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(54) A HOUSE EXCHANGE TELEPHONE SYSTEM

(71) We, THE PLESSEY COMPANY LIMITED, a British Company of 2/60 Vicarage Lane, Ilford, Essex, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a House Exchange telephone system.

House Exchange systems are known which provide for (a) five extensions with access to one exchange line; this configuration being designated 1+5, (b) five extensions with access to two exchange lines i.e. 2+5, and (c) eleven extensions with access to two exchange lines i.e. 2+11. House Exchange systems having these configurations are commonly known by the commercial name 'Keymaster' systems.

Hitherto, systems of this type have operated with conventional relay circuits both for switching and control purposes.

Each instrument in a 5 extension system is interconnected in tandem to the rest of the system by 10 or 12 pair cables, and those in the 11 extension system are interconnected by 20 pair cables.

The method of cabling is such that those extensions located on the cable-run nearest to the exchange-line termination have priority access to the exchange lines. This may often be inconvenient, it being preferable either for all extensions to have equal priority or for priority to be allocated at the discretion of the system user rather than dictated by the system design.

The power to operate a House Exchange system is normally provided at 50 volts d.c. by a local battery or mains power supply.

It is an object of the present invention to provide a House Exchange system capable of giving all the facilities available in the known 'Keymaster' systems, but with less complex cabling between extensions, a larger number of extensions and of exchange lines connected to the system and more modern

switching and control technology. It is also desirable that the extension instruments should all have the full signalling facilities and yet be smaller than the known 'Keymaster' instruments.

The invention provides a House Exchange telephone system including a plurality of extension line units which are radially connected to a switching matrix using a first conductor pair for each extension and to a common control unit using a second conductor pair for each extension, the first conductor pair being used for speech transmission and signalling to a public exchange whilst the second conductor pair is used for supplying power to the extension and for system signalling, the extension line units being successively connected to the common control unit in an associated time slot; and a number of exchange line units which are radially connected to the switching matrix and to the common control unit, wherein the switching matrix is arranged so that the first conductor pair of each extension line unit crosses the first conductor pair of each of the other extension line units at a unique crosspoint and also crosses a speech conductor pair of each exchange line unit at a unique crosspoint, the switching matrix including a crosspoint switching circuit at each of the said crosspoints and wherein the switching of the crosspoints is controlled in a time division multiplex mode.

The foregoing and other features and advantages of the House Exchange telephone system according to the present invention will become apparent from the following description with reference to the accompanying drawings in which:—

Figures 1A and 1B illustrate in block diagram form the House Exchange Telephone system embodying the invention,

Figures 2A, 2B and 2C diagrammatically illustrate in side, front and front elevations respectively extension instruments for the House Exchange system of Figure 1,

Figure 3 diagrammatically illustrates the

principle of the switch matrix configuration of Figure 1,

5 Figure 4 illustrates an arrangement of the switch matrix of Figure 1 that facilitates modular expansion of the House Exchange system,

Figure 5 illustrates line unit logic for effecting crosspoint control,

10 Figure 6 illustrates the logic associated with each crosspoint, where two internal lines interconnect,

Figure 7 illustrates the control logic associated with each crosspoint where an internal line connects to an external line,

15 Figure 8 illustrates the exchange line unit logic,

Figure 9 illustrates the exchange line common logic,

20 Figure 10 illustrates the extension instrument signalling sequence and the system timing sequence,

Figure 11 illustrates the timing diagram for the extension instrument signalling,

25 Figure 12 illustrates schematically the extension instrument's logic circuit,

Figure 13 illustrates the interconnections for the push buttons of the extension instrument,

30 Figure 14 illustrates the system encoder logic,

Figure 15 illustrates schematically the system timing and waveform generating circuits,

35 Figure 16 illustrates the line powering and signalling circuit arrangements,

Figure 17 illustrates a circuit arrangement for the balanced voltage modulator of the line unit of Figure 16,

40 Figure 18 illustrates the circuit arrangements for the series voltage regulator, the current modulator and the constant current generator of the extension terminal of Figure 16.

45 Figure 19 illustrates the balanced threshold detector of the line unit of Figure 16,

Figure 20 illustrates the circuit of a balanced amplifier for the threshold detector of the extension terminal of Figure 16,

50 Figure 21 illustrates the powering arrangements for the system, and

Figure 22 illustrates the ringing detector circuit arrangements.

55 The system described in this specification has been designed to meet the stated objects, and is characterised by the use of solid state integrated circuits and semi-conductors for the control logic, and sealed reed relays can be used for all the switching crosspoints. In the interests of economy, particularly in the smaller systems as much as possible of the control logic has been allocated to line terminations, only a minimum of necessary shared facilities being provided in a common control section of the system.

To minimise installation costs a further feature of the system is that all extensions are wired radially from a central control unit, using 2 conductor pairs per extension and the common control facilities are shared on a time division basis.

The House Exchange telephone system embodying the invention is illustrated in block diagram form in Figure 1A of the drawings. The basic system can be adapted to accommodate up to 24 extensions, although 16 is the preferred capacity. The number of exchange lines can be 6, or even more, although four is expected to represent the normal number with this design.

If the need should arise to extend a system to 32 extensions and say 8 exchange lines this could be achieved by interconnecting two 4+16 systems, sharing some common circuitry and with the addition of certain additional circuits.

Each extension instrument 1 is interconnected with the central switching equipment by two conductor pairs 1a, 1b. One pair 1a is used exclusively for speech, system tones, and dialling (or V.F. tone codes) to the public exchange, the other 1b is used for internal control signalling, and power supply. The control signalling is effected in a time division multiplex (T.D.M.) polled arrangement, most of the control features appertaining to one line being accommodated in a line signalling interface 2. The speech paths between extensions and from extensions to exchange lines are provided by means of a switch matrix 3 which preferably although not essentially utilises reed relay crosspoints. The crosspoints are each individually controlled by their own unique circuit, a number of which may be accommodated on a single integrated circuit chip. A speech interface unit SI is interposed between the instrument 1 and the switch matrix 3.

Each exchange line, such as the line EL1 is terminated on an exchange line interface unit 4 which interconnects it to the switch matrix 3 and to a central common control unit 5 which derives its clock pulses from a master clock MC and which is connected to several centralised functions as indicated by the lead 5a.

The interrelationship between the system blocks of Figure 1A is illustrated in more detail in Figure 1B of the drawings in order that the general operating principles of the system can be readily understood.

As illustrated in Figure 1B, the switching matrix 3 for interconnecting N extensions and M exchange lines is contained within the dotted line 3a and, as will be subsequently outlined in relation to Figures 3 and 4 of the drawings, is based on a so-called folded matrix. The extension instruments 1 which are numbered 1 to N are each interconnected with control equipment over four distribution

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wires. One pair 1a, as previously stated, provides speech transmission and terminates on the transmission interface SI of the associated line unit (enclosed by the chain dotted lines) in the central equipment, and the other pair 1b, as previously stated, carries bidirectional, digital signalling and power for the extension instrument control circuits and terminates on the signalling interface 2 of the associated line unit.

The line unit contains the majority of the circuits needed for controlling call connections but, as will be subsequently outlined, it is a matter of expediency as well as necessity that some control functions should be provided by the common control unit 5.

The common control unit is associated with each line unit by means of a number of common highways which operate in a time divided mode. Each line unit is assigned a time slot, shown as T1 to TN during which each line has access to common equipment. During the time slot assigned to a particular line, signals appropriate to that line are sent to the instrument and signals are received from the instrument. A control action resulting from the received signals in a time-slot is enacted during that same time-slot.

Each line unit has its own speech connecting link 141 which traverses all other connecting links in the system. They also traverse exchange line connecting links 142 which are associated with exchange lines via exchange line units 4 which are numbered 1 to M. There are crosspoints at the points of coincidence of all connecting links which give full availability, non-blocking interconnection of all lines. Only one crosspoint is required between two lines. For example, when the extension line 1 sets up a call to extension line 4, the encircled crosspoint is operated. The same crosspoint is also used when extension line 4 calls extension line 1.

Control connections 143 enter the matrix 3 from the extension line units and from the exchange line units. The control connections run in parallel with the speech links and carry signals for setting up and releasing crosspoints in the matrix.

The condition of the exchange lines is sensed by equipment in the exchange line units and passed to the common equipment 5 in control path 144. The common equipment causes signals relating to these conditions to be generated and passed, via common T.D.M. highway 140, to the extension line units. Where necessary the signals are then retransmitted to the instruments during the appropriate time-slots.

The individual circuits and the signalling philosophy for the system illustrated in Figures 1A and 1B will now be described in detail.

The Extension Instrument 1 of Figures 1A and 1B

A probable external arrangement of the extension instrument is illustrated in Figures 2A and 2C of the drawings. The detailed appearance of this instrument which could be of the loudspeaking telephone type, will depend on styling considerations, but functionally the instrument will include a conventional Post Office handset 16 of known design and conventional dial 7 (Figure 2B) or press button keypad 8 (Figure 2C) situated on the top of the instrument and in front of the handset. An array of up to 16, 20 or 24 labelled keys 9 (Figure 2B) are situated alongside the dial 7 to provide the direct key-calling facility.

At the front of the instrument, or elsewhere if so dictated by styling considerations four keys 10, 11 are provided which are to be used to give access to exchange lines, to mute the audible external calling signal and for the operation of the "hold" and "privacy" functions. Two lamps 12, 13 are also provided for respectively signalling incoming calls and for indicating the existence of the hold and privacy condition on this extension.

Alongside the lamps and keys at the front of the instrument it is envisaged that a type-written directory 14 (Figure 2B) identifying the 16, 20 or 24 "named" buttons might be provided. This directory could readily be updated as the names associated with extension instruments change from time to time. Figure 2C illustrates an alternative configuration in which the named buttons situated alongside the press button keypad 8 are rectangular in shape and are actually labelled with the names of the parties to whom the buttons give access, so obviating the need to use the "directory" 14 of Figure 2B.

Each extension instrument includes the normal circuitry of a standard known telephone, so that it can be directly connected through the switch matrix, to an external Post Office line. For signalling direct to the public network it is equipped with a normal switch-hook, off-normal switches, dial or keypad, microphone and receiver. When connected through the system to a Post Office line, the microphone and dial will also be energised by power from the public exchange in a manner to be subsequently outlined. A tone sounder is fitted for the signalling of incoming external and intercom calls. Provision is also made for an additional bell or tone sounder to be connected for direct operation from the exchange line under power fail conditions.

For the origination of internal calls, the 16, 20 or 24 named buttons can each be provided with one or two make contacts for producing a code of 5 binary digits that identify the selected extension. The details of the technique will be subsequently outlined,

the necessary diode coding circuit and associated gates being housed in the extension instruments. The 5-bit code, which also includes codes for signalling the "on-hook", "off-hook", "privacy", "hold" and "exchange line seize" conditions is transmitted from the extension to the internal line interface unit 2 of Figures 1A and 1B when interrogated thereby. During the same T.D.M. time slot, the interface unit transmits three binary digits to the extension instrument, to convey information about external and internal calling and hold or privacy conditions respectively. The extension instrument also contains the necessary delay circuits to enable the coded responses to be sent back appropriately after each interrogate pulse, and the decoding circuits needed to apply the calling signals to the "lamps" and audible calling device. A muting switch is provided to enable the audible signal for incoming exchange calls to be silenced, leaving only a visible signal in this case. The audible signal for internal cells cannot, however, be muted.

