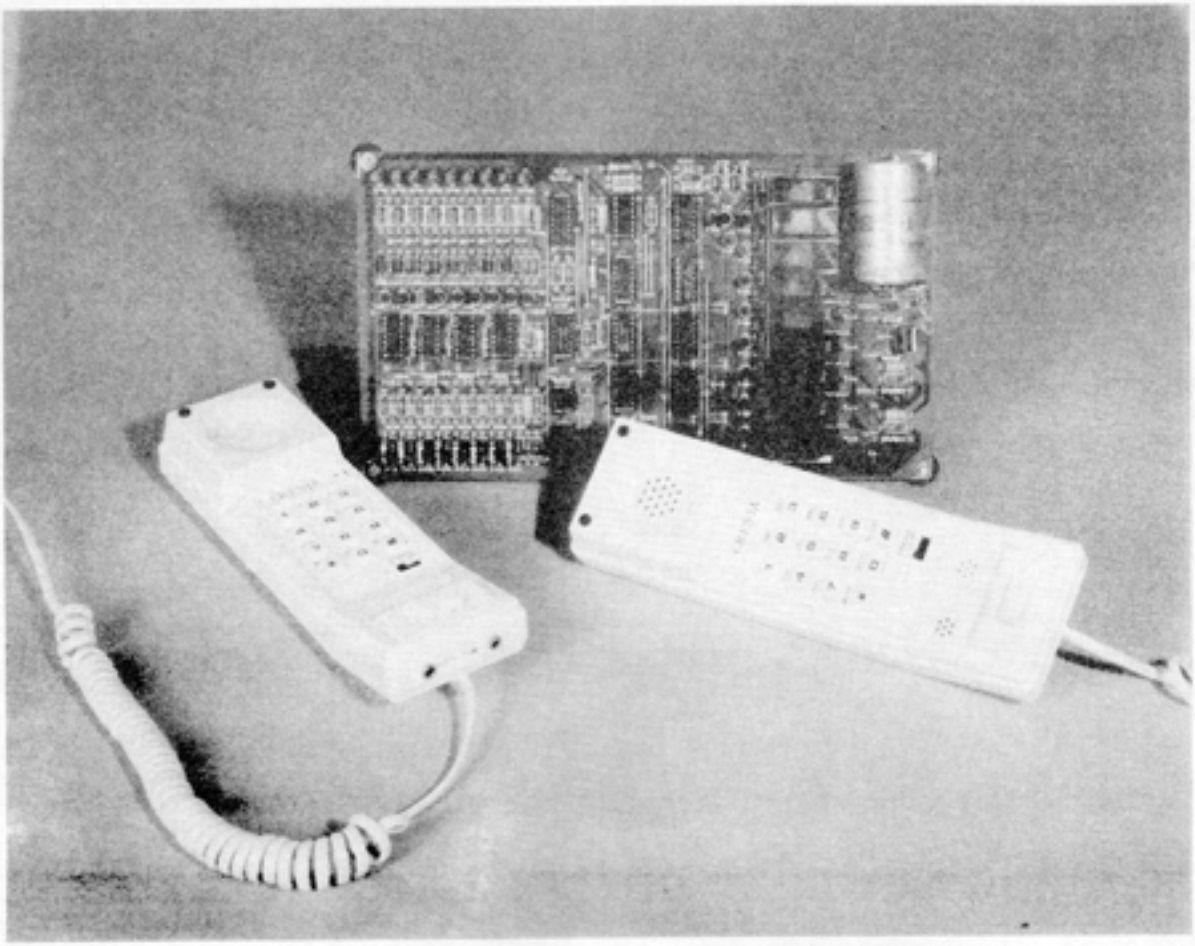


telephone exchange

by J Steeman

Nowadays, there is a variety of inexpensive, yet sophisticated, telephone sets on the market. Not all of these are permitted to be connected to the British Telecom network, however. None the less, two or more of such sets may be used to form a simple, but effective, internal telephone system for the home, an office, or anywhere where a number of people want to communicate from different locations within the same building.

The proposed system may, of course, also be built around British Telecom approved sets. Note that the system is intended for up to eight sets each of which generates a pulse code when a number is dialled or keyed in.

