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SYLLABIC COMPANDOR TYPE CPR. 12

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This article describes the design of a compressor and expander or 'compandor', for general use in speech communication circuits and having facilities for incorporation into existing systems. Both cross-talk and noise can be reduced by the use of this device, which has compression and expansion ratios of 0.5 *and* 2.0 *and gives a subjective improvement of signal/noise ratio of up to* 30 *db without material distortion of transmitted voice-frequency signals.*

Economy of space and simplified field inspection are secured by the use of plug-in printed-wiring assemblies incorporating transistors and other components of small size. Supply voltages of 12, 24 *or* 50*V d.c. may be employed, thus ensuring compatibility with most existing installations.*

COMPANDORS have been in use for some time as a means of reducing noise and interference on both line and radio circuits, and the advent of transistors and miniature components has made it possible to design smaller units having the added advantages of low power consumption and lower relative cost. As the demand for reliable communication channels is steadily increasing, any device which will enable noisy circuits to be improved economically is worthy of consideration.

The compandor consists of two separate units, compressor and expander, inserted at points in a communication system where the 'go' and 'return' channels have been separated; that is, at 4-wire points. The compressor is inserted in the transmitting path and operates in conjunction with an expander fitted in the distant receiving path. Normally a compandor is inserted in both 'go' and 'return' channels. (See Figure 1).

TYPICAL APPLICATIONS

Some advantages to be gained from the use of compandors in connection with various types of communication circuit are given below:—

(*a*) *Audio-Frequency Circuits*

Compandors may be used on 4-wire physical or phantom circuits to reduce noise and crosstalk resulting from line unbalance or other causes. This may make available for phantom working pairs which were previously unsuitable.

(*b*) *Carrier Circuits*

The filters used in a frequency division multiplex system account for a large part of the overall cost. If compandors are included as an integral part of the system, the filter requirements necessary for a given crosstalk level may be relaxed.

More economical use of line plant may also result, as it is possible to increase the spacing and/or reduce the number of repeaters required and to minimize the amount of equipment necessary for line balancing and longitudinal noise suppression. Satisfactory operation at frequencies up to 4 times the maximum previously usable (on account of line unbalance, etc.), may result in more effective use of existing installations.

(*c*) *Radio Circuits*

In this application it may be possible to operate with a lower transmitter power for a given signal/noise ratio. If the signal/noise ratio with a 10-watt transmitter is only 40 db and the requirement is for 60 db, this may be achieved by increasing the transmitter power to 1 kW Alternatively, by introducing compandors into the speech circuit(s) a similar signal/noise ratio improvement can be obtained with the original transmitter. Apart from economic considerations, there are the advantages of reduced interference with other radio installations and lower power consumption, heat dissipation, maintenance costs, etc.

GENERAL PRINCIPLES

In any communication circuit the ultimate limit to the effective range achievable is set by noise, interference to or from other circuits, and by economic considerations.

The ratio of received signal power to received noise power is usually expressed logarithmically, in nepers or decibels.

If Ps = signal power

Pn = noise power

$$\text{Signal/noise ratio} = \log_e \frac{Ps}{Pn} \text{ nepers}$$

$$\text{or } 10 \log_{10} \frac{Ps}{Pn} \text{ decibels}$$

It is obvious that no amount of amplification at the receiving end will improve this ratio. An increased transmitting level will effect an improvement, but may be uneconomic as the whole system must cater for the increased maximum level without distortion. The increased sending level may also cause interference with other circuits (crosstalk).

What is required is some means of boosting low sending levels (e.g. due to a subscriber's extension with high attenuation) without overloading on normal signals. This is the function of the compressor.

The above procedure, though improving the signal/noise ratio, introduces distortion, since the received signal amplitude is no longer directly proportional to the original.

If another device is inserted at the receiving end to reduce the received signal to the level it would have had without the compressor, it will also reduce any noise or crosstalk introduced along the transmission path. An expander is therefore fitted at the receiving end and, in principle, must have a characteristic complementary to that of the compressor at all instants to avoid distortion (See Figure 2).

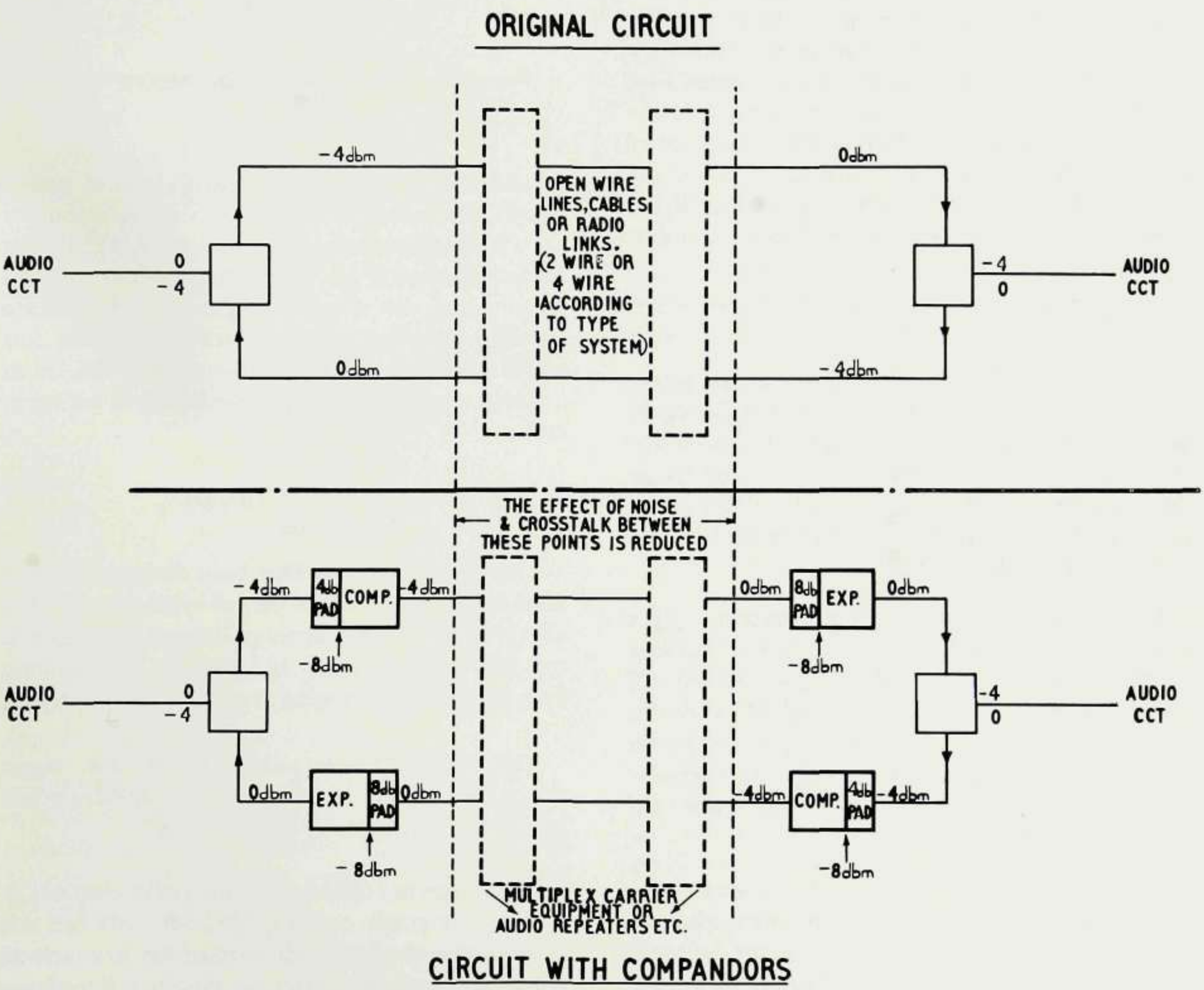

Figure 1—Use of CPR 12 Compandor in a Communication System

The rate of response of compressor and expander to changes in input level is such that each syllable is treated as a separate signal. This signal usually consists of components at various frequencies, most of the energy in speech signals occurring within a frequency range of 500-1,000 c/s.

The automatic adjustment of compressor or expander gain or loss is based on the mean power level of the signal.

The compressor has an input/output characteristic defined by:—

$$P_2 \propto P_1^{\frac{1}{n}}$$

while the expander has the complementary characteristic:—

$$P_2 \propto P_1^{n}$$

where P_1 and P_2 are respectively the input and output power, and 'n' is the expansion ratio. Although 'n' may have any value greater than unity for effective compandor action, considerations of reproducibility, distortion and cost have led to the almost universal acceptance for normal purposes of n = 2. This means that the output power of the compressor is proportional to the square root of the input power over the range of levels for which it is intended. The expander gives an output power which is proportional to the square of the input power.

It is arranged that at some predetermined power level into the compressor or expander (usually a level equal to or somewhat greater than the maximum expected level at that point), no compression or expansion takes place. Input levels below this are amplified in the compressor and attenuated by the same amount in the expander.

For a compression ratio of 0.5 the compressor gives a gain of 1 db for every 2 db by which its input falls short of the selected level. Thus, a poor signal 20 db below the selected level will be boosted by 10 db, giving a significant improvement in signal/noise ratio throughout the rest of the circuit. The expander will reduce this level by 10 db, at the same time reducing the noise level.

The most impressive effect of fitting a compandor in a noisy circuit is on the residual noise when no speech signals are present. If noise or crosstalk introduced into the circuit is 30 db below the normal maximum signal level without compandors, it will be reduced by the expander, in the absence of speech signals, by a further 30 db. The above improvements are shown graphically in Figure 3. Although the measured steady state improvement is not so great when signals are present, subjective tests indicate that the reduction of noise between syllables and words leads to an oral assessment of signal/noise ratio improvement not far short of the no-signal improvement.

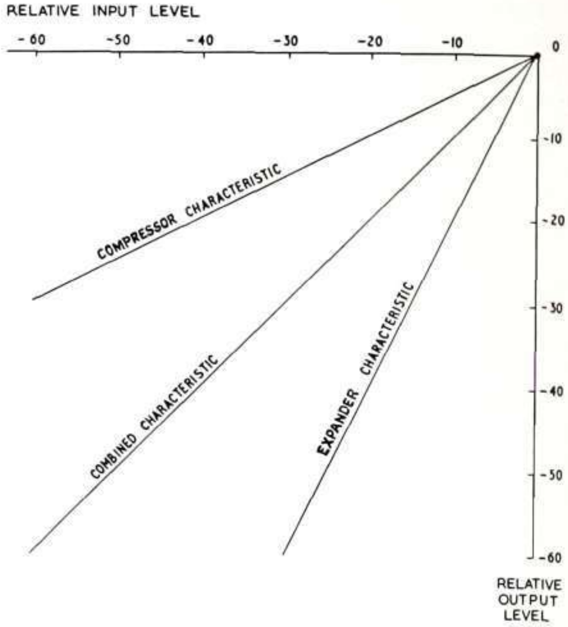

Figure 2—Relative Levels in Compressor and Expander

The CPR 12 Compandor

The compandor units have been designed to allow for their use as an integral part of individual channels of the RC 101 Rural Carrier equipment (described in the January 1961 issue), and also for incorporation into proposed or existing communication systems.

The CPR 12 compandor caters for signal frequencies in the range 300 c/s to 4,000 c/s and operates at output levels up to 0 dbm.

Transistors are employed as the active elements to achieve low power consumption, but their use also confers other benefits such as relatively low pick-up from other circuits, due to the low impedance involved, and freedom from microphony (some parts

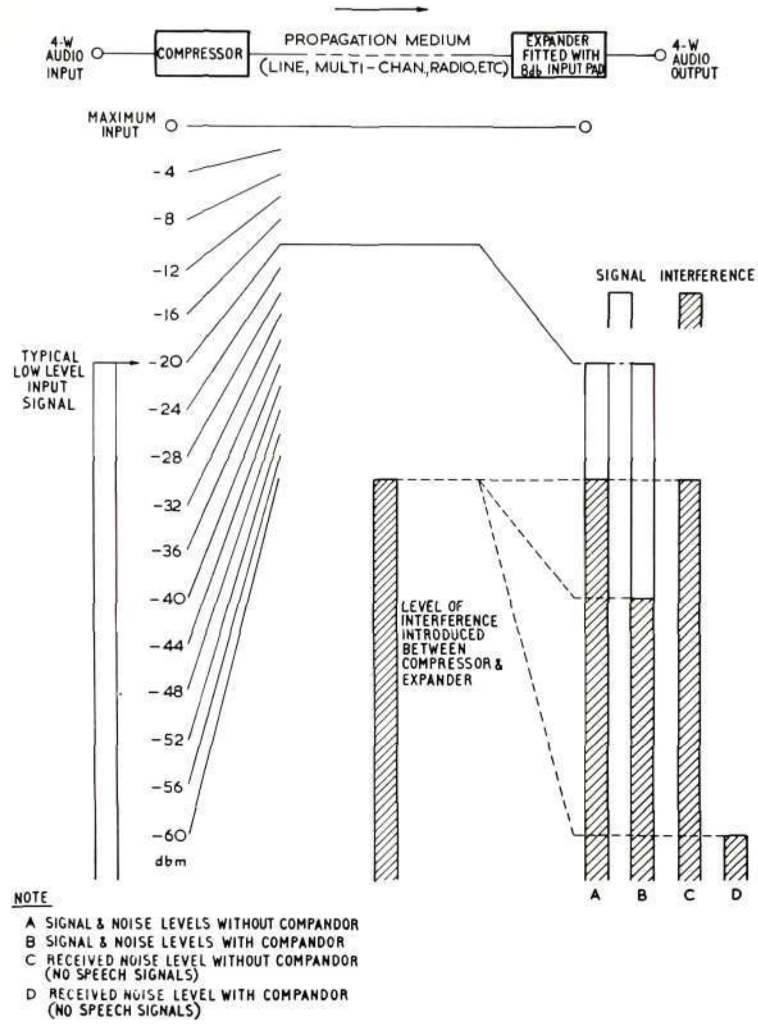

Figure 3—Typical Signal and Interference Levels with and without Compandors

of the compandor circuit operate at very low power levels). The small size of transistors is also advantageous, as a range of associated circuit components of similar dimensions is also available.

