Build this automatic telephone exchange

This is a description of a simple automatic telephone exchange which can be built from surplus PMG telephones and exchanges components. It may be built simply as an educational exercise or as a practical inter-office telephone system.

by GRAHAM LEADBEATER *

The Private Automatic Exchange (P.A.X.) is often used in offices to remove the load of internal traffic from the telephonist, who is then freed to deal with incoming and outgoing calls. It is thus a closed system, not connected in any way with PMG circuits.

A commercial P.A.X. can be a quite complex system, catering for heavy traffic (many calls at once) and a large number of lines (50 to 100 are common).

The system described here is not intended as a competitor to such systems. It provides (in its simplest form) for up to 10 lines and can handle only one call at a time. While the latter restriction may appear to be fairly severe, the simplicity which results makes it ideally suited for amateur construction. It requires only one uniselector and four relays, plus one relay for each line. Thus, a 10 line system would require 14 relays.

To some it may appeal as nothing more than an interesting exercise, aimed at providing a practical insight into the elementary principles of automatic telephones.

For school science groups, YRCS or similar radio club groups, such an exercise would be invaluable, particularly as the cost could be spread over a relatively large number of people. A further advantage of such a project is that the end result has a high appeal to those non-technical persons — parents and others — who sponsor the organisation.

Any club which can demonstrate a working model of an automatic telephone exchange which they built themselves, will earn high praise indeed.

But the system need not be limited to a building exercise and simple demonstrations. It has been seriously suggested, by an independent telephone technician who studied it, that it would provide a perfectly practical intercom for a small group of offices.

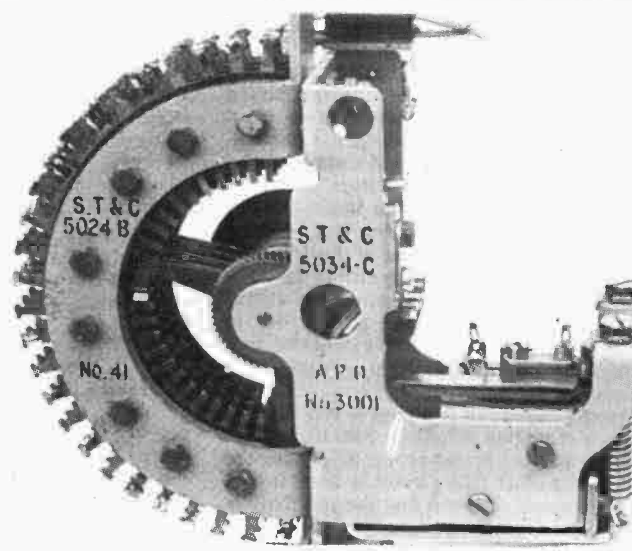
The restriction of one call at a time is not, statistically speaking, as severe as it might appear at first, and compares favourably with similar restrictions encountered in commercial exchanges.

In a typical commercial P.A.X. a group of 200 lines would normally be restricted to handling 11 simultaneous calls, or approximately one call for every group of 18 lines. On this basis one call at a time for a group of 10 lines is not bad odds.

While a call is in progress the remaining phones are simply blocked out of the exchange circuitry. Complete privacy is provided for all calls. Only one pair of wires need be provided for each extension.

Before discussing the operation of the circuit it may be helpful to consider some of the components used in an automatic telephone exchange; components which, in most cases, are only vaguely understood by electronics enthusiasts outside the telephone industry.

Most readers would appreciate that the heart of an automatic exchange is the uniselector or its big brother, the bimotional switch; stepping switches which respond to impulses dialled from the calling phone. But, beyond that, they probably know little about them.



This uniselector is typical of the type which could be used. It has three rows of contacts plus a "homing bank;" the latter just visible at the rear. The coil housing is on the right with the interrupter contacts just above it. Other units may have more banks of contacts, but would be just as suitable.

In greater detail the uniselector could be described as a multi-pole, 25 position switch, stepped by an electromatnetically operated pawl which engages a ratchet wheel. Every time the magnet coil is energised the pawl moves forward and engages one tooth on the ratchet wheel. When the coil is de-energised, powerful springs pull the pawl back to its original position and step the switch arms forward one contact.

The contacts are arranged in a semicircle and there are two sets of moving arms 180 degrees apart. This avoids any need to reverse the stepping action. As one moving arm leaves contact number 25, the other moving arm engages contact number one.

The unit illustrated has three moving arms; two non-shorting and one shorting type. The non-shorting ones are used in this unit, the shorting one being ignored for the moment.