Facilities

A telephone exchange does, of course, more than just connecting one set to another. In fact, this is about the only thing it need not do, because the set with which communication is required is already accessed by the pulses generated when the relevant number is dialled or keyed in. What the exchange is required to do is:

- to decode and process the pulses generated by the telephone sets;
- to generate a dialling tone;
- to generate and pass on a ringing tone;
- to interconnect sets as soon as the receiver is lifted;
- to prevent a third set listening in;
- to generate and pass on to a third set an engaged tone.

In addition, the system allows communication between two sets to be established in two ways:

- by dialling or keying in the required number and waiting till the other set responds;
- semi-automatic: when the receiver of one

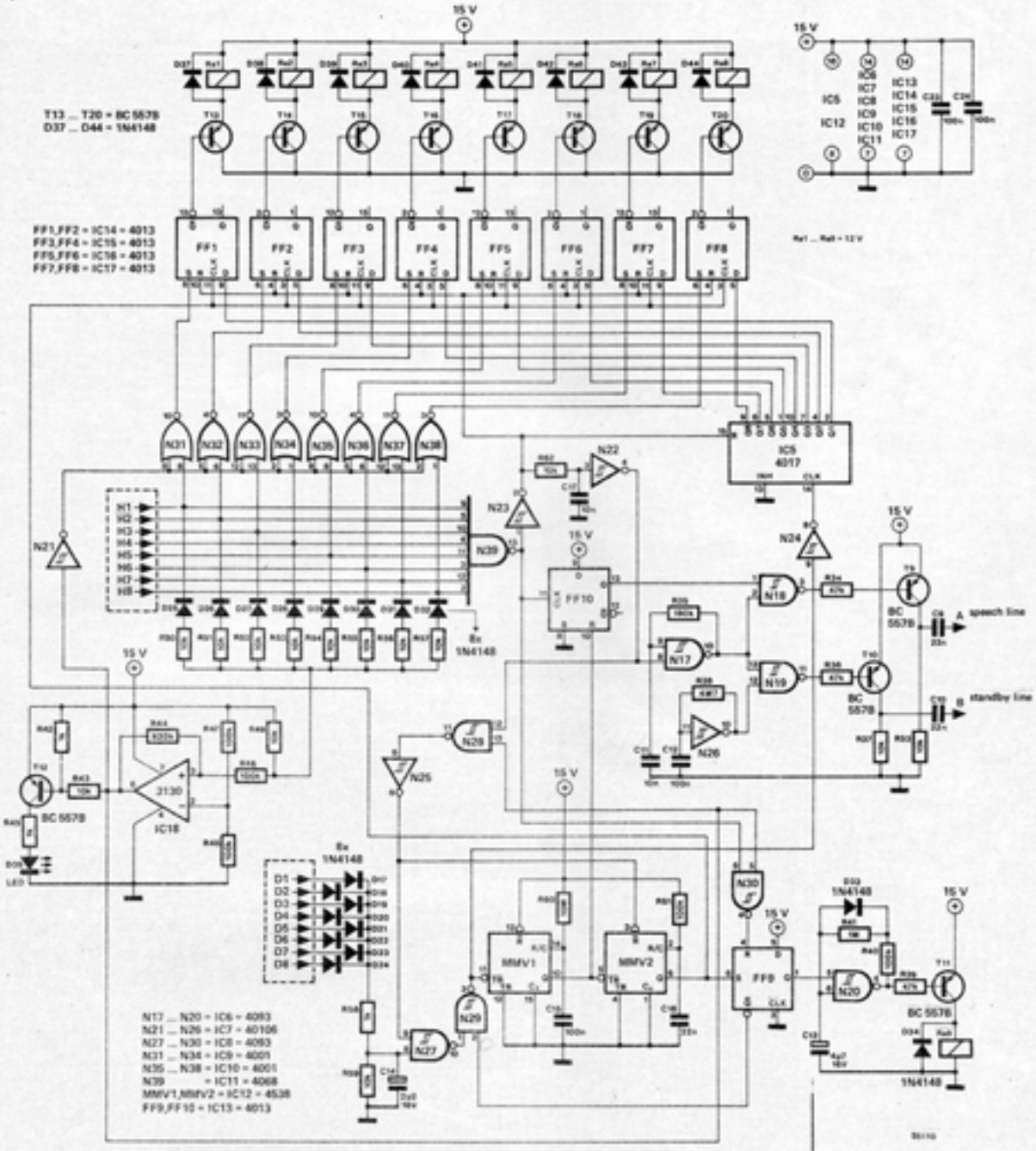


Fig. 1. Circuit diagram of the home telephone exchange.

set is off the hook, and the receiver of another set is lifted, the two sets are interconnected, even when no number has been dialled.

