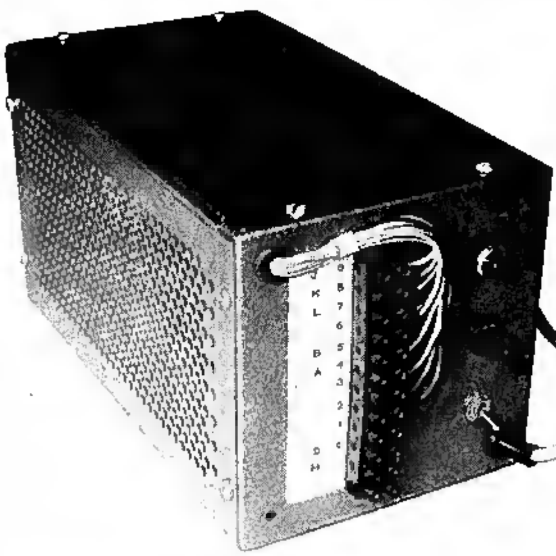
ELECTRONIC HOME TELEPHONE EXCHANGE

J. Thornton Lawrence T.Eng (C.E.I.)

SEVERAL mail order firms dealing in surplus electronic equipment are offering for sale, at very reasonable prices, ex G.P.O. telephones complete with dial and bell. Two of these telephones can be connected to provide ringing and speech communication between, for example, workshop and house, bedroom and downstairs, office and shop, etc. A simplified circuit of the telephone is shown in Fig. 1 and the method of connection in Fig. 2.

TWO TELEPHONE OPERATION

The two telephones are connected in parallel and fed with direct current through an LF choke as shown in Fig. 2. When calling, the caller lifts his handset and the rest contacts close thus energising



his transmitter (carbon microphone) as shown in Fig. 1. He then dials "0" and the "normally open" dial contacts close causing a short circuit across the line and heavy current through the LF choke. On releasing the dial, the "normally closed" dial contacts open and close ten times producing a substantial pulsing voltage across the line.

This voltage is passed through the bell series capacitor of the called telephone and rings the bell. When the dial comes to rest the N.O. contacts open and current again flows through the transmitter. The called subscriber lifts his handset and his transmitter is also energised.

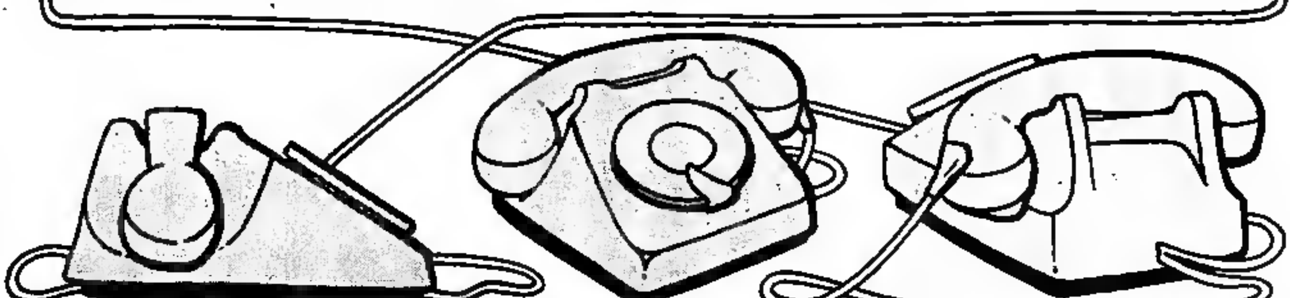
During speech, variations in transmitter resistance will cause speech voltages to be developed across the line and incoming speech voltages will operate the receiver (earphone). The LF choke provides a direct current path to energise the transmitters whilst presenting a high AC impedance to the speech signals.

The dial pulsing rate is different from the frequency normally used for ringing the bell and some improvement in ringing can be made by suitable adjustment to the bells. To do this the base of the telephone should be removed. The bell fixing hole is made off-centre and loosening the fixing screw will allow the bell to be rotated, then tightened, to give the best sounding ring.

After using a simple two telephone system for some time the need was felt for a system incorporating several extensions and the automatic telephone exchange, which is the subject of this article, was developed. In the past, home telephone exchanges have used Uniselectors for calling and speech routing, but as the Uniselector is very noisy in operation an alternative system was designed using solid state devices and reed relays. The reed relays are used for ringing purposes and the diodes used for speech routing.

SPEECH ROUTING

The basic arrangement of diodes for speech-routing is shown in Fig. 3. With the receivers at rest, the telephones draw no current and both diodes are non-conducting. If the handset is lifted at Subscriber 1, D13 will conduct and D14 will remain non-



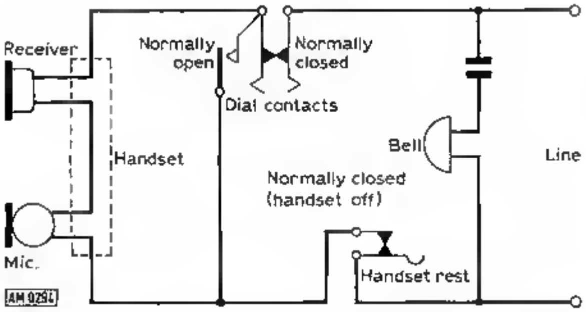


Fig. 1: With the handset lifted the contacts in a simple dial telephone circuit are in the position shown here.

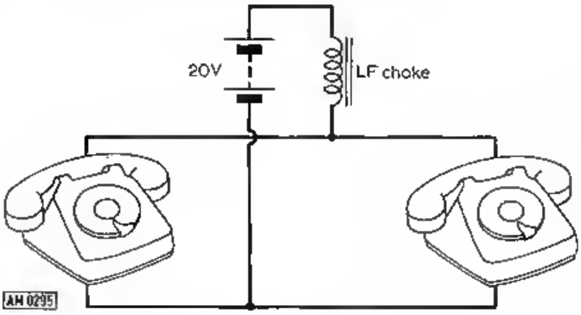


Fig. 2: Basic connections for a two telephone system.

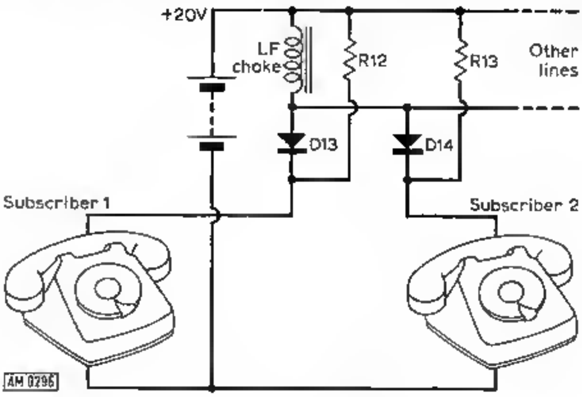


Fig. 3: Simplified speech switching circuit.

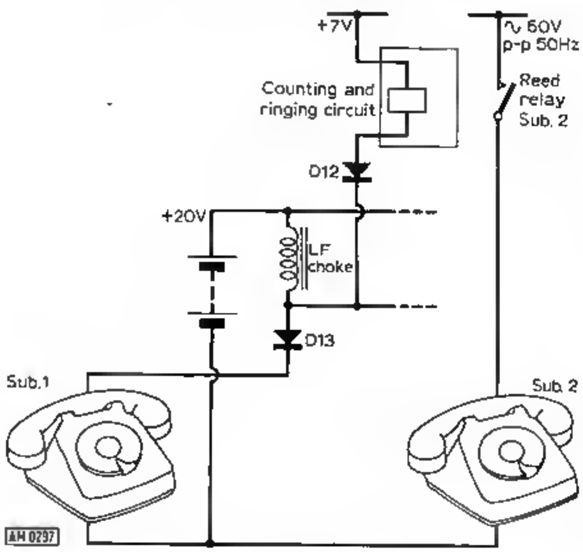


Fig. 4: Ringing circuit in a simple form.