The basic units operate from a nominal 12-volt d.c. supply for compatibility with the RC 101 equipment, versions also being available for 24 or 50-volt operation with suitable voltage dropping and decoupling arrangements.

The level at which the compressor gives no loss or gain is 0 dbm, its input and output impedance being 600Ω (balanced or unbalanced).

The basic expander provides an output of 0 dbm for an input of –8 dbm, to allow for its inclusion in the Rural Carrier equipment. Space is provided in both units for the fitting of attenuator pads to accommodate other levels, subject to a maximum output in each case of 0 dbm. Thus an 8 db pad at the input to the expander converts it to a unit having no loss or gain at 0 dbm, making its input/output characteristic complementary to that of the compressor. Figure 1 shows an example of the introduction of compandors into a circuit and illustrates the use of attenuation pads to maintain general system levels.

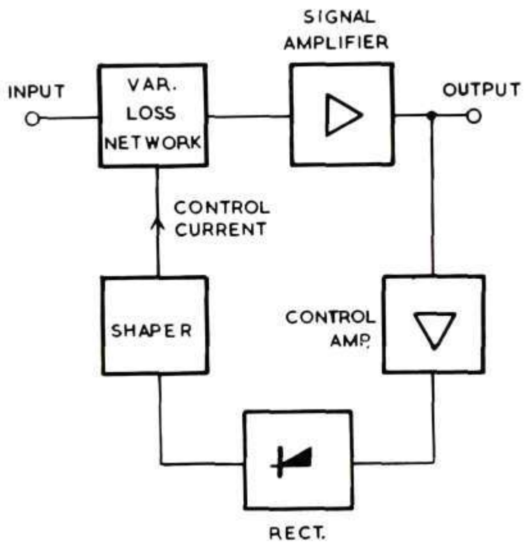

Figure 4—Block Diagram of Compressor

COMPRESSOR

A compression ratio of 0.5 has been chosen with a range of input levels of −60 dbm to 0 dbm. The output therefore ranges from −30 dbm to 0 dbm. Figure 4 shows in block form the mode of operation of the compressor. The amplifier receives its input via a variable loss network, the loss in which is arranged to depend on the amplifier output power. This is achieved by rectifying part of the output and using the d.c. to control the loss network. The latter consists of a pair of germanium gold-bonded diodes connected across a high impedance circuit so that the voltage fed to the signal amplifier is proportional to the rectifier incremental resistance (see Figure 5). This is, in principle, inversely proportional to the direct current flowing through the rectifiers, but the characteristic deviates from the above form for direct currents above a certain value. To maintain a consistent compression ratio at all signal levels, it is necessary either to restrict the input level to very low values, or to ' shape ' the control current with respect to level to counteract the deviation. To avoid the need for an excessive amount of amplification after the variable-loss network, the latter arrangement is employed in the CPR 12 compressor.

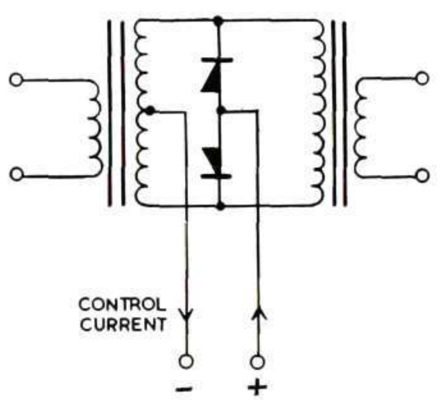

Figure 5—Variable Loss Network of Compressor

Current consumption of the compressor unit is approximately 6 mA, and space is allocated for fitting a voltage-dropping resistor if the supply voltage is greater than 12 volts.

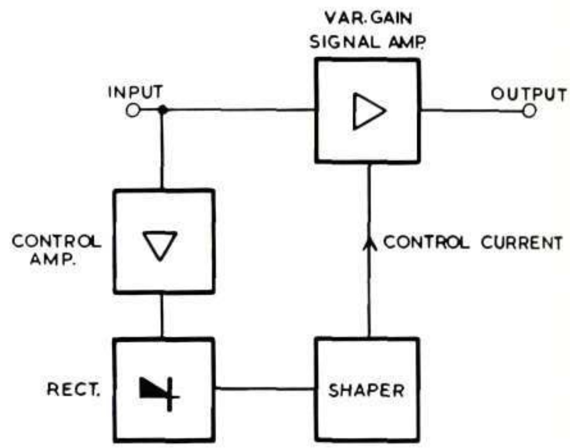

Figure 6—Block Diagram of Expander

EXPANDER

The expansion ratio of 2.0 ensures overall linearity of compressor and expander in tandem. The basic unit accepts levels from −38 to −8 dbm, and delivers an output ranging from −60 dbm to 0 dbm, the overall loss or gain in this case being controlled by the input level, so that a decrease of 1 db in input produces a decrease of 2 db in output for levels within the operating range.

The level at which the input and output powers are equal is −16 dbm, but by fitting an 8 db pad at the input the above level can be raised to 0 dbm to make the input/output characteristics of compressor and expander exactly complementary.

Figure 6 shows how the input level is caused to control the overall loss or gain of the expander. The controlled network, in this instance, consists of a

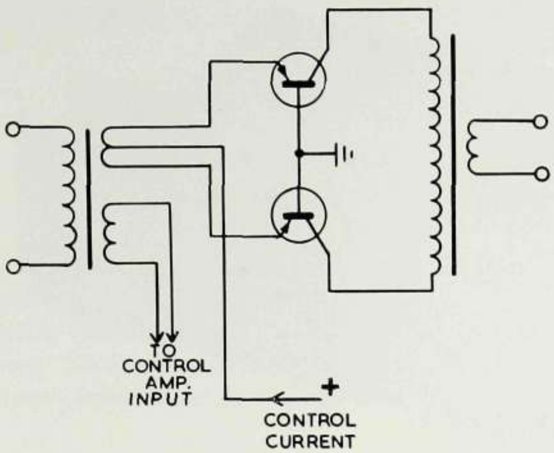

Figure 7—Variable Loss/Gain Network of Expander

common-base push-pull transistor amplifier. The emitter direct current is controlled by the input level, whilst the signal input is supplied from a low impedance winding on the input transformer, as illustrated in Figure 7. The major part of the input power is fed to the auxiliary control amplifier, the output from which is rectified by gold-bonded point-contact germanium diodes to provide the direct emitter current for the push-pull amplifier.

In principle, the small-signal input conductance of a comon base connected transistor is proportional to the emitter direct current.

Because the amplifier is driven from a constant voltage signal source, the input signal current will be proportional to the input conductance. Doubling the input voltage will double the control current, which will double the input conductance. The signal input current to the push-pull amplifier will therefore be four times its original value. Since the collector current at all levels is almost equal to the emitter current, the output signal current from the push-pull amplifier is also increased four times when the input is doubled. This square law characteristic gives the required expansion ratio of 2.0 in terms of decibels or nepers. To maintain this at the higher levels, the control current is fed via a level-sensitive network, containing diodes to compensate for divergence of practical transistor characteristics from the assumed current/conductance proportionality.

The expander consumes approximately 3 mA at 12V and also allows for a voltage dropping resistor to be fitted internally for use on higher voltage supplies.

CONSTRUCTIONAL FEATURES

The compressor and expander are arranged as separate assemblies to facilitate connection into the associated equipment.

Each unit is accommodated on a printed wiring card with an earthed metal screen to allow close spacing of units when required. A pair of these plug-in units, each approximately $6\frac{1}{2}''$ x $3\frac{1}{2}''$ x $1\frac{3}{4}''$ (16.5 x 9 x 4.5 cm) is shown in Figure 8. Figure 9 shows four compressors and four expanders in a case suitable for mounting on a 51-type equipment rack.

Up to six units, e.g. 3 compressors and 3 expanders may be accommodated with a plug-in a.c. power unit in a similar case for small installations.

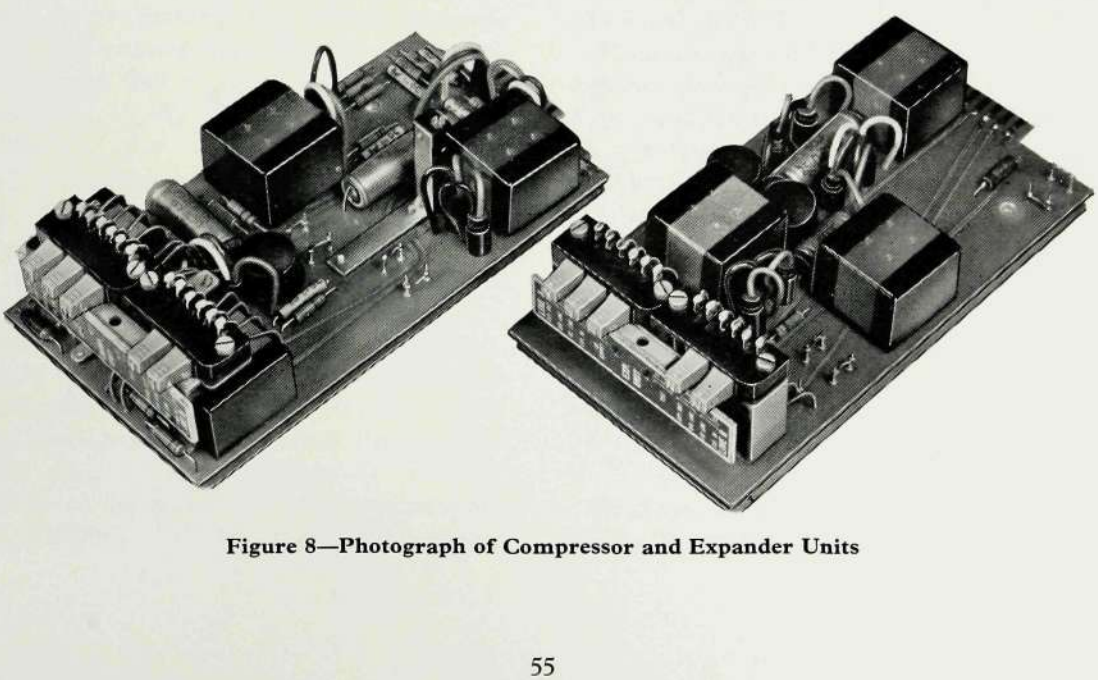

Figure 8—Photograph of Compressor and Expander Units

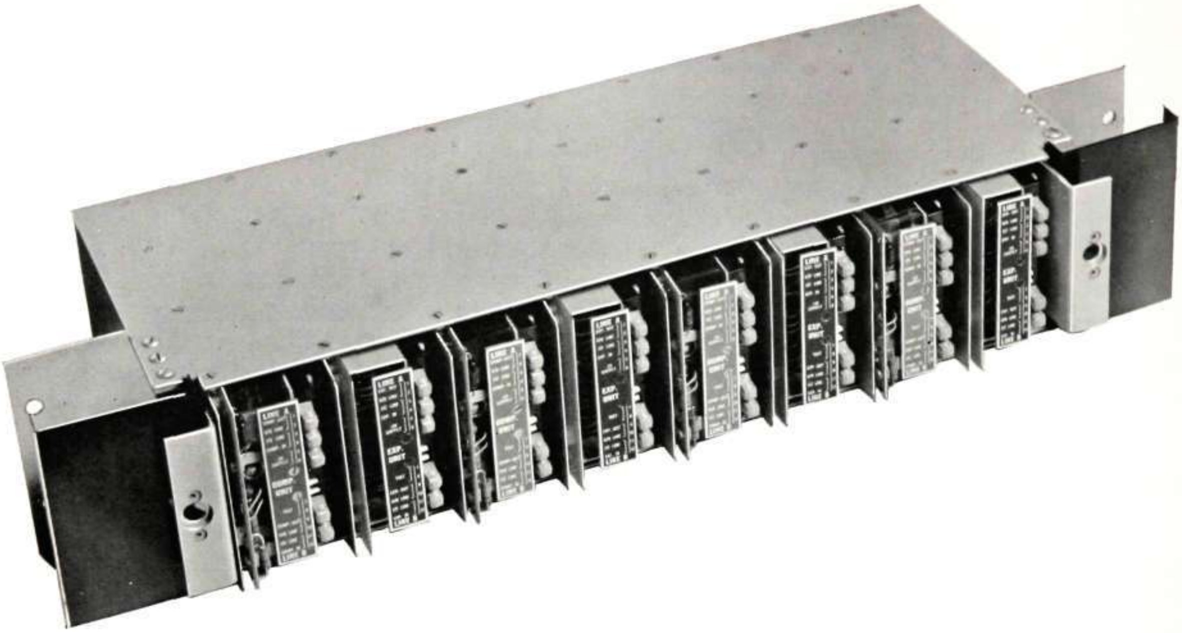

Figure 9—Photograph of 4 Compressors and 4 Expanders in Case

Conclusion

The increasing density and complexity of communication systems is liable to increase the noise and interference levels on existing circuits. To avoid complete re-organization, compandors may be usefully employed to restore the signal/noise ratio to at least its original value.

