over 4-wire circuits, the phantom circuits being used to carry the d.c. signals as already described in connexion with the provision of a d.c. path on 4-wire amplified circuits.

The outgoing and incoming relay sets each include a specially designed 2-wire/4-wire termination similar in principle to that already described but having a transformer capable of carrying, without loss of efficiency, the rather heavy d.c. signalling currents. When the outgoing circuit is seized the loop formed across the + and − wires at the outgoing exchange operates relay A. This causes an earth to be applied to the phantom of the outgoing side of the four-wire tie line, causing current to flow in the static-relay modulator at the carrier terminal.

The consequent a.c. signal produced in the signalling channel is rectified at the receiving terminal and causes earth to be applied via the phantom of the tie line to operate relay A at the incoming exchange. Contact A in conjunction with contact CD provides a loop to seize the incoming automatic equipment. (The means by which relay CD is operated is not important for our present purpose and has not been shown.) Break pulses received by relay A at the outgoing exchange are repeated over the signalling channel to relay A at the incoming exchange. The contacts of this relay repeat the pulses to the automatic equipment. On the conclusion of dialling, contact CD releases and the loop is completed via relay D.

When the called subscriber answers, the consequent battery reversal causes relay D to operate and a corresponding signal is returned over the backward-signalling path to operate relay D at the outgoing exchange. The contacts of relay D reverse the battery supply in the normal manner to give the usual call-answered signal back to the originating exchange.

The clearing signals are given in the usual way, that is by release of relays A and D, the release conditions being transmitted over the forward- and backward-signalling paths respectively to release the A relay at the incoming exchange and the D relay at the outgoing exchange.

SIGNALLING IN TELEPRINTER SWITCHING SYSTEMS

Whereas in telephony a d.c. path, or its equivalent, operationally independent of the a.c. transmission path, is normally available for the transmission of supervisory and control signals (in-band telephony signalling is an exception), in telegraphy one and the same path must invariably be used for transmission of both the supervisory and control signals and the message signals. This fact introduces some inherent differences between the signalling principles used in telephony and telegraphy. These differences will become apparent in the course of the explanations of telegraph signalling which follow. One advantage gained in telegraphy comes from the fact that high-quality signalling channels are required for the transmission of the teleprinter