★ components list

Resistors

R1	100Ω	R5	330Ω	R9	4·7kΩ
R2	330Ω	R6	33Ω	R10	4·7kΩ
R3	2·2kΩ	R7	1kΩ	R11	3·3kΩ
R4	2·2kΩ	R8	1kΩ	R12–20	47kΩ

All ½ watt 5%
R21 500Ω 2W WW R22 125Ω 5W WW
VR1 50kΩ miniature preset, horizontal mounting

Capacitors

C1	50μF 6V	C6	0·1μF
C2	10μF 6V	C7	0·1μF
C3	200μF 6V	C8	4000μF 40V
C4	0·01μF	C9	8μF 250V
C5	100μF 6V		

Semiconductors

Tr1 BC184B Tr2 BC214B Tr3 BC184B
D1–22 IS44 (or 1N914) IC1 7413
D23 VR475F (4·75V zener) IC2 7490
D24 1S3007 (7V zener) IC3 74121
D25 10DB1A (1A bridge rec.) IC4 74145

Miscellaneous

F1 fuse 250mA anti-surge. F2 500mA fuse. F3 500mA fuse. L1 LF choke 3H 350Ω (see text). LP1 Mains neon indicator. RLA to RLJ Reed relays 700Ω (Doram 348-970). S1 DPST toggle. T1 transformer mains/16·3V (Doram 196-218). T2 transformer mains/20 + 20V (Doram 196-319). Case 5" x 5" x 8" long (Lektrokit, Home Radio) or similar.

The PCB can be obtained from J. Stuart, 40 Aberconway Road, Prestatyn, Clwyd, LL19 9HL for £2 inclusive of post and packing.

conducting because of the associated resistor R13 maintaining line 2 at the battery supply voltage.

If Subscriber 2 handset is now lifted D14 will now also conduct and speech communication can take place through D13 and D14, the LF choke being the common impedance as before.

RINGING SYSTEM

The simplified arrangement for ringing is shown in Fig. 4. When the handset is lifted at Sub. 1, D13 conducts as before and as the voltage on the line is greater than +7 volts D12 remains non-conductive. When the dial on Sub. 1 is operated, the line voltage falls to zero and D12 conducts and passes dialling pulses into the counting and ringing circuit.

If the caller, Sub. 1, has dialled "2," the counting and ringing circuit will energise reed relay Sub. 2 and cause a 60 volt peak-peak AC signal to be connected to line 2 thus ringing the bell at Sub. 2. As soon as the handset at Sub. 2 is lifted, D14 (omitted from Fig. 4 for clarity) conducts, allowing speech communication as described previously. A separate reed relay is required for each subscriber.

CIRCUIT OPERATION

The full circuit is given in Fig. 5 and Fig. 6. The circuit operation begins when the caller lifts his handset. Assume that, as before, the caller is Sub. 1 When the handset is lifted, current will flow from the +20 volt supply through L1, D13 and Sub. 1 telephone to the common line, Fig. 6. This telephone is now energised and the voltage across the line is approximately 8 to 16 volts, depending on the total resistance of the telephone.

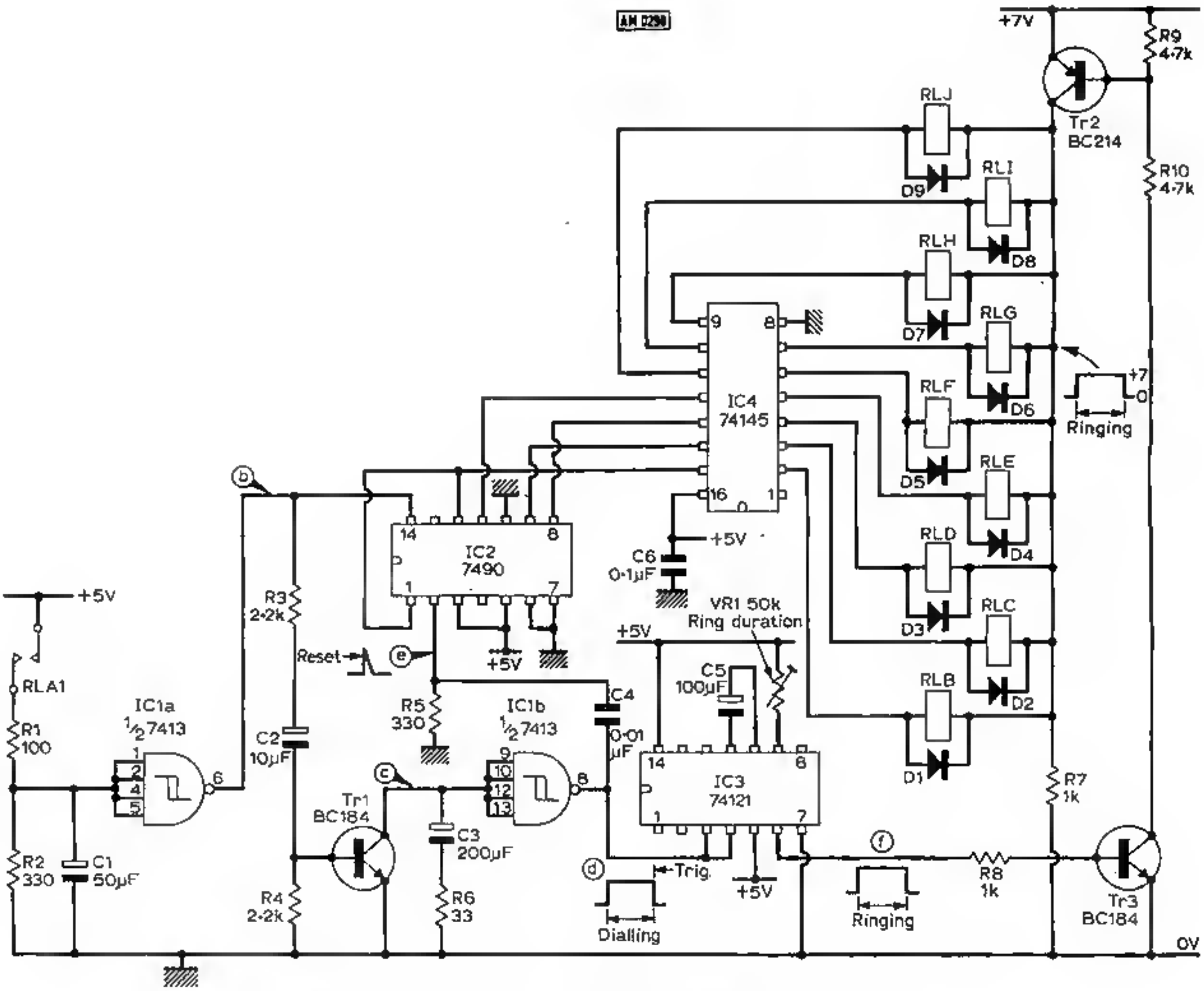


Fig. 5: Counting and ringing circuit in the exchange described in the text.

Assume that Sub. 1 dials Sub. 3. On the backward rotation of the dial, the line is shorted by the dialling contacts and the voltage across the line is zero. Current now flows through relay A, D12 and D13, thus energising relay A (Fig. 6). When Sub. 1 releases the dial it returns to rest and in so doing contacts open and short the line three times, finally coming to rest with the telephone energised as previously. The waveforms are shown in Fig. 8.