The uniselector normally steps forward one contact at a time, in sympathy with impulses from the telephone dial. On completion of a call it is necessary to reset the moving arms to the "at rest" position, but without the benefit of dial pulses.

For this purpose the uniselector carries its own set of interrupter contacts which generate the required pulses. There is also a fourth switch pole which engages a continuous semicircular contact covering 24 of the 25 positions. The remaining position is a separate contact occupying the "at rest" position. This is called a "homing run" or "homing bank" and the single contact the "home contact."

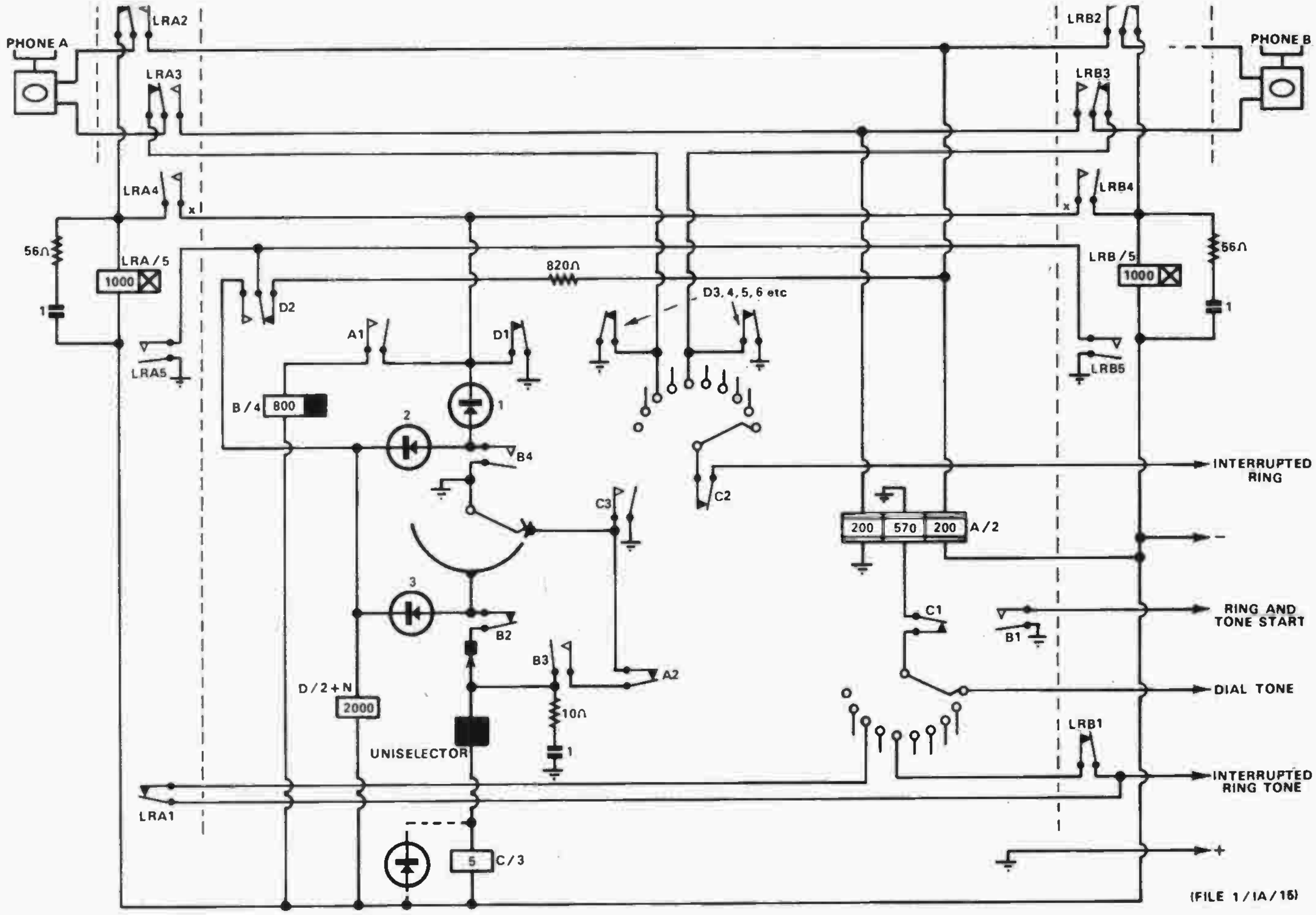
The unused bank of contacts, discussed a moment ago, can also be used to provide a "homing run" by strapping together all the contacts or as many as may be desired. This permits some useful variations on the basic idea, which we may discuss later.