Since the signalling and control circuitry for the extension instrument is powered over the signalling pair 1b (Figures 1A and 1B) from the central equipment, and this pair may vary considerably in length as well as carrying control signals in both directions, it is provided, as will be described later, with a special regulating circuit to produce a stable voltage supply to drive its logic circuits. The stable voltage supply is derived from the voltage supply of the central equipment.

Details of the above-mentioned circuits will be subsequently outlined as part of the descriptions of the control and signalling functions of the system.

The Switch Matrix 3 of Figures 1A and 1B The switching matrix of the House Exchange system embodying the present invention is based on a so-called folded matrix in which shared connecting links are dispensed with, and the circuit from each extension line crosses that from each other extension line at one unique point, so that interconnection of two extensions involves only the identification and the operation of a single crosspoint in the array. This type of matrix is diagrammatically illustrated in Figure 3 of the drawings.

Connection to exchange line circuits is similarly arranged with single crosspoints, but since exchange-line circuits do not need to be connected to each other the crosspoints associated with these connections have been excluded from the folded matrix. Again, only one crosspoint needs to be selected to interconnect a given extension line to a given exchange line.

The complete matrix is illustrated in its simplest form in Figure 3. Each point where

a vertical line crosses a horizontal line, defines the location of a crosspoint.

Figure 4 illustrates an electrically equivalent arrangement of the switching matrix which is designed to facilitate expansion of the matrix in increments of 1+4 lines.

The lines in the matrix of Figure 4 which are connected to exchange lines are drawn thicker in order to identify them and to draw attention to the fact that the crosspoints are omitted at the points where these lines cross each other since there is no need, and indeed it is forbidden, that exchange lines should be interconnected in the matrix.

It will be seen that the number of crosspoints in such an arrangement is

$$N\left(\frac{N-1}{2} + M\right)$$

where N is the number of extension lines, and M the number of exchange lines which in the case of a 4+16 system is 184. This, while being more economical than the equivalent rectangular matrix is also easier to control.

In Figure 4, four of the required 16 extension line interfaces 15 are shown together with one of the four exchange line interface units 4. The triangular group of 10 crosspoints (identified by X's) immediately adjacent to the interface units 15 could, if desired, all conveniently be located on the same printed circuit card as the interface units 15 and 4, together with their control circuits, Figures 6 and 7. Each matrix expansion module, a typical set of which is identified by circles in Figure 4, together with their control circuits Figures 6 and 7 may also be accommodated on a single printed circuit board. By this means it is easy to arrange for the expansion of a small system to one of larger line capacity by plugging in one group of "X" crosspoints and their associated interface circuits and an appropriate number of boards carrying "O" crosspoints and their control logic according to the stage of expansion reached in the system.

It should be noted that when reed relay crosspoints are used, each crosspoint comprises two hermetically sealed reed relay inserts one in each side of each speech pair and that, therefore, Figures 3 and 4 should be visualised as being duplicated in terms of the actual number of contacts. Each set of reed inserts is located in a solenoid which, in turn, is controlled by its own circuit module. This module is controlled by pulses on two sets of signal lines running parallel to the speech lines shown in Figures 3 and 4.

The complete circuit of an extension to extension crosspoint can, therefore, be represented by Figure 6, whilst that of an exten-

sion to exchange line crosspoint is represented by Figure 7.

The operation of the extension to extension crosspoint logic will be explained by referring simultaneously to Figures 5 and 6, where Figure 5 represents the crosspoint control logic located in each extension line unit.

Crosspoint Selection and Release Logic for Intercom. Calls.

For a terminal i.e. extension instrument, to select any given crosspoint on its line, the line is marked during the time-slot. During the same time-slot, the terminal marks the line of an extension terminal that it wishes to call. The coincidence of marks at the selected crosspoint sets a latch in the cross-point logic.

Each extension terminal is allocated a time-slot (see Figure 10) within which it may seize a common marker/translator and thus set up a crosspoint connection. Within this time-slot the originating extension terminal transmits a code, typically 5 or 6 bits, which signals the state of the push buttons of the extension instrument, viz. calling codes, privacy, hold, exchange line control keys, and also the cradle switch. The extension terminal receives in the same time-slot, signals indicating internal or external calling and hold or privacy conditions. The terminal scan period must be small enough to enable the code to be picked up by the scan, i.e. the key should remain pressed for at least one scan period. The system of time-divided allocation of control functions avoids the need for multiple common registers, and consequently the need for "time-outs" to prevent equipment being held excessively. The system is workable because of the low number of extension terminals to be scanned.

To avoid multiple crosspoint selection, it is necessary to ensure that a mark corresponding to a wanted terminal's line occurs only in the time-slot of the calling terminal originating the mark. To prevent coincidence with other marks each line unit receives a scan pulse. TN once per scan period and the line No. 1 is marked by pulse T1 only in the time-slot assigned to line No. 1.

Intercom crosspoints are located at the intersection of control wires which originate in associated extension line units. Each control wire carries a T pulse or a mark pulse M which corresponds to a called line. These wires are used to operate the crosspoint. The crosspoint is released by means of a pulse on a common R wire. An R pulse can occur on the common wire only in the time-slot of the line originating the release condition.

As illustrated in Figure 6, the speech pairs SP1, SP3 respectively for extension lines No. 1 and No. 3 run in parallel with the associated (T1+M1), (T3+M3) and the common release R wires and are connected to each other speech pair, at points of inter-

section, via two reed contacts 18 and 18a. Supposing extension terminal No. 1 is making a call, a code, identifying the party being called will be received from terminal No. 1 and will generate a mark, say at extension line unit No. 3 if this is the called party. In order to allow time for the code to be clocked in from the calling extension terminal, the mark associated with the called party i.e. mark M3 in the above example, will appear after the start of the time slot of the calling party i.e. time slot T1 in the cited example. If the called extension terminal is neither in privacy mode nor on an exchange line call, the mark M3 will be allowed through to the crosspoints. At the crosspoint where (T1+M1) and (T3+M3) coincide (Figure 6) a bistable 20 is set via an AND—gate 20a the inputs of which are connected to the (T1+M1) and (T3+M3) wires. A solenoid 22 associated with the reed contacts 18 and 18a is energised by the set output of the bistable 20 and, therefore, the reed contacts 18 and 18a are closed. If either terminal goes back on hook, the common release wire goes high for one pulse period in the time-slot of the clearing terminal. This condition will be combined at an AND gate 20b with the (TN+MN) condition of the clearing extension terminal in order to reset the bistable 20 and to thereby release the crosspoint logic and open the reed contacts. The (TN+MN) condition of the clearing extension terminal is applied to the gate 20b via an OR gate 20c. The first terminal to hang-up therefore releases the crosspoint; this is termed first party release.

At the same time as the crosspoint is being set, a calling signal is transmitted to the called extension terminal and a buzz-back signal is transmitted to the receiver at the calling extension terminal. Both of these signals endure for the length of time an extension instrument push button is pressed and are, therefore, related to the presence of a condition at the calling line unit, which, as will be subsequently outlined, gates the buzz-back signal, or to the presence of a mark at the called line unit which, as will be subsequently outlined, controls the internal calling signal. Buzz-back is a tone inserted on the calling line unit's speech pair, 'internal calling' generates a digital signal which sets a latch in the extension terminal.

If the called line unit is in fact either in privacy mode or engaged on an exchange line call, the mark from the calling line unit is not allowed through to the crosspoint matrix. Rather, as will be subsequently outlined, a busy signal is returned on a common bus and gated into the appropriate line unit by the appropriate time-slot pulse. The busy signal must override the buzz-back signal which has been originated by the calling code.

Busy is a modulated tone which is inserted onto the calling party's speech pair.

Crosspoint Selection and Release Logic for Exchange Line Calls

5 Figure 7 illustrates the control logic associated with each crosspoint where an internal i.e. extension, line connects to an external i.e. exchange line. This crosspoint logic is associated with the more complex
10 exchange line interface logic illustrated in Figure 8 and the common logic appertaining to all exchange lines is illustrated in Figure 9.

15 In this section, the procedures for setting up, holding and transferring exchange line calls are explained with reference to Figures 7, 8 and 9.

Exchange Line Crosspoint Logic.

20 The speech pair in Figure 7 which constitutes the exchange line connecting link runs in parallel with three control wires which originate or terminate in the associated exchange line unit 4 of Figures 1A and 1B. These control wires are the "Exchange Line
25 Horizontal", the "Exchange Line Association" and the "Exchange Line Held" buses.

Control wires (TN+MN), where N is the number of the associated extension line, and "On-hook" are extended across the
30 exchange line crosspoints from the associated line unit logic circuitry (Figure 5). A bistable latch 25 is set by combining, at gate 26, the condition (TN+MN) and a time-coincident mark on the "Exchange Line Horizontal"
35 bus. A crosspoint driver associated with the reed contacts 18 and 18a is energised by the set output of the bistable latch 25 and, therefore, the reed contacts 18 and 18a are closed. As will be subsequently outlined, the time-coincident mark may be produced by
40 several conditions. The latch 25 is reset when the associated terminal goes on-hook. The reset condition is created by combining the (TN+MN), "Exchange Line Held" and
45 "On-hook" conditions at gate 27. It should be noted that the "Exchange Line Held" bus, which originates in the exchange line unit (Figure 8) also carries the release R condition which is present on the common R wire.
50 (Figures 5 and 6).

The latch 25 is set under the following conditions:—

- (i) When an exchange line is "free" and an extension terminal originates a "seize to
55 call" code.
- (ii) When an exchange line is "calling" and an extension terminal originates a "seize to answer" code.
- (iii) When an exchange line is "held" and
60 an extension terminal is called for consultation by another party.

If all the exchange lines of the House Exchange System are busy, then attempts to

seize an exchange line as in (i) above results in a busy tone being returned to the caller.

In cases (i) and (ii) above the "exchange line horizontal" is marked at TN in response to the codes generated by an extension terminal and detected by central equipment during TN. Coincidence of TN and a
70 mark on the "exchange line horizontal" sets the latch 25 as previously described via the gate 26.

In case (iii) above the "exchange line horizontal" carries a mark in the time-slot of the consulting extension terminal and this mark results, in part, from gating the set output of the latch 25 with the time-slot pulse
75 TN of the consulting extension terminal at gate 28 of Figure 7. The output from the gate 28 is combined with the "Hold" condition on the "exchange line held" but at gate 29 and taken to the "exchange line horizontal" via an OR gate 21. Coincidence of this mark, and a calling mark MN on the
80 consulted extension terminal's line causes the latch 25 associated with the add-on extension to be placed in its set condition.

Exchange Line Common Logic

An exchange line may be in one of three
85 states:—

- (i) Free (idle)
- (ii) Ringing (incoming call)
- (iii) Busy.

If the line is free it may be seized for
95 an outgoing call. If it is ringing it will be seized so that the incoming call may be answered. If the line is busy it is protected against intrusion unless the user adds on another extension or extensions using the hold
100 procedure.