Compandors may also be used to reduce filter requirements in multi-channel systems by accepting a higher initial crosstalk figure to be improved by compandor action.

The CPR 12 Compandor offers an economical means of achieving the above improvements especially when extra space and power consumption are at a premium.

U.D.C.621.395.23

A SMALL DESK-TOP KEY-OPERATED P.M.B.X. SWITCHBOARD

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The new cordless desk-top switchboard described has capacity for two exchange lines and six extensions, and is the first of a new range of cordless B.P.O. - approved private manual branch exchange switchboards developed by the Company for use in subscribers' premises. Attractive appearance, small size and better facilities, including lamp signalling and power unit operation, are some of the interesting features of the new switchboard, the overall design of which is such as to merit serious consideration when a simply attended switchboard is required at reasonable cost.

THE importance of cordless-type private manual branch exchanges has long been recognized as an economic means of providing exchange and local connections in many business organisations served by a small number of lines. Up to now, the B.P.O. have met these requirements with a range of switchboards of various sizes, the largest having capacity for three exchange lines and nine extensions. Indicators are used for signalling and supervision, and ordinary lever keys for switching. These boards, similar in general appearance, are housed in wooden cabinets and present an unduly bulky and outmoded appearance incompatible with present day commercial office equipment and furnishings.

A new range of small desk-top cordless switchboards of most modern and efficient design has therefore been developed in conjunction with the B.P.O. The new switchboards, in three sizes, have capacities for two exchange lines and six extensions (2 + 6), three exchange lines and twelve extensions (3 + 12), and four exchange lines and eighteen extensions (4 + 18). The smallest of these is described.

The 2 + 6 is intended to replace the existing 2 + 4 version. The capacity has been raised from four to six extensions, because it has been found that the traffic can be handled on three connecting circuits, the same number as provided on the older design, thus increasing the usefulness of the switchboard. Despite its increased capacity, the new switchboard is considerably smaller than its predecessor, the increase in the number of extensions together with improved facilities being provided in the most economical way by the use of a new type of extension circuit employing a 4-wire line. Other factors contributing to its reduced size are, the use of a separate operator's telephone of the popular Etelphone type (B.P.O. 706); small 1,000-type switchboard keys, lamps instead of indicators, and the deletion of the hand generator, which has been replaced by an external a.c. mains-operated ringing supply unit.

The 4-wire extension line, used for the first time on this type of board, is simple in principle and consists of two conductors in addition to the normal speaking pair. The extra wires are used to enable an earth connection via a cradle-switch contact in the extension instrument to control the line lamp independently of the speech pair. From this it follows that the P.B.X. re-call facility can be easily added by fitting a press-button key on the extension telephone, the key having a contact in parallel with the contact of the cradle-switch. Flashing the line lamp without disturbing the line loop or earthing the line is thus obtained.

The additional cost of the extra line wires is low and more than offset by the reduction in components in the switchboard and, since most local telephones are a short distance from the switchboard, a definite economic advantage is secured.

In some installations, it may not be convenient to have a 4-wire extension line as, for example, when long extensions over lines in the public network are used. For these, a relay unit is utilized to convert the 4-wire circuit to 2-wire. However, when a long extension using a 4-wire line is required, the limiting loop resistance of the speech pair is 500 ohms, a very satisfactory limit made possible by the use of a new calling lamp—the P.O. lamp No. 2/45.

Parallel-feed connecting circuits designed by the B.P.O., have been adopted for extension-to-extension

Figure 1—General View of 2 + 6 P.M.B.X. Switchboard without operator's telephone

conversations and are suitable for use with the 706-type (Etelphone) or less modern instruments of the 300 series.

Below is a summary of the main facilities provided by the new switchboard.

(*a*) Lamp signalling on all lines.

(*b*) Exchange-to-extension line limit of 1,000 ohms, or 900 ohms if 4-wire to 2-wire auxiliary unit is used.

(*c*) Extension-to-switchboard line limit of 500 ohms speech pair loop resistance on 4-wire lines.

(*d*) Separate clearing signals on extension-to-extension connections.

(*e*) Secretarial hold—permitting an exchange line to be held and the operator to speak on another line without the held exchange-line caller overhearing.

(*f*) Auxiliary units—for connecting private wires and inter-switchboard circuits; no alteration to the switchboard's internal wiring being necessary.

(*g*) Mains fail—when a power unit is employed and a mains failure occurs, an established exchange-to-extension connection is not interrupted and, additionally, incoming calls are signalled on the operator's telephone.

(*h*) P.B.X. recall, regardless of line polarity, and without the need for a relay in series with the line on both exchange-to-extension and extension-to-extension calls.

(*i*) Night service—allowing exchange lines to be left through to any selected extension at night.

PHYSICAL DESIGN

The new switchboard shown in Figure 1 is approximately $9\frac{1}{2}''$ wide, $6\frac{1}{8}''$ high, and 11″ deep (24 x 15.5 x 28 cms) and is normally provided in two-tone grey with matching operator's Etelphone.

The one-piece cover, which is formed in impact resisting thermo plastic and polished, is easily detached from the base to give full access to the key panel, relay plate and other components. The plastic-coated key panel and the relay plate are

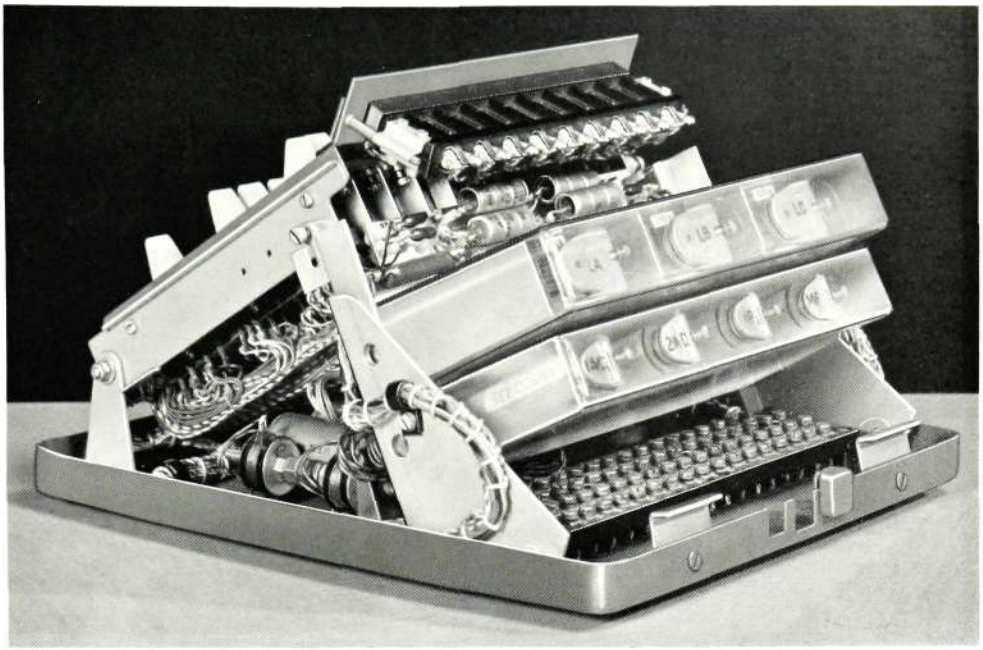

Figure 2—Rear View of Switchboard with cover removed

respectively hinged to the front and rear of the switchboard's base; the chassis, when closed, forming a triangular rigid construction, with the lamp panel conveniently positioned at the top as shown in Figure 2.

The hinges enable the key panel and relay plate to be opened like a book, and Figure 3 shows the high degree of accessibility afforded by this method of construction, all components, terminals and wiring being in full view.

The new keys (1,000 type) are fully described in Bulletin No. 35, p. 38, and are of miniature pattern, having comb-operated relay-type springs and wedge shaped handles.

The lamps are housed behind a diakon lens-strip also of new design and, when the strip is removed by releasing phosphor-bronze clips at each end of the cover, the lamp-jack fixing screws are revealed. These are unscrewed to draw the lamp-jack forward and allow the lamps to be easily removed without using a lamp extractor or removing the switchboard cover.

The relays are either 3,000 or 600 type, fitted with clear plastic dust shields. Resistors are small, wire wound, ceramic enclosed and the capacitors are of tubular type mounted on tags fixed into the rear panel of the chassis.

A 70-way terminal block is mounted on the base to provide connections for the operator's telephone cord and also a 38-way cord for exchange and extension line connections. The remaining terminals provide convenient strapping and connection facilities for auxiliary relay units used to convert certain extension circuits into 2-wire extensions, private wires, or inter-switchboard lines. Should the switchboard be mounted in a fixed position, the cord may be omitted and the cables terminated direct on the block.

Circuit Description

Some of the innovations have been briefly mentioned, but before proceeding in more detail, a brief outline of the circuit employed in the old pattern board is necessary to bring out the reasons for, and the advantages of, the new design.

The previous circuit has indicator calling signals operated by the extension loop. When the extension is switched through to the exchange, a ' series ' relay is necessary to detect when the extension loop is removed, and a contact of the relay re-operates the line indicator via connecting keys to give a clearing signal.

The same ' series ' relay performs a similar function on extension-to-extension calls, with the disadvantage that no clearing signal is given until the handsets are

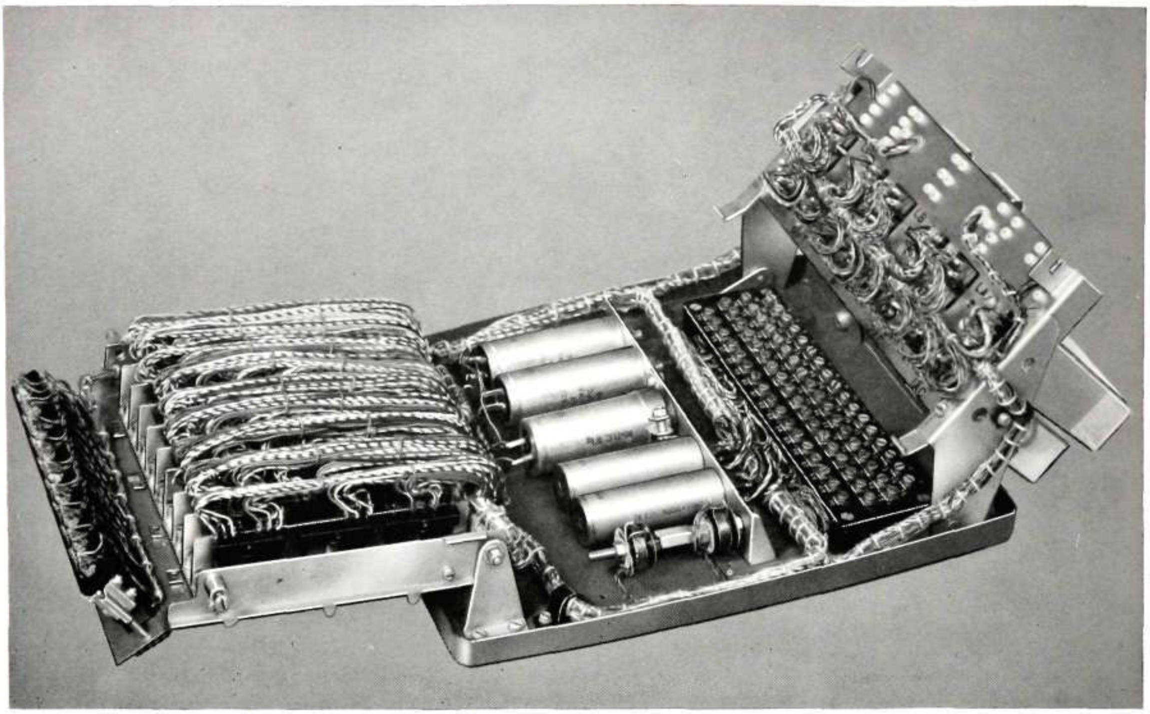

Figure 3—Switchboard Chassis Opened

replaced at both extensions. Also on exchange calls, the line loop resistance is reduced by the resistance of the 'series' relay, and 'operator re-call' is dependent upon the exchange line polarity if an earthing-button method is used.

In the new switchboard, these drawbacks have been overcome by separating the supervisory and re-call functions from the speech pair, whilst still using the same lamp for both calling and supervisory purposes. This has been made possible by the use of a four-wire line for extensions, two wires constituting the speaking pair, and the other two controlling the line lamp when the connecting key is operated. The circuit diagram in Figure 4 illustrates in simplified form the essential features of a single exchange line, one extension line and a connecting circuit.