The exchange is provided with LEDs that show at all times which of the sets, if any, are engaged. A ninth LED indicates whether the exchange is engaged or not; this only goes out when the communication has been terminated, i.e., when the two relevant receivers have been replaced on their rests. All sets are powered from a common source via the standby and speech lines; the connection between each of the sets and the exchange is, therefore, in many cases possible, via two lines only. The bell voltage is placed on the speech line via a relay.

Calling one set from another is done by simply dialling or keying in the number of the wanted set, i.e. 1...8.

Circuit description

Since the telephone sets can only be connected to the exchange — see Fig. 1 — via the interface shown in Fig. 2, it is important to know how many sets the exchange will control before all the parts are bought. If, for example, only three sets are envisaged, the relevant part of the circuit in Fig. 2 needs to be built only three times. If, however, the full capacity of the exchange is used, eight interfaces are required.

As soon as the receiver of a set, say, number

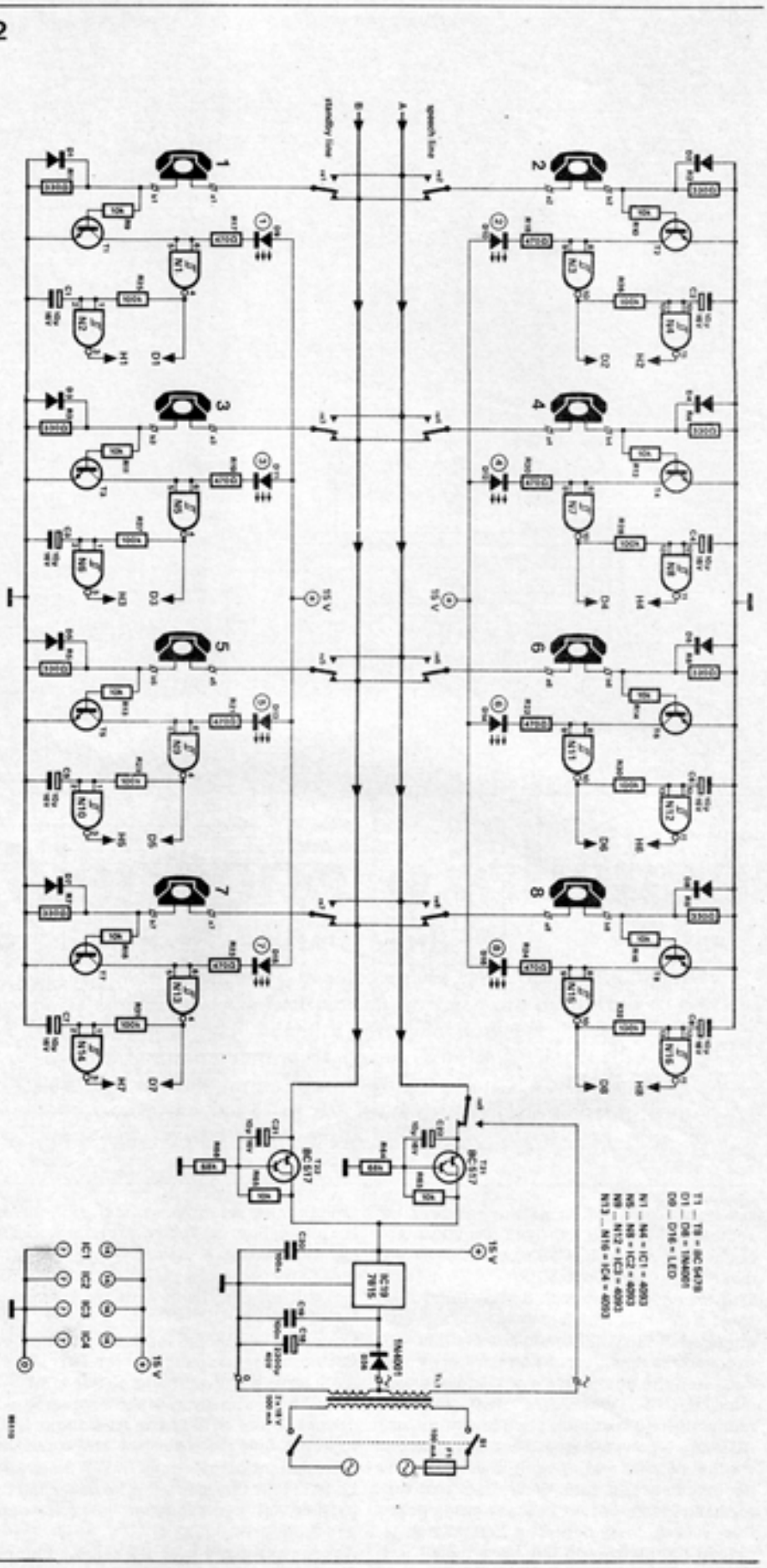
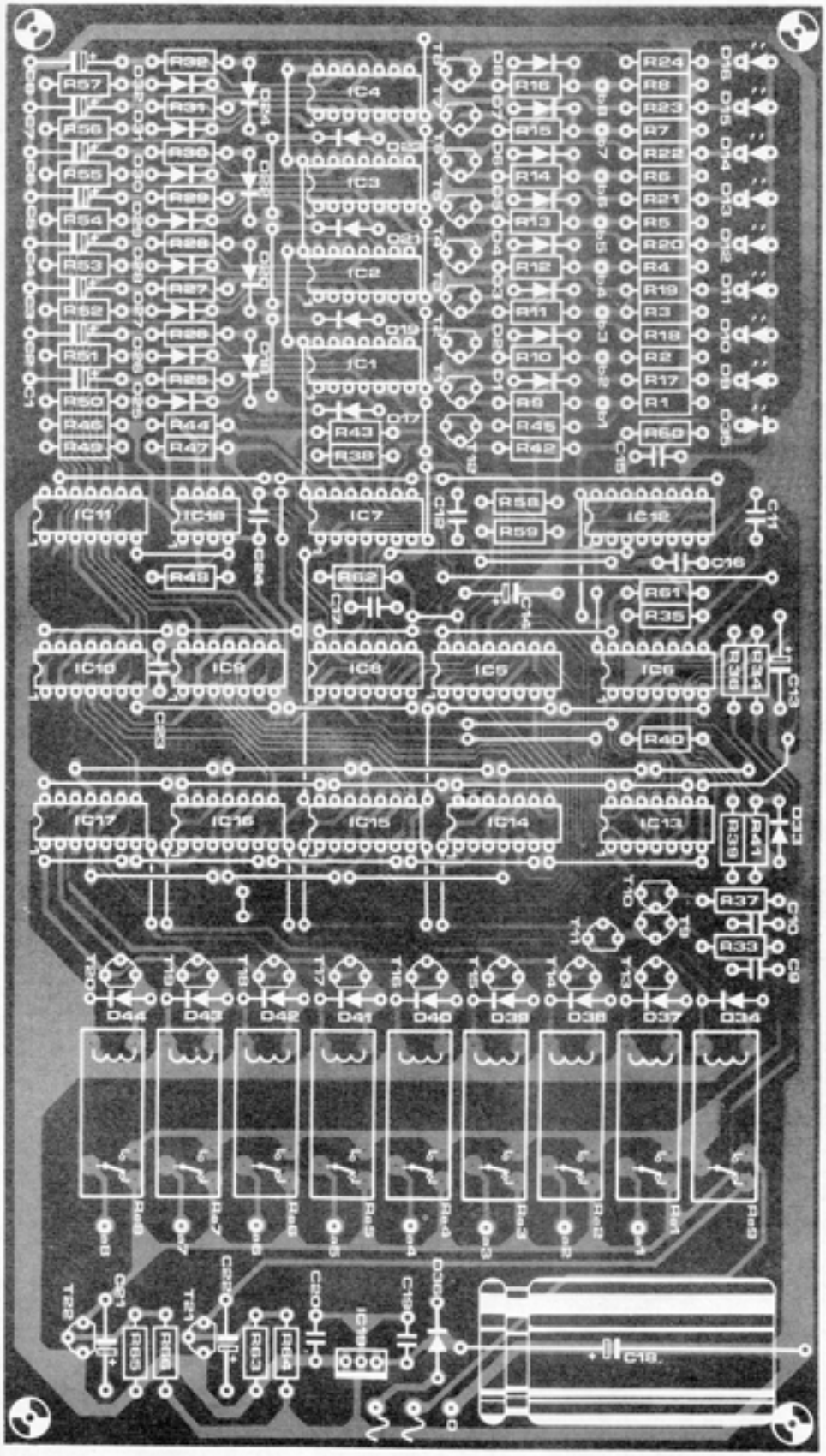