The exchange line common logic illustrated in Figure 9 controls the marking of exchange line horizontals (Figures 7 and 8) in
105 accordance with the state of the exchange lines and the requirements of extensions. Each exchange line is scanned in turn and a four-way counter 19 which is needed for scanning the four exchange lines of the system, is illustrated in Figure 9. The
110 counter 19 is advanced once per frame of sixteen time-slots under control of clock pulse TL16. The logic outputs vary according to the state of the exchange line when scanned. For example, if exchange line 3 is free when
115 scanned, there is an output on the "Use 3" output. If during the scan when the "Use 3" output is present, an extension terminal originates a "seize to call" request, a "seize to call" condition is gated (see Figure 8) with
120 the "Use 3" condition to cause the horizontal of line 3 to be marked. This mark occurs only in the time-slot of the extension terminal originating the seize condition, and it coincides with the extension terminals
125 (TN+MN) mark to operate a crosspoint latch 25 (Figure 7). The latch causes, in a

manner as previously outlined, operation of the crosspoint which connects the seizing extension terminal's line to the exchange line 3. Exchange dial tone is heard in the earpiece of the extension instrument at the seizing terminal as confirmation of seize.

If an exchange line such as the line 3 is calling when scanned, an "Answer Line 3" condition exists for the duration of the scan. If, during the scan, an extension terminal originates a "seize to answer condition", the "exchange line horizontal" is marked in substantially the same manner as above, and the answering extension terminal is connected to the calling exchange line 3.

The "exchange line horizontal" marking logic is illustrated in Figure 8. The two AND gates 77 and 78 combine the scanned outputs "Answer N" and "Use N" from the common logic (Figure 9) and, outputs "Answer" or "Seize to call" from a common decoder (Figure 15) to mark the "exchange line horizontal" via an OR-gate 79 and an AND gate 74.

If all the exchange lines are busy all the "free" inputs (Figure 9) will be suppressed and there will therefore, under these conditions, be an output from gate 70 to Figure 9. If a "seize to call" code is presented by an extension terminal, indicating that an attempt is being made to seize an exchange line when all are busy, an output is produced by AND gate 70a of Figure 9 and applied to the 'Busy' bus. This bus traverses all line units (Figure 5) and returns a busy condition in the time-slot of the extension terminal that is attempting to seize an exchange line. The busy condition is indicated to the extension user as an audible tone in the earpiece of the extension instrument.

A desirable effect of scanning exchange lines in the manner described is that, in quite traffic periods, it ensures that the same exchange line is not always seized for the occasional outgoing call. This tends to even out the wear on exchange line equipment.

Exchange Line Unit

The exchange line unit circuits are illustrated in Figure 8 wherein it can be seen that each exchange line unit contains a ringing detector, a Seize (S) relay, a Hold (H) relay and logic circuitry, some of which has been previously referred to.

The functions of the S and H relays are illustrated by Figure 21. When an exchange line is idle, the S relay connects the exchange line to the ringing detector in a manner which will be subsequently outlined in relation to Figure 21 of the drawings. When the exchange line is seized, the S relay changes over to connect the exchange line to its connecting link.

The H relay, as illustrated in Figure 21, normally provides a physical connection be-

tween the connecting link and the exchange line. When the H relay is operated, it disconnects the connecting link from the exchange line, and terminates the exchange line so as to maintain the line in a busy condition. The exchange line termination is depicted in Figure 21 by a resistance RT.

The ringing detector is, in practice, a.c. coupled to the exchange line and it includes a persistence check circuit to ensure that line noise does not produce false ringing indications. When the ringing condition has been validated, a bistable latch 30 of Figure 8 is set. The set output of the latch 30 is taken to common logic (Figure 9) as a "line n calling" condition where n is the number of the line effecting the call. It is also taken to the common "external calling" bus (Figure 15). As will be subsequently outlined, this produces audible and visual calling indications at the extension terminal instruments. The latch 30 is reset if the exchange line stops calling or when it is answered. The "1.6 sec. clock" input to the persistence check circuit is used to produce a delay of 3.2 seconds. This is necessary in order to provide and check that the ringing condition on the exchange line has actually ceased rather than merely interrupted during its normal cadence.

When an exchange line crosspoint is operated, the (TN+MN) mark is gated onto the "association" bus by the gate 28 of Figure 7. As illustrated in Figure 8 one effect of this mark, when first presented, is to set a bistable latch 76, the set output of the latch 76 operating the S relay. The reset output of the latch 76 is taken to common logic (Figure 9) as a "line n free" condition where n is the number of the free exchange line. When set, the set output of the latch 76 also triggers a delay circuit 73 which operates the H relay for a period of typically, 350 mS. The purpose of this delay is to prevent ringing current reaching the telephone earpiece of the seizing extension terminal when answering an incoming call. The "Hold" loop, as previously stated in relation to Figure 21, provides an answering condition, to suppress ringing, and ensures that the exchange line is not through connected until ringing is suppressed.

A second effect of the mark on the "association" bus is to prevent multiple seizures of exchange lines. The "seize to answer" or "seize to call" signals persist for several frames, subject to the length of time the associated push buttons on an extension instrument remain depressed, but only one exchange line can be seized. A mark on the "association" bus means that the exchange line has been seized and this mark is gated by means of a gate 150 in Figure 8 onto a common multiple seizure bus. This bus, as is illustrated in Figure 8, is connected to all

exchange line units to inhibit via the gate 74 the generation of "horizontal" marks which could lead to multiple seizures.

The remaining circuits are largely concerned with "Hold" facilities. An exchange line may be held for the following purposes:

- (i) To call and consult another party using intercom call procedures.
- (ii) To add another party onto the exchange line following consultation so creating a three party connection.
- (iii) To transfer the exchange line call to the consulted party.

When the "Hold" push button of an extension terminal on an exchange line connection is pressed, the common decoder (Figure 15) provides, in a manner to be subsequently outlined, pulses on a common Hold line (Figure 8) i.e. common to all exchange line units, in the time-slot of the extension terminal originating the Hold condition. These pulses are associated with the correct exchange line unit by gating them with the (TN+MN) marks on the 'Association' bus at an AND gate 57. The output from this gate consists of a stream of pulses which persist for as long as the Hold push button on the extension terminal is pressed. A first operation of the Hold push button puts the exchange line to Hold and a second operation of this push button restores the exchange line. In order to achieve this function the envelope of the pulse stream from the gate 57 is detected by a pulse stream envelope detector 151, the outputs of which are used to set and reset a bistable latch 58 accordingly. The set output of the latch 58 operates the H relay. When reset, release of the H relay is delayed by the delay circuit 73.

The set output of the latch 58 is gated by a gate 152 onto the (Held+R) bus which traverses all exchange line latches associated with the exchange line in question. Normally, when an exchange line is held, two extension terminals will be connected to the exchange line connecting link. The reason for this is that, although consultation connections are made in the intercom section of the matrix, as will be subsequently outlined, there is a high probability that the consulted party will be added onto the exchange line call, or will take it by transfer. It is convenient, therefore, for the consulting party's line to be connected to the exchange line connecting link at the same time as the consultation connection is made. It is then a requirement that both extension terminals should have an indication that they are associated with a held exchange line. Consequently, the held condition is gated to the extension terminals by a gate 24 in Figure 7.

Upon completion of a consultation, the consulted party goes on-hook, thereby releasing his extension line and exchange line cross-

points. This leaves the consulting party in control of the exchange line, and he returns to the exchange line by pressing his Hold push button and releasing the H relay. If the consulted party is to be added onto the exchange line connection, he remains off-hook. Either of the parties can effect reconnection to the exchange line by pressing their Hold push button. If the consulted party is to take the call by transfer, the consulting party goes on-hook, thereby releasing his cross-points, and the consulted party presses his Hold push button to take the call. In all cases the Hold indication at the extension terminals is suppressed when the Held condition on the (Held+R) bus is disabled.

In the event that a party wanted for consultation does not answer, the crosspoints operated on his line during the calling process must be released. This release occurs when the Hold condition is suppressed by the consulting part, using release procedures described elsewhere with reference to Figure 8.

Line Unit Logic

Figure 5 illustrates in outline form the logic circuitry for an extension instrument's line unit. It will be clear to those experienced in the art that the logic is simplified in order to assist explanation.

It has been previously stated that one feature of the system is that as much system control as possible should be distributed on a per line basis. This section of the specification deals with much of this distributed control. As with any control process, the circuits of Figure 5 accept control inputs, shown at the left hand side of the drawing, and translate them into control outputs, shown at the right hand side of the drawing, which cause the required system responses. In some cases the outputs at the right hand side of Figure 5 are connected to common buses which also serve to provide control inputs to the line unit.

The timing pulses transmitted to a line N where N represents the number of any one of the extension lines, during the associated time-slot TN are produced by combining in a gate 100, waveforms TN and t1 to t8, the pulses t1 to t8 being applied to a common bus. The wire on which TN is applied is specific to each line unit and one of N wires and hence one out of N units is selected during each time slot. These waveforms are derived from a common timing circuit which is illustrated in Figure 15 of the drawings.

When an extension terminal N is "on-hook" there is an "on-hook" condition on the "on-hook" bus during TN. The "on-hook" condition is produced, in a manner to be subsequently outlined, by the common decoder of Figure 15 in response to signals received from the extension terminal N when "on-

hook". When the extension terminal N goes "off-hook", the "on-hook" signal at TN is suppressed and, using similar processes, is replaced by an "off-hook" condition on the "off-hook" bus at TN. These two conditions are extracted from the respective buses, using the gates 101 and 102 of Figure 5 and are used to control the state of a toggle 103. The set output from the toggle 103 is taken to the "any off-hook" bus.

A set condition on this bus serves to keep the condition on the Reset (R) bus high except when a pulsed reset condition inhibits a gate 104. This inhibit pulse is produced by a pulse circuit 153 which responds to the toggle 103 being reset by an "on-hook" condition by giving an output for one pulse period of the high speed (H/S) clock in a single time-slot TN.

It is a requirement of the system embodying the invention that an extension line should be guarded against intrusion when it is engaged on an exchange line call or an intercom call which is in the "privacy" mode. A toggle 108 in association with gates 105 to 107 provides the guard condition. It is set either by a "privacy" condition via gates 105 and 107 at TN, or by an "exchange line condition" via gates 106 and 107 at TN. The "privacy" condition is produced by the common decoder (Figure 15) in response to a "privacy" code from extension terminal N. An "exchange line latched" condition will be present whenever an exchange line cross-point on extension line N is operated (Figure 7).

The (TN+MN) marks used for controlling extension line and exchange line crosspoints (Figures 6 and 7) are produced by combining TN and the output of a gate 117 which is the 'mark forward' bus, in a gate 111.

If an extension terminal is engaged on an exchange line call or on a private intercom call when called, the combination of a calling mark MN and the set output of the toggle 108 puts a mark on the 'busy' bus via a gate 114 during the time-slot of the calling extension terminal. The MN mark is an output from the common decoder (Figure 15) in response to an intercom calling condition from an extension terminal. The mark MN will always occur during a time-slot other than TN according to which extension terminal is calling extension terminal N. At the calling extension terminal, the busy condition is gated from the bus by a gate 115 and is used to set a toggle 116. The set output from the toggle 116 gates a 'busy' signal to the tone-driver via gates 123 and 124. The tone-driver injects the signal onto the speech circuit of the calling extension terminal. The 'busy' signal is produced by combining a 412 Hz pulse waveform with the 'busy modulation' waveform at an AND gate 121 and combining the output of the

AND gate 121 with the set output of the toggle 116 at the gate 123, the output of the gate 123 being gated to the tone-driver via the OR gate 124. The 412 Hz waveform and the 'busy modulation' waveform are both derived from the common timing circuit of Figure 15.