The contacts of relay A connect R1 to the +5 volt supply, Fig. 5, and a logic 1 level is applied to the Schmitt trigger gate IC1a. A Schmitt trigger is used in this position so that the input signal can be smoothed by R1, C1 to eliminate spurious signals caused by contact bounce and yet provide a fast-switching clean output suitable for driving the logic circuits. The output of IC1a, containing the dialled information now follows two routes, to Tr1 and IC2.

In order to detect the completion of a group of dialling pulses and to produce a signal at the end of this group it is necessary to have an electronic circuit equivalent to a "slugged" relay. This is formed by Tr1 and IC1b. The first of the dialling pulses turns Tr1 hard on, discharging C3 and causing the inputs of IC1b to be at logic 0 and thus the output of IC1b to be at logic 1. This positive transition is differentiated by C4 and R5 to produce a positive pulse to logic 1 which resets the 7490 decade counter to zero.

Between each dialling pulse C3 begins to recharge from the input current of IC1b but does not reach logic 1 level because the next dialling pulse discharges it again. However, after the last dialling pulse, the input to IC1b rises to logic 1 and the output flips to logic 0. The other route for the dialling pulses is direct to the input of the 7490 decade counter, IC2. The counter counts on the negative-going edge of each dialling pulse and in our example would count 3 (binary 0011).

It will be noted from the waveforms that a negative step (to logic 0) occurs when the dial is first rotated and this is counted by the decade counter, but as the counter is reset to zero on the leading edge of the first true dialling pulse, it does not cause a dialling error.

The binary coded decimal output from IC2 is fed directly to the 74145 decoder-driver, IC4, where, in our example, output 3 would be clamped to the 0v line and all other outputs would be non-conducting.

Returning now to IC1b, at the end of a group of dialling pulses, the output flips from logic 1 to logic 0. This negative transition triggers the 74121 monostable IC3, which produces a logic 1 output pulse having a duration set by VR1 (1-5 seconds approx.). The positive pulse from IC3 turns on Tr3 and Tr2, thus energising only relay D as this is connected to the 0v line through the No. 3 output of IC4.

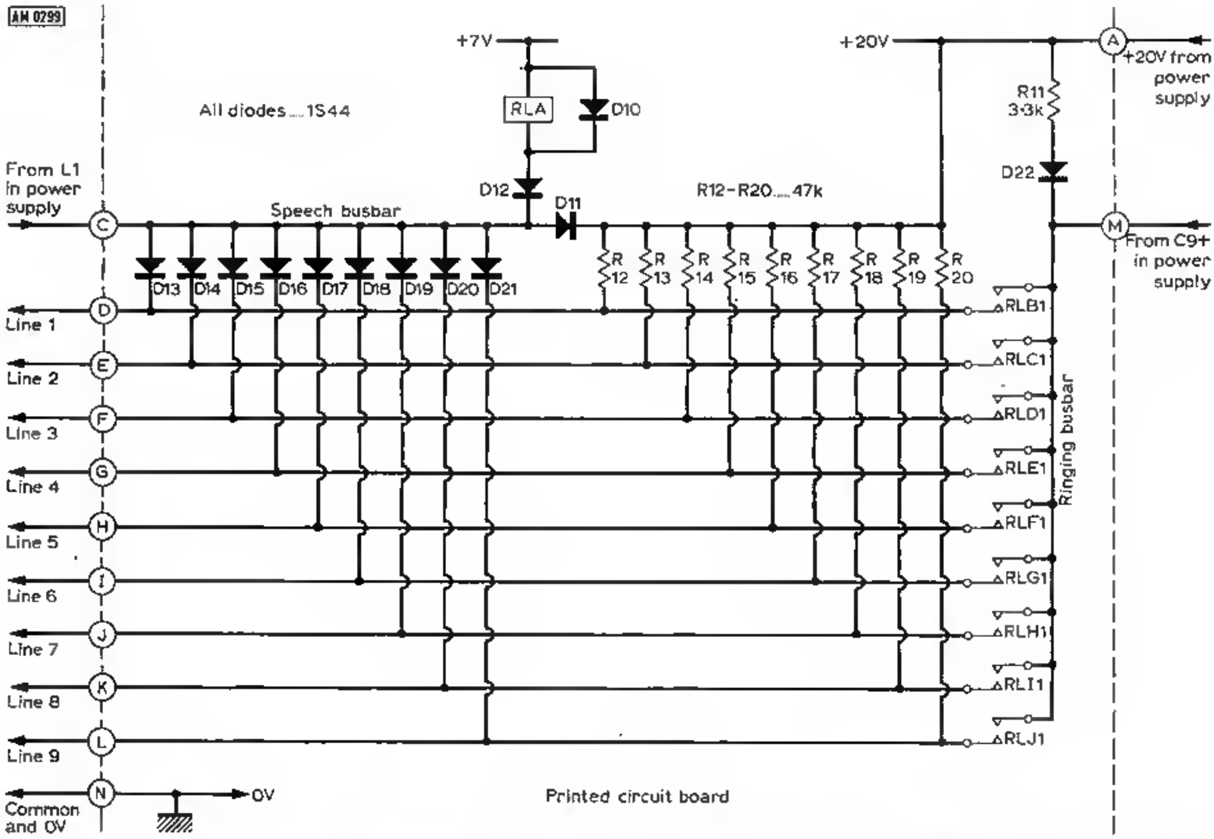
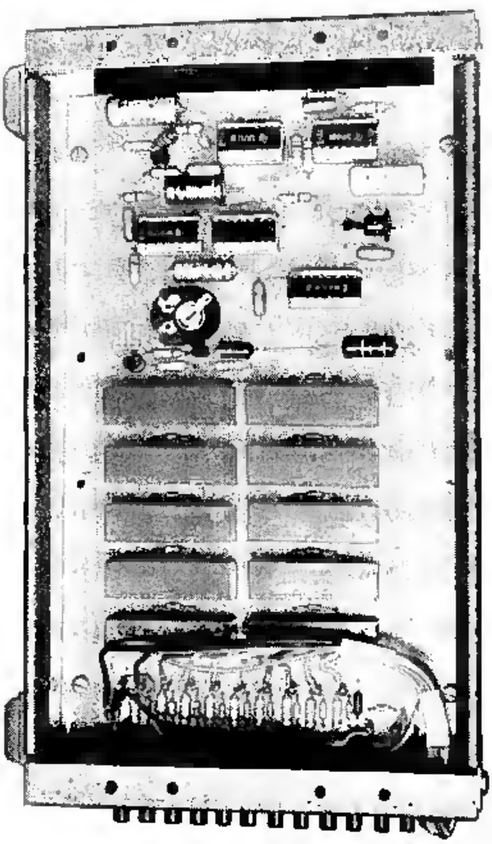
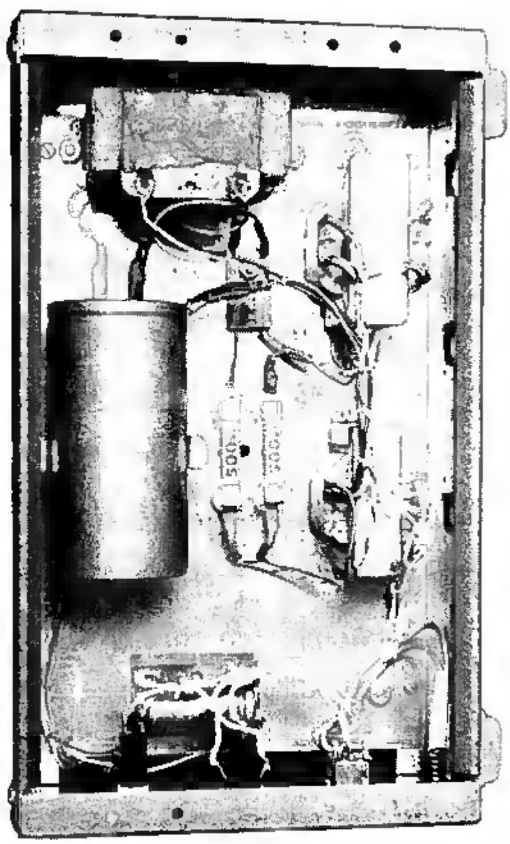


Fig. 6: Remainder of the exchange, showing the speech switching and ringing circuitry. Below left, the finished PCB of an earlier version of the exchange in which five IC's were used instead of four. Below right, power supply panel.