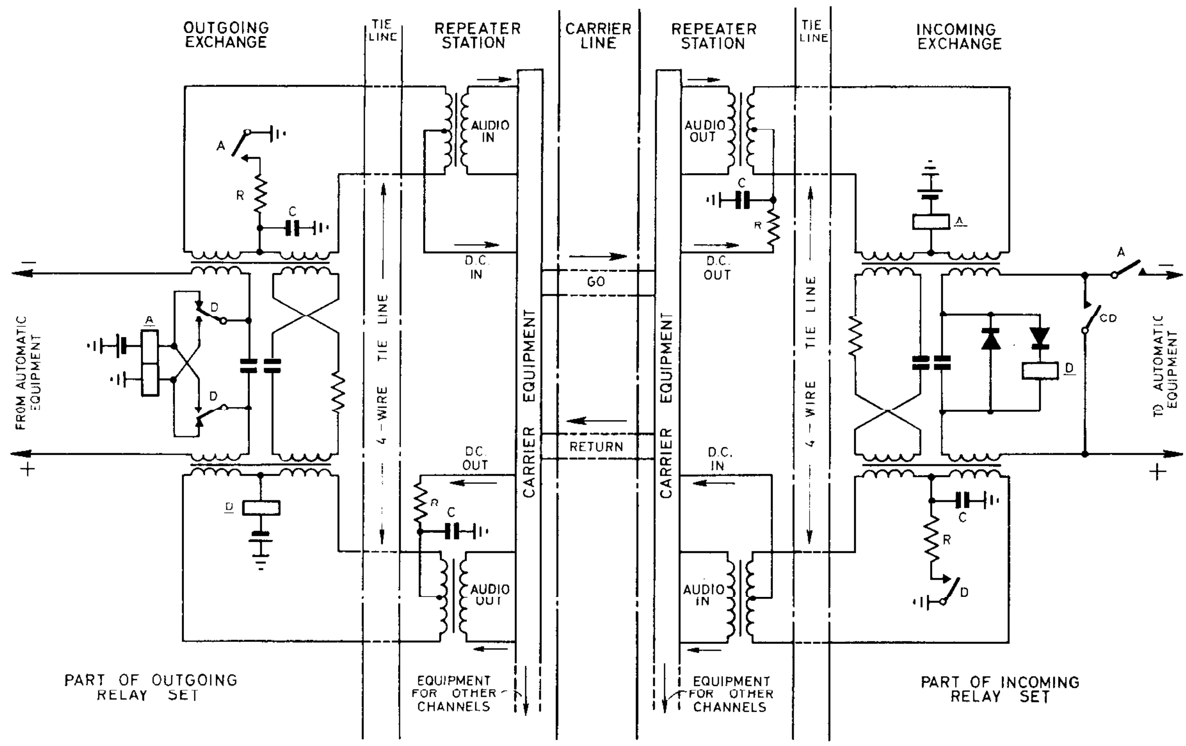

FIG. 6.23. PRINCIPLES OF D.C. SIGNALLING ARRANGEMENTS ON CARRIER CHANNELS WITH OUT-BAND SIGNALLING

signals, and therefore the channels are inherently suitable for the transmission of dial pulses and supervisory signals, while the amount of signal distortion introduced during transmission is normally very small.

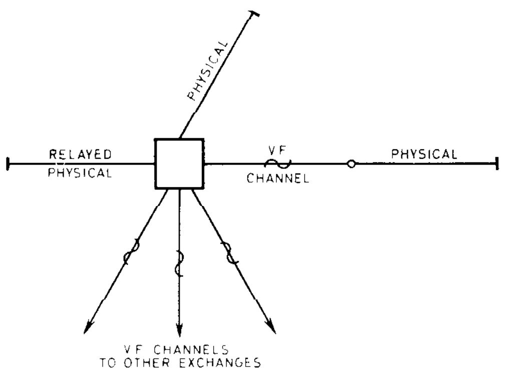

FIG. 6.24. CIRCUITS AT A TYPICAL TELEX EXCHANGE

The general transmission and switching plans for the automatic switching networks used in the public telegraph and telex services were outlined in Chapter 1, and it was there explained that the inter-exchange circuits are normally provided by means of voice-frequency telegraph channels. These channels provide the operational equivalent of two independent d.c. circuits working in opposite directions, and therefore automatically give two-way simplex facilities, and the inter-exchange circuits are always operated on a two-way simplex basis. This applies whether the signals are routed on voice-frequency telegraph channels or on physical circuits.

On the physical circuits between an exchange and its local teleprinter stations (i.e. stations situated within a few miles of the exchange) it is possible to use the loop-disconnect method of signalling, and this is in fact the practice followed in some countries. However, a telegraph exchange usually serves teleprinter stations distributed over a wide area, and many of the station lines have to be provided by means of d.c. relayed circuits or voice-frequency channels extended over d.c. circuits from the voice-frequency terminal to the subscriber's premises. In neither case are these circuits suitable for loop-disconnect working, and in the interests of standardization there is some merit in extending the two-way simplex method of operation used on the inter-exchange circuits to the local circuits also. Therefore, in the teleprinter services operated by the British Post Office, the station lines are always operated on a two-way simplex basis. This arrangement also permits the use of double current working, whereas the loop-disconnect system is only suitable for single-current operation. The adoption of double-current operation results, as explained earlier, in reduced signal distortion on local lines, particularly on the longer physical circuits. Fig. 6.24 indicates the make-up of the circuits on a typical telex exchange.

The transmission limits in respect of the transmission of teleprinter signals over physical circuits are quoted in terms of circuit length, since the signal distortion is largely determined by capacitance and interference effects. The limits for supervisory signals, however, are quoted in terms of maximum loop resistance. Typical limits are given in Table 6.3. The circuits are assumed to be routed in underground cable.

Table 6.3

Limits for Physical Telex Subscribers' Lines

Type of line	Transmission limits*	Signalling limits
Non-relayed	miles 20	Ω 3000
Relayed	40	8000
Extension from v.f. channel	10†	3600

* The transmission limits quoted apply to 20 lb underground cable. Multiplying factors are used to obtain limits for other conductor weights.

† Increased to 25 miles for London subscribers, as they have direct access to international trunk circuits.

The foregoing limits apply to the telex service; somewhat different conditions and limits apply to the public telegraph service.

Signalling Arrangements

In general, two signalling conditions are available on telegraph circuits, and with two-way simplex circuits using double-current signalling these correspond to either positive or negative battery applied as required to the sending ends of the two transmission paths. At each end of a two-way simplex circuit it is usual to refer to the *send* and *receive* sides of the circuit, or to the *send wire* (*S wire*) and *receive wire* (*R wire*). It follows that the S wire at one end of a circuit becomes the R wire at the distant end. Also, when two circuits are switched together, each incoming R wire must be connected to an outgoing S wire. In manual switching the necessary reversal is made in the connecting cord circuit. In automatic exchanges the reversal is introduced in the connexions leading away from the automatic equipment (final selectors) used for calls outgoing to a subscriber's line (see Fig. 6.25).