If the extension terminal N is not engaged, the mark MN received from the calling extension terminal sets a toggle 112 which produces an output on the 'internal calling' bus via a gate 113 at time-slot TN. This condition is used to inhibit the internal calling width modulation (see subsequent description in relation to Figure 10 of the drawings) at TN, t6 in the common timing logic of Figure 15 so that an 'internal calling' signal is sent to the called extension terminal N. The toggle 112 is reset at TN, t7. If a further mark MN occurs in the next frame toggle 112 is again set and the calling condition is again sent to the called terminal and the toggle 112 is reset in TN, t7. This sequence will continue every frame while an MN signal is being sent, and when the MN signal stops the toggle 112 will remain reset for the whole frame and the internal calling signal at the called terminal will stop.

When extension terminal N is not engaged, and it is being called, the calling extension terminal requires confirmation in the form of 'buzz-back' that extension terminal N is actually being called. The toggle 108 is reset if extension terminal N is not engaged and under these conditions the calling mark MN is combined with the reset output of the toggle 108 at an AND gate 117 and passed to the 'mark forward' bus. At the calling extension terminal this mark sets a toggle 119 via an AND gate 118 at the time slot TN of the calling terminal and applies the 'buzz-back' signal, which is a continuous 412 Hz pulse train, to the tone-driver via gates 125 and 124, the set output of the toggle 119 being combined with the 412 Hz signal at the gate 125 to provide via the OR gate 124 the pulse train for the tone-driver. As with the 'internal calling' signal, 'buzz-back' persists only for as long as the intercom calling push button remains pressed.

When an exchange line is seized by extension terminal N, and the exchange line is held, there are simultaneous marks at the output of the gate 106 and on the 'exchange line held' input. These two marks are combined by an AND gate 109 and applied to a toggle 110. The toggle 110 may constitute the first stage of a two-stage shift register which is clocked by TN, t7. The effect of this is to produce a delay equal to a frame period before a change on the input to the first stage is effective on a driver wire for a P relay. As will be subsequently outlined with reference to Figure 21, the P relay is utilised to connect local microphone excita-

tion power to the extension terminal speech pair for intercom calls, or when an exchange line is held, but disconnects it when the extension terminal is through connected to an exchange line. Operation and release of the P relay is delayed because of system noise considerations.

It can be a requirement of the system embodying the invention that, when an extension terminal is involved in a private call which is established by both parties to the call operating their privacy key, or on a held exchange line, visual indication of the 'privacy' or 'hold' conditions should be given at the extension terminal. The same visual indicator is used for both cases, the 'privacy' condition being a steady indication and the 'hold' indication being modulated at the busy cadence. The hold indication is produced by combining the output of the gate 109 with the 'busy modulation' signal at a gate 120. Except when there is an output from the gate 109, the output of the gate 120 is high. The output from the gate 109 is modulated at the gate 120 by the 'busy modulation' signal and this appears on the 'hold/privacy' bus at the output from a gate 122 at TN, the toggle 108 being set under these conditions and its output is connected to the gate 122 at TN by means of a gate 154.

When on a private intercom call, an exchange line cannot be held and the output from the gate 120 remains high. This combined with the output from the toggle 108 at TN, produces an output on the 'hold/privacy'

bus at TN. This determines the signal sent to the extension terminal at TN. 18 which controls the 'hold/privacy' indicator.

Signalling between Extensions and Central Control

It has been shown that if all the control functions for a House Exchange system were centralised, while this could prove economical in a system with about 16 extensions, the lack of flexibility resulting from this approach would lead to a significant increase in cost per line when the control had to be used in a small system. An alternative approach is to be preferred in which an appreciable part of the control is decentralised, is allocated on a per line basis and is expanded with the number of lines.

The extent to which the control of the switching crosspoints is decentralised has been outlined in preceding paragraphs. The following section of the specification is concerned with the control incorporated in the extension line interface units and in the extension instruments, and with the method of signalling between these units.

There is a two-way signalling requirement between the instrument and the central equipment. The outgoing signalling that is, from central equipment to the instrument, is minimal in the present system, but due to the provision of named push button calling, signalling in the opposite direction is rather more complex. The signalling requirement for the present system is as follows:—

Incoming (extension to control)

Named push button calling
On-hook
Off-hook
Seize to originate exchange line call
Seize to answer exchange line call/
Hold
Privacy
Total

16 codes (possibly 24 or 32)

1 code

1 code

1 code

1 code

1 code

1 code

22 codes (possibly 30 or 38)

Outgoing (control to extension)

External calling signal }
Internal calling }
Hold/privacy }

visual and audible

visual

An objective for the system is to minimise the number of distribution wires to the instrument. Inasmuch as several of the signalling conditions are required when the subscriber is 'off-hook', it is difficult to devise a signalling system which satisfies all requirements using just the 2 wires of the speech pair without introducing complexities resulting in high cost. This implies that the reasonable minimum number of wires is four.

Regardless of how the coded signals are transmitted, in order to decode them, they have to be staticized. There is the choice of

decoding on a per line basis, involving a complete decoder per line, or of providing a decoder which is shared by all lines. In this last case, the gating requirements for serial access are less than they would be for parallel access, this recommending serial signalling on the line. If signals were decoded at each line unit, parallel presentation of signals would be preferable. As will be made clear later, a common decoder is used for translating the named push button codes, this constituting the major decoding requirement. However, this is not sufficient by itself to

justify the choice of serial signalling. A brief study of the problems of encoding and decoding on a parallel basis has been conducted with the conclusions that the serial scheme, which is described later, is probably as cheap as the best parallel scheme whilst offering a cost advantage in installation, because a parallel scheme would inevitably necessitate an increase in the number of wires per extension. It also permits a bothway signalling method which is simply adapted for changes in requirements, whereas provision of outgoing signals with parallel schemes would introduce considerable complexity.

Power feed and signalling information co-exist on the two-wire circuit with outgoing and incoming signals being handled on a time-sharing basis.

The method for feeding power and signal modulation to the line will be subsequently outlined. This results in a system capable of bidirectional baseband pulse transmission in the presence of power feed current which drives a stabilised supply at the extension instrument.

The present approach is to derive timing information directly from clock pulses sent from the central equipment.

A preferred arrangement is outlined below. Each extension instrument is scanned cyclically about 40 times per second as illustrated by Figure 10. During each time-slot period of about 1.6 mS, the control equipment sends eight clock pulses t1 to t8 i.e. the pulses towards the associated extension instrument. The extension instrument responds by sending five code bits T1 to T5 i.e. the pulses 32, to the central equipment, successive bits being sent to line in the period between the received clock pulses t1 to t6. The last three of the eight clock pulses i.e. the pulses t6, t7 and t8 from central equipment are binary width modulated by known methods. The sixth pulse 33 refers to 'internal calling' conditions, the seventh pulse 34 refers to 'external calling' conditions and the eighth pulse 35 refers to the 'hold/privacy' indication. Whilst pulse width modulation is preferred an alternative is to use pulse repetition following t6, t7 and t8 according to which signalling conditions apply. It will be noted the the polarity of the pulses 32 is inverted with respect to the polarity of pulses 31 and the reason for this inversion will be subsequently outlined.

Figure 11 illustrates the signalling principle in the form of a timing diagram for the circuit housed in an extension instrument.

Waveform A constitutes the eight clock pulses t1 to t8 received from central equipment during the time-slot assigned to the extension, with, as previously stated, with reference to Figure 10, the last three pulses' t6 to t8 pulse width modulated.

Figure 12 is a schematic of the logic circuit of an extension terminal and this circuit consists of three functions which are each shown within dotted lines. The circuits of the block 154 are used to derive and control the timing for the extension terminal function. The circuits of the block 155 are used to decode incoming signals and the circuits of the block 156 are used to encode the outgoing signals.

Waveform B of Figure 11 is generated as a result of driving a monostable 37 in block 154 of Figure 12 from the rising edges of the clock pulses t1 to t8 of waveform A. The nominal period of the monostable 37 is

125 μ s. By gating the waveform A.B. of Figure 11 with the first five outputs from an 8-way counter 38 in the block 154 of Figure 12, which is driven from the waveform B of Figure 11, five pulses T1 to T5 are derived and used in Figure 12 to gate five data bits d1 to d5 to line.

The falling edge of waveform B, in conjunction with the last three outputs from the 8-way counter 38 of Figure 12 define the sampling points for the pulse width modulated pulses t6 to t8 of Figures 10 and 11.

At the central equipment the incoming data pulses from the extension terminal are sampled 25 μ S after the falling edge of the transmitted clock pulses t1 to t5. This permits large variation in the period of the monostable 37 of Figure 12 without adversely affecting signalling performance. Similar tolerances apply to the derivation of sampling points for the width-modulated pulses.

A second monostable 39 in block 154 of Figure 12 which is of a period greater than 2 mS but less than a frame period (25.6 mS), is driven by the last output T8 from the 8-way counter 38. The counter 38 is reset when the monostable period elapses, thus ensuring that inadvertent advance of the clock due to detectable noise on the signalling pair does not multilate more than one time-slot.

Decoding of the incoming signals to the extension instrument results in the control of the state of three one bit stores 40, 41 and 42 in block 155 of Figure 12, the stores 40, 41 and 42 being associated respectively with the 'internal', 'external' and 'hold/privacy' signalling conditions. The signalling conditions are gated into the stores 40, 41 and 42 at T6, T7 and T8 respectively and each store is reset one bit period before its associated signalling bit is decoded at T6, T7 or T8. If a bit remains width modulated the associated store remains reset and thus gives no output. If the width modulation of a bit is suppressed then the associated store is set one bit period after being reset, and the store remains in the set state until reset in the next time-slot which will occur one frame period

later. The outputs from the stores are used to drive audible and visual indicators in the terminal via intermediate circuits which are not illustrated in Figure 12.

- 5 The output from the store 40, as previously stated, relates to the 'internal calling' condition and when an extension terminal is being called for intercom purposes there is a continuous output from the store 40 apart from the one bit reset period between T5 and T6 which occurs once per frame. This output from the store 40 persists for as long as the calling extension presses the calling push button, and the output is used to drive a tone-sounder that emits an audible indication that a call is present. The audible indication persists until the caller releases the calling push button or the handset of the called subscriber is lifted.
- 20 The output from the store 41, as previously stated relates to the 'external calling' signal, and is present whenever an exchange line carries a ringing condition. The 'external calling' signal is modulated at the standard ringing cadence, and the output of store 41 follows this cadence apart from the one bit reset period between T6 and T7 which occurs once per frame. The output from the store 41 drives a light emitting diode at the extension instrument, regardless of whether the extension is 'off-hook' or not and, if the extension is 'on-hook', it will also drive the tone-sounder at the ringing cadence. The tone is suppressed when the extension comes 'off-hook', but, if there is still a ringing condition on an exchange line, the visual indication will still persist. The external audible indication may be suppressed by operation of a mute push button on the extension instrument. This has no effect on the intercom audible signal nor does it affect the external visual indication. The system is arranged so that the intercom audible condition will always override any external condition that may be present.

