Miniature Automatic Telephone Exchange

Constructing a telephone system for private use

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Telephones designed on the standard G.P.O pattern which can be bought very cheaply are shown in a simplified form in the circuit of Fig. 1. The audio circuit consisting of a ,carbon microphone and magnetic earpiece (plus induction coil etc.) is completed through the line by lifting the handset from its cradle. The microphone operates by modulating the d.c. passing through it with the speech waveform and consequently modulating the line current. The bell is designed to operate on a.c. only and is isolated from d.c. in the line circuit by a capacitor. The dial operates by breaking the line circuit the number of times corresponding to the number dialled.

Thus the requirements of a telephone exchange are basically d.c. for the line, a counting system to count the dial impulses, a connecting system to join the two relevant telephones together, and an a.c. source to ring the bell.

If, however, only two telephones are to be used in a system, the requirements can be simplified.

Connecting two telephones

The telephones are wired in parallel and applied with d.c. from a 50V supply in series with a 1kΩ resistor (R, Fig.2.). When both handsets are on their cradles no current is drawn. If one handset is lifted and the dial turned to its fullest extent, the impulses produced will be transmitted to the bell of the other telephone via its built-in capacitor, and cause it to ting. Then, on lifting that handset, both d.c. circuits will be complete and speech modulation produced in the microphone of one telephone will be transmitted to the receiver of the other. The resistor drops the voltage across the telephones to about 5V while talking, but allows the capacitors to charge up to the full battery voltage for ringing. Some telephones may have three or four wires coming out. If this is the case it is necessary to remove the base of the telephone and refer to the circuit diagram and notes within. This will show which two wires to use and which to join together.

The automatic exchange

The operating sequence of the exchange is as follows:
1. The handset is lifted from the cradle of a calling telephone and d.c. passes through

it to energize a relay at the exchange. This causes a uniselector to lock onto that particular line and inactivate all the other lines in the system. When this has happened a dialling tone is connected to the calling line to indicate it is clear to dial. If the exchange was already being used by another telephone the dialling tone would not appear until the exchange was free.
2. The calling telephone dials the number of the called telephone and the impulses from the dial are counted by a second uniselector.
3. At the completion of dialling an a.c. ringing signal is sent to the called phone and a ringing tone to the calling telephone.
4. When the called telephone is answered the d.c. that passes through it activates a relay which disconnects the ringing current and connects the telephone to the calling telephone.
5. When the handsets are returned to their cradles, the second uniselector returns to zero and the exchange switches itself off.

Fig.1. Simplified telephone circuit.

Fig.2. Method of connecting two telephones. R should be selected to suit the battery employed as follows: for 50V use 1kΩ, for 67.5V use 1.5kΩ and for 90V use 1.8kΩ.

The switch contacts on the uniselector, a large rotary switch rotated by an electromagnetic mechanism (see Fig.6), are mounted in semicircular banks. Each impulse to the electromagnet moves the wiper contacts round one position. Each wiper has two contacts; when one comes off the end of the bank of contacts the other makes contact at the beginning. This means that the wipers can go round and round over the contacts without any discontinuity. There is also a contact breaker attached to the electromagnet, which, if wired in series with it, will cause the wiper to rotate continuously when a supply is applied.

Circuit

The complete circuit of the automatic exchange is shown in Fig.3. The relay and uniselector coils are represented as lettered blocks, and the contacts and wipers are lettered and numbered. For example contact RLB/2 is the second contact of relay RLB.

The unit is powered by 50V d.c. from the mains via a transformer and rectifiers, but, to prevent excessive power consumption and for safety reasons the mains is switched on only when the exchange is in operation. A small battery is included as an auxiliary power supply.

Referring to Fig.4 it can be seen that when no telephones are in use there is no current being drawn from the battery. As soon as one handset is lifted a current passes through RLA and the resistor R for the particular telephone. RLA/1 operates switching on the mains and RLA/2 energizes the coil of uniselector 1. The uniselector coil is wired in series with its contact breaker so that the current sets the wiper in motion around its contacts. When the wiper reaches the contact to which the particular telephone is connected current passes through RLC and this stops the wiper at that point. All other telephones are therefore rendered inactive and no dialling tone will be heard if they are lifted.