Fig. 2. Circuit diagram of the power supply (for up to eight telephone sets) and the interface required for connecting the telephone to the exchange. One interface is required for each and every telephone.



Parts list

Resistors:

$R_1 \ldots R_8 = 330\Omega$
$R_9 \ldots R_{16}; R_{33}; R_{37}; R_{43}; R_{49}; R_{50} \ldots R_{57}; R_{59}; R_{63}; R_{65} = 10$ k
$R_{17} \ldots R_{24} = 470\ \Omega$
$R_{25} \ldots R_{32}; R_{40}; R_{46} \ldots R_{48}; R_{61} = 100$ k
$R_{34}; R_{36}; R_{39} = 47$ k
$R_{35} = 180$ k
$R_{38} = 4M7$
$R_{41} = 1$ M
$R_{42}; R_{45}; R_{58} = 1$ k
$R_{44} = 820$ k
$R_{60} = 10$ M
$R_{64}; R_{66} = 68$ k

Capacitors:

$C_1 \ldots C_8; C_{21}; C_{22} = 10\ \mu$;16 V
$C_9; C_{10}; C_{16} = 22$ n
$C_{11}; C_{17} = 10$ n
$C_{12}; C_{15}; C_{19}; C_{20}; C_{23}; C_{24} = 100$ n
$C_{13} = 4\mu7$;16 V
$C_{14} = 2\mu2$;16 V
$C_{18} = 2200\ \mu$;40 V

Semiconductors:

$T_1 \ldots T_8 =$ BC547B
$T_9 \ldots T_{20} =$ BC557B
$T_{21}; T_{22} =$ BC517
$D_1 \ldots D_8; D_{38} =$ 1N4001
$D_9 \ldots D_{16}; D_{35} =$ LED
$D_{17} \ldots D_{34}; D_{37} \ldots D_{44} =$ 1N4148
$IC_1 \ldots IC_4; IC_6; IC_8 = 4093$
$IC_5 = 4017$
$IC_7 = 40106$
$IC_9; IC_{10} = 4001$
$IC_{11} = 4068$
$IC_{12} = 4538$
$IC_{13} \ldots IC_{17} = 4013$
$IC_{18} = 3130$
$IC_{19} = 7815$

Miscellaneous:

S_1 = double pole mains switch
$Re_1 \ldots Re_9 = 12$ V relay for PCB mounting (e.g., Siemens type V23027-B0002 – may be available from Electrovalue (0784) 33603 or (061 432) 4945)
Tr_1 = mains transformer; 2 × 18 V at 500 mA; 0-18-36 V at 500 mA; or 0-18 V at 500 mA + one of 0-36 V at 50 mA
F_1 = fuse, 100 mA
PCB 85110

Fig. 3. Printed circuit board of the telephone exchange. Note that the mains transformer is not fitted on this board. The track side of the PCB is shown on page 45.

1, is taken off the rest, the relevant transistor, here T_1, is switched on, so that the output of N_1 goes high. After a time determined by the RC network at the input of N_2 this gate toggles and its output goes low.