- 45 The store 42, as previously stated, relates to the 'hold/privacy' condition and its output is used to drive a light emitting diode at the extension instrument. The store 42 is reset at T7 and set at T8 if either a 'hold' or a 'privacy' condition is present. The 'privacy' condition is steady, apart from the
- 50

one bit reset period between T7 and T8 which occurs once per frame, and the 'hold' condition is modulated at the busy cadence.

The block 156 of Figure 12 illustrates the main elements of the encoding circuits. A more detailed description of some of the functions of these circuits will be subsequently outlined in relation to Figure 14 of the drawings, but the circuits' basic operation is to load various conditions from five coding wires into a staticiser, that consists of five stores 43 that are scanned during each time-slot.

The contents d1 to d5 of the stores 43 are transmitted to line at T1 to T5 as a serial code via gates G1 to G5 and an OR gate as illustrated by the pulses 32 in Figure 10.

The five coding wires are outputs from a coding matrix 45, which takes inputs from the extension terminal pushbuttons and hook-switch. The inputs to the matrix 45 are translated by the matrix into five bit parallel codes and a coding control 44 detects, having allowed for contact bounce on the push buttons, when each five bit parallel code is ready for loading into the staticiser i.e. the stores 43. The coding control 44 then ensures that the contents of the staticiser are not altered by a change of code during the extension terminal time-slot when the staticiser is scanned.

Signal Encoding

As mentioned previously, there are 22 codes to be transmitted from the instrument to the central equipment. There now follows a brief description of a method for doing this. The signals are initiated by operation of switch contacts, either as a result of the extension handset being lifted, or by manual operation of push buttons. It is economically advantageous if the push buttons can be spring return, not involving any interlocking arrangements, and have a minimum of contacts; for example, one or two. The description that follows of one possible encoding technique is based upon these assumptions.

Codes are to be selected from the 32 combinations provided by a 5 level code, and a convenient selection for a 16 line system could be as follows:

	Code E D C B A	Named Push button	Code E D C B A	Other Push buttons
	1 0 0 0 0	1	0 0 0 0 0	on-hook
	1 0 0 0 1	2	0 1 1 1 1	off-hook
5	1 0 0 1 0	3	0 0 0 0 1	Hold
	1 0 0 1 1	4	0 0 0 1 0	Originate Call
	1 0 1 0 0	5	0 0 1 0 0	Answer Call
	1 0 1 0 1	6	0 1 0 0 0	Privacy
	1 0 1 1 0	7		
10	1 0 1 1 1	8		
	1 1 0 0 0	9		
	1 1 0 0 1	10		
	1 1 0 1 0	11		
	1 1 0 1 1	12		
15	1 1 1 0 0	13		
	1 1 1 0 1	14		
	1 1 1 1 0	15		
	1 1 1 1 1	16		

It will be noted that the named push button codes all have a '1' in the most significant position (E) whereas the remainder all have an '0' in this position. The code difference between the 'on-hook' and the 'off-hook' states is as large as this basic rule permits. The other four codes each have a single '1' in one of the four positions as shown. This permits very simple decoding of these conditions. Other variations of this somewhat arbitrary allocation of codes are obviously equally possible including an arrangement to accommodate another 8 named push buttons.

Figure 13 illustrates how all coded conditions may be set up on six coding wires (A, B, C, D1, D2 and E) using 2-contact push button switches.

The named push button codes in position A, B and C for codes 1 to 8 are respectively the same for the codes 9—16, the difference between the codes of the two groups being in position D. This permits very simple coding for both groups of codes. The contacts are connected to the appropriate code wires in accordance with the code combinations given above and when a set of contacts is connected to more than one code wire coding diodes are utilized to effect isolation of the code wires from each other. The first contacts of push button 1 to 8 which are normally open make as appropriate to the vertical code wires A, B and C, thereby connecting them to V which represents the logic 1 state. The other contacts of push buttons 1 to 8 which are also normally open make to the wires D and E thereby completing the code. The wire D1 is connected to the said other contacts of the pushbuttons 1 to 8 via an isolation diode which is poled such that there will always be an '0' on the wire D1 for this group of codes. Since only one push button should be operated at one time, it is possible to use the same coding diodes for both groups of codes.

An 'off-normal' signal is needed to initiate action by the logic circuits, and when code position 'E' is '1' it is convenient to use this, the first digit signalled, to provide this signal.

The second group of codes, except for 'off-hook' which is explained later, all contain an '0' at code position 'E', but otherwise use a similar approach.

In this case, however, since code position 'E' is '0', a contact is not needed to generate it, and, therefore, the second normally open contact is used to generate a special 'off-normal' signal as shown in Figure 13.

The 'hold', 'seize to originate' and 'seize to answer' codes are produced by connecting their first normally open contacts to code wires A, B and C respectively, all other digits in these case being zero.

When the privacy push button is operated, since it is not feasible to produce a 'D' pulse on line D1 because this would also produce an output on E, a section line D2 is provided over which to signal the 'D' pulse in this case, the two 'D' lines are buffered where they come together on the OR gate G14 in Figure 14.

Figure 14 illustrates the encoder logic. The gates G1 to G5 at the right hand side of the drawing appear also in Figure 12. The gates G1 to G5 correspond to code positions E to A respectively. It will be noted that the most significant bit E is gated at T1 and the least significant bit A at T5.

The codes are applied to the gates G1 to G5 via one bit stores S1 to S5 which correspond to the stores 43 in Figure 12. When the extension instrument is 'on-hook' a toggle 130, which is the first of a two-stage shift register comprising toggles 130 and 131, is reset. The reset output of the toggle 130 is combined with the 'on-hook' condition at a gate G6 and, at T6 this output is gated via a gate G7 to the reset inputs of the stores S2 to S5. The store S1 has its reset input tied to 0V. The reset outputs from the stores

are low and result in the 'on-hook' code 00000 being gated to line via the gates G1 to G5 respectively at T1 to T5.

5 When the extension instrument goes 'off-hook', the output from the gate G7 at T6 is suppressed, and replaced at T6 by an output from a gate G9 via a gate G8 in response to the 'off-hook' condition and the reset output of the toggle 130. This output
10 is applied to the set inputs of the stores S2 to S5, S1 being, as before, held in the reset state. The set outputs from the stores are high and result in the 'off-hook' code 01111 being gated to line via the gates G1 to G5
15 when these gates are scanned at T1 to T5.

If a push button is operated, there will be an 'off-normal' output from a gate G10 which is applied to the toggle 130. This toggle is set by clock pulse T8, and the toggle 131 is set
20 one frame later when the next T8 clock pulse is present. The output of the toggle 131 goes high when it is set and this output is used to clock the stores S1 to S5. The code wire inputs A, B, C, (D1+D2) and E carry a parallel code subject to which pushbutton
25 produced the 'off-normal' input, and the stores S1 to S5 are set or remain reset in dependence on the generated code. The frame delay produced by the toggles 130 and
30 131 is sufficient to ensure that any contact bounce has subsided before the stores S1 to S5 are loaded with a new code.

When the push button is released, the 'off-normal' condition is suppressed and the
35 toggles 130 and 131 are reset. The reset output from the toggle 130 enables the 'off-hook' input at the gate G8 and the 'off-hook' code is loaded into the stores S2 to S5 at the next T6 pulse.

40 When the extension instrument goes 'on-hook', the 'on-hook' code is loaded into the stores S2 to S5 via gates G6 and G7. The toggles 130 and 131 are held in the reset state by the output from G7 to ensure that codes
45 are not transmitted by inadvertent push button operation when the instrument is on-hook.

It will be noted that code changes can be effected only at T6 or T8, these pulses occurring
50 after the staticiser has been scanned.

Power Supply to Extension Instruments and Signalling between Instrument and Central Equipment

55 A major system feature is that powering for the extension terminal control circuits, and the bidirectional signalling between the extension terminal and control equipment (and vice versa) is combined on a single pair of conductors. Typically, this conductor pair
60 will be provided on 6½ lb cable with a loop resistance limit of 100 Ω. A power feed and bidirectional signalling arrangement is described in our co-pending Patent Application Number 13039/74 Serial No. 1437032.

In designing circuits to satisfy these requirements, due regard was paid to techniques for limiting the effects of interfering sources and of minimising signal distortion due, primarily, to the effect of line parameters at the higher frequency end of the
70 signal spectrum.

The necessary circuits which meet these requirements are described in the following paragraphs, initially with reference to
75 Figure 16.

The block within the dotted line 157 at the left hand side of Figure 16 represents the circuits of the extension line unit that are located in the central equipment, and the block within the dotted line 158 at the right hand side of Figure 16 represents the circuits of the extension terminal. The two blocks are interconnected by the line which is represented in Figure 16 by resistances RL, the maximum value of RL being 50 ohms.
80

The line RL is fed from a voltage source VL, a low impedance source being preferred to a high impedance source as regards the effect of interference. Likewise, the signal modulation and detection circuits are
85 balanced as far as possible so as to provide good longitudinal interference rejection.

At the line unit circuits 157, the 'data to line' signal modulates the constant voltage VL using a balanced voltage modulator 47, the voltage modulation on the line RL being
90 detected by a balanced threshold detector 48, the output of which is fed to the extension terminal load 51 which corresponds to the circuit illustrated in Figure 12 of the drawings.
100

Since the line voltage at the extension terminal 158 varies, due to line signalling and line length variations the voltage supply for the circuits of the extension terminal 158 is derived from a series voltage regulator 49. The input impedance of the voltage regulator 49 is arranged to be 120 Ω in order to match the line RL at the upper signal frequencies.
105

The output from the series regulator 49 is a 'primary' voltage reference for the balanced threshold detector 48 and for a current modulator 52 which provides for signalling from the extension terminal 158 to the line unit circuits 157. A 'secondary' voltage Vs for the load 51 is derived from a constant current source 50 in order to prevent load variations from reflecting into the line RL and thence into the signal detectors.
110

Signalling from the extension terminal 158, as just indicated, is by means of the current modulator 52. The series resistance of the current modulator 52 is varied in a binary manner in accordance with the 'data to line' signals that are applied to the modulator. This variation of the modulators series resistance effects modulation of the current drawn from the constant voltage source VL at the line unit circuits 157. The current
115
120
125

variations are differentially detected at the line unit circuits 157 in terms of the resulting voltage variations across a series resistance RD in each of the lines RL. These voltage variations or pulses are a.c. coupled by the capacitors C1 and C2 into the line unit's balanced threshold detector 53 the output of which is a 'data from line' signal.

The combined values of the resistances RD and the output impedance of the line unit's balanced voltage modulator 47 approximate to 120 Ω so as to match the line RL.

As previously stated, with reference to Figure 10, the current modulation from the extension terminal 158 is arranged so that the resulting voltage pulses on the line RL are of inverse polarity with respect to the voltage pulses from the line unit circuits 157. The purpose of this is to avoid extension terminal signals feeding back into the extension terminal logic via the balanced threshold detector 48.

The detailed arrangements and functions of the various circuits of Figure 16 will now be outlined in greater detail with reference to Figures 17 to 20 of the drawings.