Extension Calls

When the extension handset is removed to initiate a call, a calling lamp lights via the extension loop and the common pilot relay P operates. Contacts Pl and KA (normally operated) complete the buzzer circuit to give an audible alarm. Should two or more extensions call simultaneously, overhearing between extensions across the common pilot relay impedance is prevented by the low impedance shunt of the electrolytic capacitor C 1. The call is answered in the usual way by operating the appropriate KX (extension) and KO (operator) keys in the same free connecting circuit to energize both the extension and operator's telephones in parallel via the associated feed relay L.

The bottom 'throw' of each vertical row of extension connecting keys is a 'ring' key, not shown in the diagram, and the appropriate KR key is pressed to ring the required extension. A second extension may be switched in parallel by operating the associated 'extension' key in the same connecting circuit; that is, in the same horizontal row. On completion, the operator restores the 'operator' key, leaving the two extensions connected to the parallel feed via L relay coils, with the 'exchange' key KE normal.

At the end of the conversation and as the extension telephone handsets are individually replaced, the associated calling lamp lights to provide separate clearing signals. The clearing circuit is from earth, via CS auxiliary cradle-switch contact, to the lamp on each extension line.

Exchange Calls

After answering a calling extension, it may be required to switch the call through to the exchange,

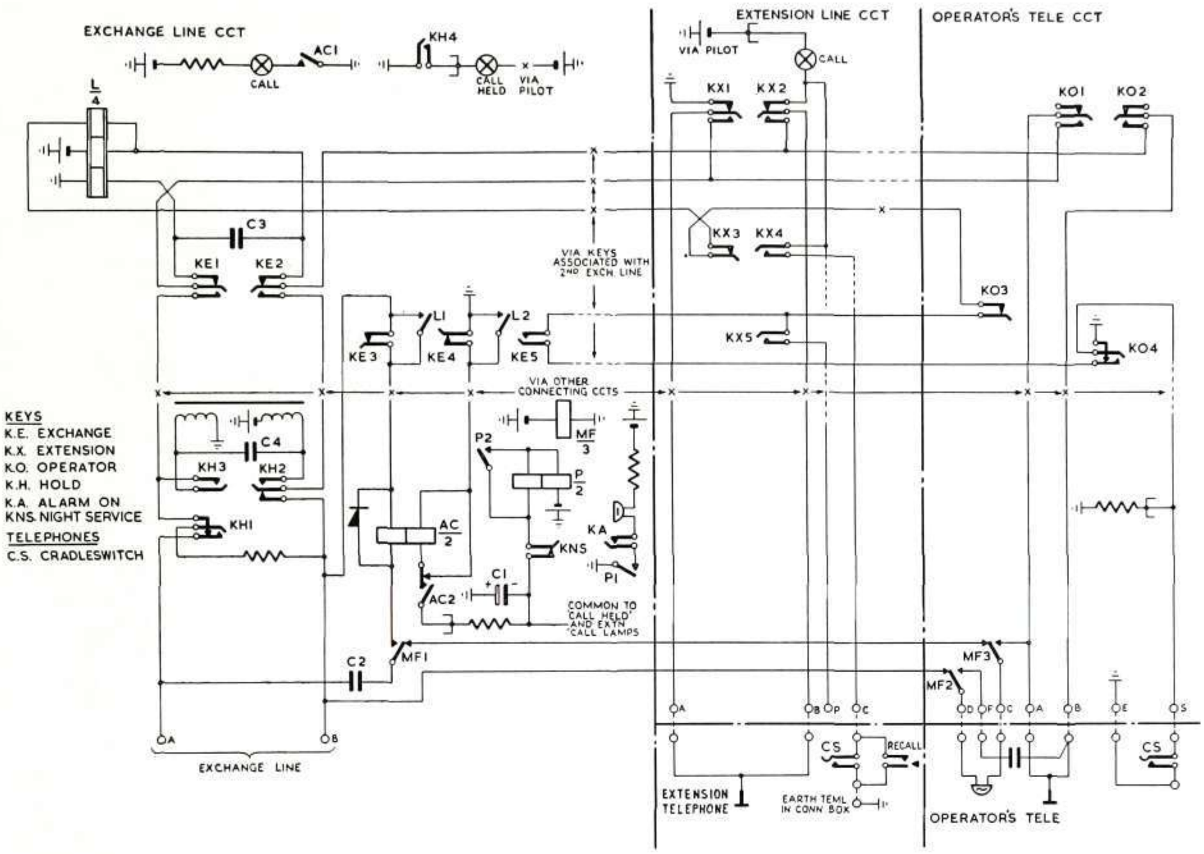

Figure 4—Simplified Schematic of the New 2 + 6 Switchboard

and this is done by operating a free exchange line connecting key (KE) in the same connecting circuit as the extension. Contacts KE1 and 2 change over the line pair from the feed relay coils to the exchange line, the calling extension telephone then being energized from the exchange battery, with no series supervisory relays in circuit. Supervision of the exchange call is dependent upon the extension cradle-switch earth via the fourth wire to light the extension lamp.

Following usual practice, the exchange-line connecting circuits are arranged to prevent two exchange lines being connected together.

Incoming ringing on either exchange line operates relay AC in series with all KE3 contacts in the connecting circuits, MF 1 (normally operated) and capacitor C2. Relay AC holds from the pilot relay battery to earth via the ' night service ' key KNS, contacts AC2 and KE4. A separate contact, AC1, lights the calling lamp, so that should the lamp become disconnected, the call will still be signalled by the buzzer. The short circuit normally presented across the hold winding of relay AC provides a slow-to-operate condition, thus guarding against false operation of the relay by transient voltages on the line caused by switching.

Incoming exchange calls should be answered in a similar way to extension calls. To guard against misoperation, however, some novel features are incorporated. Firstly, if the ' exchange ' key only is operated, the calling lamp remains lit and the ringing is not tripped. The circuit for this feature is provided by additional ' break ' contacts on the ' extension ' and ' operator ' keys which, when all are normal in the associated connecting circuit, cause relay L to operate via its third winding; contacts L1 and 2 (L3 and 4 in exchange line 2) reconnect the AC relay previously disconnected by KE3 and 4. A second safeguard ensures that the operator must not only operate the appropriate ' exchange ' and ' operator ' keys to answer a call, but must also take up the handset of the operator's telephone. When the ' operator ' key is thrown, relay L is released at KO3 and incoming ringing is diverted to the operator's telephone bell which rings until the handset is lifted.

The holding circuit for exchange line calls has also been improved, the 'hold' key KH, provided in each exchange line circuit, having several functions. In addition to its primary purpose of applying a 200-ohm loop across the line to hold the exchange equipment, it disconnects the exchange line from the switchboard, connects the 50-volt supply via a bridging coil to the connecting circuit, and lights the 'call held' lamp. The operator can then converse with the particular extension user without the exchange party overhearing, the 'call held' lamp serving as a visual reminder to restore the 'hold' key later.

Power Supply and Mains-fail Arrangements

The switchboard is designed for 50-volt working primarily from a power unit connected to an a.c. mains supply. Where the electrical supply is unreliable and occasional interruption of extension-to-extension calls cannot be tolerated, a battery and charging arrangement is recommended.

An important feature is that in the event of a mains failure the installation is not isolated from the exchange. Established extension-to-exchange calls are not disconnected and incoming calls on the first exchange line are automatically routed to the operator's telephone. A 'mains-fail' relay MF, as shown, controls the switching of the first exchange line and is operated by the 50-volt supply, but releases on any interruption of this source; contacts MF1, 2 and 3 release and connect the bell in the operator's telephone to the exchange line. In addition to this, the second exchange line may be switched to a selected extension as for night service, thus allowing exchange calls to be originated and received at this point.

P.B.X. Re-call

All extension telephones may be fitted with a push-button key having one 'make' contact connected in parallel with an additional cradle-switch contact to give press-button re-call. Standard keys and cradle-switch contacts are available for easy addition to existing telephones of the Etelphone or 706 type.

Auxiliary Units

Extension lines 4-6 are provided with extra terminals for simple connection of auxiliary units to convert long extension lines, private wires and interswitchboard junctions from 4-wire to 2-wire circuits.

Exchange prohibition is allowed for on the switchboard in that the P-terminal in a line circuit is connected to earth when an extension is switched to an exchange line. Earth from KO4 via KE5 and KX5 to the P terminal can be continued to the unit to operate a relay to cause the disconnection of the line.

CONCLUSION

The new switchboard, with its low maintenance costs and exclusive design will undoubtedly fulfil the increasing demand in small businesses for a compact and attractive equipment which, because of its simplicity of management, offers the additional advantage of permitting the operator's services to be combined easily with other work. From all standpoints, but particularly that of efficient service, this switchboard, as all others in the new range, will meet the most exacting present day requirements.

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APPENDIX

Perhaps it may be of interest to note, in brief, the salient points of the 3 + 12 which, together with the 4 + 18 switchboard, will form the subject of a subsequent article.

The 3 + 12, similar in style to the 2 + 6, allows six of its twelve 4-wire extensions to be used as desired with the same auxiliary conversion units mentioned above, and includes two outstanding facilities which are novel for a board of this type and size. These are :—

Automatic Hold

This takes place when an incoming exchange call is switched through to the required extension, enabling the operator to withdraw from the circuit before the called extension answers. Thus, no 'hold' key is necessary and economy of operator effort obtained. Visual indication of the held call is also given.

Follow-on Call Trap

The exchange line circuit is arranged to prevent a follow-on call ringing the extension telephone bell. Indication of such a call is given to the switchboard operator by the intermittent flashing of the associated exchange line lamp, and also by buzzer when audible warning is desired.

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Patents :- UK, 838348. Canada, 731737. Australia, 29049/57. South Africa, 1987/57. New Zealand, 119072/57.

U.D.C.621.396.664

A REMOTE CONTROL AND SUPERVISORY SYSTEM

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A flexible and economical system is described, designed to enable the electrical condition of equipment at remote stations on a network to be ascertained and controlled manually or automatically from a central point. The system is capable of functioning over any existing transmission path and offers the additional advantage that a common signal frequency is used to select any station as well as the appropriate item of equipment.

OVER the years communication systems have expanded increasingly into remote areas of the world where maintenance facilities are usually restricted. It has therefore become necessary to ensure that these systems are extremely reliable so that the number of routine visits by maintenance staff to remote locations is reduced to the minimum. To achieve this reliability, it is desirable to provide duplicate equipment at these locations, with arrangements for automatic changeover in the event of a fault and also to include a means of supervising and controlling the condition of the equipment from a central point.

The system described is basically designed to interrogate and control the condition of up to 23 items of equipment at each of nine remote stations. Although primarily developed for use on a particular radio link system, the equipment is also suitable for the maintenance of any remote equipment locations where a ' go ' and ' return ' transmission path to the control station exists.

All control and interrogation signals are basically earth/disconnect pulses relayed over the transmission paths by means of tones lying in the 3-9 kc/s band.

The majority of supervisory systems employ tones of separate frequencies to select, supervise and control each item of equipment at remote points and generally utilize complicated switching techniques. These measures are not conducive to ease of maintenance.

In this particular system, however, the remote station selection and subsequent interrogation is controlled by a single interrogation tone of 3,825 c/s. interrupted by the action of a telephone type dial or an automatic pulsing circuit. The condition of each item of equipment at individual stations is indicated sequentially by the presence or absence of an alarm tone, the frequency of which is peculiar to all equipment at that particular station.

The switching techniques utilized are well established in the field of automatic telephony and, since standard British Post Office components are used throughout, a simple, reliable and easily maintained system is ensured.

Facilities

The state of equipment at any remote location is ascertained at the control station by dial and key operation. A visual display will then indicate the equipment in use and that which is idle. If required, equipment may be changed over or switched off from the control station by dialling a code applicable to the particular item of equipment concerned and then by operating a control key.

When an automatic changeover at a remote station takes place, the alarm signal causes the equipment to interrogate itself automatically and the display to show the particular item affected. If, however, equipment is changed over manually at a remote station, no alarm signal is transmitted to the control station, but subsequent interrogation will indicate that the changeover has taken place.

Pilot tones are applied continually around the system to check the transmission paths. Any loss of signal (due perhaps to a complete station failure which would make it impossible to transmit a station alarm identification) or a predetermined drop in level causes a Pilot alarm to be given at the control station. To localize a fault of this type, the loop gain to a particular station may be measured directly on a Level Measuring Set by dialling the code digit of the required station.

Guard circuits are incorporated in the system to indicate erroneous station selection or interrogation which may be caused by a fault condition in the bearer circuit.