For signalling purposes it is often convenient to refer to the *forward* and *backward* signalling (or transmission) paths. The forward signalling path is the one corresponding in direction to that in which the call is established, i.e. from the calling station towards the called station, the backward path being the path over which signals are returned. The positive battery condition is often referred to as *spacing*. It is also called the *start* condition with reference to the teleprinter start signal which uses the same spacing polarity. Similarly the negative battery condition may be referred to as the *marking* or *stop* condition. In international relations the start condition is also known as the *A polarity*, and the stop condition as the *Z polarity*. However, for the present purpose the signalling conditions will, in general, be defined by reference to the battery polarity used in the internal services of the British Post Office, as this helps in following circuit operations, particularly when rectifiers are involved. A third signalling condition can be used on wholly physical circuits, namely a *no-current* condition, and this is used for certain purposes on telex subscriber's lines. The two cases concerned will be mentioned later.

In the following explanations of the principles adopted in telegraph switching, the practices followed in the automatic telex service [6.4] will be referrred to by way of example. The principles used in the public telegraph service are similar, but for various reasons there are a number of differences in detail.

The various signals required and the corresponding d.c. conditions used during the establishment and clearing of a call are given in Table 6.4. The d.c. polarities quoted in the table apply both to physical circuits and the d.c. input and output circuits used at the ends of voice-frequency telegraph channels. The direct voltages used in all cases are +80 V and −80 V.

Service Signals

For such indications as busy, spare line, etc., ordinary teleprinter signals are used, the signals being received and printed on the calling subscriber's teleprinter. The conditions catered for and the corresponding printed indications are given in Table 6.5.

The abbreviations used are internationally agreed and are based on English or French expressions:

OCC	occupé
NC	no circuits
NP	no plant
DER	dérangé
ABS	absent

Table 6.4

Supervisory Signals in the Telex Service

Title	Characteristic indication
Free-line condition (i.e. normal condition of a disengaged circuit)	Positive potential on each transmission path.
Calling signal	Negative potential on the forward-signalling path.
Call-confirmation signal (used on trunk circuits only—confirms proper receipt of call)	Pulse of negative potential of duration of 20 ms on backward-signalling path (combined with proceed-to-select signal for certain international traffic).
Proceed-to-select signal	Pulse of negative potential on backward-signalling path of duration of 50–100 ms on subscribers' lines, and 20 ms on inland trunk circuits.
Call-connected signal (upon connexion to called subscriber)	Steady negative potential on backward-signalling path from called subscriber's station equipment (receipt of this signal at the objective exchange initiates transmission of the "Who are you?" teleprinter signal, releasing the answer-back unit of the called teleprinter, the signals so transmitted being received on the calling subscriber's teleprinter. In the case of calls completed automatically, receipt of the call-connected signal at the originating exchange also prepares for metering of chargeable calls.
Clearing signal (either party can clear)	Positive potential applied to the forward- or backward-signalling path, as the case may be, for 300–1000 ms.

Telex Subscriber's Installation

In addition to the teleprinter itself and any auxiliary teleprinter equipment, for example an automatic transmitter, a telex subscriber's installation includes a signalling or *dial unit*. This unit, which is to be seen in Fig. 5.17, contains the circuit components and relays necessary to provide the required signalling conditions. It also mounts the dial, two supervisory lamps (red and green) and several press keys.

Table 6.5

Printed Service Signals in the Telex Service

Condition	Printed indication
Subscriber's line engaged	OCC
Trunks or equipment engaged	NC
Spare outlet reached	NP
Subscriber's line out of service	DER
Subscriber's installation closed	ABS
Number changed	NCH

The installation derives its power from the mains. The teleprinter motor (a.c. or d.c. as required) is driven directly off the mains. A relay fitted on the teleprinter and connected across the governor contacts of the motor is used to prevent the sending and receiving of signals until the teleprinter has reached governed speed. The signalling supplies consist of +80 V and −80 V for line signalling and −50 V for relay operation. These supplies are derived from an a.c. supply by means of a rectifier power pack. When the mains supply is d.c. the a.c. supply for the signalling unit is obtained from a d.c./a.c. vibrator unit.