With reference to Figure 17 of the drawings, a circuit diagram of the balanced voltage modulator 47 of Figure 16 is illustrated therein with typical values for the various circuit components being indicated. Transistors TR1, TR2 and TR3 and their associated circuitry provide the necessary control for line feed transistors TR4 and TR5, the collector/emitter circuits of which are each connected in series with one of the previously mentioned line resistances RD. A minimum voltage swing of 2 volts is required at the extension terminal 158 of Figure 16 in order to effect signalling which means that in order to cater for all line lengths, a voltage swing of about 5.5 volts is needed at the line unit 157.

When there is no 'data to line' signal applied to the bases of the transistors TR1 and TR2 via the associated resistance/capacitance parallel combination, the transistors TR1, TR2, and TR3 are switched off and, therefore, the voltages at the bases, and hence, the emitters of the transistors TR4 and TR5 are defined by the voltage drop across the 620 Ω resistances R1 and R2 which are respectively connected across the base/collector circuits of the transistors TR4 and TR5 and which are each connected in series with a separate one of the 5.6 K Ω resistances R3 and R4 across the electrical supply. The collectors of the transistors TR3 and TR2 are respectively connected to the junctions of the series resistance combinations R1/R3 and R2/R4 and the collector/emitter circuits of these two transistors are respectively connected in series with diodes D1 and D2. The emitter voltages of the tran-

sistors TR4 and TR5 are about 30.8 volts and 4.2 volts respectively.

When there is a high 'data to line' input signal at the bases of the transistors TR1 and TR2, the transistors TR1, TR2 and TR3 are caused to conduct and the transistors TR2 and TR3 become saturated. The resistances R1 and R2 are, therefore, under these conditions each shunted by a saturated transistor in series with a diode. This gives rise to a voltage drop of about 0.8 volts which takes the emitter voltages of the transistors TR4 and TR5 to about 33.5 volts and 1.5 volts respectively. This represents the required voltage swing of 5.4 volts.

Figure 18 illustrates the circuit diagram of the series regulator 49, the current modulator 52 and the constant current generator 50 of Figure 16 with typical values for the various circuit components being indicated.

In Figure 18 the series regulator is a well known type wherein the base, and hence the emitter of a transistor TR6 is held at a voltage defined by a reference diode Z1. The 120 Ω resistance R5 in the collector-base circuit of the transistor TR6 provides the necessary line-matching at the higher signal frequencies.

As previously outlined, the voltage supply for the load is derived from a constant current generator 50. The circuit of Figure 18 containing a transistor TR8 is a conventional constant current generator and it provides sufficient current to satisfy the peak 'steady' current for the load, any transient demand being provided by a capacitor C3 which is connected in shunt with the load. The constant current generator also provides sufficient current to ensure adequate voltage regulation from a reference diode Z2.

As previously outlined, signalling from the extension terminal 158 of Figure 16 is effected by means of current modulation. The requirement of the circuits in this respect is that a minimum current change of 9 mA, should be effective in the two series resistances RD in the line unit 157 of Figures 16 and 17. In order that this change can be guaranteed with all lengths of line, a current change of 24—25 mA is required at the extension terminal 158. A current modulator constituted by a transistor TR7 and its associated components is operated by the 'data to line' signals which are applied via a 15 K Ω resistance to the base of the transistor TR7. When this data signal is low the transistor TR7 is switched off and there is no current in the 430 Ω collector resistance R6 of the transistor. When the data signal is high, the transistor TR7 saturates and draws collector current I_c which is given by the following equation:—

$$I_c = \frac{V_p - 0.8}{R_6} = \frac{11.3 - 0.8}{430} = 24.4 \text{ mA}$$

wherein the figure 0.8 is the approximate voltage drop across the saturated transistor TR7 and a diode D3 in the emitter circuit of the transistor TR7.

5 On a long line, the current modulation results in a minimum current change of 9 mA in the series resistances RD, which, as illustrated in Figure 17, have a minimum value of 56 Ω . This gives a minimum
10 differential voltage change of $2 \times 56 \times 9 \times 10^{-3}$ i.e. 10 volt and this differential voltage change is, as is illustrated in Figure 16, capacitively coupled by the capacitors C1 and C2 to the balanced threshold detector 53.

15 At the line unit 157, signals from line are sampled coherently at instants when they are expected to be present. This process offers adequate protection against noise on the line.

20 At the extension terminal 158 operation is asynchronous and any noise signal exceeding the detector threshold will be treated as a valid clock pulse. For this reason it is necessary to provide as high a noise immunity as possible at the extension terminal.

25 At the line unit circuits 157 of Figure 16, the balanced threshold detector 53 can be based on the well known long-tailed pair circuit and a typical arrangement of such a circuit is illustrated in Figure 19 of the drawings.
30

35 As illustrated in Figure 19, the long-tailed pair is constituted by transistors TR17 and TR18 and their associated circuitry, the differential voltage change on the line RL being capacitively coupled by the capacitors C1 and C2 of Figure 16 to the bases of the transistors TR17 and TR18. The data output i.e. data from line signal, of the circuit for application to the system's logic
40 circuits is taken from the collector of a transistor TR16 whose base is resistively connected to the collector of the transistor TR18.

45 At the extension terminal 158 of Figure 16 the threshold detector is preceded by a linear, balanced amplifier the circuit of which is illustrated in Figure 20 of the drawings.

50 In Figure 20, a transistor TR9 and its associated circuitry constitutes a constant current source which ensures that two transistors G10 and G11 operate in a non-saturating linear mode. The bias conditions on the transistors TR10 and TR11 are arranged to provide adequate signal swing at the collector of the transistor TR11 when the two inputs,
55 which are capacitively coupled via capacitors C4 and C5 of Figure 16, are unbalanced by the presence of a line signal. If longitudinal noise is present, the base potentials of the transistors TR10 and TR11 are affected by an equal amount and their collector currents do not change. The output from the collector of the transistor TR11 is taken to the extension terminal logic via a simple threshold
60 detector which can be of any known type.
65

System Control

As mentioned earlier, to achieve the required cost characteristic for the (4+16) system, it is necessary to minimise the amount of common control equipment. The alternative to common control is to provide distributed control circuitry which increases as the system expands.

70 For both external calls and intercom. connections one function that is conveniently provided on a shared basis is a common decoder/marker which can be accessed by all lines and which responds to an intercom. code or exchange line calling conditions by marking the connecting link of the wanted extension. The coincidence of this mark with another mark extended on the link of the calling extension or exchange line causes the appropriate crosspoint to be operated as has been explained in preceding paragraphs. Access to the common devoder/marker is assigned to each line in turn in a scan which corresponds with the cyclic signalling scan described in preceding paragraphs. This prevents simultaneous seizure clashes, and, provided that the scan cycle is not unduly long, gives the impression to the users that instantaneous access to control equipment is always available.
80
85
90

95 The line unit, crosspoint and common circuitry needed for intercom. call connections have been described in preceding paragraphs together with the logic circuitry for exchange line access connections. From these descriptions it will be appreciated that it is not always economically beneficial nor is it possible, for the control equipment to be wholly distributed and that some common functions are unavoidable. Because of the number of crosspoints in the larger sizes of system, the objective has been to minimise the amount of logic at each crosspoint. To do this, it has been necessary to increase the line unit logic and it is clear that a careful trade-off analysis is needed to see that the relative balance of costs between these two areas is such that the overall system cost is optimised for all sizes of system.
100
105
110

115 Another objective which influences this trade-off is to minimise the number of control wires extended from the line units over the line links. If there are too many wires, the packaging on printed card boards may be rendered inefficient by interconnection limitations.
120

125 Apart from the common decoders, there are other items of common equipment such as the master clock and timing waveform generation circuits, power supplies, tone and signal generation equipment etc. Efforts have been made to minimise the cost accruing from these areas since they represent a per line cost factor which acts against the smaller sizes of system.

These aspects of the system embodying the invention are described in the following sections.

5 System Timing and Waveform Generation and Common Decoder:

10 In each of the time-slots eight clock pulses are, as previously stated in relation to Figure 10, transmitted to an extension terminal, the last three pulses of which may be width modulated. The signal received by each extension terminal consists of the clock pulses, at relatively high frequency, each burst occurring at the frame rate, which is low frequency. Since this signal is carried on a conductor pair adjacent to the speech pair, it is desirable to choose signal parameters which minimise the chances of crosstalk into the speech pair. For this reason, in the system being described, the 8 clock pulses are transmitted at a minimum rate of 5 kHz, which is above the telephone speech band, each burst occurring at about 40 Hz, which is below the speech band.

25 As has been previously mentioned, the required signal resolution demands that the signals are derived from a clock rate several times higher than 5 kHz, conveniently 40 kHz or 80 kHz.

30 Figure 15 illustrates the timing and waveform generation circuits in schematic form. The illustrated circuits use well known techniques and can be realised using commercially available or custom built integrated circuits.

35 The system is arranged so that high timing stability is not required. This means that a master clock 64 can be conveniently in the form of a commercial or custom built RC timer with external timing components. 40 The output from the master clock 64 is applied to a set of dividers and gates 65 which are arranged to produce in known manner several of the signals required by the system as explained in preceding paragraphs. 45 These signals include the 'high speed (H/S) clock', the 412 Hz 'busy tone' and the 'channel sampling pulses' which occur 25 μ s after the falling edge of the clock pulses which are transmitted to line. Another output from the block 65 is a stream of clock pulses at the 50 5 kHz rate which are divided by an 8-way counter 66 to give the eight pulses t1 to t8 that make up each time-slot. Each t8 pulse drives a 16-way counter 67 at the output of which is provided the sixteen time-slot pulses T1 and T16 referred to in preceding paragraphs, in general terms as TN. In addition to the high speed master clock 64 there is a low speed clock 68 having a clock rate of about 10 Hz. The clock 68 may be 60 derived from the master clock 64 by dividing down. Alternatively, because the required rate is only about 10 Hz, a more economical approach would be to provide a separate

timer for this purpose. The low speed clock 68 does not need to be synchronous with the master clock 64.

The output from the low speed clock 68 is applied to a set of dividers and gate 68A which produce the 'busy/hold modulation' waveform, the 'ringing cadence' waveform, and the '1.6 second delay' waveform.

The last three pulses t6 to t8 on each time-slot are binary width modulated by another output of the block 65 according to the presence or absence of the associated signalling conditions. These associated conditions are presented on the 'hold', 'privacy', 'external call' and 'internal call' buses at the left hand side of Figure 15 in synchronism with the time-slots to which they refer. The outputs t6, t7 and t8 from the counter 66 combine with their associated signalling condition in gates 53, 52 and 51 respectively. If, for example, there is an 'internal call' signal present in time-slot TN, the output from the gate 53 will go low at TN.t6 so disabling a gate 55 via a gate 54. This means that the width modulation output from the block 65 is suppressed during t6 so that a normal length clock pulse is transmitted by a gate 56 at TN.t6. Similar processes apply to the pulses at t7 and t8.