In Fig.3 RLC is a fast acting relay and will respond to impulses produced by the dial. Thus, to hold the rest of the circuit operational during the impulsing, RLC/1 energizes the slow release relay RLD. RLE is another slow release relay, which is energized by RLD/1. The purpose of this relay is to sense when the dial
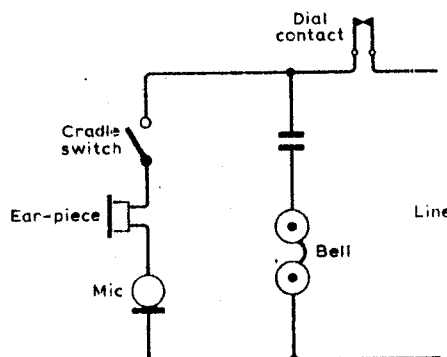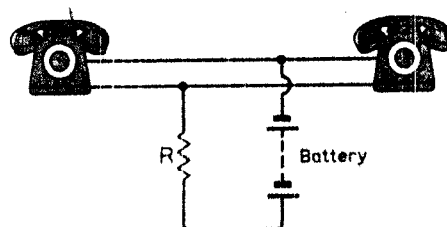
U1. STOPS ANYWHERE (LINE FINDER) RLJ

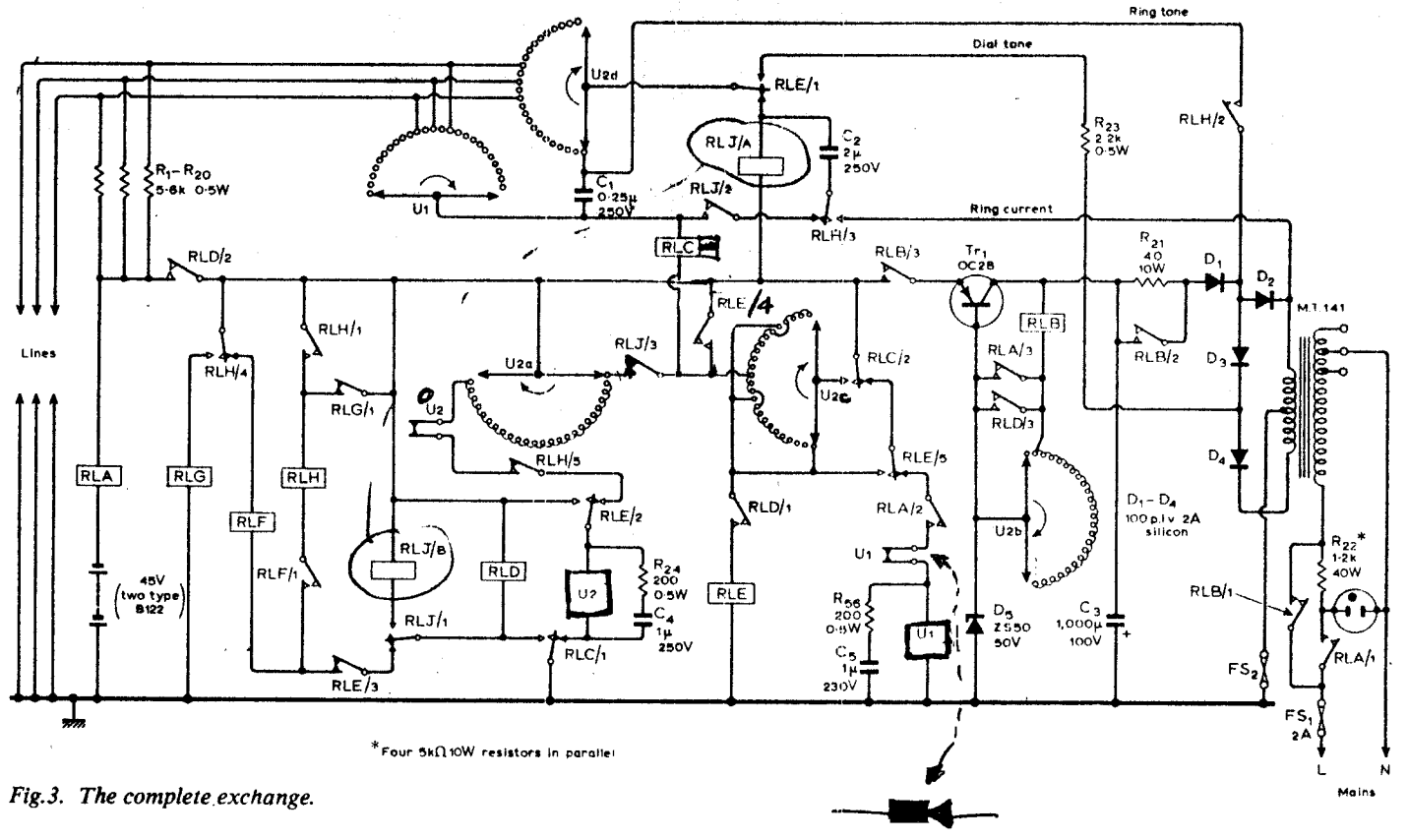U2. HOMES (SELECTOR)