A simplified diagram of the installation illustrating the principal signalling features is given in Fig. 6.25. The equipment contains rectifier units at several points to permit discrimination between positive and negative applied potentials. The rectifier bridge arrangement consisting of rectifiers MR3, 4, 5 and 6, which is associated with relay CM, enables it to hold for both positive and negative potentials, and also to remain operated during teleprinter signalling when the direction of the current is continually reversing. Relay CM is prevented from operating to positive potential, because of the short-circuit produced across the rectifier bridge network by the parallel-connected rectifier (MR2) when it is carrying current in the forward direction.

When the installation is disengaged and in the service condition, i.e. with the power switched on, +80 V is fed out over the send wire to the exchange, the loop-connected relay LS being held operated by current flowing through its coil and back over the receive wire to earth at contact CM1, the current passing through the associated series rectifier MR2 in the forward direction. The reason for this particular loop-signalling arrangement at the exchange is to avoid unnecessary drain on the exchange +80 V supply and to exclude from the exchange earth-electrode system the relatively heavy current which would otherwise flow to earth at the exchange from all free station lines.

It will be observed that the dial is fitted with change-over contacts so as to give double-current signals. The dial pulses have a nominal ratio of 60/40 to comply with the agreed standards for through dialling on international telegraph services.

The processes involved in making an ordinary dialled call will now be described.

CALLING AND DIALLING

In order to make a dialled call the subscriber operates the dial key (Fig. 6.25). This causes relay DC to operate and −80 V is applied to the send wire via contact DC1 (operated). With the consequent reversal of line potential, the flow of current through relay LS is blocked by the series rectifier. This produces a virtual disconnexion for the time being on the return path to the subscriber's equipment. By means of contacts not shown, the release of relay LS causes the subscriber's line to be extended via the H relay contacts to the automatic equipment for outgoing calls. When the line has been connected to a free automatic selector the proceed-to-select signal (negative potential pulse of 50–100 ms duration followed by positive potential) is returned to the subscriber's equipment over the R wire, i.e. over the backward-signalling path. Relay PD now operates to −80 V potential, lighting the green call lamp, starting the teleprinter motor, and thus indicating to the operator that the calling signal has been received and dialling may proceed. The operator now releases the dial key. Relay DC remains held via contacts DC2 and PD1 (operated). Relay PD is also held via contacts PD2 and DC3 (operated) and CM2 (normal). (Relay CM was not operated by the negative potential pulse on the R wire during the proceed-to-select signal, although rectifier MR2 was then polarized to the high-resistance condition, as the relay circuit was at this time disconnected at the dial key.) The operator now proceeds to dial.

