Miniature, ten-line telephone exchange

Small relays give low power, quietness and secrecy

by L. D. Gunn

With the better availability of dial telephones now on the market several articles have been published in various magazines with the object of improving their utility. Some articles have given circuitry which uses uniselectors to establish connexions between up to 23 telephones, and others have used integrated-circuit modules for selective ringing systems. The disadvantages of using uniselectors are the high power requirement and the mechanical noise, while designs using integrated circuits use a common speech path, which does not give secrecy to the established conversation. The system described overcomes these objections by using miniature relays, which are fairly easily obtainable from surplus stores at reasonable prices.

There are four elements to the system. The Call Sensor identifies the calling line and provides for it a discrete circuit to the Transmission Feed, which supplies the telephones with power for their microphones. It also monitors the progress of a call and relays information to the Control, which sequences the system according to information received from the transmission feed. The fourth element is the Binary Counter, which consists of a group of relays which count the dialled pulses from the caller to select the wanted line, and provide a discrete path from it to the transmission feed, which also supplies ringing current for the a.c. bell until the handset is lifted.

When the system is in the normal state all the lines are connected to the call sensor via the contacts of two relays in the control. When a call is originated, the call sensor identifies the calling line and provides a discrete connexion from it to the transmission feed, which then tells the control that a call is about to mature. The control disconnects all the lines from the call sensor and prepares a path for the dial pulses to be transferred from the transmission feed to the binary counter. When dialling is completed, the control connects ringing current to the wanted line, via the transmission feed and the appropriate contacts of the binary counter relays. The ringing current is interrupted periodically by a transistorized timing circuit in the control, since continuous ringing would be very irritating. When the called telephone is answered, the transmission feed signals to the control that the ringing current can be disconnected. The speech path is then established. The control holds all the appropriate relays operated until both telephones are replaced on their rests.

Circuit operation

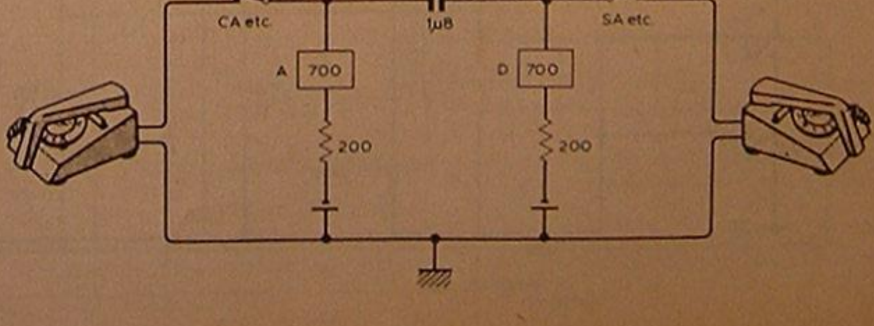
Originating calls sensor. The circuit consists of six relays and twenty-one diodes. Two of the relays, BC and BD connect the four sensing relays, CA, CB, CC and CC, to the lines via diodes which are coded so that different combinations of the sensing relays operate when a telephone is lifted to make a call. The relays are operated in accordance with Table 1 and their contacts are arranged to provide a path for one line to connect with the transmission feed relay A. One contact on each of the sensing relays is used to hold the relay operated under the control of the transmission feed and control elements.

