

Looking Back at Strowger – One Reader’s Recollections

Strowger technology first appeared in the UK at Epsom in 1912, and finally disappeared from the public telephone network in 1995, with the completion of the BT local exchange modernisation programme.

In this special Centenary edition of *The Journal*, with the theme of ‘looking back’, the author looks back at Strowger, and reflects on some of its more interesting and unexpected features.

Almon Brown Strowger set about devising a system of automatic switching using an electromechanical switch, based around electromagnets and pawls, and, with the help of his nephew and others, produced a working model in 1888

Introduction

For many years the Strowger-based telephone system was the main artery of the Post Office and BT’s public switched telephone network (PSTN). Based originally on the principle of a ‘two motion’ selector, conceived by an eponymous Kansas undertaker of the same name, Strowger proved versatile and was successfully adapted for trunk switching, rural unit automatic exchanges, periodic metering, director, and register-translator working, as well as Telex, and PABX systems. Some would say there was simply nothing it could not do.

Everyone involved with Strowger remembers its ‘clung, clung, clunk; ching, ching, chink’ sound – but in this short article, as well as looking back at Strowger, I hope to throw a little light on some of the more innovative things it did, as well.

History

Almon Brown Strowger (1839–1902), a veteran of the American Civil War, was an undertaker in Kansas City, USA. The story goes that he was convinced that calls were being deliberately routed to his competitors, and so set about devising a system of automatic switching using an electromechanical switch, based around electromagnets and pawls. With the help of his nephew

(Walter S Strowger) and others, he produced a working model in 1888. The Strowger Automatic Telephone Exchange Company was formed, and it installed the first commercial exchange in La Porte, Indiana on 3rd November 1892, with 70 subscribers.

Strowger technology appeared in the Post Office (PO) network at Epsom local exchange in May 1912, just a few months after the nationalisation of the former National Telephone Company to become part of the PO, on 31 December 1911.

The *Post Office Electrical Engineers’ Journal* (POEEJ) reported that Epsom was chosen for the first public automatic exchange, on account of ‘its relatively high percentage of local traffic, the nature of its climatic conditions, the character of its telephoning public, and its proximity to London’¹.

This latter point allowed the performance to be readily monitored by headquarters personnel, an important consideration, as competing systems, such as the ‘Lorimer’ system, and the ‘Relay Auto’ system, were also being considered.

Connectivity and Facilities

Straightforward connectivity between telephone users could easily be established in Strowger – but some additional facilities were incorporated with a little more circuit development, as explained in the following paragraphs. Much of the versatility of Strowger was due to the relay logic that supported it, thanks in part to the work of the experts who specialised in designing ingenious relay circuits to add functionality to Strowger exchanges, working in the so-called PO ‘Circuit Lab’, in Armour House on the corner of Gresham Street and St Martins Le Grand, not far from the present BT Centre.

Many of the principles adopted for the logic design of later electronic circuits, e.g. gates, were used many years previously by the designers of Strowger circuits.

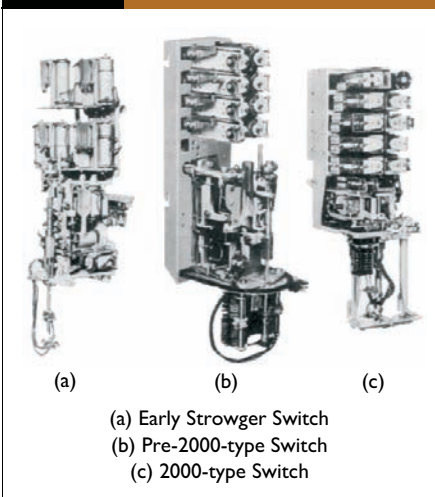
Figure 1 illustrates Strowger connectivity, while Figure 2 shows Strowger 2-motion switches.

Figure 1 Illustration of Strowger connectivity



Courtesy Just Write Publishing Ltd

Figure 2 Strowger 2-motion switches



(a) Early Strowger Switch
(b) Pre-2000-type Switch
(c) 2000-type Switch

Unit Automatic Exchange (UAX) trunk offering facility

One of the most innovative and cost-effective Strowger circuits, in terms of added functionality, was the UAX trunk offering (TKO) facility.

TKO facility – brief summary

In an entirely manual system, the operator is able to interrupt established calls, so that the connection of (urgent) incoming *trunk* calls may be offered, where appropriate.