Four 5kΩ 10W resistors in parallel

Fig.3. The complete exchange.

impulses have stopped, and then actuate the ringing circuit.

When RLE is energized RLE/1 switches the dial tone through to the calling telephone via U2d, C_1, and U_1, indicating that the exchange is ready for dialling pulses. In addition RLE/2 switches the coil of U_2 to the negative supply, thus making it responsive to the dial pulses which also de-energize RLC.

The uniselector U_2 will move round one position for each dialling pulse. There are 25 positions on the uniselector enabling the telephones to have the numbers 3 to 9, 01 to 09, and 001 to 004.

RLE initially get its supply via bank c of U_2, but as the impulses send the wiper round away from the homing position, the relay remains energized only by pulses from RLC/2. As soon as the impulses stop RLE will turn off unless 0 or 00 has been dialled. in which case current will again pass through U_{2c} before RLE has a chance to turn off.

When RLE de-energizes RLE/3 energizes RLH via RLG/1, RLF/1 and RLC/1. RLH/3 switches the ringing current to the telephone being called and RLH/2 feeds the ringing tone to the calling telephone. RLF and RLG are both very slow release relays, and together with RLH they break up the ringing, producing a ring for a few seconds, etc. This ringing pattern is not the same as the G.P.O's, and can easily be distinguished. The timing can be altered by adjusting the tension of the spring contacts of RLF and RLG.

On lifting the called telephone d.c. passes through it and energizes RLJ using winding A, and it holds itself on by energizing winding B via RLJ/1. Its action is to stop the ringing signals and connect

the called telephone to the calling telephone with RLJ/2. The purpose of RLJ winding B is to stop the relay turning off when the called telephone's handset is replaced, as in some circumstances this would otherwise cause the ringing current to switch on again, and the bell would again ring. The final speech pathway is shown in Fig.5.

The power supply is 50V d.c. zener stabilized. The mains transformer is switched on initially by RLA/1 via a surge limiting resistor R_{22}. The rectified output is smoothed by C_3 via R_{21}, and stabilized by D_5 and Tr_1. The coil of RLB forms the bias resistor of Tr_1 and the relay operates only when C_3 has charged up to 50V, i.e. when the bias current starts rising. When RLB/1 closes R_{21} and R_{22} are short-circuited (RLB/1 and RLB/2) and RLB/3 connects the power to the rest of the circuit.

RLD/2 bypasses the 45V battery by applying the 50V to it in a reverse direction from the power supply. Thus the battery is used only for the first few seconds of a call.

The dialling tone is derived from the

TABLE 1

Post Office type 3000 relays

No.	Coil resistance	Contacts			Plug length in inches
		make	break	change over	
RLA	5000Ω	3	—	—	
RLB	800Ω	3	—	—	1 or 1.5
RLD	400Ω-5kΩ	3	—	—	1
RLE	400Ω-5kΩ	1	1	3	1
RLF	400Ω-5kΩ	1	—	—	1.5
RLG	400Ω-5kΩ	—	1	—	1.5
RLH	400Ω-5kΩ	2	1	2	—
RLJ/A	3000Ω				
RLJ/B	400Ω-5kΩ	1	1	1	1

RLC 3000

rectifying circuit, and is the coarse half-wave, rectified, unsmoothed 50Hz. The ringing tone is full-wave rectified 50Hz appearing as 100Hz. Both are passed to the calling telephone via C_1 and U_1.