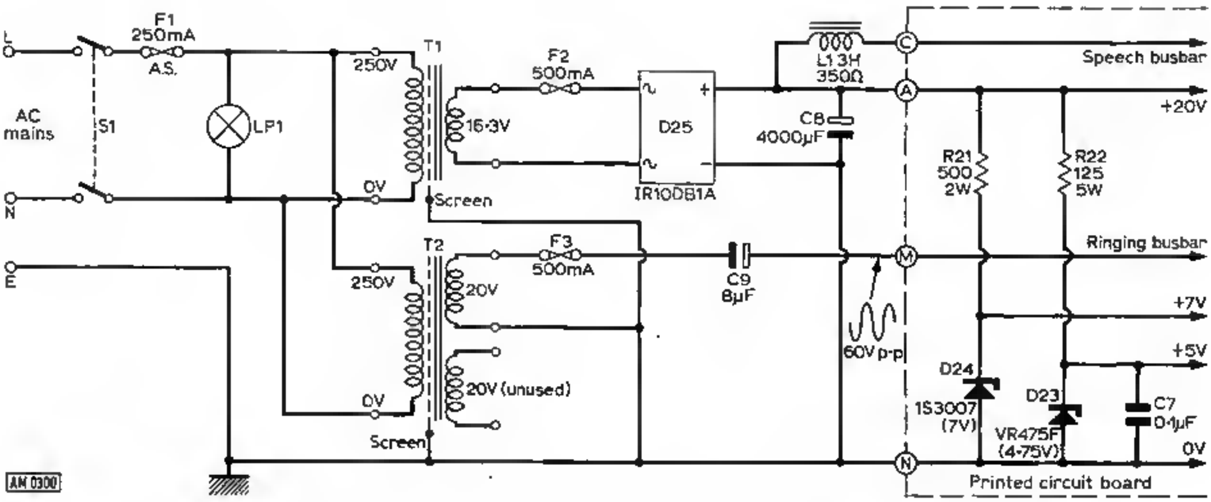


Fig. 7: Power supply circuit, the panel for which is mounted on the righthand side of the unit shown on the first page.

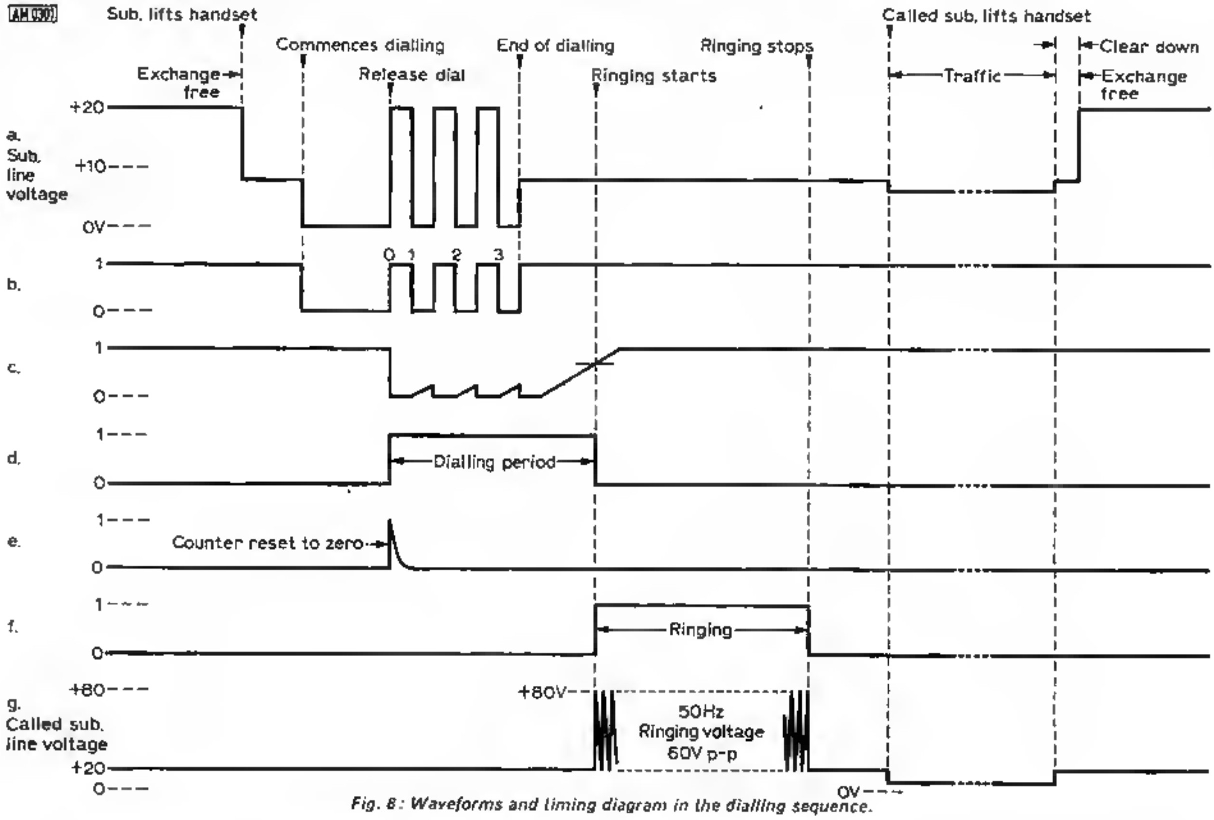


Fig. 8: Waveforms and timing diagram in the dialling sequence.

The reed relay D connects an AC ringing signal of 60 volts peak-peak from T2 to line 3 which rings the bell in Sub. 3 telephone for a duration set by VR1. When Sub. 3 lifts his handset, current flows through D15 thus connecting both telephones to the Speech Bus bar, permitting two-way conversation. At the completion of the call the caller and the called replace their hand sets causing D13 and D15 to disconnect. No other "clearing down" is required, the decade counter is reset to zero at the commencement of the next call.

The 50Hz ringing voltage from T2 is AC coupled to the Ringing Bus bar, by C9 and the negative peaks cause D22 to conduct, charging C9 and thus preventing the negative half cycles from swinging below +20 volts. This ensures that when the ringing signal from the Ringing Bus is connected to a subscriber it will not cause the associated speech routing diode to conduct and will prevent the ringing signal from appearing on the Speech Bus.

The inductance of the LF choke, L1, is not critical but the resistance should be approximately 350 ohms. If a choke of the correct resistance is not available, one having a lower resistance may be used with a suitable resistor connected in series to raise the total resistance to the correct value.