Upon conclusion of dialling, and assuming the called

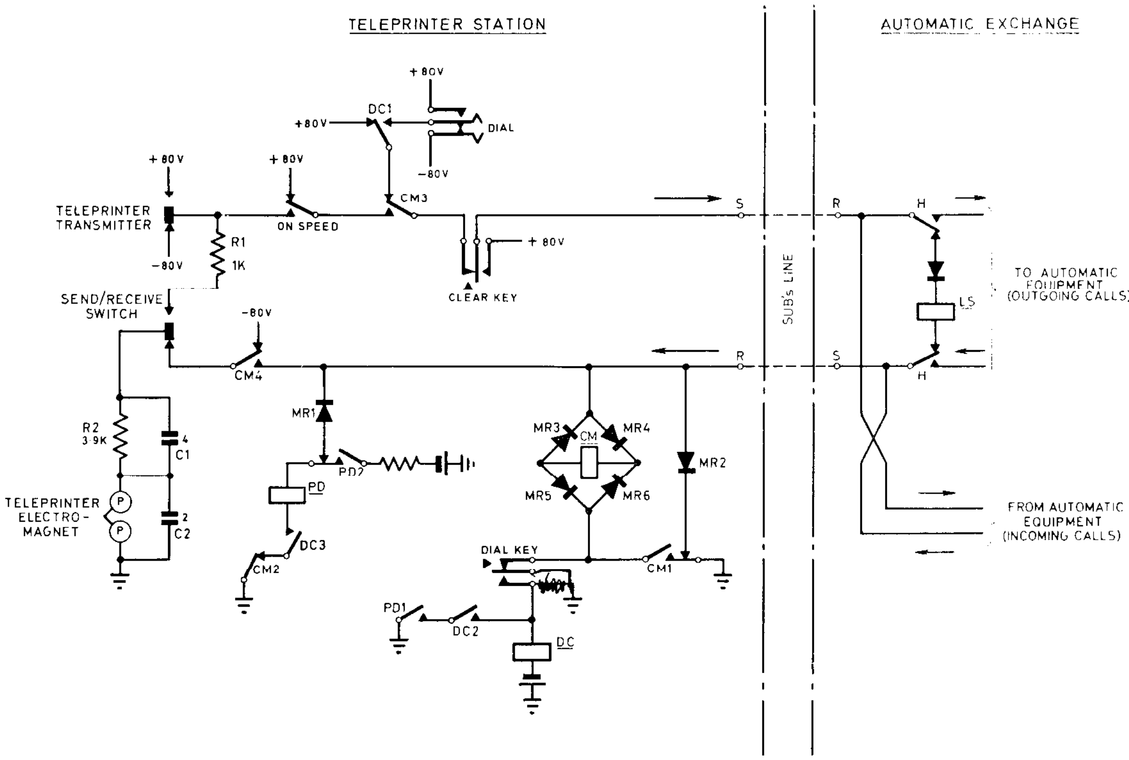

FIG. 6.25. SIGNALLING FEATURES OF TELEX SUBSCRIBER'S INSTALLATION: SIMPLIFIED DIAGRAM

subscriber is free, the call-connected signal is returned over the backward-signalling path. The negative potential thus received on the R wire at the calling subscriber's installation operates relay CM, the parallel-connected rectifier MR2 being polarized to the non-conducting condition. The teleprinter magnet is now connected to line via contact CM4 (operated) in readiness to receive the answer-back signals which are automatically transmitted from the called subscriber's teleprinter. The S wire is at the same time switched through to the teleprinter transmitter via contacts CM3 (operated) and the on-speed relay contacts, the latter relay having operated as soon as the teleprinter came up to speed. With the operation of contacts CM2, relays PD and DC restore to normal, and control of the motor and green lamp circuits is now taken over by contacts of the CM relay. Following receipt of the answer-back signals, signalling may proceed in either direction at will.

Although the two-way simplex connexion which is provided between the two teleprinters is capable of giving duplex operation (simultaneous working in both directions), it is normal practice, as explained earlier in this chapter, to arrange for a local record of all messages transmitted to be printed on the receiving side of the sending machine, and this precludes duplex operation. Duplex working can, however, be catered for by means of special arrangements.

The local record of the transmitted teleprinter signals is obtained via the medium of the send/receive switch, whose moving contact automatically changes over to the send side, connecting the teleprinter electromagnet in parallel with the teleprinter transmitter each time the transmitter operates. Resistor R1 limits the current taken through the shunt path. Resistor R2 and capacitors C1 and C2 provide a signal-shaping network for the teleprinter electromagnet circuit.

The foregoing sequence of events is illustrated graphically in the timing chart (Fig. 6.28) which follows the description of the circuit operations.

CLEARING

The call is cleared by operating the clear key until the call lamp is extinguished and the teleprinter motor stops, indicating that the clearing signal has been effective and the station line is now free for a further call, either outgoing or incoming. When the originating subscriber clears, positive potential is applied to the forward-signalling path, causing release of the connexion and of all switching equipment which has been held. This causes a no-current condition to be returned over the physical receive-wire to the station equipment. This allows relay CM to release, and the station equipment then reverts to the free condition, the call lamp being extinguished and the teleprinter motor switched off when relay CM releases. This use of the no-current condition is one of the cases mentioned earlier in which a third signalling condition is used on physical station lines.

Should the called subscriber clear first, the clearing signal is transmitted over the backward-signalling path towards the calling subscriber and is recognized in the automatic equipment at the originating exchange. This causes the clearing condition to be applied to the calling subscriber's line (no-current on the physical receive-wire), and the calling station equipment is thereby released. In reverting to the free condition with release of relay CM, positive potential is applied to the calling-station send wire, via contacts CM3 and DC1 (normal). The positive potential acts as a clearing signal on the forward path, causing all equipment held to be released and so completing the clearing of the call including the release of the called station; the signal is consequently referred to as a *clear confirmation signal*.

INEFFECTIVE CALLS

Should the call encounter busy conditions or one of the other conditions indicated in Table 6.5, the appropriate printed indication will be returned from a special signal generator at the exchange. The service signals are preceded by negative potential for 200 ms to operate relay CM and prepare the teleprinter to receive the service signals. Transmission of the required teleprinter signal sequence is automatically followed by a clearing signal, so releasing the connexion immediately and avoiding unnecessary holding of equipment.

INCOMING CALL

On an incoming call −80 V is sent from the exchange to operate relay CM. This causes the teleprinter motor to start and lights the call lamp. When the motor has come up to speed the on-speed relay operates and extends −80 V via contact CM3 (operated) from the teleprinter transmitter over the send wire to the exchange, thus giving a call-connected signal. Receipt of this signal in the exchange causes the WRU signal to be returned to the station to actuate the answer-back unit as already described. Receipt of an incoming call can, if desired, also be caused to sound a buzzer.