The uniselector coil has a resistance of about 100 onms and needs at least 40V across it for reliable operation. The interrupter contacts must have a suppressor network across them to minimise sparking, which otherwise would destroy them in a short time. A 1uF capacitor and 10 ohm resistor in series is a typical arrangement.

Most readers will be familiar with relays, but not necessarily with the special types encountered in telephone systems. The main difference is in the response time of these relays. While some are required to operate and release in the fastest possible time, others are required to operate and / or release only after a significant time delay.

While this effect can be obtained in a number of ways, the most common method to date has been to fit a copper slug

* 16 Ellison St, Ringwood, Victoria, 3134



The exchange circuit. Only two phones are shown, designated "a" and "B", but up to 10 can be accommodated. Apart from the line relays (LR) all the components are common to the entire system. One line relay is needed for each phone, but is located at the exchange.

to one end or the other of the relay coil. Such slugs can provide time delays of up to 500mS, although 300mS is a more usual value. If the copper slug is fitted at the armature end of the coil, the relay becomes a "slow operate, slow release" type. If it is fitted at the heel end of the coil it becomes a "normal operate, slow release" type.

Another special type of relay is used in the automatic exchange. This has three windings, two of which are connected in series to provide the normal magnetic field. The third one is magnetically coupled to the other two, and is fed with dial tone or ring tone signals, which are thus magnetically coupled into the telephone circuit. The unit is really a combined relay and simple audio transformer.

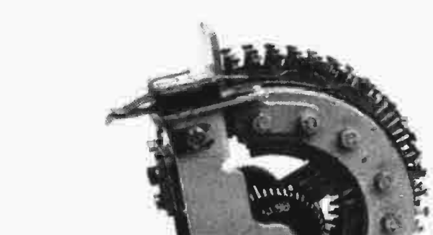
Relays having these various characteristics are essential to the operation of the automatic exchange, and they must be kept in mind when studying the way in which it functions.

In the circuits presented here the relay coils are identified by a code letter or letters over a number, the latter indicating the number of contact sets operated by that coil. Thus, "B/4" indicates that the B relay operates four sets of contacts. The contacts themselves are scattered throughout the circuit and identified as "B1", "B2" etc.

To understand how the system operates, consider first that all telephones are hung up and, as a result, all relays released. In the hung up condition a telephone presents an open DC path, but a closed AC path through the calling bells and a capacitor. (The circuit shows all relays in their "normal" — non activated — position.)

It may also be helpful to point out that, contrary to what one might expect, the uniselector does not switch the speech circuits directly. Its main function is to apply ringing power to the called phone and allow it, and it alone, access to the speech circuits in the exchange.

Assume telephone A is picked up. It now presents a DC path of about 75 ohms and a circuit is completed from the negative supply rail through the relay coil LRA (Line Relay A), contact LRA2, the telephone,



Close up view of the uniselector coil and terminals. The terminal on the left is common, on the right goes direct to the coil, and between them, at the rear, to the coil via the interrupter contacts.

LRA3, and the appropriate D relay contact to chassis (positive supply rail).

Note that LRA4 is an "x" contact; it must make first, before LRA2 or LRA3 breaks. LRA locks up via LRA4 and D1 to chassis.

Contacts LRA2 and LRA3 switch the calling telephone across the A relay, connecting the two 200 ohm windings effectively in series and across the power supply. When relay A operates contact A1 completes a circuit through relay coil B. Contact B1 then starts the ring and dial tone circuits. Dial tone is fed via the uniselector home contact and relay contact C1 to the 570 ohm winding on relay A. This relay functions as a transformer and the tone is coupled into the 200 ohm windings and heard in the telephone.

Contact B4 closes and replaces the chassis connection via D1 and simultaneously operates relay coil D via diode 2. Contacts D1, D3, 4, 5, 6, etc all open. Contacts D3, 4, 5, 6, etc are break contacts in each line and, when D operates, prevent any other line from operating its line relay. Relay LRA is already locked up on its own number 4 contact.)

Contact D2 is a changeover set which provides protection against accidental lock-up of a line with resultant loss of privacy. This function will be described later.

When a number is dialled the DC path through the telephone is opened once per impulse dialled. The A relay opens and closes once per impulse in sympathy. A2 is normally closed but is open prior to dialling, coil A having been energised via the telephone and contacts LRA2 and LRA3.