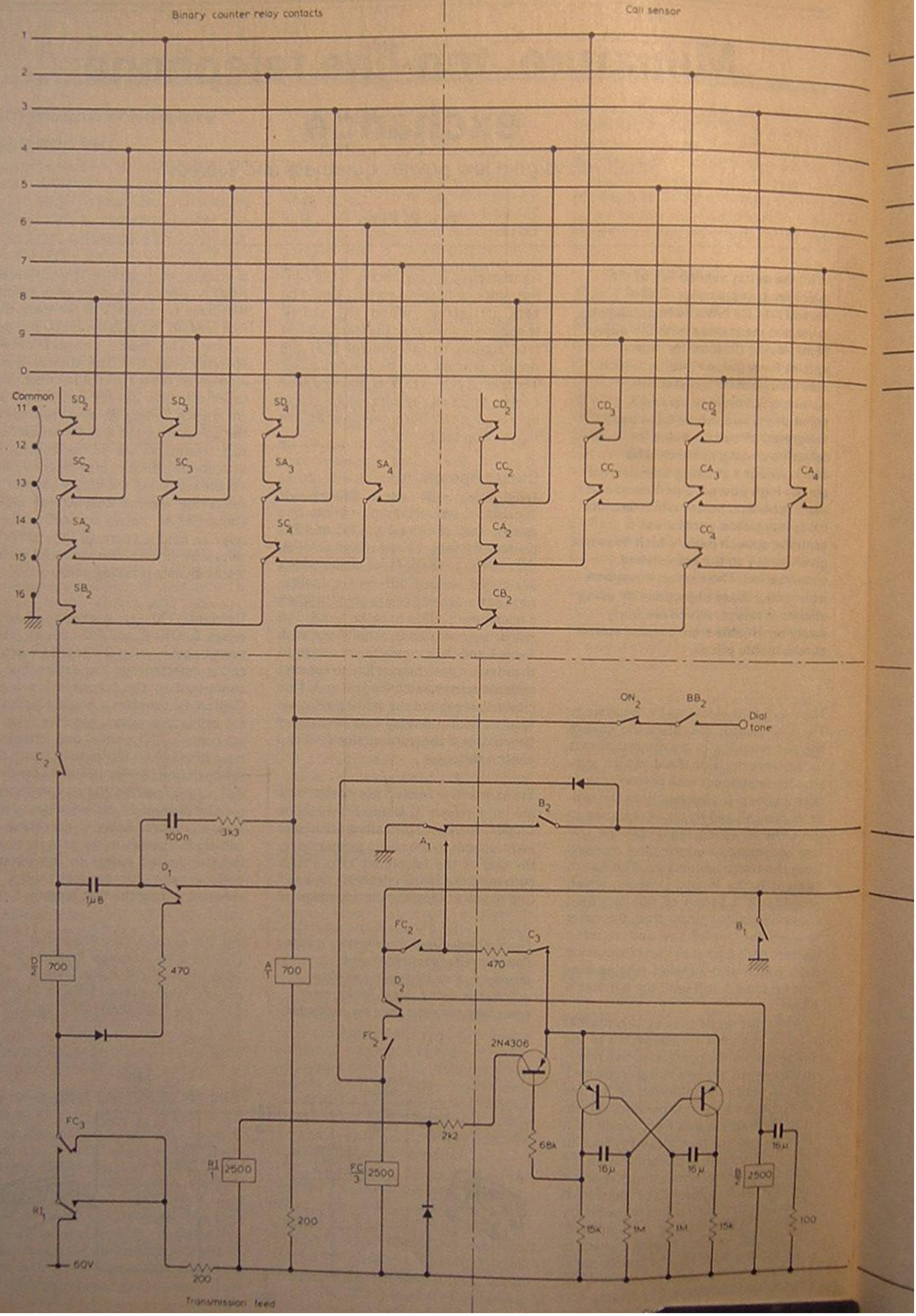
Transmission feed. This comprises the three relays, A, D and FC. Relay A supplies current to the calling telephone and responds to the pulses generated by the dial of the telephone. D provides current to the called telephone, in addition to controlling the disconnexion of the ringing current when it is answered. Relay A operates when the circuit of the telephone is extended to the transmission feed on the path set up by the call sensor. The make contact of A1 operates relay B in the control. Soon afterwards (about 20 milliseconds) the caller will hear dialling tone and may commence dialling. Relay A responds to the pulses from the dial, its break contact sending pulses to the control to indicate that dialling is in progress, and via the control to the binary counter to select the wanted line. At the make contact of A1, pulses are sent to the B relay to hold it operated (it is slow to release by virtue of the shunt capacitor) whilst dialling is taking place.

Control. This is a group of four relays B, ON, C and BB and, as mentioned above, relay B operates when a call is detected and the calling line is connected to the transmission feed. Contact B1 provides a holding path for the call sensor relays, operates relay C via contact ON1 normal and energizes relay BB. Contact B2 prepares a path for the operation of relay ON when the first dial pulse is received and also prepares a path for passing the dialled pulses to the binary counter. Relay C operating at contact C1 completes the path for passing the dialled pulses to the binary counter and for holding relay C operated during the dial pulsing. Con-