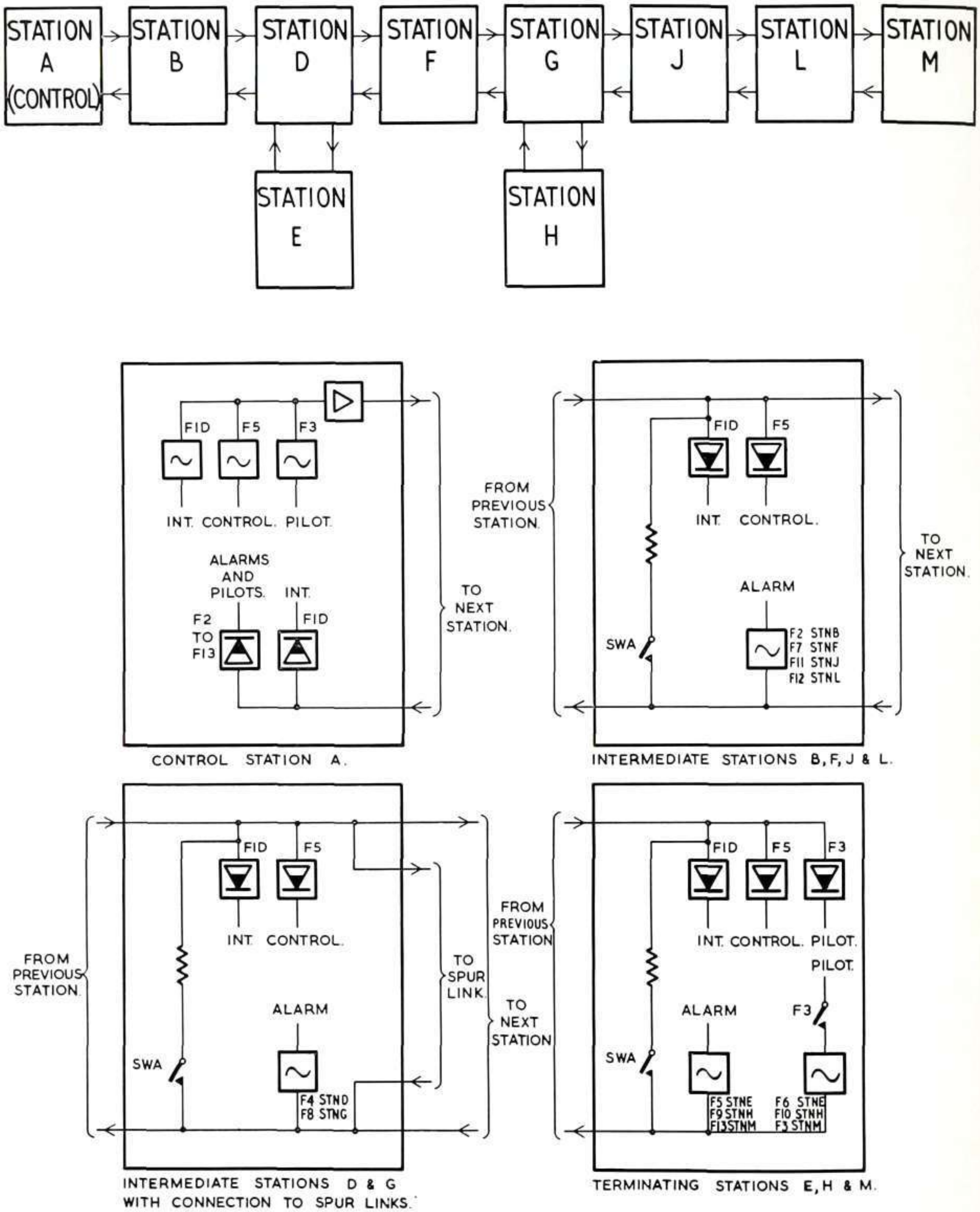


Figure 1—Typical System Schematic

Equipment

The switching circuits employ relays and single-motion switches of the types approved by the British Post Office, and the individual tone units are constructed in accordance with the equipment practice adopted by the British Post Office under the title ' 51 type '. The equipment may be enclosed in a cabinet or mounted on transmission-type racks 3 feet (91 cms.), 6 feet (183 cms.) or 9 feet (274 cms.) high to conform with the mounting arrangements of the existing equipment.

Power panels to provide 230 volts d.c. and 6.3 volts a.c. for the tone equipment and 50 volts d.c. for the control relay equipment are available for cabinet, rack or wall mounting.

Tone equipment, utilizing transistors, may be employed in the system if desired, in which case only the 50 volt d.c. power panel is required.

OPERATION

The remote stations may be connected to the control station individually; in the form of a series chain, or in a more complex manner. Figure 1 shows a typical system schematic with a series of stations A to M and spur links to stations E and H. A simplified block schematic showing the basic arrangement of the tone equipment at each of the four types of station employed on the system is also included in the figure.

All stations have an interrogation tone detector FID connected permanently to the transmission path to permit station selection. Any station, when selected, can retransmit the interrogation tone back to station A and can also detect the control tone if required. Each station transmits to the control station an alarm tone, which is used for checking correct station selection and also for interrogation purposes. The frequency of the alarm tone is peculiar to the station concerned.

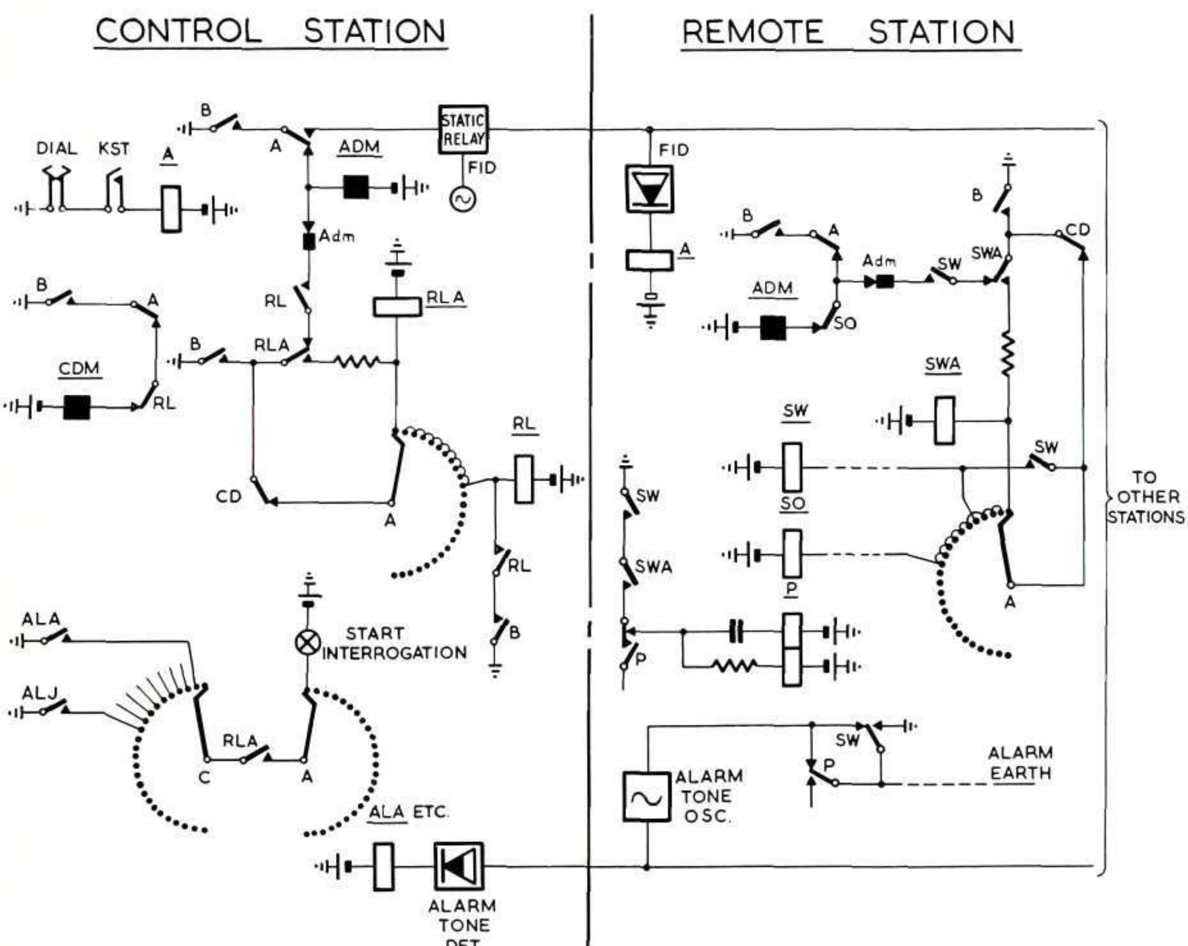


Figure 2—Station Selection Switching Elements

Terminating stations E, H and M can also detect a pilot tone continuously fed from the control station and return individual pilot tones to station A to indicate continuity of the bearer circuit.

Manual Supervision and Control

Station Selection

Figure 2 shows the circuit elements concerned with the selection of a remote station and the checking equipment incorporated to ensure that correct selection has taken place. Operation of the 'Start' key KST energizes the A relay which in turn operates relay B (not shown). An earth is now extended to the Static Relay to cause interrogation tone FID to be transmitted to all stations along the system. This tone is detected at each station to operate relay A and seize the switching equipment.

The single digit code applicable to the required station is now dialled. The A relay at the control station operates and releases to the dial pulses and

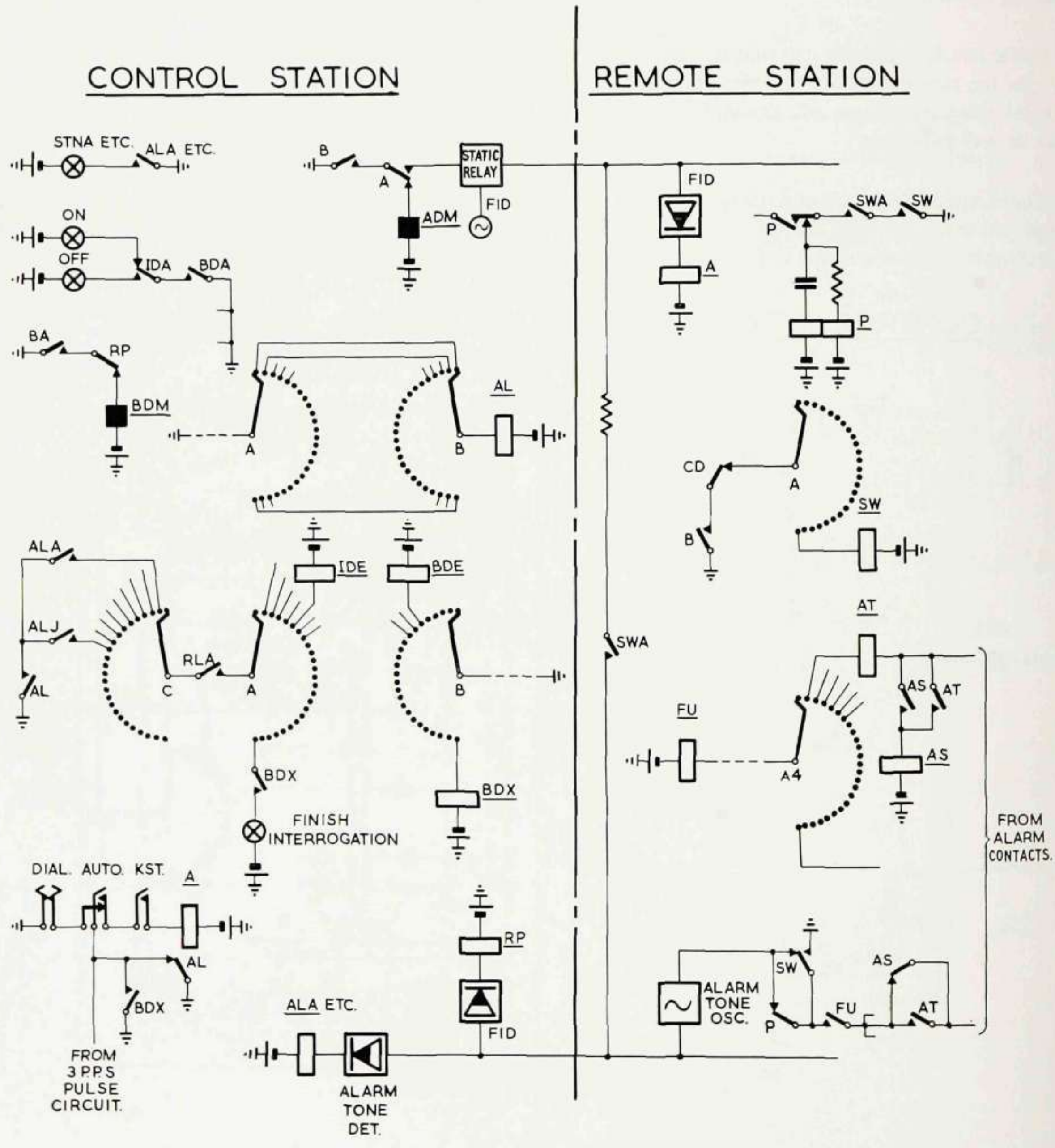


Figure 3—Interrogation Switching Elements

interrupts the interrogation tone accordingly. The A relays associated with the detectors at each station respond to these interruptions to step the uniselectors at all stations simultaneously. At the required station, determined by the code dialled, relay SW operates to home the uniselector preparatory to interrogation, and relay SWA operates. At all other stations, the SO relay operates to prevent further pulsing. The operation of SW and SWA at the particular station cause the P relay to pulse at approximately 3 p.p.s. to interrupt an earth on the alarm tone start lead. The control station now receives a pulsing alarm tone at the frequency peculiar to the selected station to operate and release the relevant alarm relay AL(X).

At the control station, the code digit train steps the uniselectors A and C. At the end of the pulse train, RL operates to home the A switch in preparation for the interrogation cycle, and RLA operates. The C switch marks the code dialled. If the position of the C switch corresponds to the particular pulsing alarm relay AL(X), the relevant ' Station Alarm ' lamp and the ' Start Interrogation ' lamp will flash to the interruptions of alarm tone. This indicates that the station selection is correct and that interrogation may now proceed.