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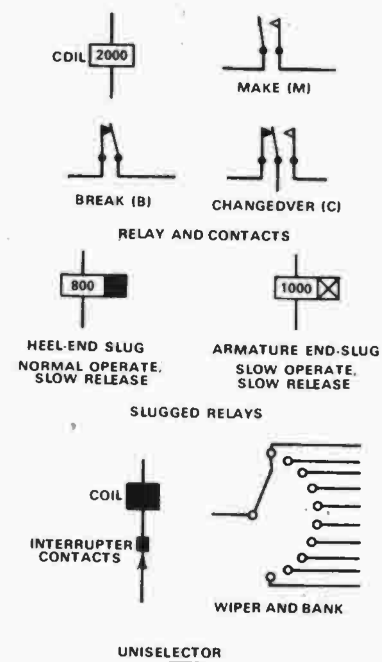
When the dialling contacts open, relay A releases, A2 closes,and the uniselector coil is energised. When the dialling contacts close, relay A pulls in, A2 opens, and the uniselector steps one contact. A1 does not release B, since B holds on its slug.

(The uniselector steps on the removal of power, rather than the application of it.)

At the same time as the uniselector is energised, relay coil C is also energised, the two being in series. Relay C is required to have a slow release time, so that it does not



Symbols commonly encountered in telephone circuits. Note particularly those for the differing types of slugged relays.

follow the individual dialling impoulses. Instead, it holds in until the dialling sequence is completed. Contact C1 removes dial tone from the calling phone and C2 removes the ring power from the uniselector contacts while they are stepping, to prevent interference to other lines.

Contact C3 closes, replacing the chassis connection from A2, previously provided via the uniselector home contact.

At the end of the dialling sequence, relay C releases. Contact C1 closes and applies ring tone to the calling phone (phone A) via the 570 ohm A relay winding. Contact C2 closes and applies interrupted ring voltage to the called line (phone B). Now that C3 has opened, no more dialling is possible.

In order that relay C exhibit a suitably slow release time it may be necessary to shunt the coil with a power diode as shown dotted in the circuit.

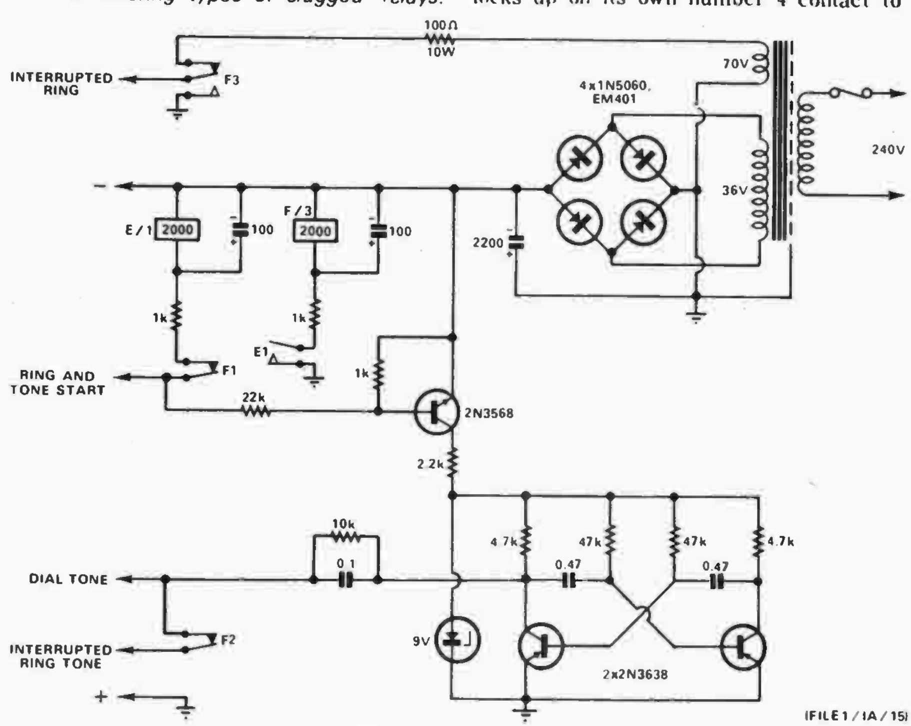
In greater detail the path is as follows: From the interrupted ring supply to C2, the uniselector contact, LRB3, telephone B, LRB2, 56 ohm resistor, 1uF capacitor, and the DC negative supply rail. (The AC ring current is fed in series with the DC supply. The capacitor in the phone blocks the DC component until the handset is lifted.)