On completion of a telephone call the exchange starts to switch itself off when the calling telephone's handset is returned to its cradle. RLC de-energizes as do RLD and RLJ. A supply passes through U_{2a} and the coil of U_2, and this returns the wiper of U_2 to its homing position by the action of the contact breaker. Bank b of U_2 breaks the supply of the coil of RLB, which switches off the mains. RLB is a slow release relay so that the short breaks as the uniselector wiper passes between contacts, or short breaks between calls do not turn it off. U_1 does not have a homing position; the wiper stays where it was left at the end of the call.

Other points

There are no telephones with the numbers one or two because they could easily be accidentally called by rapid movement of the cradle switch. Instead, dialling one or two causes the dialling tone to reappear.

The purpose of some of the contacts in the circuit still remain unexplained; they are to maintain consistent operation of the exchange however the telephones are used.

Components and construction

Details of the Post Office 3000 type relays employed are given in Table 1. The only other relay is RLC; this should be a high-speed relay with a total resistance of about 3kΩ operating at about 24V. This may be more easily achieved by using a lower voltage and lower resistance relay with a series resistor. If RLC is not

✱ AFTER 112 has homed

sensitive enough it will not stop U₁ rotating, on the other hand if it is too sensitive it will not de-energize at the end of a call. It is therefore an advantage to be able to adjust the tension of the relay contacts to give optimum sensitivity.

Uniselector U₁ needs one bank and U₂ four banks of contacts. The coils should be 75 Ω and the uniselectors 50V working.

It does not matter in which order the line wires are connected to the bank of U₁,

they need not be matched with those on U₂. There have been references to a homing position on U₂; this is for convenience, the first contact in the bank.

Construction

Layout is not important although one should bear in mind that relays and uniselectors are noisy components and therefore the exchange should be mounted where the noise is not going to be a

nuisance. Do not use a common earth line when connecting telephones to the private exchange as a faint conversation will be heard on all telephones using the same earth line; use two wires for each telephone.

Testing

After completing the construction, the exchange should be tested on the bench using two or three telephones. Connect up the batteries and the mains, and lift a handset. RLA should operate, then, after a few seconds pause as C₁ charges, RLB will also operate. U₁ should rotate, then stop when RLC energizes, RLD and RLE should then energize and the dialling tone should be heard. Problems may arise due to the sensitivity of RLC as mentioned earlier.

Dial the number of another telephone. U₂ should rotate, then RLE should break and RLF, RLG and RLH should turn on. The called telephone should ring. The tension in the spring contacts of RLF and RLG should be very low so that their slow release action is made as long as a few seconds each.

RLF, RLG, and RLH will continue clicking, as they break up the ringing signal, until the called telephone is answered. RLJ should then operate and RLF, RLG and RLH should cease operating and speech should be possible between the two telephones.

When the handsets are replaced U₂ should return to its homing position and everything else should switch off which will be indicated by the neon.

It may arise that one or two of the relays buzz instead of operating properly. This may be caused by a contact which is acting too early or too late relative to the rest of the system. The problem can be solved by bending the contact nearer or further away, as the case may be. Note that change-over contacts should 'break before make' to prevent this occurring.

The frequency of the ringing current used is 50Hz a.c. This is higher than normal so it is necessary to move the two gongs of the bells closer together to make the bells ring smoothly. This is easily done by loosening the gong-retaining bolts and rotating the gongs, and then re-tightening the bolts.

Editor's Note: It is illegal to connect any private equipment such as described here to the public telephone system without Post Office approval.
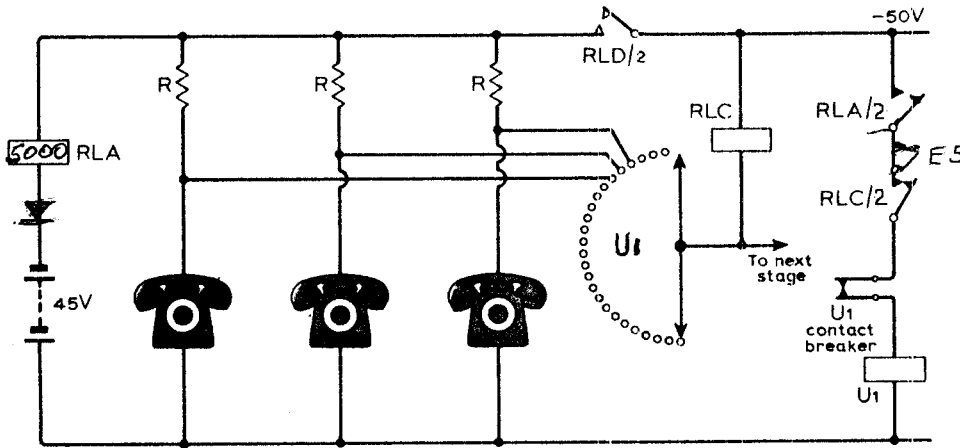