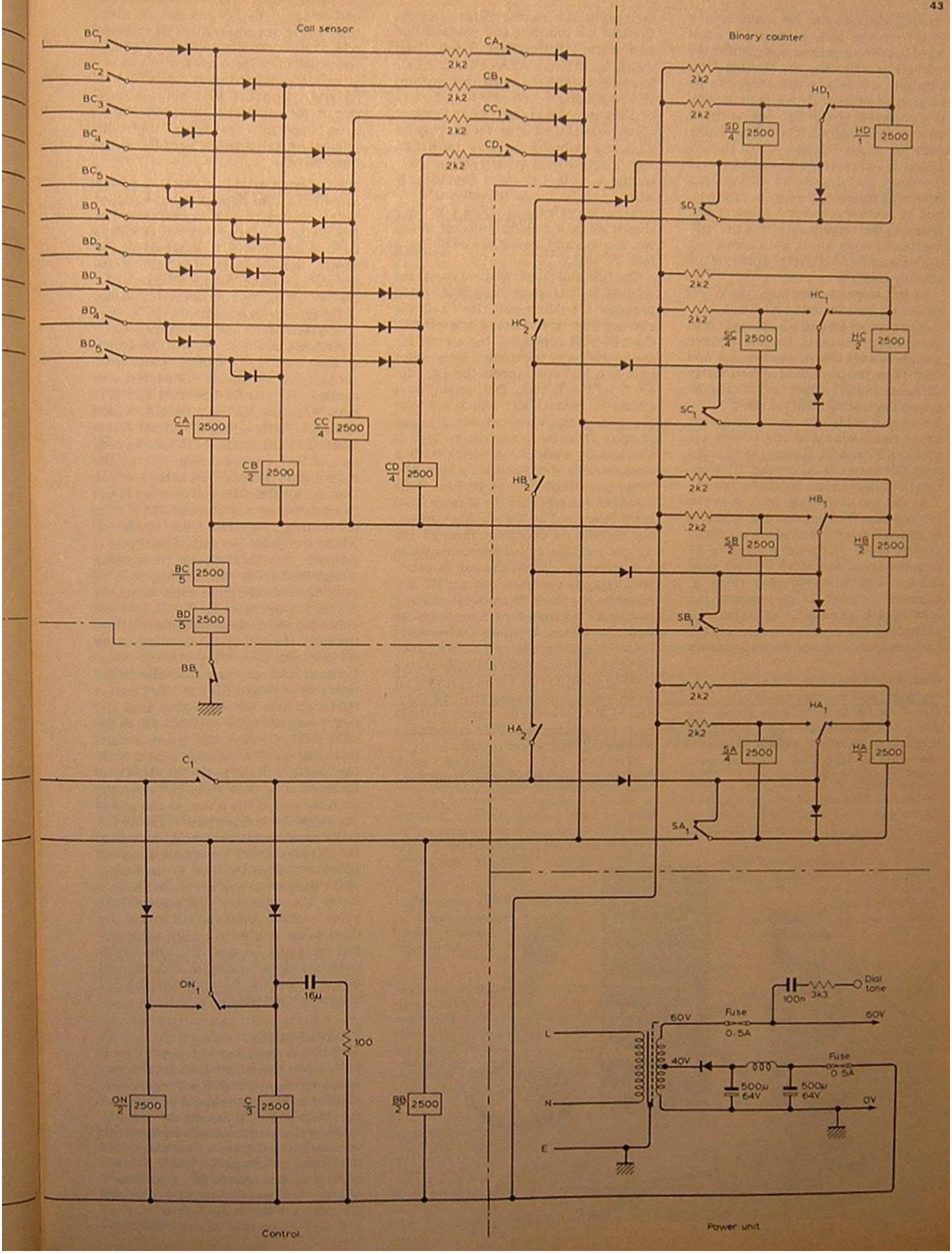
Fig. 1. Divided-feed transmission dridge. Power is fed separately to each telephone, thus eliminating problems which arise with a single-feed system when long and short lines are connected.

Fig. 2 (over page). Complete circuit diagram of the exchange. Resistors of 200Ω in series with A and D relays are 1W; 100Ω resistors across B and C relays are ½W; all rest are ¼ types.