MISCELLANEOUS FACILITIES

Reference to the teleprinter code given in Fig. 5.2 shows that the secondary of letter J can be used as a calling signal. On an established telex connexion either subscriber can sound a buzzer or bell alarm on the distant teleprinter by sending first the figure-shift signal and operating the J key. This also lights the red lamp on the dial unit.

Certain other facilities are provided on the subscriber's installation, such as allowing the teleprinter to be used for preparing perforated tapes or copying messages, without busying the installation for incoming calls. The station may also be closed down, if desired, and the power supply switched off, whereafter the ABS signal

(Table 6.5) is returned from the exchange to any caller. The methods by which these facilities are provided are outside the scope of the present treatment. However, it should be mentioned that station-closed is indicated by means of a no-current signalling condition on the send wire from the subscriber's equipment, representing the second of the two uses of no-current as a signalling state on physical station lines.

If the call is one which requires operator assistance, such as, for example, certain international calls, when the call is connected to the switchboard a printed *wait* signal is returned to the caller; it consists of the letters MOM (moment).

Supervisory Arrangements

During an established call, supervisory devices must be included in the connexion to recognize the occurrence of a clearing signal (positive potential for more than 300 ms). While teleprinter signalling is in progress, teleprinter signals consisting of varying numbers of (Signal No. 32 in the International Teleprinter Alphabet) might be received, giving a 120 ms period of positive potential. The clearing signal detector must be immune to these signals and also to several rapid repetitions of teleprinter signals containing a preponderance of positive signal elements. Furthermore, the transmitted signals may be subject to bias or other distortion resulting in an increased preponderance of positive potential at the point of detection. To guard against false clearing of established calls, the supervisory signal element is designed so as to be immune to a continuously repeated signal of 150 ms duration and consisting of 135 ms of positive potential (spacing) followed by 15 ms of negative potential (marking), but to be responsive to a period of positive potential within the limits of 325 and 475 ms in duration.

The supervisory arrangements on an established call are illustrated in Fig. 6.26 by reference to a call between two subscribers on the same exchange, each subscriber's line being wholly routed on physical pairs. When the calling party initiates the clearing signal, the supervisory