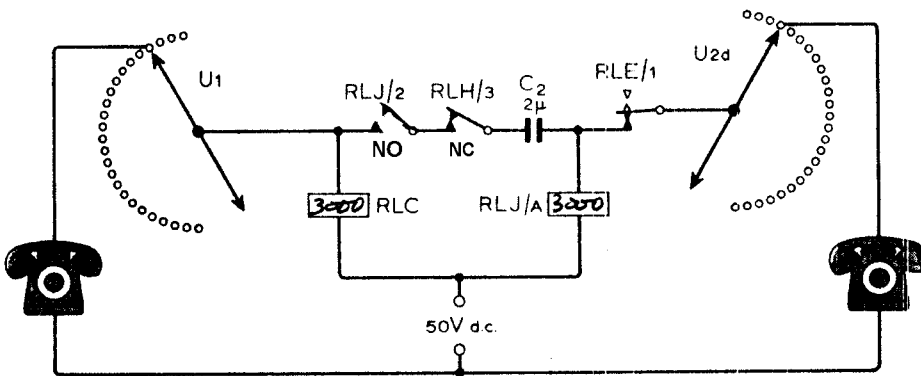Fig.4. Simplified circuit of part of exchange.

Fig.5. The final speech path through the change.
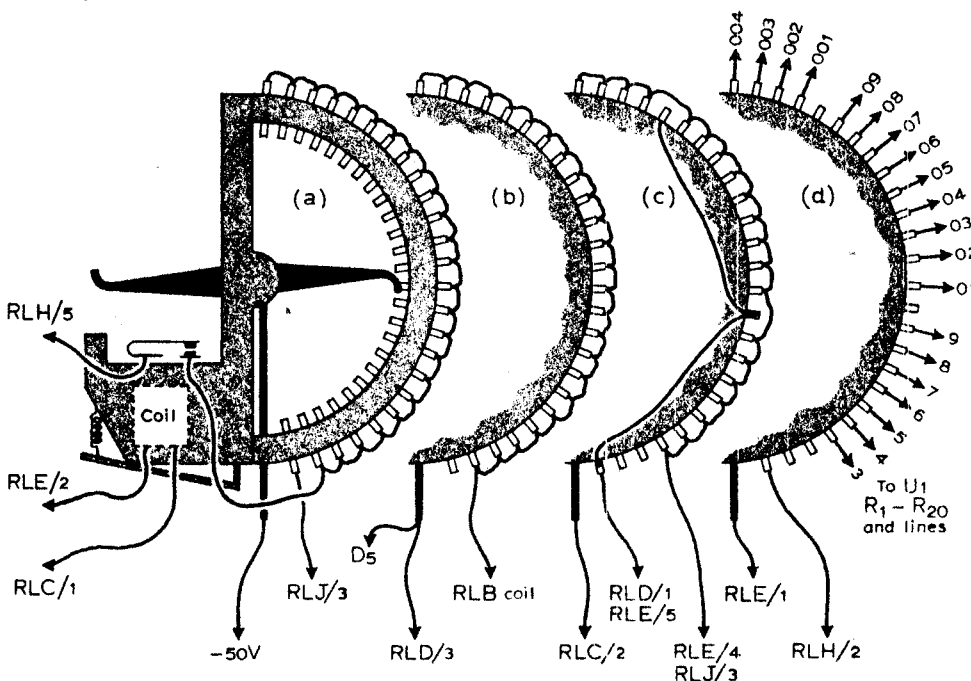

Fig.6. Connecting uniselector U₂