The power supply for the telephone exchange is in operation continuously and consumes approximately

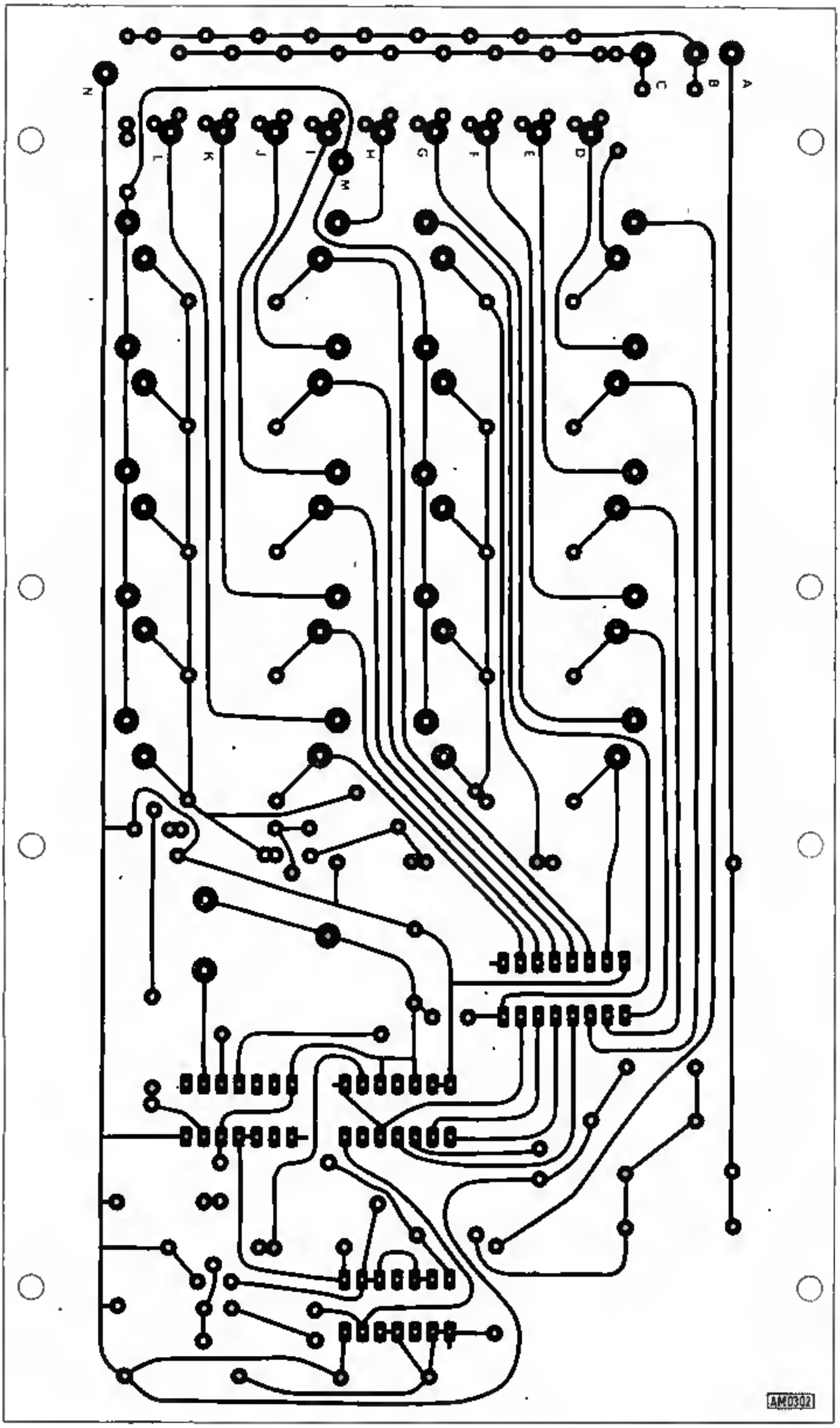


Fig. 9: The PCB layout is given here actual size so that it may be copied.

3 watts. Transformer T1, bridge rectifier D25 and C8 provide the +20 volt supply for powering the telephones and this is also the source of the +5 volt and +7 volt supplies which are regulated by zener/breakdown diodes D23 and D24 respectively, Fig. 7.

Transformer T2 provides the ringing voltage for the Ringing Bus. Both transformers are adequately fused for safe unattended operation.

All the circuitry with the exception of the power supply components is built on a 8in x 4¾in printed