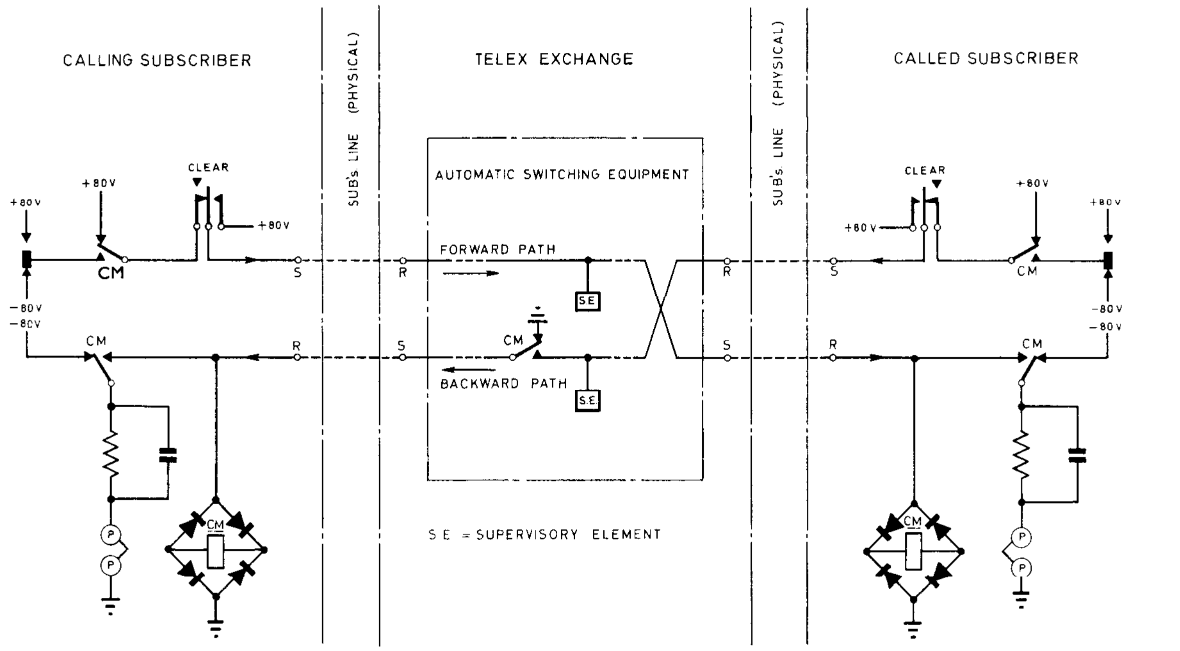

FIG. 6.26. SIGNALLING PATHS FOR TELEX CALL VIA AN AUTOMATIC EXCHANGE, SHOWING SUPERVISORY ARRANGEMENTS

positive and negative elements are transmitted. In any intervals in sending, the signalling condition remains as negative potential (i.e. stop or marking polarity). The longest period of continuous positive potential (spacing or start polarity) is normally obtained with letter T, the code for which is (SSSSM). This, together with the start signal, gives a period of positive potential of 5 × 20 ms. Exceptionally the all-space signal element on the forward-signalling path responds and causes all the automatic equipment held to be released. A no-current condition is produced on the physical receive wires at each station to release the CM relay in each dial unit, the subscribers' equipment then reverting to the normal or free condition. If the called party clears first, the supervisory element associated with the backward-signalling path responds, and a CM relay associated with the supervisory element in the originating exchange releases. Upon release of the contacts of this relay a no-current condition is passed back to the calling subscriber's equipment. The station equipment

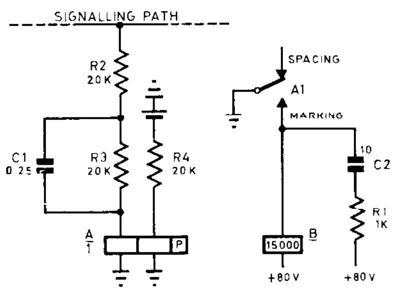

FIG. 6.27. PRINCIPLES OF TELEX SUPERVISORY SIGNAL

then reverts to the free condition and positive potential is applied to the send wire. This positive signal (i.e. the clear confirmation signal) is recognized as a clearing signal in the supervisory element connected to the signals passing, a sensitive polarized relay, A, connected to a high-resistance shunt path consisting of resistor R2 in series with the shunted-capacitor network C1, R3, is used to monitor the transmitted signals. The moving contact of the polarized relay follows all signal changes occurring on the main transmission path, and when the calling signal is transmitted on the forward path the relay operates to the negative (marking) contact, so operating relay B. In the backward-signalling path the polarized relay operates to marking when the call-connected signal is transmitted. (The supervisory signal element connected to the backward signalling path is similar in principle to that shown in Fig. 6.27, but the relay operated from the contacts of the polarized relay is, in this case, known as a CM relay.) When contacts A1 operate, capacitor C2 is charged to 80 V, and when the moving contact changes over during positive-potential signals, capacitor C2 discharges through the coil of relay B. The resistance and capacitance in the discharge network are such that relay B will remain held unless a positive-signal condition having a duration between the prescribed limits of 325 and 475 ms is received. Capacitor C2 is adjustable

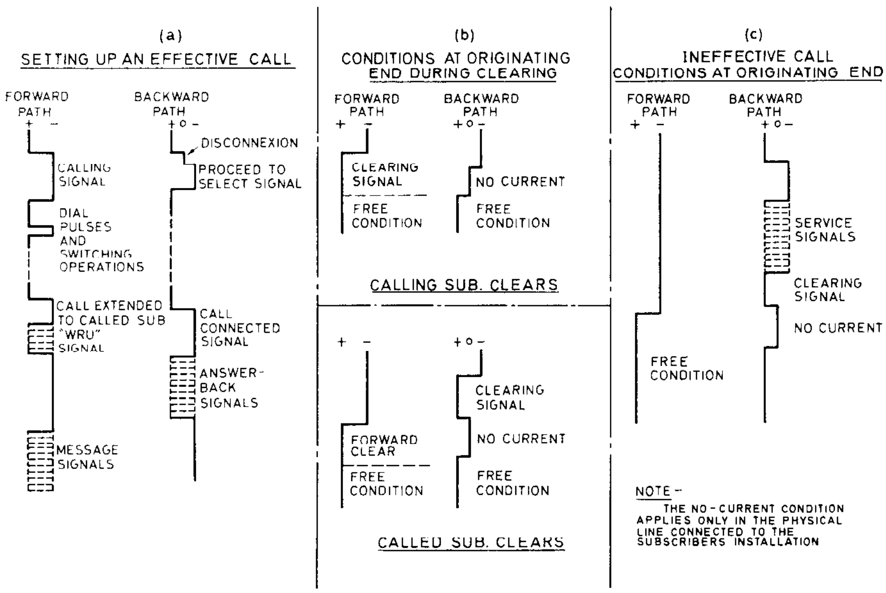

FIG. 6.28. TIMING CHARTS INDICATING THE SIGNALLING PROCESSES IN TELEX CALLS

The charts indicate the sequence of events only, and are not drawn to any fixed time scale. The charts for both the forward and backward directions are to be read from top to bottom.

forward-signalling path, whereupon the automatic equipment is released and a no-current condition is applied to the called subscriber's line to release his station equipment.