Interrogation

Each item of equipment at a remote station is allocated a code number and associated with an outlet on the uniselector bank. Two earths are extended from equipment in the ' off ' condition to mark the appropriate uniselector outlet and control the alarm tone oscillator.

Figure 3 shows the circuit elements concerned with the interrogation of equipment at a remote station. Interrogation is performed manually by means of a telephone dial, or automatically, and the result displayed on a panel comprising 23 pairs of lamps designated ' On ' and ' Off ' as shown in Figure 4. With manual operation, rapid selection and interrogation is achieved since all digits dialled are additive. For example, to interrogate items eight and twelve and subsequent items, digit ' 8 ' is dialled followed by digit ' 4 ' and so on. When the automatic method is used by operating the ' Auto ' key all equipment is examined by transmitting a succession of single pulses at approximately 3 p.p.s.

Following selection of the required station, the SWA relay at that station is operated to feed back the interrogation tone to the control station and operate relay RP. The dial or automatic pulses interrupt the interrogation tone, which operates the A relay at the remote station and also the RP relay in the receive path at the control station. The A relay at the control station steps the A switch, the RP relay the B switch and, similarly, the remote station A relay steps its associated A switch. All three uniselectors step in unison. Should outgoing pulses to the remote station be lost, causing the remote station uniselector to get out of step, the returned pulses to the control station will also be lost. This will result in loss of synchronism between the A and B switches at the control station. This condition is detected by the AL relay which prevents further pulsing and causes a ' Re-dial ' alarm lamp to glow.

On the first interrogation step at the remote station, both the SW and P relays restore to normal to reassociate the alarm tone oscillator with the start lead common. After each digit the A4 arc outlet is tested by the FU relay for an earth from the appropriate equipment. An earth from equipment in the idle condition operates relays FU and AT to extend an earth to the alarm tone start lead and transmit alarm tone to the control station. The receipt of this alarm tone operates the relevant alarm relay AL(X), which in turn operates the ID(X) relay to light the appropriate display lamp. The AS relays at the remote station remain operated after the uniselector steps off the outlet, to prevent re-transmission of alarm tone.

On the 24th outlet, the SW relay at the remote station operates to reconnect the pulsing alarm tone. At the control station relay BDX operates to complete the circuit for the ' Finish Interrogation ' lamp, which now flashes with the relevant ' Station Alarm ' lamp to indicate that correct interrogation has taken place. This gives a further check of synchronism of the three switches in case a mechanical fault has occurred. Relay BDX also stops the automatic pulsing circuit generating further pulses.

Control Functions

Various control functions at the remote stations may be performed from the control station. These may be changeover or On/Off switching of individual items of equipment. To initiate a control function, the relevant remote station is selected and the code of the individual item dialled as previously described. The ' On ' display lamp, corresponding to the required outlet, will then light. Depression of the ' Control ' key extends an earth to the control tone

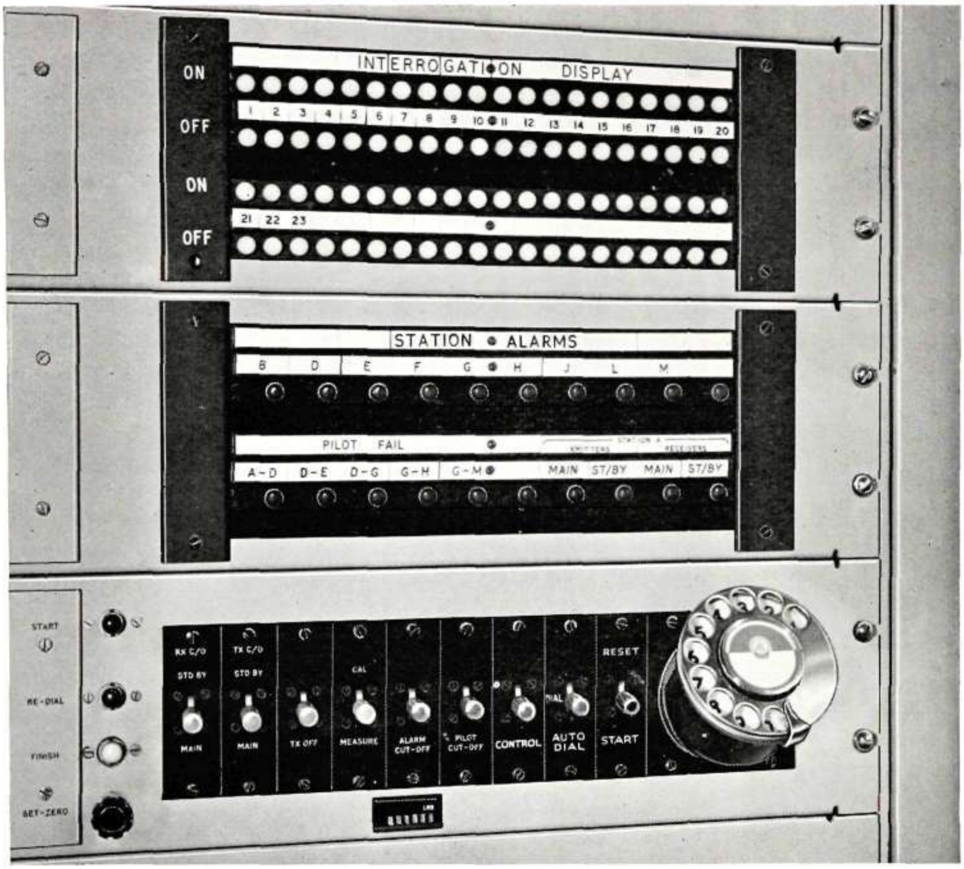


Figure 4—General View of Control Panel

oscillator which transmits tone F5 to the remote station. The tone is detected and an earth is extended to the appropriate item of equipment to perform the required function. At this stage the display lamp indication is changed to ' Off ' and the equipment may then be interrogated as previously described to check further that the control function was effective.

Automatic Self Interrogation

If an item of equipment at the remote station changes its state as a result of automatic changeover, the system is arranged to interrogate the relevant station and identify the particular item concerned. The circuit elements are shown in Figure 5. As stated previously, after an interrogation, all outlets corresponding to equipment in the ' Off ' condition have the alarm signal locked out by means of the AS relay, which is held to the alarm contact of the equipment. If an automatic changeover takes place, the equipment switched off extends the earth to the alarm tone oscillator and to the uniselector bank outlets of arc A5 via AS released. Thus, when this bank is scanned, only equipment which has changed to the ' Off ' condition since the previous interrogation will cause the operation of the FU relay.

The earth on the alarm tone start common from the faulty equipment will operate AL at the remote station and the relevant alarm relay at Control. Relay AL operating before B at the remote station, results in the operation of SA, thus switching the FU testing circuit to the A5 bank and preparing the necessary circuit conditions for automatic self interrogation. Similarly, at the control station, because the alarm relay AL(X) operates before B, relay ALZ operates.

The ALZ contacts prepare all the necessary locking circuits, operate A and start the 10 p.p.s. pulsing relay CL. This latter relay pulses the A relay at all stations to drive the A and C switches at station A and the A switch at each of the remote stations. With the relevant alarm relay operated, the outlet on the C switch bank is marked and pulsing is stopped

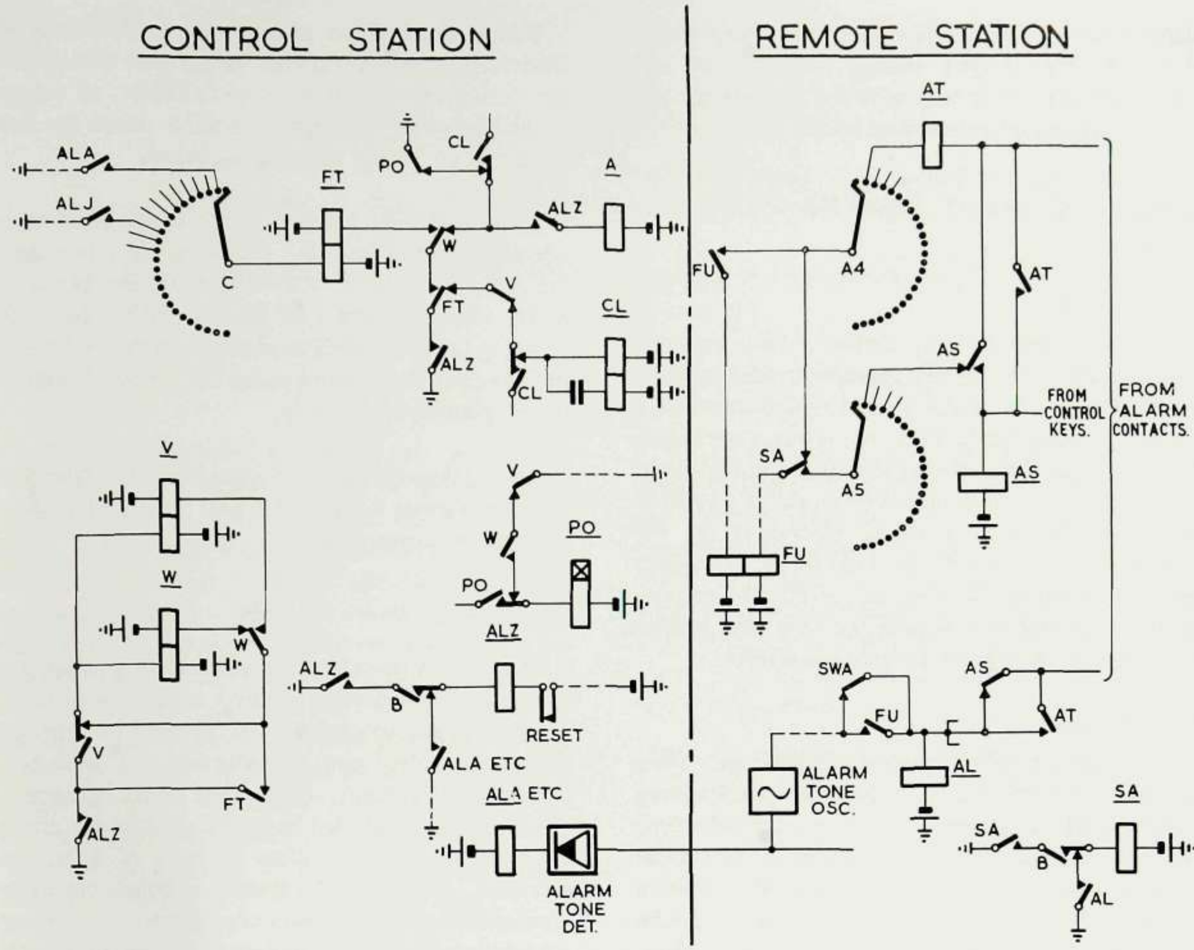


Figure 5—Automatic Self-Interrogation Switching Elements

by the cut-drive relay FT after the appropriate number of pulses. At the required station, relays SW and SWA operate to pulse relay P and consequently the alarm tone. The station alarm relay AL(X) at the control station responds to the pulsing alarm to release and re-operate the FT relay. The first operation of FT operates relay V. When FT releases, V holds and W operates. Relay FT re-operating, releases V and holds W to provide a locking circuit for FT. This arrangement ensures that correct station selection has taken place and that interrogation may now proceed. With relays W operated and V released, the circuit is completed for the 3 p.p.s. interrogation pulse generator PO, which transmits the succession of single pulses to step the uniselectors.

When the switches reach the outlet corresponding to the faulty equipment, FU relay operates over the A5 arc and applies a holding winding over the A4 arc to operate AT and AS to cancel the alarm. Relay FU extends the earth to the alarm tone start lead to cause the appropriate ID(X) relay at the control station to operate and light its corresponding ' Off ' lamp. All other lamps show the ' On ' condition.

The audible non-urgent alarm sounds to indicate that interrogation has taken place and the flashing of the ' Finish Interrogation ' lamp shows that the interrogation is correct. The equipment may then be restored to normal by momentary operation of the ' Reset ' key. If the interrogation is faulty, the normal interrogation procedure must be followed, and the results compared with the records to determine which equipment has changed its state.

Local Manual Control

The equipment at each station may be controlled locally by key operations. In this case, the AS relay is operated from the local key contact to prevent the alarm tone caused by the changeover being transmitted to the control station. Marking of the uniselector A4 arc is still provided to indicate the ' Off ' condition on subsequent interrogations.

The equipment at Station A is always controlled manually and separate display lamps indicate its condition.

Loop Testing

The loop gain to a particular station may be ascertained by dialling the appropriate station code. A ' Calibrate ' key at the control station connects a Level Measuring Set (L.M.S.) to the output terminals to monitor the level of outgoing interrogation tone. The L.M.S. is then calibrated by means of a variable attenuator to read 0 dbm. Operation of the ' Measure ' key connects the L.M.S. to the receive path to monitor the received level, the reading obtained directly representing the loop gain around the transmission path to the required station.

Pilot Alarms

The pilot tone F3 is normally transmitted to the outstations continuously. At the terminating stations E, H and M the tone is detected by pilot tone receivers which connect a return tone. Since these tones are received at the control station over a common path, separate frequencies are used. In the typical system schematic shown in Figure 1 these frequencies are F6 for Station E, F10 for Station H and F3 for Station M.