Relay LR must have a slow operate — slow release characteristic so that it does not chatter during ringing.

When the handset on phone B is lifted a DC path is completed which operates phone B line relay: from the negative rail to the LRB coil, LRB2, phone B, LRB3, uniselector contact, and via the ring supply to chassis.

(The latter circuit is completed via the F3 relay contact in the power supply, used to interrupt the ring current. This is a changeover set and the ring current line is returned to chassis between each ring. This means that the LRB circuit closes during a silent period between rings.)

When LRB relay for phone B operates it locks up on its own number 4 contact to



Power supply and tone generators. The multivibrator generates 33Hz for ring and dial tone, while relays E and F pulse at the interrupted ring rate. The AC voltages are not critical, nor does the rectified output require a great deal of filtering.

chassis via B4. Contact LRB1 opens, and cuts off ring tone to phone A. Contacts LRB2 and LRB3 transfer phone B from the ring circuit to the A relay. Phone A and phone B are now connected in parallel across the A relay which provides transmission current, so that a conversation can take place.

When the conversation is completed and both phones are hung up, relay A releases, relay B releases. Contact B2 closes and completes the self interrupted drive circuit for the uniselector which drives it back to the home contact. Contact B4 opens and releases both line relays. When both line relays have released and the uniselector is on the home contact, relay D releases and the exchange is back to normal.

One limitation of the circuit described so far concerns a possible loss of privacy. If a telephone user were to give his cradle switch a quick flick it would be possible for his line relay to lock up without operating relays A or B. This LR would remain locked up until the exchange was next used and the locked up line would be able to listen to another conversation.

To prevent this an 820 ohm resistor is connected between LR2 and D2. This allows the A relay to be operated via LR5, instead of via the phone. The sequence is: A "flick" operates LR which locks up via LR4 and D1 to chassis; LR5 operates A via 820 ohm resistor; A1 operates B; B4 operates D; D2 releases A; A1 releases B; B4 releases LR; LR releases D and the exchange is back to normal.

Apart from the exchange proper, it is necessary to provide a basic power supply, a dial and ring tone generator, and interrupted ring current.

The basic power supply calls for a mains power transformer delivering about 35V AC and 70V AC. The 70V AC is used directly to operate the calling bells, while the 35V AC is rectified via a bridge rectifier and simple filter to give about 50V DC. This is used to operate the relays, uniselector etc.

The interrupted ring is generated by a simple pulsing network employing two relays, E and F. These are cross connected so that contact F1 controls power to relay E and contact E1 controls relay F. Each relay is shunted with a 100uF capacitor to provide the necessary time constant. To simplify switching, this circuit is allowed to operate throughout a conversation, even though it is not required.

The ring and dial tones come from the one generator; an astable multivibrator operating at approximately 33Hz. Continuous output provides dial tone and interrupted output provides ring tone. This also operates throughout the conversation.

Contacts F2 and F3 control these functions. Contact F2 interrupts the output of the multivibrator to provide interrupted ring tone and F3 interrupts the 70V AC supply to provide interrupted ring power. Note that F3 is a changeover contact, providing a chassis connection for the exchange ring circuit during the silent period between rings. This is to complete the called line relay circuit as previously discussed.

The voltages specified are not unduly critical. The DC supply could vary from 40 to 55V and the AC from 50 to 80. Note, however, that a 40V DC supply may call for careful adjustment of the uniselector spring tension in some case.

If transformers designed to deliver these voltages are not readily available, it may be possible to improvise with discarded radio power transformers. One suggestion is to use a pair of old 385V-0-385V units working backwards. The whole of the old secondary winding (770V) of one is used as the 240V primary, so that the old 240V primary delivers approximately 75V.

The second transformer is used to deliver about half this voltage. It is used in the same way except that it is connected between one side of the mains and the centre tap of the previous transformer primary winding, and is thus fed with 120V.

The circuit presented in the foregoing is not the only way to make an exchange of this type; it is not necessarily the best way to do it. It is simply one compromise between complexity and performance. As such, it has a few weaknesses which should be considered before construction.

Two or more telephones picked up simultaneously will operate their respective line relays and both will receive dial tone. However, dialling will not be possible and both must be hung up before one can dial normally. The chances of this happening should be fairly remote, however.

Since a parallel transmission feed is used a call between a high resistance line and a low resistance line will result in the low resistance line shunting current from the high resistance line. In practice, this is not a problem with lines under 1000 ohms (half a mile or so).