The supervisory circuit element is shown in Fig. 6.27. To prevent it introducing any appreciable loss of signal current or causing any appreciable distortion to the in 2 μF steps to facilitate the production of an acceptable release lag.

The auxiliary winding of relay A is supplied via R4 with a small energizing current just sufficient to hold it to the positive (spacing) side during line disconnexions, or when the equipment concerned is disengaged, and there is therefore no current flowing in the signalling path. The shunted capacitor network R3, C1 in series with the relay operating coil serves to improve the signal shape in the manner referred to earlier in this chapter, and thus to permit a more faithful response by the relay to the monitored signals.

Fig. 6.26 relates to a local call between two subscribers having wholly physical lines. When a subscriber's line contains a voice-frequency telegraph channel, the inability of the channel to transmit the no-current signalling conditions employed on the send and receive wires of the physical lines entails some changes in the signalling arrangements at the exchange end. However, a relay set inserted between the voice-frequency channel terminal and the physical line to the subscriber produces signalling conditions similar to those described for the physical line used to extend the voice-frequency channel to the subscriber's premises.

For calls passing via two or more exchanges similar signalling principles are used. A supervisory signalling element is included in the forward-signalling path at each exchange and controls the release of any equipment held in that exchange.

Signal Timing Charts

The various signalling processes in the setting up and clearing of telex calls as described in the preceding paragraphs are further illustrated in the timing charts given in Fig. 6.28. These indicate the sequence of events during the calling and clearing processes. It should be remembered that the charts for both the forward and backward directions are each read from top to bottom, since they are related to time and not to the direction in which the signals are transmitted. No time scale is given, as the lengths of the various signals as drawn are not proportional to their duration. It should also be remembered that the WRU signal transmitted to the called subscriber upon return of the call-connected signal is sent out by the originating exchange, and while it is being transmitted the signalling condition applied to the send wire of the calling subscriber's line remains as steady negative.

Strictly speaking the charts apply only to calls between subscribers on the same exchange, each having a wholly physical station line. Calls involving inland trunk circuits, however, follow identical signalling principles.

A description of the metering arrangements, and the signalling systems used on international calls, is outside the scope of the present treatment.

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EXERCISES

6.1. (*a*) Distinguish between a single-wire signalling path and a loop signalling path.
(*b*) Distinguish between single-current signals and double-current signals.
(*c*) Give circuit sketches to illustrate the following: (i) double-current signals transmitted over a single-wire signalling path, (ii) single-current signals transmitted over a loop signalling path. Give an example of the use of either (i) or (ii). (*C. & G., Telephony and Telegraphy A, 1964*)

6.2. What do you understand by the term "duplex working"? Give an outline description of the bridge and differential systems of duplex working. Instance an example of the differential principle used for junction signalling in telephony, and give a simple diagram of the arrangements.

6.3. Discuss the causes of distortion of d.c. signals transmitted on short lines employing (*a*) single-current working with single wires and earth return, (*b*) loop-disconnect working. Illustrate your answer by simple sketches indicating the shape of the received signals.

6.4. Give some account of the nature of the signal distortion produced in d.c. signalling on long lines. Compare loop dialling, battery dialling and double-current dialling using the single-commutation method. Illustrate your answer by means of graphs of the sent and received signals.

6.5. Distinguish between the following two types of direct-current signal, and give an example of the use of each: (*a*) loop-disconnect, (*b*) double-current. Why are voice-frequency alternating-current signals sometimes used instead of direct-current signals? (*C. & G., Telephony and Telegraphy A, Dec.*, 1964)

6.6. Give some account of the methods of providing a d.c. signalling path on amplified telephone circuits. What are the disadvantages of using d.c. signalling methods on very long lines?

6.7. Give a simple explanation of a method of signalling by means of alternating current, giving sketches of typical signal pulses. What are the principal advantages of this method of signalling (*a*) in telegraphy, (*b*) in telephony?

6.8. What do you understand by the term "amplitude modulation"? Indicate two methods by which such modulation may be effected, giving diagrams. Give a simple explanation as to how such modulated signals can be received and converted to d.c. signals.