In Strowger, a 'trunk offering' facility was provided by means of a mechanism-only final selector, connected via a dedicated TKO network, which allowed connection to the called subscriber, irrespective of condition (engaged, free, etc). A similar switch was used for engineering test facilities, and the two mechanism-only selectors, along with the 'normal' final selectors, comprised the final selector unit – typically 10–30 switches serving one 200-line block, depending on calling rate. (The test final selector was installed in the last shelf position in the final selector unit, so that, as well as testing an individual customer's line, it also tested the bank multiple wiring.)

Unit automatic exchanges

In most Strowger exchanges, equipment racks were installed in suites, alongside similar racks, so that there were suites of group selectors, final selectors, etc. This was fine for medium–large exchanges, but a different approach was needed for small exchanges.

For small exchanges, known as unit automatic exchanges (UAXs), which served typically 200–600 lines, a variant of Strowger practice was used. Equipment was (originally) designed to be housed in airtight dust free cabinets in unheated, unattended buildings. Each cabinet or 'unit', hence the name unit automatic exchange, housed a proportion of the equipment, and so several cabinets (depending on the size of the exchange) made up the exchange's total equipment requirement.

Standardised 'units' were used – 'A' units housed calling equipment, group selectors, and final selectors for 50 lines, 'B' units housed the junction relay sets and junction hunters, 'C' units housed the main distribution frame (MDF), intermediate distribution frame (IDF), and tone

generating equipment, etc. Figure 3 shows UAX equipment – a 'C' unit (left) and an 'A' unit (right).

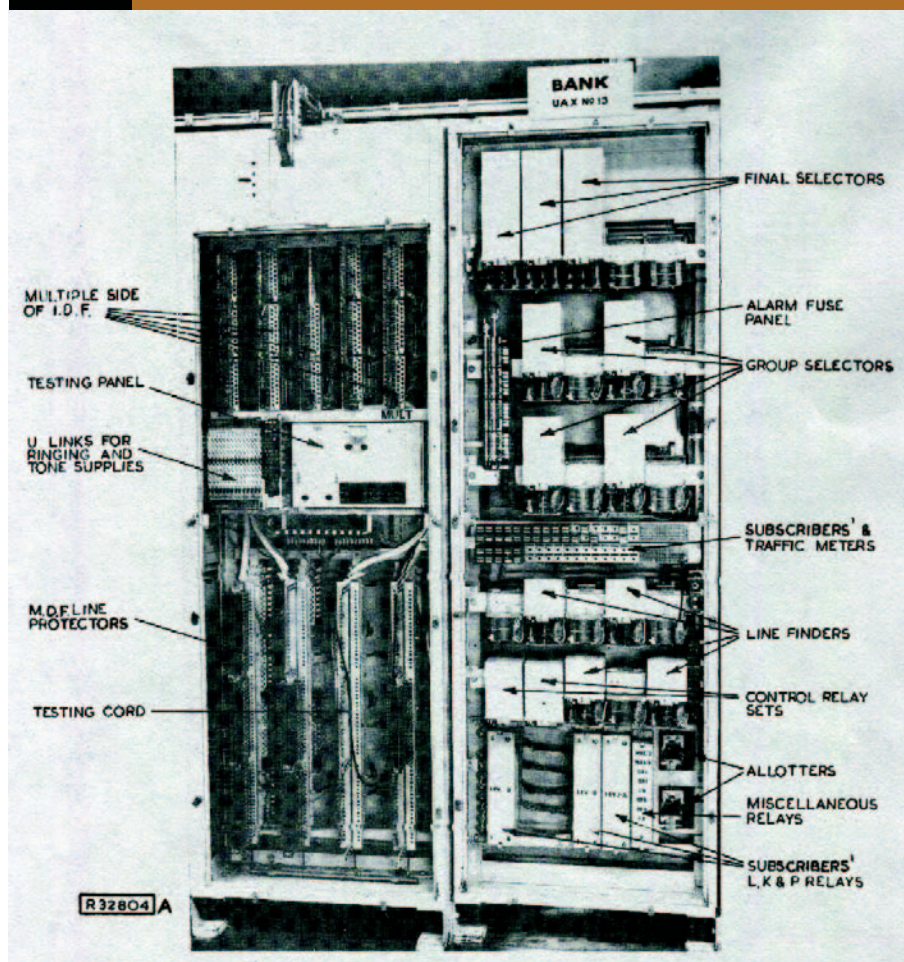
UAXs were installed in rural areas where line plant was generally at a premium, with combined '1/9/0' circuits, sometimes with 'both-way' working, and with no provision for separate TKO junctions, or separate TKO switches. How then was a TKO facility provided at UAXs?