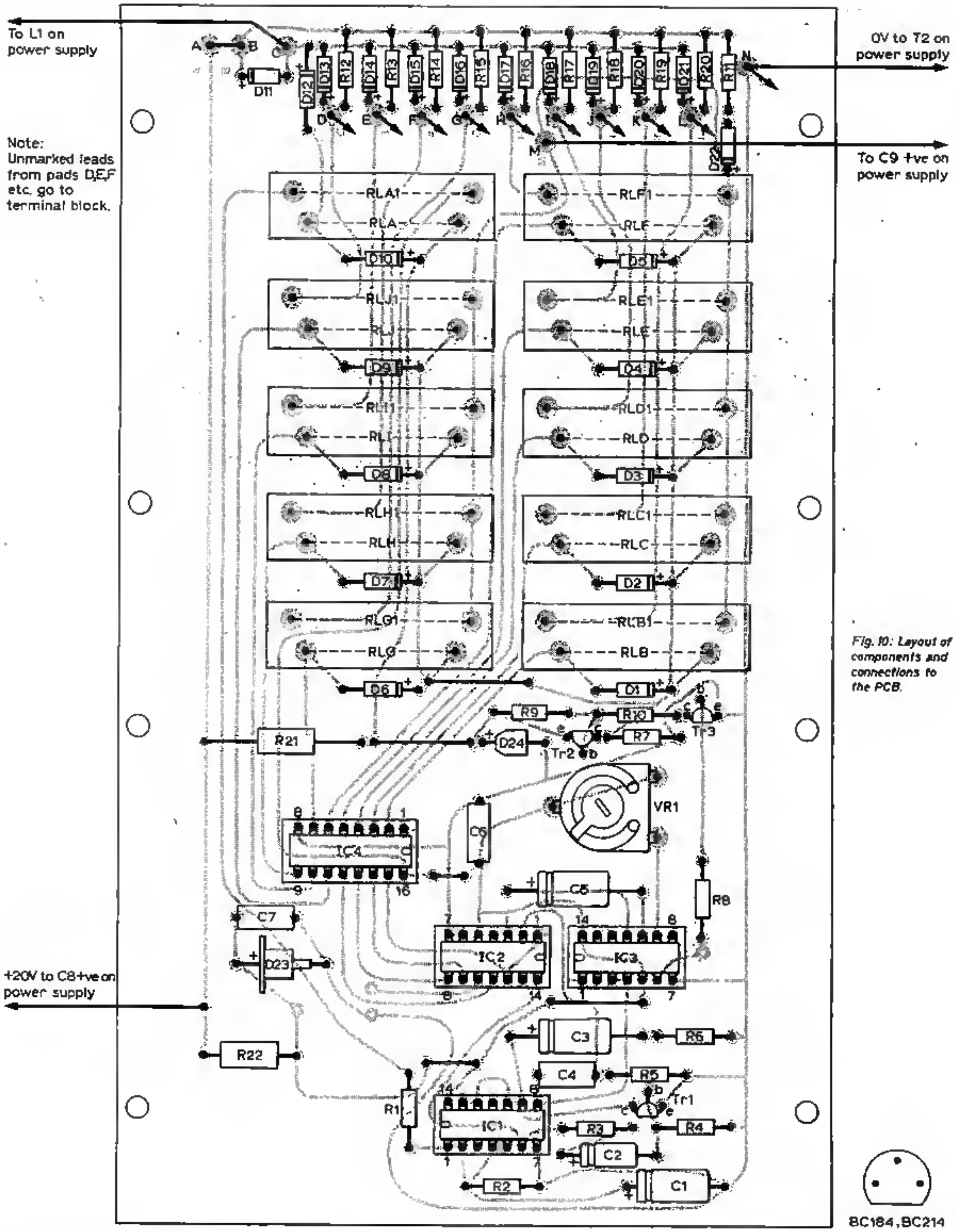


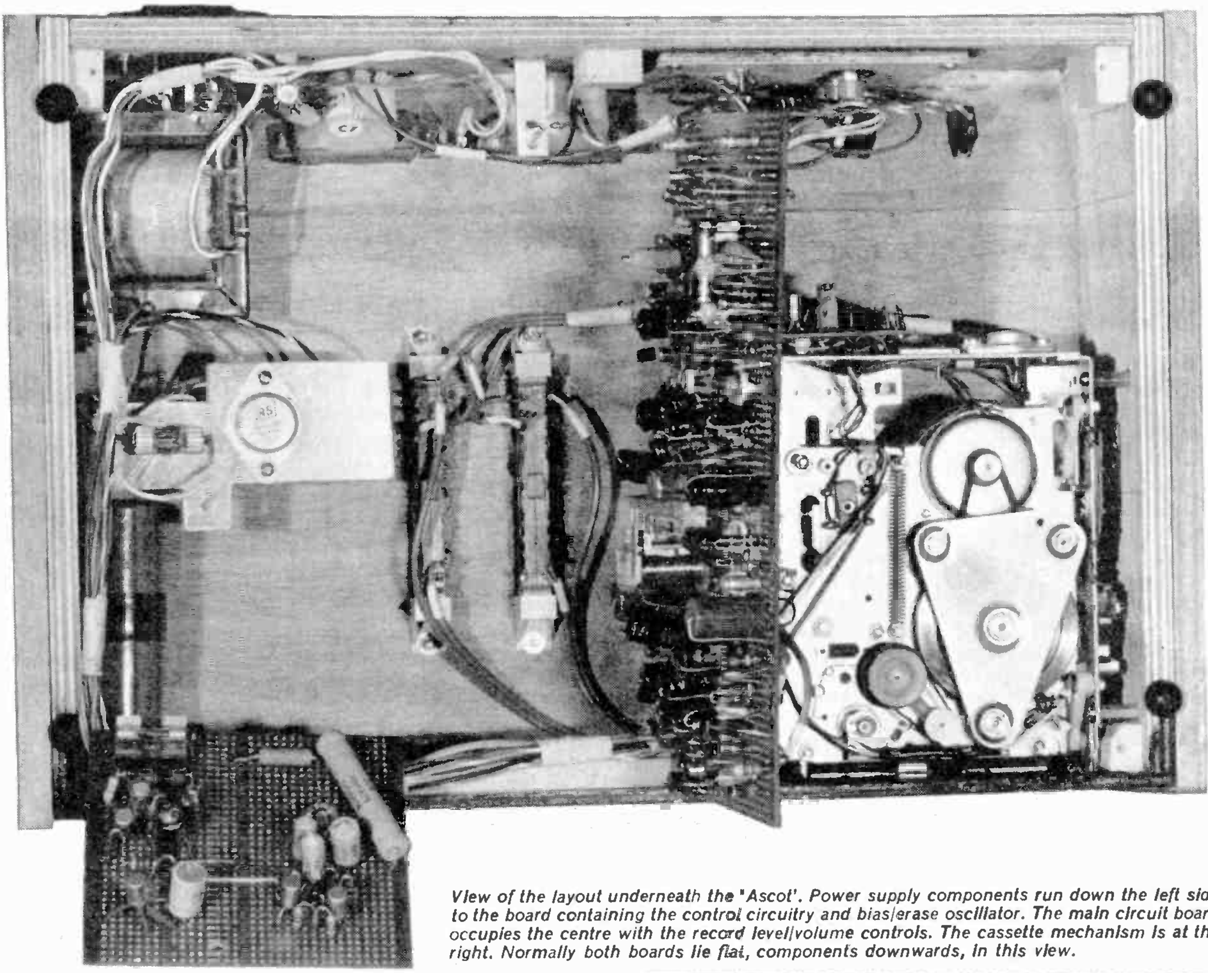
Fig. 10: Layout of components and connections to the PCB.

circuit board, Fig. 9/10. The power supply components are mounted on a similar sized metal plate and the complete unit is housed in a 5in x 5in case $8\frac{1}{2}$in long, constructed from Lektrokit parts.

CONNECTION AND OPERATION

Each telephone is connected between the appropriate line terminal and the common line terminal. Dialling is carried out in the usual way and VR1 may be adjusted to give the required length of ring. The telephone bells may be adjusted for best ringing as described previously.

The system has the advantage that when the two subscribers are in communication a further subscriber may be dialled and join in the conversation. Two telephones may be connected in parallel on one line if required.



View of the layout underneath the 'Ascot'. Power supply components run down the left side to the board containing the control circuitry and bias/erase oscillator. The main circuit board occupies the centre with the record level/volume controls. The cassette mechanism is at the right. Normally both boards lie flat, components downwards, in this view.

commutating switch will be inoperative and the cassette will be promptly ejected again.

CONSTRUCTION

The motor control board, Fig 8, is quite straightforward but take care to cut the tracks in the correct places. When completed, the board is mounted on the rear panel of the cassette mechanism in the position shown in the photograph. Nylon nuts and bolts should be used to avoid shorting or earthing any of the tracks.

The rear panel also acts as the heatsink for Tr19 and is supplied already punched with the necessary pattern of holes. An insulating mounting kit must be used for this transistor.

Part 3, next month, will deal with the construction of the circuit boards, cabinet and general wiring.

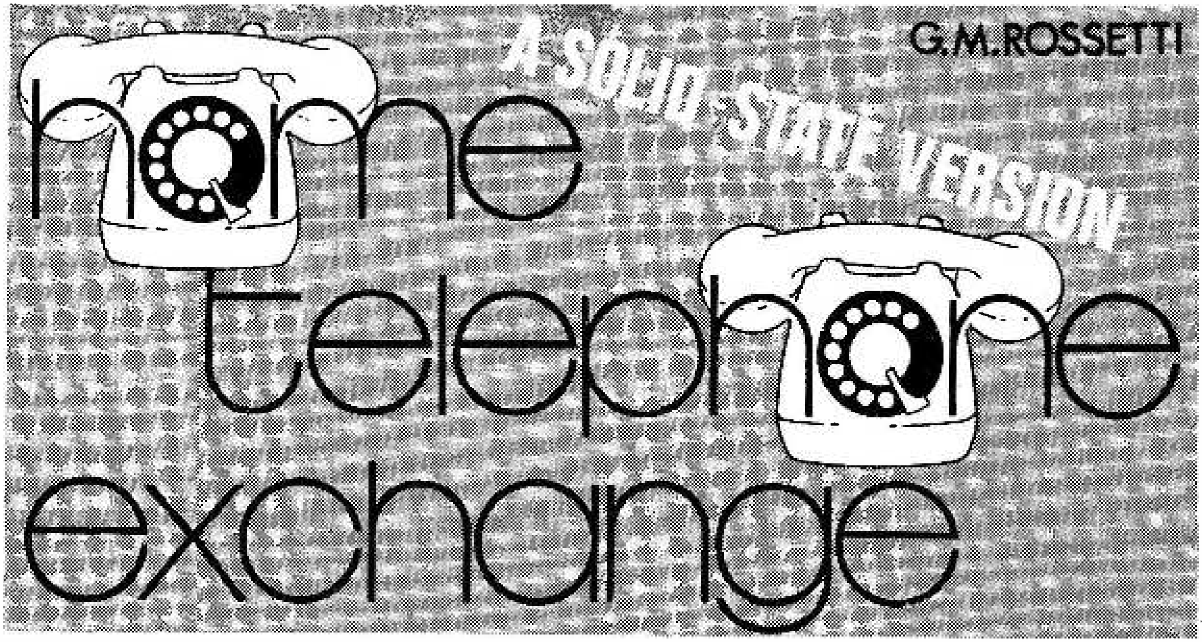
points arising...