Binary counter relay contacts
Call sensor
1
2
3
4
5
6
7
8
9
0
Common
11
12
13
14
15
16
SD2
SD3
SD4
SC2
SC3
SA3
SA4
SA2
SC4
SB2
CD2
CD3
CD4
CC2
CC3
CA3
CA4
CA2
CC4
CB2
ON2
BB2
Dial tone
C2
100n
3k3
D1
1μ8
470
B2
A1
FC2
470
C3
B1
D2
700
700
FC2
2N4306
FC3
RI1
2k2
68k
16μ
16μ
16μ
2500
2500
2500
200
15k
1M
1M
15k
100
60V
200
Transmission feed



Call sensor
Binary counter
BC1
BC2
BC3
BC4
BC5
BD1
BD2
BD3
BD4
BD5
CA1
CB1
CC1
CD1
2k2
CA/4 2500
CB/2 2500
CC/4 2500
CD/4 2500
BC/5 2500
BD/5 2500
BB1
HD1
SD/4 2500
HD/1 2500
SD1
HC1
SC/4 2500
HC/2 2500
SC1
HC2
HB1
SB/2 2500
HB/2 2500
SB1
HB2
HA1
SA/4 2500
HA/2 2500
SA1
HA2
C1
ON1
16μ
100
ON/2 2500
C/3 2500
BB/2 2500
100n
3k3
Dial tone
60V
Fuse
0·5A
L
N
E
40V
500μ 64V
0V
Control
Power unit

tact C2 disconnects the transmission feed from the binary counter contact 'tree' to prevent bells tinkling whilst the counter is selecting the wanted line. Contact C3 delays the start of the ringing interrupter circuit until dialling is completed. Relay BB, operating at contact BB1, disconnects the operating path for relays BC and BD in the originating call sensor, thus causing them to release and disconnect all the lines from that element to prevent interruption by another telephone. Contact BB2 connects the ringing supply to the calling line through a leak path consisting of a resistor and capacitor to provide the 'dialling tone'.

At this stage dialling takes place and pulses are sent from the A1 break contact to contact B2 and via contact C1 to the binary counter. The first pulse operates relay ON in the control and relay FC in the transmission feed. Relay ON operating at contact ON1 breaks the original operating path for the C relay, which still holds due to the resistive/capacitive shunt and the pulses via contacts B2 and C1. Contact ON1 holds relay ON operated via contact B1. Contact ON2 disconnects the dialling tone.

At the end of dialling, relay A in the transmission feed remains operated and holds the B relay operated via the make contact of A1. The break contact of A1 remains open and after a short time (about 150 milliseconds) relay C releases. Contact C1 disconnects the holding path for relay C and the path for extending the pulses into the binary counter. Any further pulsing cannot then affect the setting of the counter. Contact C2 connects the selected line to the transmission feed D relay coil which, by the operation of contact FC3 has been connected to ringing current via the ringing interrupter RI1; the bell of the wanted line is now rung. Contact C3 completes the circuit for the ringing interrupter which uses three transistors and relay RI in a resistive/capacitive timing circuit, the time constant of which can be made to suit the constructor's preference. (The circuitry shown gives a ringing pulse of about two seconds and a silent period of about four seconds.)

The first dial pulse received energizes relay FC in the transmission feed, which provides a holding path for itself via contact FC1 to the break contact D2. Contact FC2 completes the circuit for the operation of the ringing interrupter unit, and FC3 disconnects the d.c. supply from the D relay coil, providing a circuit to contact RI1 which controls the ringing and silent periods. The coil of relay D in the transmission feed is shunted by a diode, in series with a resistor and a capacitor, whilst the ringing current is sent to line. This arrangement prevents the D relay from being energized by the ringing current, but permits its operation through the d.c. path via the called telephone when it is answered. When the call is answered, relay D operates: contact D1 disconnects the shunt from the D coil and completes the speech path between the two telephones. Contact D2 releases relay FC and completes a holding path for relay B. Contact FC1 disconnects the holding path of relay FC and prevents it from re-operating during the call. Contact FC3 restores the d.c. supply to the D relay coil and contact FC2 disconnects the ringing interrupter circuit.

When a call is finished, both telephones are replaced on their rests and relays A and D release. In turn, relay B releases and contact B1 releases relays ON and BB in addition to all the relays which were operated in the originating call sensor and the binary counter. Contact BB1 completes a circuit for relays BC and BD, which operate and re-connect the lines to the originating call sensor in readiness for the next call.

Binary counter. Four pairs of relays are wired as flip-flops. The left-hand, or 'S' relay of each pair operates at the beginning of a pulse and the 'H' relays operate at the end. Contact B1 in the control provides a holding path for all the relays once they are operated. Diodes are used to mask the transients of the change-over contacts.