If now from set 1 a number is dialled, the output of N_1 will toggle in rhythm with the pulses produced by the telephone set. Because of the RC network at its input, gate N_2 will not follow suit: its output remains logic low during the dialling of a number. The low logic level indicates to the exchange that the receiver is off its rest. As soon as the receiver of one of the other sets is also taken off its rest, the output of comparator IC_{1B} goes low, which renders all other sets inoperative. How this is achieved will be reverted to later.

The pulses generated during the dialling of a number trigger monoflops MMV_1 and MMV_2 via one of the lines $D_1 \cdots D_8$, and also serve as clock signal for IC_3, a counter with ten outputs. The contents of this counter, i.e., the dialled number, is only accepted by bistables $FF_1 \ldots FF_8$ if two conditions are met: (a) only one receiver is off its rest, and (b) FF_9 is not generating a ringing tone. As long as pulses keep arriving at pin 11 of MMV_1, the Q output of this monostable will remain high. When this pulse train comes to an end, a short pulse is provided at the Q output (pin 6) of MMV_2. This pulse sets FF_9 (which generates the ringing tone) and clocks bistables $FF_1 \ldots FF_8$, depending on the output code of IC_3. The wanted set is then connected to the speech line via its associated relay. At the same time, N_{20} (an oscillator with a long '1' and a short '0') intermittently connects the bell voltage onto the speech line via contact re_9 (see Fig. 2). The wanted telephone will then ring until its receiver is lifted.

To ensure that a third set cannot listen in, the logic levels at the Q outputs of $FF_1 \ldots FF_8$ are held: this is done by making both the set and reset inputs of these bistables low when the receivers of two telephone sets are off their rests. The set inputs are made low via IC_{1B}: the output of this opamp is low when two telephones are interconnected. The output of Schmitt trigger N_{21} is then high, and since this output is connected to $FF_1 \ldots FF_8$ via NOR gates $N_{31} \cdots N_{38}$, the set inputs of the bistables are low. As long as two receivers are off the hook, the output of N_{39} is logic high. The output (pin 2) of N_{23}, and consequently the reset input of bistables $FF_1 \ldots FF_8$, is then low.

An engaged tone, generated by gates N_{19} and N_{26} in combination with transistor T_{10}, and applied to the wait line, indicates that the exchange is busy. This tone generator, as well as the dialling tone generator consisting of N_{17}, N_{18}, and T_9, is actuated by FF_{10} as soon as the receiver of any one of the sets is lifted. The dialling tone generator is provided to indicate that the exchange is processing a number: is has no connection with the actual dialling pulses. In fact, as soon as a dialling pulse appears on one of the D lines, the dialling tone generator is switched off immediately by FF_{10}.

Semi-automatic operation is achieved as follows. As stated, bistables $FF_1 \ldots FF_8$ are rendered inoperative when two telephone sets are communicating. When only one receiver is off the hook, the output of N_{21} is low, and the bistables can still be accessed. When in that condition a second receiver is lifted, it takes a second before the bistables are really inoperative, and the two telephones are interconnected. Note that it is not necessary in this case to dial a number.

Power supply

The +15 V power supply is provided to the exchange via the speech and standby lines. The bell voltage — here chosen at 2 × 18 V — is also applied to the speech line, but in this case via relay Re_9. Transistors T_{21} and T_{22} ensure a high supply impedance to prevent attenuation of the speech signal.

Construction

As no presetting or alignment is necessary, the exchange may be fitted in a suitable enclosure as soon as the wiring of the PCB shown in Fig. 3 has been completed. The telephone sets are connected to terminals $a_1 \ldots a_8$ and $b_1 \ldots b_8$ on the board respectively. Note that British Telecom approved sets need a four-wire connection to the exchange, because their bell circuits need to be connected separately to the standby and speech lines respectively. The bell wires in these sets are coloured red and green, while the other two are blue and white respectively.

Finally

Because of the *RC* network between gates N_1 and N_2 (or $N_{3,5,7}$ and $N_{4,6,8}$) in the interface circuit of Fig. 2, the bell rings briefly when the wanted extension picks up the receiver. This could have been eradicated, but it was not thought that the cost of the additional electronics required was justified by this very minor flaw.

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