Whilst these three pilot tones are received at Station A, no alarm is given. If any pilot tone is lost, due perhaps to a complete station failure, an urgent alarm is given and a lamp indication shows the link section in which the fault has occurred.

The three pilot receiver alarm relays have their contacts wired so that the release of the relays light the appropriate ' Pilot Alarm ' lamp. For example, if the tones F3 and F10 are lost, then the lamp denoting section D-F-G would light, as this is the only path where a fault would cause the failure of both of these pilots simultaneously.

Having determined in which section the fault lies it can be further localized by loop testing all stations in the appropriate section.

Conclusion

The system described, in addition to providing a simple and economical solution to the problem of supervision and control without the need for separate signalling paths, also incorporates the attractive feature of flexibility. Firstly, the basic equipment can be readily expanded beyond the initial maximum of 23 interrogation outlets at each of 9 remote locations. Secondly, the system, although primarily arranged for the supervision of equipment employing automatic changeover under fault conditions, is equally suitable for any type of equipment capable of providing a signal to indicate its state.

Patent Application 25020/61.

U.D.C.681.142

DIGITAL DATA TRANSMISSION

F. BECKETT, Grad. I.E.E. — Computer and Data Processing Section

In this article the principal problems of data transmission are introduced, certain methods of attack discussed and an equipment briefly described.

THE transmission of information in the form of discrete symbols, which is the essence of digital data transmission, is not a new technique. The earliest electrical communication systems were in service over a century ago, and these have developed into the various telegraph systems and the ' Telex ' network of the present day. The considerable broadening of interest in data transmission over the last few years has been largely due to the increasing use of automatic data processing equipment. This trend will continue as more organizations install computers and large scale data processing systems, particularly where the organizations are decentralized and deal in commodities which have a rapid turnover.

Punched paper tape has long been established as an input and output medium for many telegraph systems. Most early computers also used paper tape, and although other forms of input and output media have become more widely used, paper tape is likely to remain in common use particularly in view of the steady development of higher speed tape readers and re-perforators.

The ' Telex ' network is being used by a number of automatic data processing installations, but its use is rather limited by the low data transmission rate of six and two thirds 5-bit characters per second. For example, if a fair sized branch of a bank wished to transmit its current account transactions, it would take several hours per day at this speed. The data rate can be increased by using a channel of greater bandwidth together with higher speed telegraph equipment. In principle, at least, this has been possible for some time by hiring a private telephone circuit from the G.P.O. and fitting approved terminal equipment; however, this approach is rarely economic.

One difficulty encountered in the use of the public telephone network is associated with supervisory tones and the voice-frequency signalling equipment used for setting up and clearing down calls other than local calls. In general, these limit the available frequency range for data transmission to the band between 900 c/s and 2,100 c/s. The bands below 420 c/s and above 2,100 c/s may be used, but then the type of signal is restricted.

The received data signals must be resolved into individual binary digits and then into character groups. For this purpose, timing or synchronizing signals must be provided. The systems used fall broadly into two classes; start-stop, and continuously synchronous systems.

In the start-stop system, the first change of state of the signal starts the timing sequence. The signal is then sampled at ' n ' pre-arranged time intervals (where ' n ' is commonly in the range five to ten) to determine the ' n ' code elements forming the character or group. The sequence is then stopped until the next change of state of the signal when the cycle of operations is restarted. A disadvantage of this system is that the loss of one start signal through interference can spoil the transmission for a number of characters.

In the continuous systems, the data is sent at a steady rate and the timing circuits in the receiver must adjust to the appropriate rate and phase by comparison with some regularly repeating aspect of the received signal. This synchronization system is more complex and may require several seconds to synchronize, but is quite insensitive to interference.

A large number of long distance telephone circuits use a suppressed-carrier single side-band modulation system so that many channels can be carried on one cable. The carrier introduced for demodulation is not phase locked and may in fact cause frequency shifts of up to two cycles per second. Although the human ear can barely detect this amount of distortion, the received signal might be quite unrecognizable to a telegraph receiver. The usual way of overcoming this difficulty is to modulate a sub-carrier (usually in the range 1,500 to 2,500 c/s) prior to transmission, and to de-modulate in the receiver. The choice of modulation system is a compromise. The order of preference on three different counts is given below.

	FOR SIMPLICITY OF EQUIPMENT	FOR RATE OF TRANSMISSION	FOR REJECTION OF INTERFERENCE
	Amplitude modulation (AM)	V.S.A.M.	P.M.
	Frequency modulation (FM)	Q.P.M.	Q.P.M.
	Vestigial sideband amplitude modulation (VSAM)	A.M.	F.M.
	Phase modulation (PM)	F.M.	A.M.
	Quadrature phase modulation (QPM)	P.M.	V.S.A.M.

Some of the differences are rather marginal and interdependent, e.g. a very complex V.S.A.M. system may have better interference rejection than a simple A.M. or F.M. system.

Another important aspect of data transmission is caused by the occurrence of errors and the need for their detection and, if possible, correction. Errors may be introduced by faults in the preparation of the original punched tape and also during transmission by electrical noise along the transmission path.

If ordinary English text is transmitted, the inherent redundancy of the language together with the reader's anticipation of the sense of the text enables most errors to be detected and corrected. If the data is an arbitrary list of symbols, however, errors cannot be detected by these means, and to overcome this difficulty, redundancy is deliberately introduced into the transmitted information. A simple method for detecting errors, known as a parity check, is shown in the following example.

DECIMAL DIGIT	BINARY EQUIVALENT	CHECK BIT	TOTAL NO. OF '1's' IN GROUP
0	0 0 0 0	0	0
1	0 0 0 1	1	2
2	0 0 1 0	1	2
3	0 0 1 1	0	2
4	0 1 0 0	1	2
5	0 1 0 1	0	2
6	0 1 1 0	0	2
7	0 1 1 1	1	4
8	1 0 0 0	1	2
9	1 0 0 1	0	2

The check bit is chosen so that the total number of ones in a group is an even number; thus an odd number of errors can always be detected. An even number of errors will not be noticed, however, since the total of ones will still be even. Although single errors are the most common, multiple errors also occur and so a system which gives a good chance of detecting both kinds with the possibility of correction would be advantageous. This can be achieved by arranging the information so that it can be regarded as being in the form of blocks, parity checking then taking place along both the rows and columns in the block. For example, to encode the number 2548314265 it could be divided into two blocks, each containing five decimal digits and arranged as shown below:—

	DECIMAL DIGIT	BINARY EQUIVALENT	ROW CHECK
First block	2	0 0 1 0	1
	5	0 1 0 1	0
	4	0 1 0 0	1
	8	1 0 0 0	1
	3	0 0 1 1	0
Column Check		1 0 0 0	1
Second block	1	0 0 0 1	1
	4	0 1 0 0	1
	2	0 0 1 0	1
	6	0 1 1 0	0
	5	0 1 0 1	0
Column Check		0 1 0 0	1

By this method any single error in a block can be detected and moreover corrected, and so can any odd number of errors confined to either a single row or a single column. In addition, most groups of errors can at least be detected, only those which change an even number of digits in both rows and columns escaping detection. There are about one thousand million possible different digit patterns in a block of thirty binary digits of which only about one million fit the check conditions; thus, the probability of an undetected error in such a block with this type of coding is about one in a thousand. In practice, the block size would usually be rather larger and the error detection better than in this example.

This type of code is of particular importance when automatic repeat facilities are available, a block being repeated until the check conditions are met. However, since the transmission delay is significant on most circuits, the block size must be fairly large, probably containing at least a hundred bits, and the cost of storing this amount of data and varying the input rate must be weighed against the advantages of the system.

If a simple tape reader is used, then automatic re-transmission is not feasible, and some form of error correction should be very helpful in cutting down the number of requests for sections to be repeated, or for other forms of intervention by operators to correct mistakes. An error-correcting code which has a high redundancy (one check bit per message bit) but can correct errors associated with a group of digits, has been described by D. W. Hagelbarger[1]. This code can be fully serial so that no defined blocks need exist. In addition, it is simple to realize and does not require an excessive amount of equipment. Even so, the encoding and decoding equipment is likely to be larger than the telegraph transmitting and receiving equipment with which it is associated.

The amount of error correction and detection equipment which it is economic to provide as part of a data link operating on the public telephone network is rather indeterminate. There have been no really large scale trials on the G.P.O. network, and opinions of acceptable error rates vary over the range of one in five thousand to one in one hundred million. This range is not so unreasonable as it may at first appear. Where data is prepared for transmission by normal clerical work and manual keyboard perforators with only simple checking, the errors may already be one per thousand before transmission. By more elaborate checking, such as the use of a machine which gives a printed copy as the tape is prepared and block totals for all numerical data, errors in preparation of tape can be greatly reduced and, in some cases, an error rate of one in one hundred thousand is quite realistic. Where data is prepared directly from a computer system, undetected error rates on the tape may even be as low as one in a hundred million. This is equivalent to two wrong characters per year of continuous operation at normal teleprinter speed, or one error in two hundred average-length novels.

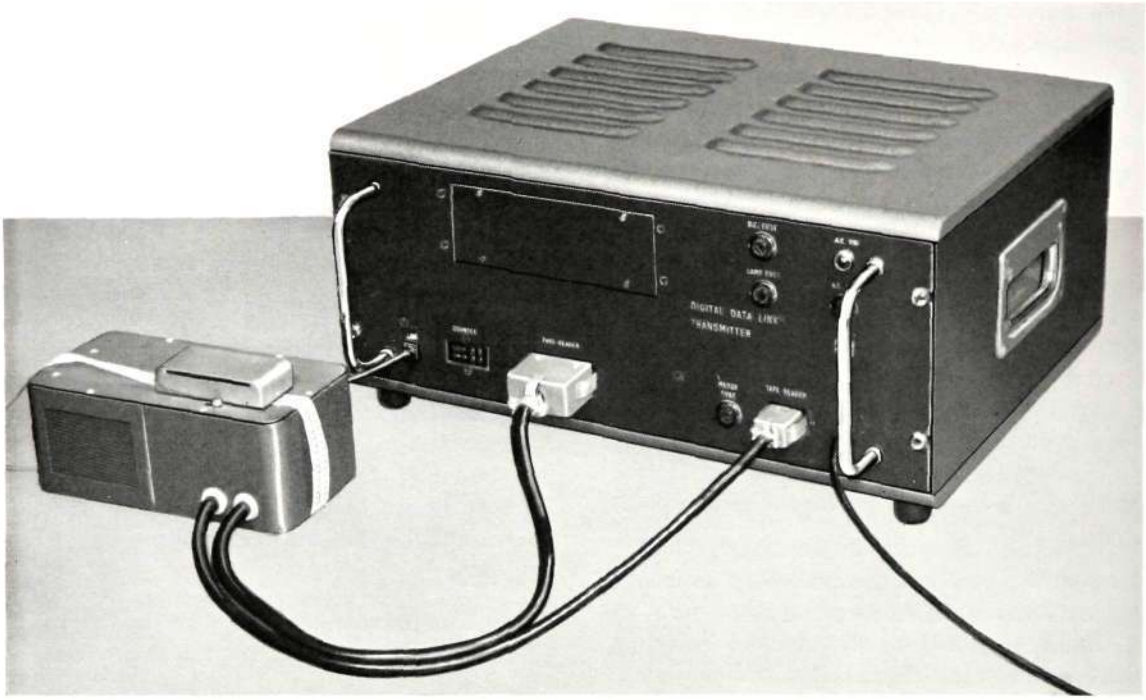
The usual practice in general purpose computers is to provide very little built-in error detection, but to design the programmes in such a way that suitable checks are made by the machine. This is a very flexible method and enables the more important items to be more thoroughly checked. It seems reasonable to make the same approach with data transmission, particularly where very low error rates are required, and to leave the detection to the subsequent processing, thus reducing the equipment associated with the actual transmitting and receiving apparatus.

For a more exhaustive review of the subject, with an extensive bibliography, the reader is referred to a paper by J. M. Wier[2].

The Bendix Ericsson Digital Data Link Type 430A.

This equipment has been designed primarily for use in the public telephone network. The transmission rate is 67 characters/sec., with five message bits per character and seven redundant digits added for error correction and synchronization. The standard equipment accepts five hole punched paper tape as the input medium, encodes this data with an equal number of check bits using a code of the type described by D. W. Hagelbarger[1] and inserts two synchronizing bits after every ten encoded bits. The encoded message then frequency modulates a carrier centred on 1,650 c/s and the output is fed to the G.P.O. line via a band pass filter and isolating transformer. The filter pass band is from 1,000 c/s to 2,300 c/s with at least 15 db attenuation at 865 cycles per second.

The receiver has a similar line transformer and filter, followed by an amplifier with automatic gain control. A limiter and frequency discriminator follow, with a further limiter to re-shape the signal feeding the synchronizing and decoding equipment. For monitoring and control functions, a signal is returned to the transmitting terminal. The frequencies used are 340 c/s and 410 c/s alternating at about one cycle per second to avoid confusion with other G.P.O. supervisory tones.



General view of Tape Reader and Transmitter used on Field Trials

The equipment will work satisfactorily over lines of at least 35 db attenuation, and the code used will correct error bursts up to one complete character length if separated by slightly more than three character lengths.

The output can be used to drive a paper tape re-perforator or it can be recorded on magnetic tape. Either form of tape can then feed various devices (teleprinter, computer, etc.) at a suitable speed.