ELECTRONIC HOME TELEPHONE EXCHANGE

Feb. 1975. In Fig. 6 page 895 the diode D10 is shown reversed. The bar (+) should go to the +7V line. Note:—the diode is shown correctly on the pcb layout, Fig. 10 page 898.

Also in Fig. 6 the line numbers 1 to 9 are in reverse order, should be 9 at top, down to 1. Relay contacts RLB1 to RLJ1 are in reverse order, should be RLJ1 at top, down to RLB1. The pcb layout is correct, Fig. 10, and these discrepancies do not affect the correct operation of the exchange.

In Fig. 10 C5 polarity is incorrect, the positive side should be at the right, pin 10 IC3. There should be a link between the two pads immediately left of IC2, pin 10 to earth.



THIS article has been written to supplement the Home Telephone Exchange published in February 1975. For a home telephone exchange however, cheapness and size are major considerations, and it is for these reasons that the circuitry described here is entirely solid state. Cost has been cut by about £6·00 by leaving out ten reed relays, shunt diodes and several other components. However two more low cost IC's are needed, a 7413 and a 7408. Also a 74141 decoder has been used instead of the 74145.

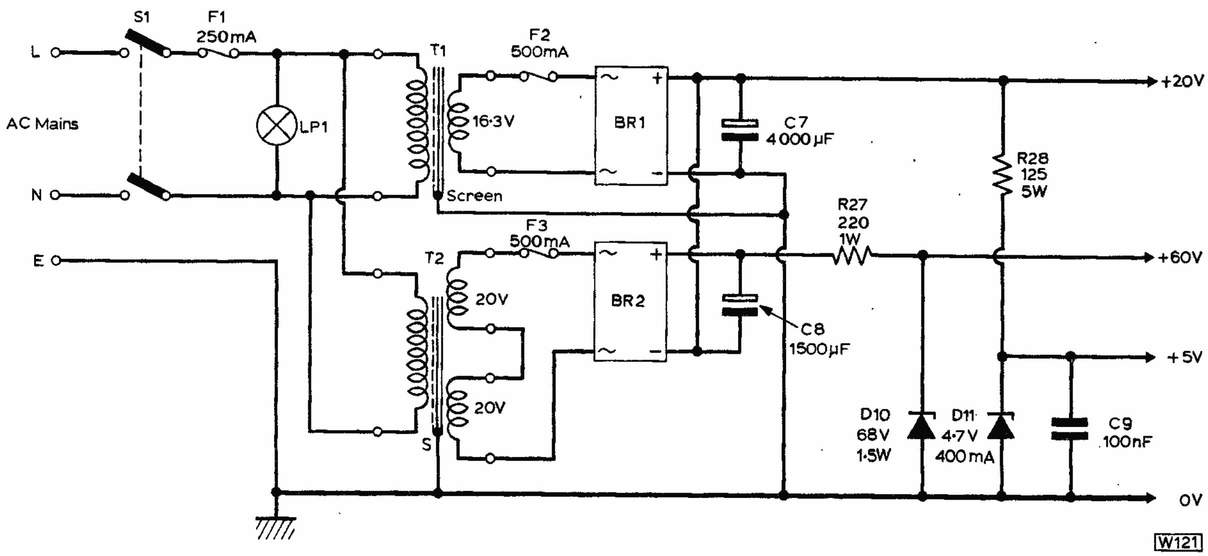
In the power supply section the 7V supply is not required, and a 60V supply has to be found. This is simply achieved, because the ringing supply is no longer required and the same transformer can be used to produce this 60V supply.

Circuit operation is identical so far as counting and generating the ring pulse is concerned. However a transistor, Tr1 is used to detect the dial pulse instead of RLA.

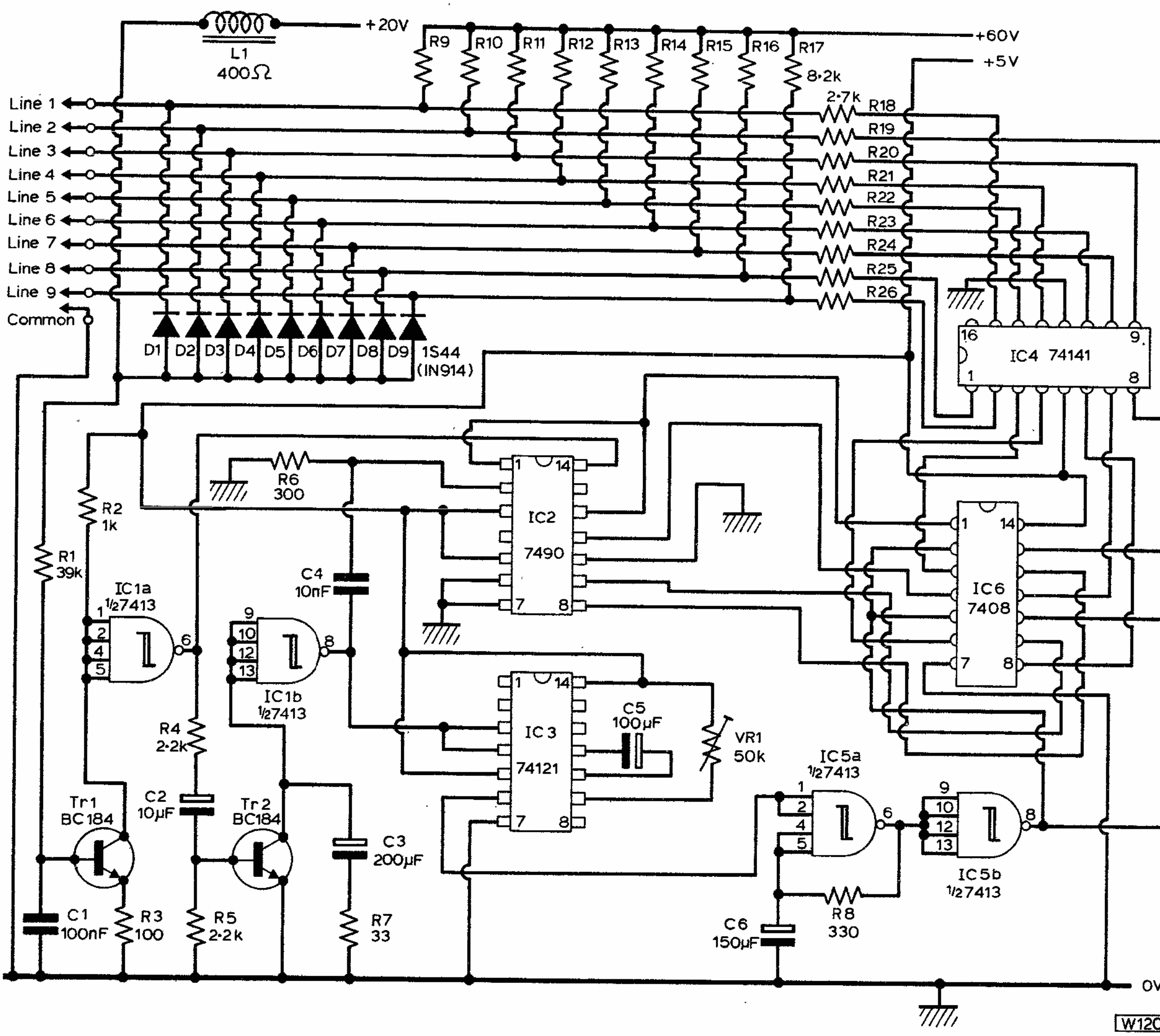
Circuit description

The major difference to the circuitry is in the way the selected line is rung. The binary output of IC2 is fed to the decoder, IC4, through AND gates. IC5b is normally low and until it goes high the decoder will not operate. At the end of the dial period the monostable IC3 goes high for the duration of the ring pulse. IC5a is enabled and produces a pulse train with a frequency of 16Hz. This is now inverted by IC5b and the pulses enable the AND gates of IC6. The decoder is thus pulsed on and off at 16Hz.