One phone left off the hook, or one line shorted, will put the whole system out of action.

These problems could be designed out but it was felt that the extra complexity which would be involved would not be justified.

As mentioned earlier, there are some possible variations on this basic design. One

RELAY	COIL	RESIDUAL AIR GAP	CONTACTS	REMARKS
A	200, 200, 570 ohm Hi-z transmission feed coil	Adjustable	M.B.	Must follow dial impulses
B	800 ohm 1½" heel-end slug	Adjustable	M.M.M.B.	Release time approx 300mS
C	5 ohm May need diode across coil	Adjustable	M.B.B.	Must hold during impulsing and self-drive
D	2000 ohm	.012in	B.C. B per line	A number of relays in parallel may be required to accommodate the contacts
LR	1000 ohm ½" armature end slug or extra winding short circuited	.012in	C.C.M.B.	1 per line required. Must not chatter when line is rung LR4 must make before LR2 and LR3 break

Most of the relay requirements have been covered in the explanatory discussion but the summary in this table may help the constructor select his requirements from what is available. Miniature cradle relays are not recommended (except for D). Use of cradle types throughout would call for circuit changes. The 3000 type relay lends itself to modifications and the units required can be built up from sections salvaged from other relays. An old relay set is a good source of relays, and may also provide a chassis for the exchange.

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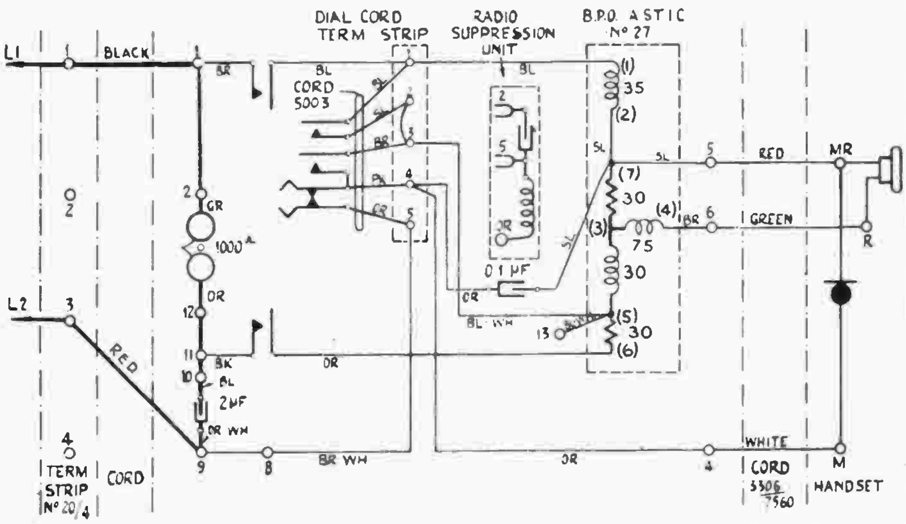
is relatively minor and is aimed at reducing the length of the "home run" on the uniselector, thereby reducing wear and tear.

The other increases the number of extensions to a maximum of 22. Either of these modifications could be made easily after a dial should be satisfactory. Such telephones are offered for sale through disposals outlets from time to time, as are uniselectors, relays etc. Failing that, a search through the Pink Pages of the telephone directory under "Telephone Supplies" may reveal firms who have second hand items for sale.

One point which might require attention in the telephones is the bells. These are normally adjusted to operate on 16 2/3Hz



Circuit of a typical handset as might be acquired through disposals sources. Normally, such a circuit will be found inside the telephone. Although the draughting style may vary, there is very little difference between circuits of the same general class.

the basic unit just described has been completed and tested. We imagine most readers would prefer to tackle the job on this basis if they favour these modifications. We may detail these in a later issue if there is sufficient interest in them.

Incidently, don't try adjusting a uniselector without guidance; they are easily damaged. Ask a telephone technician or, better still, obtain a uniselector adjustment leaflet from the "Publications Sales Office" at the GPO in your capital city.

The telephones themselves require very little comment. Almost any unit fitted with and may not operate properly on 50Hz.

To adjust them for 50Hz it is necessary to provide a shorter stroke for the hammer action. First move the gongs clear of the hammer by rotating them on their mounting bolt (the mounting hole is offset).

An adjustment is available on the magnet assembly which permits the gap between the armature and the poles to be varied. This gap should be substantially reduced so as to shorten the hammer stroke, then the gongs readjusted to suit.

Each gong should be set so that it is just clear of the hammer when the latter is at its extremity for that gong.