Solution adopted

The solution adopted was to modify the normal final selector design to include TKO facilities, which would operate in response to a selective line condition. It was generally arranged that the last two circuits on the route from the parent exchange to the UAX also appeared on the automanual switchboard. Operators would use these circuits for TKO purposes.

The UAX final selector circuit included a differential relay. Similar in appearance to a straightforward relay, a differential relay was wound so that the two relay coils, when energised, were 'out of phase', and so the relay would not operate. Under these circumstances, when circuit passed through

Figure 3 UAX equipment – a 'C' unit (left), and an 'A' unit (right)



only one coil, but not both, the relay operated. Figure 4 shows the principle of the differential relay.

Circuit operation

To apply trunk offering, the operator activated the ring key, which applied an earth condition to the negative leg of the loop circuit in the outgoing relay set at the parent exchange, on the junction to the UAX. The imbalance of current caused by the 'earthed loop' operated the differentially wound OC (operator call) relay in the final selector. This operated the F relay (at contact OC1), which then (at contacts F5 and F6) connected the incoming call, in this case the operator, to the called number, irrespective of condition, engaged, etc – so that the operator could 'offer' the incoming trunk call.

Against the possibility that a fault condition might produce an 'earthed loop', and thus leave engaged lines unguarded, other contacts (not shown) short-circuited the OC relay to inhibit its operation, on circuits other than from the parent exchange.

The main circuit elements involved are illustrated in Figure 5.

Additional feature

A very useful additional feature was that – having agreed to take the offered call, once the subscriber had finished the first call, and replaced his receiver – the operator could throw the ring key a second time to provide ringing.

Following clear-down, relay H had operated to the battery on the P-wire, and this time the OC relay, in operating, released the F relay. This provided ringing current, and the called customer could then accept the call in the usual way.

Call Holding

Caller hold – brief summary

In a straightforward Strowger call, the exchange equipment was initially seized when the customer lifted the receiver, completing the exchange calling circuit; this circuit, from the customer's telephone to the exchange, was often referred to as the 'customer loop'. As the call progressed, the customer 'loop' was extended in turn to subsequent switching stages, with the preceding stages being held 'backwards' by an earth condition on the P wire. This is illustrated in Figure 6, where the A relay in the final selector is held by the customer

Figure 4 Principle of the differential relay

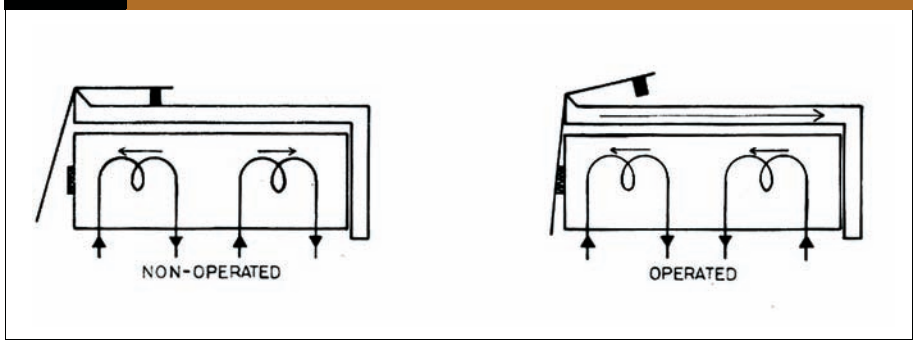
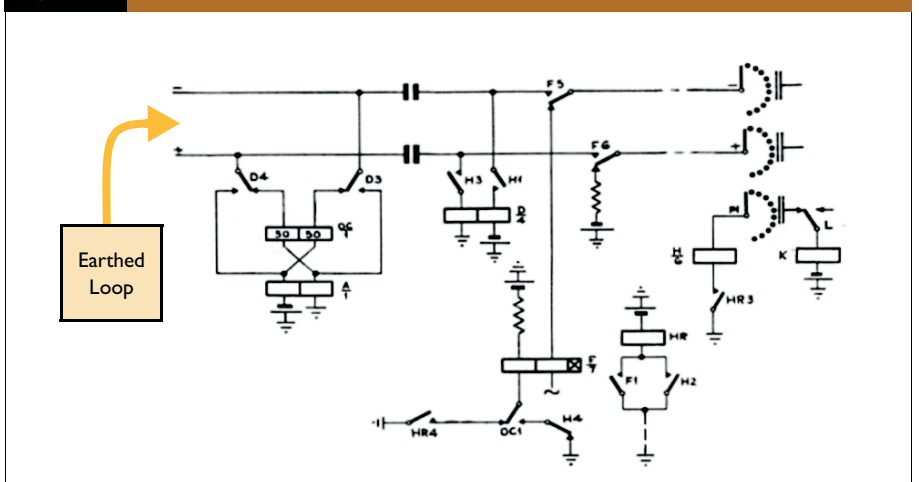


Figure 5 Circuit elements of UAX TKO circuit



loop, and preceding stages are held by the B relay contact.