The start of the first pulse is caused by the release of the A relay in the transmission feed. The earth potential from contact A1 normal is connected, via contacts B2 and C1 operated and SA1 normal, to the coil of relay SA, which operates. The breaking of contact SA1 is masked by the diode D. The make contact of SA1 connects relay SA to the main earth via contact B1 in the control. During this time the coil of relay HA is short-circuited via contact HA1, thus preventing relay HA from operating whilst the pulse persists. The diode D prevents this short-circuit from being maintained from the holding path of relay SA when the pulse ends. When the A relay re-operates at the end of the pulse, the short-circuit is removed from the relay HA coil by the opening of the A1 contact, and relay HA operates. Contact HA2 connects the pulse to the next pair of relays, SB and HB. Contact HA1 switches the circuit so that the next pulse not only operates SB of the next pair of relays but short-circuits relay SA which releases, whilst a holding path, initially via diode D, is maintained to hold relay HA operated until the end of the pulse. At the end of the pulse, the holding path for relay HA is disconnected at contact A1 and relay HA releases. At the same time, relay HB operates, since the coil is no longer short-circuited when the pulse finishes. Relay HA releasing disconnects the pulse from relays SB and HB so that the third pulse is effective only upon the pair of relays SA and HA. The fourth pulse operates relays SC and HC and releases SA, HA, SB and HB. The full sequence is set out in Table 2.

Power supply

The power requirement depends entirely upon the relays used for the system, bearing in mind that the line current for a telephone should lie between the limits of 30-100 mA. In the systems made by the writer, a mains transformer was used which gives a secondary output tapped at 0-24-30-40-48-60 V. The 0V tag is grounded and the 40V tap is taken to a silicon diode of 1A rating to give the d.c. supply which is smoothed conventionally with two capacitors, 500μF, 64V.

Photograph shows one form of the exchange, built in case measuring 10×4½×3in. Order of relays shown: top pair — D,A; second row — B,C,ON,FC,RI; third row — BB,HD,HC,HB,HA; fourth row — BC,SD,SC,SB,SA; — bottom row — BD,CD,CC,CB,CA.

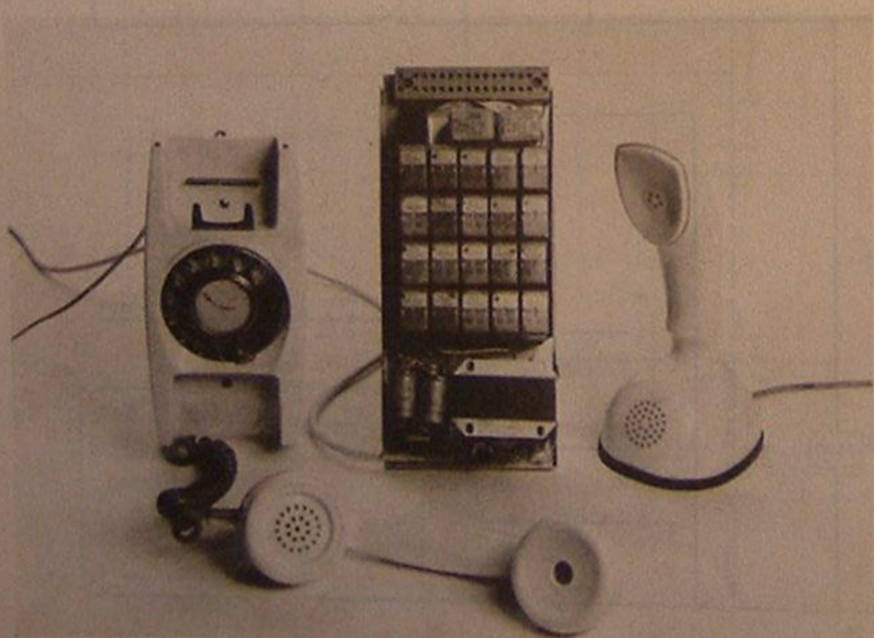


Table 1 — Relay combinations in line sensor

Calling line	Relays operated	Calling line	Relays operated
1	CA	6	CB, CC
2	CB	7	CA, CB, CC
3	CA, CB	8	CD
4	CC	9	CA, CD
5	CA, CC	0	CB, CD

Table 2 — Relay combinations in binary counter

Called line	Relays operated	Called line	Relays operated
1	SA,HA	6	SB,HB,SC,HC
2	SB,HC	7	SA,HA,SB,HB,SC,HC
3	SA,HA,SB,HB	8	SD,HD
4	SC,HC	9	SA,HA,SD,HD
5	SA,HA,DC,HC	0	SB,HB,SD,HD

wkg., and an inductor of around 150 ohms d.c. resistance. The 60V tap is used for the ringing current supply: 75V would be preferable for ringing normal telephone bells and it may be found necessary to adjust some bells to perform adequately on 60V, 50Hz.