In any time-slot, data bits are received from an extension terminal immediately after clock pulses t1 to t5 have been transmitted. These pulses appear on the common 'line multiplex' bus which is shown at the left hand side of Figure 15. The conditions on this line are sampled 25 μ secs after they are due to appear by means of the 'channel sampling pulses' and are shifted into the 5-bit store 69. The five outputs from the stores 69 are applied to a common decoder 57. The decoder 57 is enabled at t6 and it gives an output on one of 22 output lines according to the code on its input lines. Sixteen outputs M1—M16 generally referred to as MN, are wired directly to the associated line unit logic (Figure 5). The other six outputs as is illustrated in Figure 15 are passed to common buses and, thence, to the appropriate parts of the system.

Transmission Path

In considering the transmission path, which includes the transmission circuit of the extension instrument, the system distribution, cross-exchange path and the exchange line unit, the economical benefits have been demonstrated of using conventional techniques in this path where possible. To avoid costly format translation at the exchange line unit, the proposed extension instrument will have a standard transmission circuit and dial for exchange line signalling purposes. An option, is to equip the extension instrument with a push button pad. This pad would

operate directly to the exchange line or would be associated over the speech pair, and not via control equipment, with format translation equipment at the exchange line interface when necessary.

In designing the exchange line interface and extension instrument powering circuits some desirable objectives are:—

1. To avoid dial pulse repetition which normally arises from the need to isolate the exchange line loop from the extension line loop because of powering arrangements.
2. To have an arrangement which permits simple power fail fallback.

The implication of both of these objectives is that attempts should be made to provide a clean wire path between an extension instrument and the exchange line when on external connections for the purposes of originating a call.

On the majority of calls there is only one extension instrument connected to the exchange line and, in principle, there are few problems in powering this instrument from the local exchange.

When the add-on third party facility is involved, two extension instruments are connected together in parallel on the one exchange line and it has been found that it is possible to provide sufficient power from the exchange to give a satisfactory transmission level from two parallel connected extension instruments. The question of signalling to parallel connected instruments from the exchange does not arise in this case. The major problem with the add-on facility arises during the actual process of adding-on. The first extension, as previously outlined, disconnects the exchange line and puts it on to hold before connecting to the third party prior to adding him on to the exchange connection. When the exchange line is on hold it cannot provide power to the extension instrument and the necessary power must be provided locally during the add-on process.

In principle, it is possible to hold the exchange line, and to connect to another extension for consultation using that part of the matrix normally devoted to intercom connections. There is a high probability, however, that, following consultation, the consulted party may need to take control of the exchange line by transfer or be added-on as a third party. In both cases it would be necessary, to set up another crosspoint on the held exchange line link. In the system embodying the invention third party connections, either for consultation, transfer or add-on, are set up on the exchange line link seized by the first party as well as for an intercom connection. This approach permits

the minimum of control variation from the normal intercom. set-up procedure.

Before considering further details of the exchange line access path, some of which have already been discussed in connection with Figures 7, 8 and 9, the powering arrangements for intercom connections are considered. The number of power feed points should be minimised to reduce cost. If a single stage rectangular matrix were to be used, one power feed point per connecting link would suffice but, having opted for a folded matrix, on the basis that it is simpler to control there appears to be no alternative to providing a power feed point per extension. A possible arrangement by which this could be achieved is illustrated in Figure 21 of the drawings which shows a section of the matrix with balanced transformer power feed for each circuit.

Each extension is connected to the matrix by a P relay which has a changeover function. In one position the P relay contacts connect the extension to the intercom section of the switching matrix, as illustrated in Figure 21 for extensions 2 and N. In the other position, the extension is connected to the exchange access section of the matrix, as illustrated in Figure 21 for extension 1. Normally the P relays remain powered with their contacts making to the intercom section. In this position, the extension instruments are each powered when off-hook by means of an associated transformer 120. A third winding on each of the transformers 120 is used to inject supervisory tones (busy and buzz-back) onto the associated speech pairs. When on intercom connections, both extensions are powered in parallel by their own transformer 120. This means that as many extensions as required can be interconnected on an intercom conference without degradation of speech level due to power starvation.

When an extension is on an exchange line connection, local power is not required. The drive to the P relay is suppressed, and the P contacts connect the extension to the exchange line access portion of the matrix, i.e. as illustrated for extension 1 in Figure 21.

However, when the 'hold' facility is invoked the exchange line is disconnected, as will be explained later, and the exchange line power is no longer available for powering instruments during consultation etc. When an exchange line is held by an extension, the extension's P relay is operated, as has been previously explained, to connect it to its power feeding transformer 120. This permits consultation to proceed using the normal intercom procedures. When either of the extensions in consultation releases the 'hold' condition, the P relays of both parties involved in consultation are released, so interconnecting the extensions with the exchange

line using crosspoints in the exchange line connecting link. This technique ensures that local power can never be applied to an exchange line and vice-versa.

5 The logical functions of the exchange line unit have previously been described with reference to Figure 8, but the physical function of this unit, as illustrated by Figure 21 will now be outlined.

10 When an extension terminal seizes an exchange line either to answer or make a call, the extension is connected to the seized exchange line connecting link by means of the P relay and crosspoints 121 as shown for extension 1.

15 Considering the case where this is an incoming call on exchange line 1, a PF relay and the H relay are both in the illustrated state, but the S relay contacts are making to the ringing detector. When the line is seized, in response to a 'seize to answer' code from extension 1, the S relay is released and the S contacts make to the exchange line connecting link. In this condition the extension is through connected to the exchange on a line which may be carrying ringing current at the instant the line is received. The extension instrument loop, when detected at the exchange would 'trip' the ringing, but only after a delay of 200 mS or more. During this time the extension subscriber could be subjected to a high level ringing signal in his earpiece. To avoid this, the H relay is operated for at least 300 mS when the line is seized, so providing an answering loop via the resistance RT to trip ringing whilst disconnecting the extension from the exchange line. The H relay is a make before break type so that there is no transient disconnection of the exchange line when the extension is reconnected after the delay has elapsed.

40 When seizing an exchange line to make an outgoing call, a similar operation takes place, resulting in a 'clean-wire' connection between the extension and exchange line which permits loop impulse dialling from the extension instrument without impulse repetition being necessary.

50 Under system power fail conditions it is desirable to maintain some form of service on the exchange lines. The PF relay is provided for this purpose. When the system is powered, the PF relay is powered with its contacts in the state illustrated in Figure 21. When power fails, the PF relay releases and in the case shown, connects extension 1 to exchange line 1. No other connection is made since the crosspoints 121 release when the power fails. All exchange lines may be connected to nominated extensions in the same manner. Such extensions are provided with standard bell or tone sounder circuits which are responsive to the exchange line ringing conditions.

65 The function of the ringing detector circuit

has previously been referred to in connection with Figure 8, but it will now be considered in greater detail with reference to Figure 22.

The main function of the ringing detector circuit is to detect when a ringing condition exists on the exchange line and to produce a logical signal which as previously explained, produces two effects. First, it produces a 'line n calling' mark which is applied to the exchange line common logic of Figure 9 or alternatively if the line is not calling, a 'line n free' mark. Second it produces a condition on the common 'external calling bus' which gives rise to the external calling condition at all extensions.

80 It is necessary to check that a valid ringing condition exists on the line before producing the above-mentioned logical signal. The ringing condition is subjected to a persistence check producing by the integrating circuit, illustrated in Figure 22. This circuit has an integrating time constant of about 100 mS when a relay contact RR1 is open, the output from transistor TR15 is low. If the contact RR1 is closed, and remains closed, the collector output from the transistor TR15 goes high after about 100 mS. If the contact does not remain closed for this period the collector output of the transistor TR15 remains low.

85 The contact RR1 reflects the presence or absence of a ringing condition on the exchange line as detected by the associated relay RR. This relay is bridge fed from the line via contacts S1 and S2 and a capacitor.

90 When there is no ringing condition, the output from the transistor TR15, which, as previously stated, is low, is inverted and then gated at a gate G63 with the 'not seize' signal. The output from the gate G63 remains low and the toggles 130 and 131 remain reset. The reset output from toggle 131 is the 'line n free' signal whilst the set output is the 'line n calling' signal.

95 When ringing is detected, the output from the gate G63 goes high and toggles 130 and 131 are set and the 'line n calling' signal is produced.

100 When a subscriber seizes the line, the 'not seize' signal is inverted and the toggles are reset.

105 If ringing ceases before the line is seized, the output from the gate G63 goes low but the 'not seize' signal is maintained. Under these conditions the 1.6 second clock becomes effective and the toggles 130 and 131 act as a two-stage counter. This means that the toggles are not read until at least 3.2 secs. after the ringing condition is suppressed. The reason for this delay is that it is necessary to check that ringing has actually been suppressed, in so doing differentiating between 'permanent' suppression, and the normal gaps in the ringing cadence.

110 The system outlined in the preceding paragraphs gives the following operating features, 130

which are consistent with those of the present "Keymaster" type systems and which will prove attractive to telephone subscribers.

1. System Capacity:
 - 5 1 exchange line + 2 extensions (1+2) extensible to
8 exchange lines + 24 extensions (8+24) (and possibly 16+32)
2. Intercom. Calls
 - 10 (a) Intercom. calling is to be by means of individual non-locking named push buttons.
 - 15 (b) If the wanted extension is 'on-hook', operation of the named push button produces a continuous audible signal at the wanted extension instrument, and 'buzz-back' at the calling extension instrument whilst the push button is depressed.
 - 20 (c) If an extension is 'off-hook', and on an intercom. call, direct connection is made upon operation of the push button.
 - 25 (d) If the wanted extension is 'off-hook' and on an exchange line call, or has invoked 'privacy' on an intercom. call, the calling extension is parked with tone warning.
3. Exchange Line Calls:
 - (i) Outgoing Calls.
 - 30 (a) The extension comes off-hook, and presses a 'seize to call' push button. This may be locking or non-locking.
 - (b) If all exchange lines are busy the extension is parked with tone warning.
 - 35 (c) If an exchange line is free, it is seized and the local exchange dial tone is received.
 - (d) The call is set up using a dial or push button pad.
 - 40 (ii) Incoming Calls.
 - (a) A visual indication of an incoming call is given at all extension instruments. The indication may be maintained when the instrument is 'off-hook' to indicate the presence of a "queue". The indication is modulated at the standard ringing cadence.
 - 45 (b) The visual indication may be accompanied by an audible indication. Options are to provide either a limited number of switchable audible units according to individual requirements or there may be a unit associated with each extension instrument. In this last case the extension instrument must have the means for muting the signal whilst permitting an audible internal calling signal to be presented.
 - 50 (c) To answer an incoming call the handset of the extension instrument is lifted and a 'seize to answer' push
 - 55 button is pressed, the push button may be of the locking or non-locking type.
4. Hold Facilities
 - 65 (a) An extension instrument has the means for holding an answered or originated exchange line call to permit the following:—
 - 70 Consultation
 - Call transfer
 - Add on third party.
5. Supervisory Tones:
 - 75 The system provides tones, detectable in the earpiece, as follows:—
 - buzz-back (see item 2(b) above)
 - warning tone (see items 2(d) and 3(i)(b) above).
6. Privacy:
 - 80 Extension instruments may be provided with a privacy feature whereby intercom. calls may be guarded against intrusion. The privacy guard condition is cancelled when the extension instrument goes 'on-hook'.
 - 85
7. Long Line Extensions:
 - The system allows the provision of long line extensions with limited facilities.
8. P.B.X. and Tie-Line-Interworking:
 - 90 The House Exchange Telephone System or several similar systems can be interfaced to a PABX network or over tie lines in order to facilitate named push button calling through the PABX or over the lines to other House Exchange systems.
 - 95
9. Power Fail Fallback:
 - The system is designed to support communication on exchange lines under system power fail conditions.
 - 100
10. Optional Attendant's Position:
 - On the larger installations it may sometimes prove worth while to provide a special attendant instrument on which all incoming exchange calls can be terminated. This instrument would be provided with direct access to all exchange lines by individual keys and individual exchange line status lamps.
 - 105
11. Expansion of System from (8+16) to (16+32)
 - 110 A possible arrangement is one where two basic (8+16) systems are coupled together to give a (16+32) system with little increase in cost per line.
 - 115