When IC4 is in the ON mode, it decodes the binary



Modified power supply using both secondary tappings of T2 linked in series to give a +60V output. This is at the expense of the 'Ringing' supply.



Complete circuit diagram of the modified home telephone exchange. Notice the absence of reed relays and shunt diodes and the introduction of two new IC's which carry out the same tasks.

output from IC2 and the selected decimal output goes low. This output is now connected to the called telephone line through 2·7kΩ resistors. Normally the line is at a potential of 60V, but when the decoder operates to the ring pulse, this drops to about 15V. The result is that a 45V AC voltage at 16Hz is superimposed on the called telephone line and this rings the magneto bell.

There are however two disadvantages, neither of which is of much significance in a home telephone system. Firstly the transmission efficiency is slightly lowered by the shunting effect of the 8·2kΩ resistors. Secondly the bell ringing is not as loud nor as shrill as with a 60V pp voltage at 50Hz. In normal home circumstances, however, this can be an advantage! Moreover there is no possibility of the called subscriber getting an acoustic shock if the receiver is put to the ear before the ringing has stopped. In such circumstances, the AC voltage across the receiver is barely audible. PW

Resistors

R1	39kΩ	R7	33Ω
R2	1kΩ	R8	330Ω
R3	100Ω	R9–R17	8·2kΩ
R4	2·2kΩ	R18–R26	2·7kΩ
R5	2·2kΩ	R27	220Ω 1W
R6	330Ω	R28	125Ω 5W
All ¼W 5%		VR1	50kΩ min. preset

Capacitors

C1	100nF 6V	C6	150μF 6V
C2	10μF 6V	C7	4000μF 40V
C3	200μF 6V	C8	1500μF
C4	10nF 6V	C9	100nF
C5	100μF 6V		

Semiconductors

Tr1	BC184	IC6	SN7408
Tr2	BC184	D1–D9	1S44 or 1N914
IC1	SN7413	D10	BZX61 68V 1·3W zener
IC2	SN7490		
IC3	SN74121	D11	BZY88 4·7V 400mW zener
IC4	SN74141		
IC5	SN7413	Br1/2	1A bridge rectifiers

Miscellaneous

F1, 250mA anti-surge. F2, 500mA. F3, 500mA. L1, 400Ω choke. LP1, mains neon indicator. T1, mains transformer/16·3V. T2, mains transformer/ 20+20V. S1, DPST toggle switch.

Home Telephone Exchange modifications

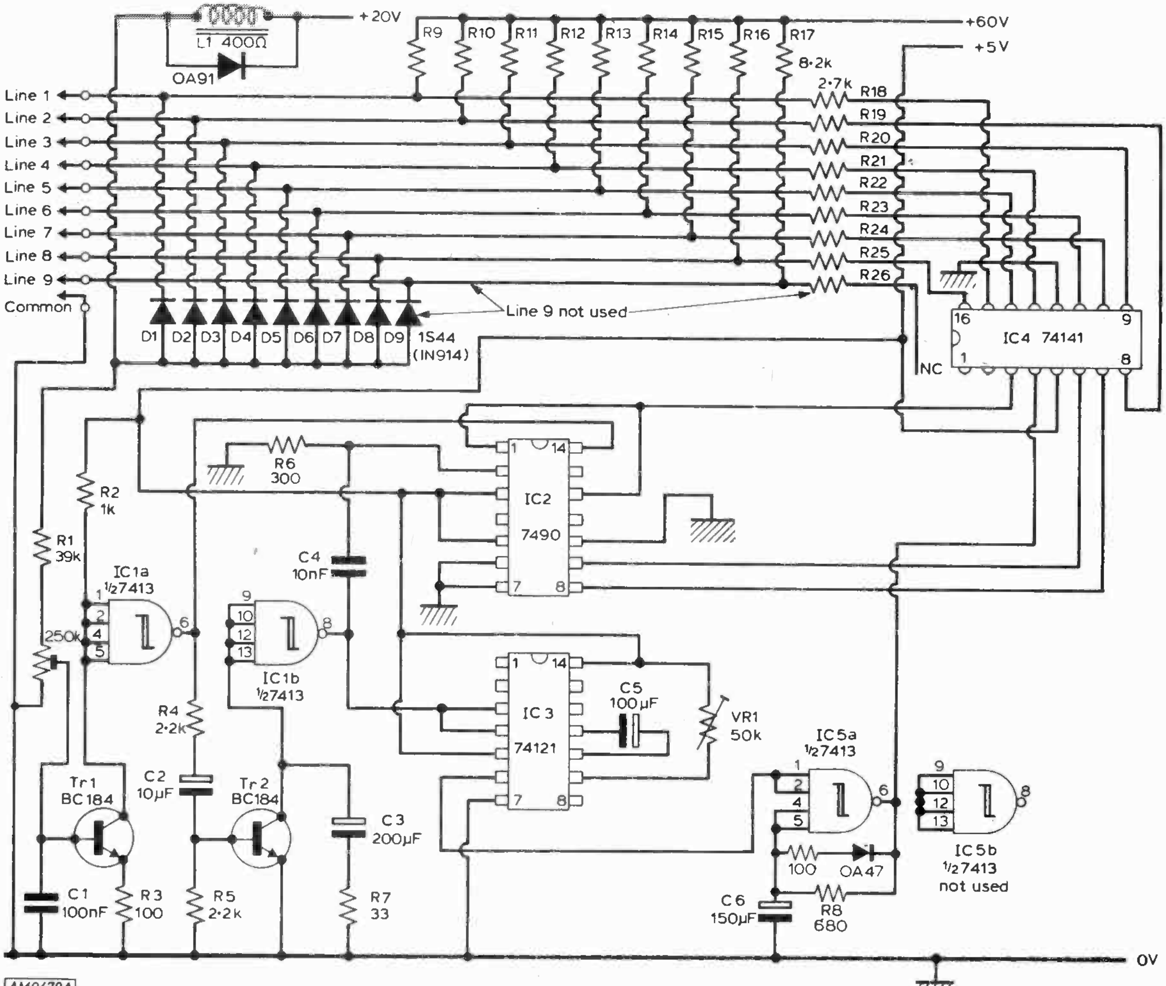
G.M. ROSSETTI

REFERRING to the design for an updated Home Telephone Exchange published in the March edition of *PW*, experience has shown that two minor modifications will almost certainly be necessary if the exchange is to function reliably.

(1) The junction of Tr1 base and C1 should not be connected directly to R1. Instead R1 should be connected to a 220kΩ preset. The other end of the preset should be grounded and C1/Tr1 base connected to the slider.

(2) The mark-space ratio of IC5a oscillator needs to be modified. To do this, R8 should be increased to 680Ω. A new resistor of 100Ω should then be connected in series with an OA47 diode and this combination be connected in parallel with R8. The positive end of the diode (cathode) should be connected to pins 9, 10, 12, 13 of IC5b.

If an exchange of 8 or less lines are required, then the circuit can be simplified by omitting IC6. The BCD outputs of IC2 should be connected directly to the BCD inputs of IC4 with the exception of the connection between IC2 pin 11 and IC4 pin 4. The latter should be connected to IC5 pin 6. IC5b and pin 11 of IC2 are not used. R25 should connect with pin 16 of IC4 instead of pin 1. Finally connect an OA91 diode across the choke—Cathode to +20V supply.



Modified circuit diagram of the exchange. This diagram also shows the connections required for operating an 8-line exchange by omitting IC6 and not connecting IC5b.