With the system as described, working on approximately 50V, the maximum current drawn from the power supply is just over 250mA. The highest value will be drawn when a call is made from a line operating two of the call sensor relays on line 7, which requires the operation of three pairs of relays in the binary counter.

The system should operate satisfactorily with lines up to 600 ohms loop resistance and is ideal therefore for use on large estates or farms.

The capacitors shunting the B and C relay coils and those in the ringing interrupter circuit are electrolytic, 64V working. It is important that those shunting the relay coils do so in series with 100 ohm resistors in order to prevent heavy sparking at the A1 relay contacts. All other capacitors must be non-electrolytic.

The relays BC and BD are permanently operated when the system is not in use in order that there is a small load on the power supply which prevents peak voltages from damaging the smoothing capacitors in the power supply. The current drain is only about 10 mA.

With different relays, the system can be adapted to operate on 24V, but this would reduce the line length over which transmission would be satisfactory. However, at least 60V a.c. is required for ringing nevertheless.

Installation

In the original models made by the author, a sixteen-way terminal strip was used for terminating the leads from the call sensor and binary counter relays. The first ten connexions were used for the lines and the remaining six were used as a 'ground' common. One wire from each telephone is connected to the appropriate numbered terminal and the other is connected to one of the 'ground' terminals. It is preferable to use two wires from each telephone back to the exchange, particularly if the lines are long. Overhearing and noise is likely to arise if a single wire is used with a ground return via a water pipe. Under no circumstances should a 'mains' earth be used.

Components list

Relays:

18, 2500Ω, 4 changeover	all relays other than those below
2, 2500Ω, 6 make	relays BC and BD
2, 700Ω, 2 change-over	relays A and D

Suitable types are made by Plessey, Thorn, Varley and Siemens-Halske.

Capacitors:

2 0.1μ non-electrolytic	250V dial and ringing tones.
1 1.8μ non-electrolytic	250V speech path.
2 16.0μ electrolytic	64V shunts for relays B and C to give slow release feature.
2 500.0μ electrolytic	64V smoothing — power supply.
2 16.0μ electrolytic	50V ringing interrupter circuit.

Resistors:

12 2200 ¼W	call sensor and binary counter.
2 3300 ¼W	dial and ringing tones.
2 470 ¼W	D relay shunt. Feed to ringing interrupter circuit.
2 15k ¼W	ringing interrupter circuit.
2 1M ¼W	ringing interrupter circuit.
1 68k ¼W	ringing interrupter circuit.
2 200 1W	series with A and D relays.
2 100½W	shunts of B and C relays.

Diodes:

42 30mA, 100V	any fast switching silicon type.
1 1000mA 150V	ITT BY135 or similar.

Mains transformer: 1 Type 124 Barrie Electronics, London EC3N 1BJ.
Coke: small output transformer — use primary winding not more than 200 ohms resistance.
Transistors: 3 2N4036 p-n-p silicon, ringing interrupter timer and relay driver.
Terminal strip: 16 way; any type available to the constructor which will provide for ten lines and adequate capacity for the common leads.
Case: The aluminium case used in the example shown in the photograph is 10×4.5×3in, but other examples have been constructed to fit into cases 8×6×2.5in. □

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Several small errors, for which we apologise, crept into this article in the August issue. Firstly, the open contact of A_1 on p.42 should go to the open contact of D_2, not the junction of FC_2 and the 470ohm resistor. Secondly, the make contact connected to the closed contact of D_2 is FC_1, not FC_2. Lastly, in Table 2 on p.45, the relays operated on called-line 2 are SB and HB.

Several small errors, for which we apologise, crept into this article in the August issue. Firstly, the open contact of A_1 on p. 42 should go to the open contact of D_2, not the junction of FC_2 and the 47Øohm resistor. Secondly, the make contact connected to the closed contact of D2 is FC_1 not FC_2. Lastly, in Table 2 on p. 45, the relays operated on called-line 2 are SB and HB.

<u>Source</u>:

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