An alternative model has additional error detection facilities at the expense of a reduction to half the normal transmission rate. This involves very little extra equipment.

Trial Results

On a series of fairly short duration tests over various circuits up to 700 miles in length, the error rates have shown very considerable variation. Long trunk circuits and short local circuits both give good results with no more than one bit in 10^5 in error and nine out of ten of these errors corrected by the code system, giving an overall error rate of about one in a million. Some circuits with fairly high attenuation and up to six or seven exchanges have given results twenty times worse than this.

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U.D.C.621.395.61

PREVENTING THE TELEPHONE FROM SLIPPING

FROM the introduction of the first table telephone the form and material of the feet presented a problem. With the early instruments, the difficulty was to prevent the marking of the surfaces on which the telephone stood, but when a dial was added to the instrument, it became necessary to ensure that the instrument did not slip during dialling. Similarly, the recent innovation of the extensible coiled H.M.T. cord has made it necessary to prevent the pull of the cord from dragging the instrument off the table and dropping it on the floor. The most unfavourable combination from this point of view is a lightweight instrument with a stiff extensible cord.

Although the elementary theory indicates that the sideways pull which the telephone will withstand depends only on the materials of the feet, the table surface, and the weight of the instrument, there are in practice a variety of complicating factors, notably the shape of the feet and the condition of the surfaces as regards dust, furniture polish, etc. Furthermore, both the shape and the material of the feet affect the degree of staining and marking occasioned by an instrument.

To improve the feet of the Etelphone, the Company's Process Laboratories have made an extensive study of the feet standardized by the B.P.O. for the Telephone 706 and have compared them with other shapes and materials. From this has come a new foot and a good measure of confidence that it is a marked improvement on the old.

Always it is necessary to accept a compromise between the requirements of not slipping and not damaging furniture surfaces. A foot that is right for all possible conditions is, therefore, unlikely; nevertheless, the new foot should be generally satisfactory. However, there are some relatively soft surfaces which any generally acceptable foot is almost certain to damage, and the only satisfactory answers to these cases are to protect the surfaces by other means or site the telephone elsewhere.

The Old and the New Feet

When the current standard domed feet (see Figure 1A) are new and clean, adhesion is generally satisfactory, and the horizontal force necessary to drag a telephone over a typical table surface may be as high as 50-60 ozs. which is more than adequate to resist the 12 ozs. pull of an average coiled cord of the original stiff pattern. In use, however, dust, dirt and wax accumulation on the foot (see Figure 2) reduced

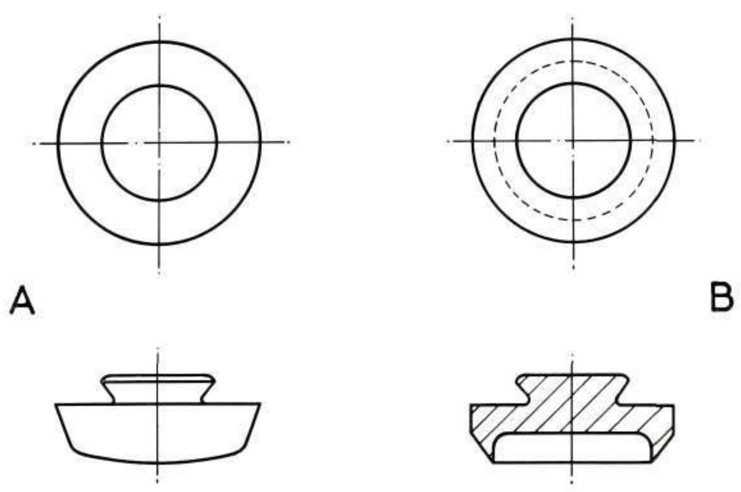
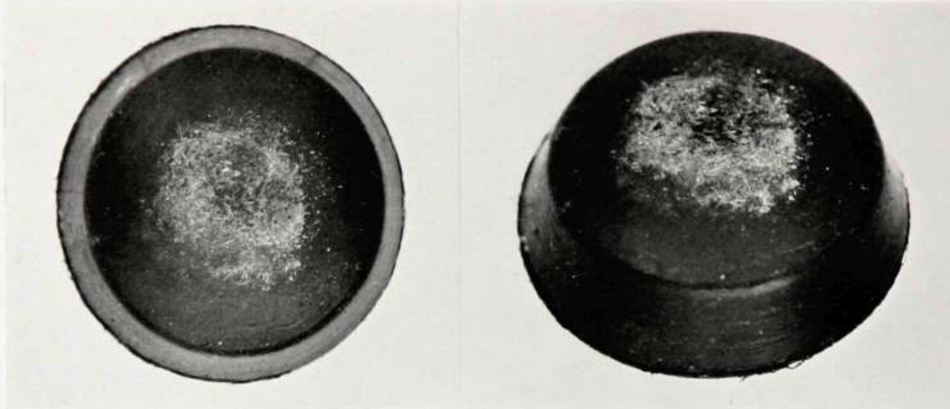
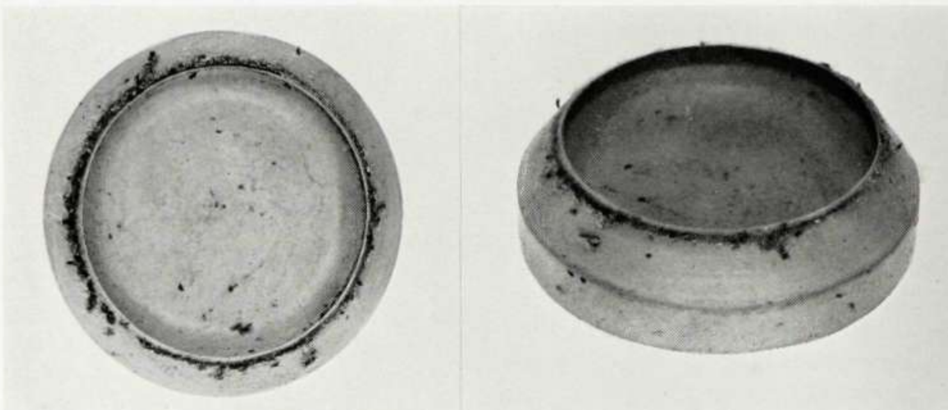


Figure 1
A—The Present Standard Domed Foot B—The New Foot



A—The existing domed foot showing the large area of dust and wax accumulation



B—The new foot in white Butakon, illustrating the clean edge

Figure 2—Examples of Dirt Adhesion on Existing and New Feet

adhesion to a remarkable degree. After a month of normal use it may be as little as 6 ozs. Figure 3 shows as a pillargraph the results of tests on 78 typical instruments in ordinary use at Beeston factory.

To reduce the chances of the cord pull dragging the telephone over the table, two steps have been proposed.

1. To replace the stiff coiled cord by a new pattern which requires a pull of only 6 ozs. to extend it to 4 feet.
2. A form of foot (see Figure 1B) with a ‘ cup ’ profile which gives a ‘ feather-edge ’ on which the instrument rests. It was hoped that this would give a self-cleaning effect and as will be seen from Figures 2A and B, this hope seems to have been realized. While dust and dirt accumulate on the faces of the foot the feather-edge seems to remain clean.

Three grades of rubber were tried with the new shape, viz:—

(*a*) Chloroprene rubber complying with B.P.O. Specification M.105A (ref. B.369).

(*b*) A softer grade of chloroprene (ref. B.139).

(*c*) Butakon, a synthetic elastomer.

Adhesion Tests

To study the problem and the effect of the proposed shape of foot, a series of tests were made in the Laboratory and on instruments in service at Beeston.

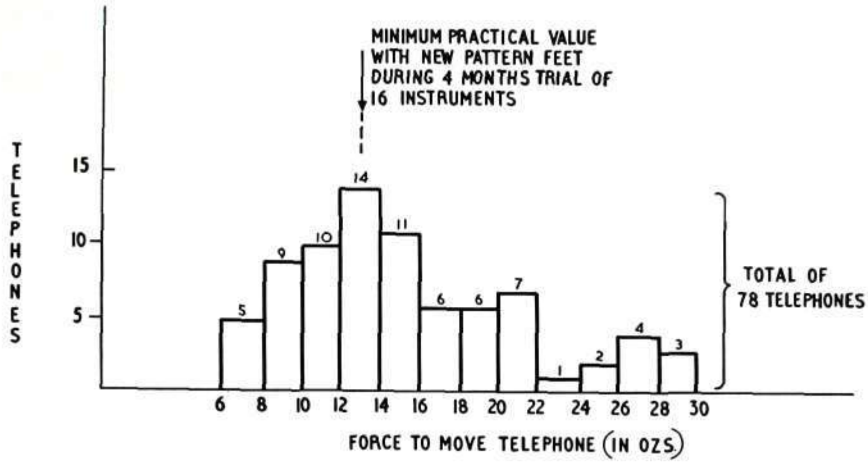


Figure 3—Results of Test on 78 Instruments, with Old Type Feet, in ordinary use at Beeston factory

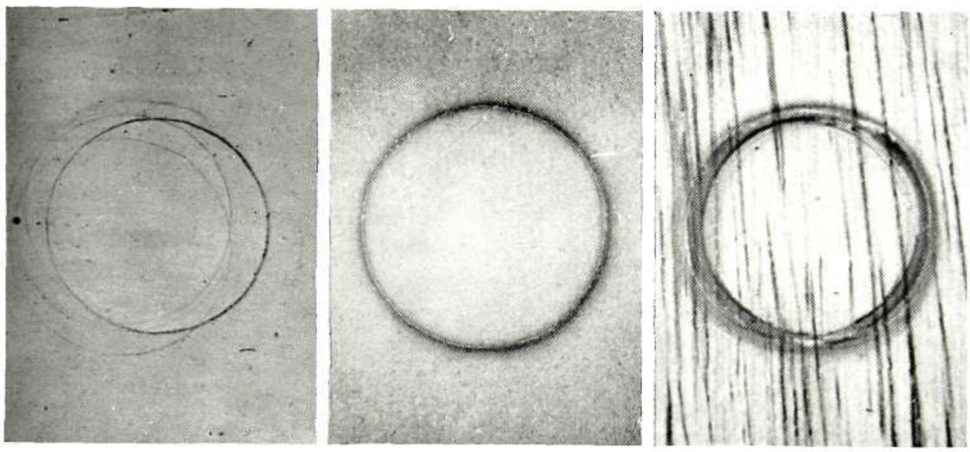


Figure 4—Typical Degrees of Staining

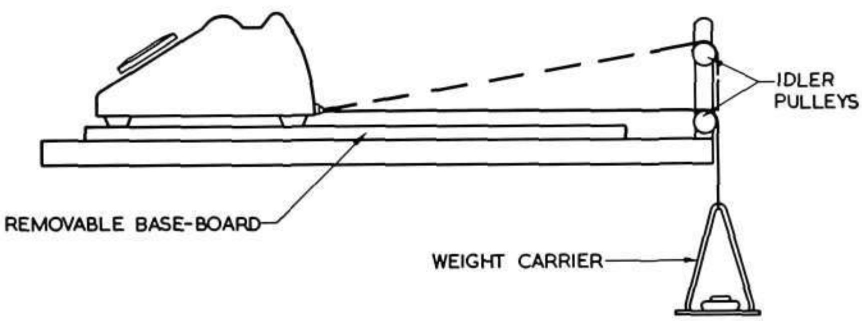


Figure 5—Method of Testing Pull

The general arrangement for the Laboratory tests is shown in Figure 5 and consists of an elementary means of measuring the smallest force to move the telephone. The tests were conducted with three 'table' materials with the two angles of pull and under clean and dusty conditions.

In every case the effect of dust and dirt was to reduce the adhesion but the reduction was most marked with the old feet and least with the new shape in B.139 and B.369.

For the telephones in service the pulley and weights were replaced by a spring balance and the initial results on 78 telephones with the old pattern feet are as already indicated in Figure 3. The following table summarizes the results obtained with 16 instruments fitted with new pattern feet of B.139.

		AFTER NORMAL USE			
	NEW	1 MONTH	2 MONTHS	3 MONTHS	4 MONTHS
Mean value	55.4	37.4	26.9	27.3	27.0
Max.-Min.	78-32	50-18	43-16	44-13	44-18

All pulls in ozs.

Marking and Staining Tests

To establish how the new foot compared with the old in its effect on surfaces, tests were conducted at 20°C. 75% R.H. and 40°C. dry in which old standard feet and the new shape of foot in the three grades of rubber were loaded with weights equal to $\frac{1}{4}$ of that of the telephone instrument and were stood on a variety of table surfaces for 35 days without movement.

The surfaces included were:—

Shellac (French polish)
Celluloses; two formulations
Enamels; two formulations
Catalysed Synthetic Resin
Leather Cloth
Linoleum; Waxed and Unwaxed

It is impossible to reproduce all the photographs showing the degrees of marking or indentation of the surface but Figure 4 indicates three degrees of staining. Using classifications of this sort it was possible to decide on the general placings of the materials and shapes of foot.

New feet of B.139 were markedly inferior to those of B.369 as regards marking and staining, the latter being generally compaiable to the old domed foot in this respect.

Conclusion

Out of this work comes a new shape of foot in B.369 rubber which it is confidently expected will be markedly superior to the existing standard foot as regards frictional properties and not noticeably worse in its liability to stain and mark furniture surfaces.