WHAT WE CLAIM IS:—

1. A House Exchange telephone system



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 - Call transfer
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The House Exchange Telephone System or several similar systems can be interfaced to a PABX network or over tie lines in order to facilitate named push button calling through the PABX or over the lines to other House Exchange systems. 95
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The system is designed to support communication on exchange lines under system power fail conditions.
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On the larger installations it may sometimes prove worth while to provide a special attendant instrument on which all incoming exchange calls can be terminated. This instrument would be provided with direct access to all exchange lines by individual keys and individual exchange line status lamps.
 11. Expansion of System from (8+16) to (16+32) 110

A possible arrangement is one where two basic (8+16) systems are coupled together to give a (16+32) system with little increase in cost per line. 115
- WHAT WE CLAIM IS:—
1. A House Exchange telephone system



including a plurality of extension line units which are radially connected to a switching matrix using a first conductor pair for each extension and to a common control unit using a second conductor pair for each extension, the first conductor pair being used for speech transmission and signalling to a public exchange whilst the second conductor pair is used for supplying power to the extension and for system signalling, the extension line units being successively connected to the common control unit in an associated time slot; and a number of exchange line units which are radially connected to the switching matrix and to the common control unit, wherein the switching matrix is arranged so that the first conductor pair of each extension line unit crosses the first conductor pair of each of the other extension line units at a unique crosspoint and also crosses a speech conductor pair of each exchange line unit at a unique crosspoint, the switching matrix including a crosspoint switching circuit at each of the said crosspoints and wherein the switching of the crosspoints is controlled in a time division multiplex mode.

2. A House Exchange telephone system as claimed in claim 1 wherein the first conductor pair of each extension is connected to the switching matrix by means of a speech interface unit and wherein the second conductor pair of each extension is connected to the common control unit by means of an associated extension unit.

3. A House Exchange telephone system as claimed in claim 1 or claim 2 wherein the crosspoint switching circuit at each crosspoint includes a reed relay unit having two reed contact inserts located in a single solenoid, the reed inserts being operable on energisation of the solenoid to effect interconnection of the conductor pairs at the crosspoint; and means for effecting energisation of the solenoid.

4. A House Exchange telephone system as claimed in claim 3 wherein the crosspoint switching circuit at each crossing of the first conductor pairs also includes first coincidence means responsive to the coincidence of a marking pulse of one of the extension line units associated with the crosspoint and a time slot pulse of the other one of the extension line units associated with the crosspoint to provide an output signal; a bistable device which is set by the said output signal of the first coincidence means to effect energisation of the crosspoint solenoid; and means for resetting the bistable device in response to either of the extension line units terminating a call.

5. A House Exchange telephone system as claimed in claim 3 or claim 4 wherein the crosspoint switching circuit at each crossing of each of the first conductor pairs of the extension line units with the speech con-

ductor pairs of the exchange line units also includes second coincidence means responsive to the coincidence of a time slot pulse of the extension line unit associated with the crosspoint and a time-coincident marking pulse to provide an output signal, the time-coincident marking pulse being generated when the exchange line unit associated with the crosspoint is faded by the said associated extension line unit and is free, or when the said associated exchange line unit is calling and the said associated extension line unit generates a call acceptance signal, or when the said associated exchange line unit is held and the said associated extension line unit is called for consultation by another extension line unit; a bistable device which is set by the said output signal of the second coincidence means to effect energisation of the crosspoint solenoid; means for resetting the bistable device in response to the said associated extension line unit terminating an exchange line call; and means for providing, and applying to each of the other extension line units, an output signal when the said associated exchange line unit is held.

6. A House Exchange telephone system as claimed in any one of the preceding claims wherein each exchange line unit includes an exchange line ringing detector which is connected to the associated exchange line; first switching means which normally connect the associated exchange line, when free, to the ringing detector and which are operated when the associated exchange line is seized to connect the seized exchange line to a matrix connecting link; second switching means which normally connect the matrix connecting link to the switching matrix and which are operated in response to the operation of the first switching means to disconnect the exchange line from the matrix connecting link and to terminate the exchange line so as to maintain the line in a busy condition during consultation and line seizing, the time lapse between operation of the first and second switching means being arranged so that a ringing condition at an exchange line seizing extension line unit is prevented; a persistence check circuit which is adapted to effect validation of a ringing condition on the exchange line and to provide an output signal in response to a valid condition; a bistable device which is set by the output signal of the persistence check circuit to provide an output signal which produces audible and visible exchange line calling indications at each of the extensions; and means for resetting the bistable device in response to an exchange line call being answered or ceasing.

7. A House Exchange telephone system as claimed in any one of the preceding claims wherein each extension line unit includes first



- gating means for gating a number of time pulses to the extension line unit during the associated time slot; second gating means for detecting during the associated time slot the condition of the hookswitch of the extension instrument associated with the extension line unit, the outputs of the second gating means effecting the setting and resetting of a bistable device, the set output of which indicates that the extension instrument is off-hook and is used to prevent release of any associated crosspoint of the switching matrix that may have been made, the reset output of the bistable device indicating that the extension instrument is on-hook and is used to effect the release of any of the said associated crosspoints that may have been made; third gating means for detecting during the associated time slot when the extension line unit is engaged on an internal call which is in a privacy mode or an exchange line call; means for pulse generating a marking for controlling the crosspoint switching circuit at each of the switch matrix crosspoints associated with the extension line unit; means for generating a pulse that indicates that the extension line unit is busy when called; means for detecting a busy condition at a called extension line unit and generating a modulated busy signal for application to a tone-driver situated in a calling extension instrument; means responsive to the receipt of a marking pulse from a calling extension line unit to provide an internal calling signal for transmission to the calling extension line unit if the called extension is free; fifth gating means for causing a confirmation signal to be transmitted to a calling extension line unit indicating that a call has been received; means responsive to the receipt of a confirmation signal from a called extension line unit to generate a modulated signal for application to the calling line speech pair; means responsive to an exchange line unit being seized when in a held condition to provide a signal for effecting the disconnection of the extension line unit from an associated power feed transformer; and sixth gating means for indicating a privacy or exchange line held condition.
8. A House Exchange telephone system as claimed in any one of the preceding claims wherein the extension line units are cyclically scanned, wherein the control unit generates and sends eight time pulses to each of the extension line units on the associated second conductor pair during the associated cyclic scanning time slot, the extension line units each being responsive to receipt of these pulses by sending a maximum of five coded information pulses to the control unit on the associated second conductor pair, successive information pulses being sent in the period between the first six time pulses, the polarity of the coded information pulses being inverted with respect to the polarity of the time pulses, and wherein the last three time pulses are each binary width modulated to respectively indicate an internal calling condition, an external calling condition and an exchange line hold or privacy mode condition.
9. A House Exchange telephone system as claimed in claim 8 wherein each extension line unit includes pulse generating and controlling means for providing eight extension timing pulses in response to the receipt of, and in the periods between, the eight system timing pulses; decoding means for decoding the binary width modulated pulses during the last three extension timing pulse periods; and encoding means for providing, in response to signals generated at the extension instrument, the said maximum of five coded information pulses during the first five extension timing pulse periods.
10. A House Exchange telephone system as claimed in claim 9 wherein the decoding means includes three one bit stores which are each associated with a separate one of the said modulated pulses; first gating means for successively gating the modulated pulses into the stores during the said three extension timing pulse periods, each of the stores being reset by the extension timing pulse which precedes the associated gating pulse.
11. A House Exchange telephone system as claimed in claim 9 or claim 10 wherein the encoding means include a coding matrix for translating signals generated at the extension instrument into five bit parallel codes; a staticiser having a store for each bit of the parallel code, the stores being cyclically scanned by the first five extension timing pulses during each time slot to cause a five bit serial code to be generated; a coding control unit for controlling the loading of each parallel code into the staticiser and for ensuring that the contents of the staticiser are not altered during the time slot of the extension line unit; and second gating means for gating the serial code to the control unit on the associated second conductor pair.
12. A House Exchange telephone system as claimed in claim 11 wherein the extension instrument includes a push button array, each push button having switch contacts associated therewith for generating the said signals, and wherein signal are also generated by switch contacts associated with the extension instrument's hookswitch.
13. A House Exchange telephone system as claimed in any one of the preceding claims which includes a constant voltage source for supplying power to each of the extensions on the associated second conductor pair; voltage modulation means for modulating the voltage supply to each of the extensions in accordance with the information data being sent from the control unit; first detection means for detect-



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- ing the voltage modulation at each of the extensions, the first detection means being capacitively coupled to the associated second conductor pair and adapted to provide an output signal representative of the voltage modulation; voltage regulation means for each of the extensions; current modulation means for each of the extensions, the series resistance of each of the current modulation means being varied in a binary manner in accordance with the information data being sent from the associated extensions, the series resistance variations effecting modulation of the current drawn from the constant voltage source at the extension time unit; means responsive to the current modulation at the control unit to provide corresponding voltage variation; and second detection means for detecting the voltage variations at the control unit, the second detection means being capacitively coupled to the associated second conductor pair and adapted to provide an output signal representative of the voltage variations.
14. A House Exchange telephone system as claimed in any one of the preceding claims which includes decoding and marking means which are common to all exchange and extension lines and accessible to each extension line unit in the associated time slot, the decoding and marking means responding to extension line unit calling conditions by initiating the establishment of a connection to the wanted line.
15. A House Exchange telephone system as claimed in any one of the preceding claims which includes third switching means for each extension line unit, each of the third switching means being arranged to normally connect the associated extension line unit to a power feed transformer via an extension line section of the switching matrix, and to connect the associated extension line unit, when on an exchange line connection, to an exchange line section of the switching matrix thereby effecting disconnection of the extension line unit from the associated power feed transformer, each of the power feed transformers having a winding associated therewith for injecting supervisory tones onto the first conductor pair of the associated extension line unit.
16. A House Exchange telephone system as claimed in any one of the preceding claims which includes means for connecting an exchange line unit directly to an extension line unit under system power fail conditions.
17. A House Exchange telephone system as claimed in any one of the claims wherein the crosspoints of the switching matrix are arranged in groups in order to facilitate modular expansion of the matrix, each group of crosspoints and the associated crosspoint circuitry being accommodated on a single printed circuit board.
18. A House Exchange telephone system as claimed in any one of the preceding claims which includes sixteen extension line units and four exchange line units.
19. A House Exchange telephone system substantially as hereinbefore described with reference to the accompanying drawings.
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For the Applicant.