In the case of a call to another exchange, a similar arrangement (not illustrated) obtained, with the forward connection to the distant exchange being held from the outgoing relay set, in place of the final selector, and the preceding stages held from the condition on the P wire.

Release

In both cases – own exchange call, or a call to another exchange – when the caller replaced their receiver, this released the A relay in the final selector (or outgoing relay set, in the case of a call to another exchange), which in turn released the preceding switching stages, by removing the

earth condition on the P wire. This meant that the point at which the switching sequence was released was under the control of the caller, and this was a practical and realistic arrangement for most types of Strowger call.

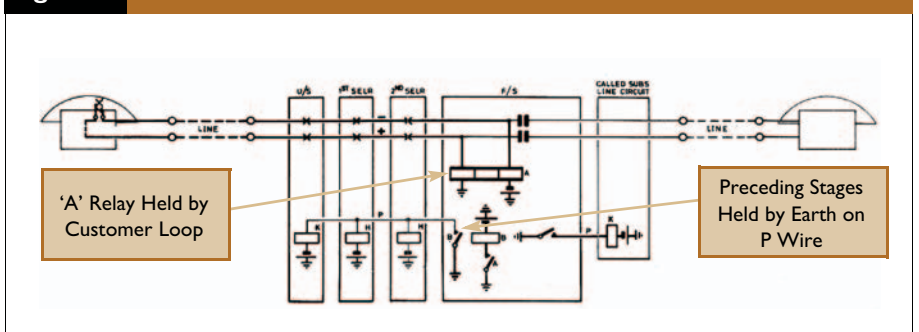
Other systems

Other arrangements were also possible, and – taking account of the differing conditions in those systems – PABXs and Telex employed 'first party' release, i.e. the switching sequence was released, as soon as either the calling or called customer cleared.

Manual hold

An important variant was, however, used on calls to the operator, where the circuit was ar-

Figure 6 Circuit elements – caller hold



ranged to provide 'manual hold' to the operator circuit, so that the connection was not released until the operator disconnected the circuit manually, rather than in a normal call, where the caller released the connection.

This was an essential operational feature, to ensure that customers could recall the operator by pressing the receiver rest momentarily (without disconnecting themselves), or in the case of emergency (999) calls, so that the caller could be traced in appropriate circumstances, e.g. should an agitated caller hang up, without giving complete information, etc.

Manual hold was relatively easily arranged for calls originating from customers in the same exchange building as the automanual centre, where a holding earth on the P wire could easily be put under the control of the assistance relay set. However, a more complex arrangement was needed for calls from other exchanges, to return a suitable manual hold condition over the incoming 2-wire junction to the originating exchange.

Circuit details

The simplified circuit elements are sketched in Figure 7. The A relay in the outgoing relay set operated to the calling customer loop. This then operated the LS relay in the assistance relay set at the automanual centre, and in turn (at contact B3) operated the appropriate calling lamps, indicating an incoming call. On operator answer, the

potential on the sleeve conductor operated the S relay, which in turn operated the SS relay, and (at contacts SS2 and SS3) extinguished the calling lamp, and disconnected the ringing tone.

Manual hold on clear-down

If the calling customer hung up before the end of the call, the LS relay (at contact LS1) in releasing, operated the OH (operator hold) relay, which (at contact OH3) connected a (negative) battery on the 'positive' leg of the junction circuit. This was detected by the MH (manual hold) relay in the outgoing relay set, which quickly applied an earth on the P-wire (at contact J1), to hold the preceding stages, and prevent clear-down. Other contacts (not shown) prepared the assistance relay set for subsequent re-seizure, when the customer loop was re-presented.

Other aspects

Because the circuit also catered for automatic metering (where applicable), and also coin and fee checking discrimination signals for pay-on-answer payphones (detected by the PA relay in the outgoing relay set), on applying the negative battery (i.e. -50 V) on the 'positive' leg, the 'negative' leg was simultaneously changed over to -100 V, i.e. so that the potential difference remained at 50 V, to avoid altering the charge potential on C1.

Summary

By careful attention to detailed circuit design, a standard outgoing relay set was adapted to cope with straightforward operator calls, calls involving pay-on-answer payphones, as well as having the very useful operational capability to prevent disconnection of incoming calls, by providing manual hold by the operator, where the circumstances necessitated.

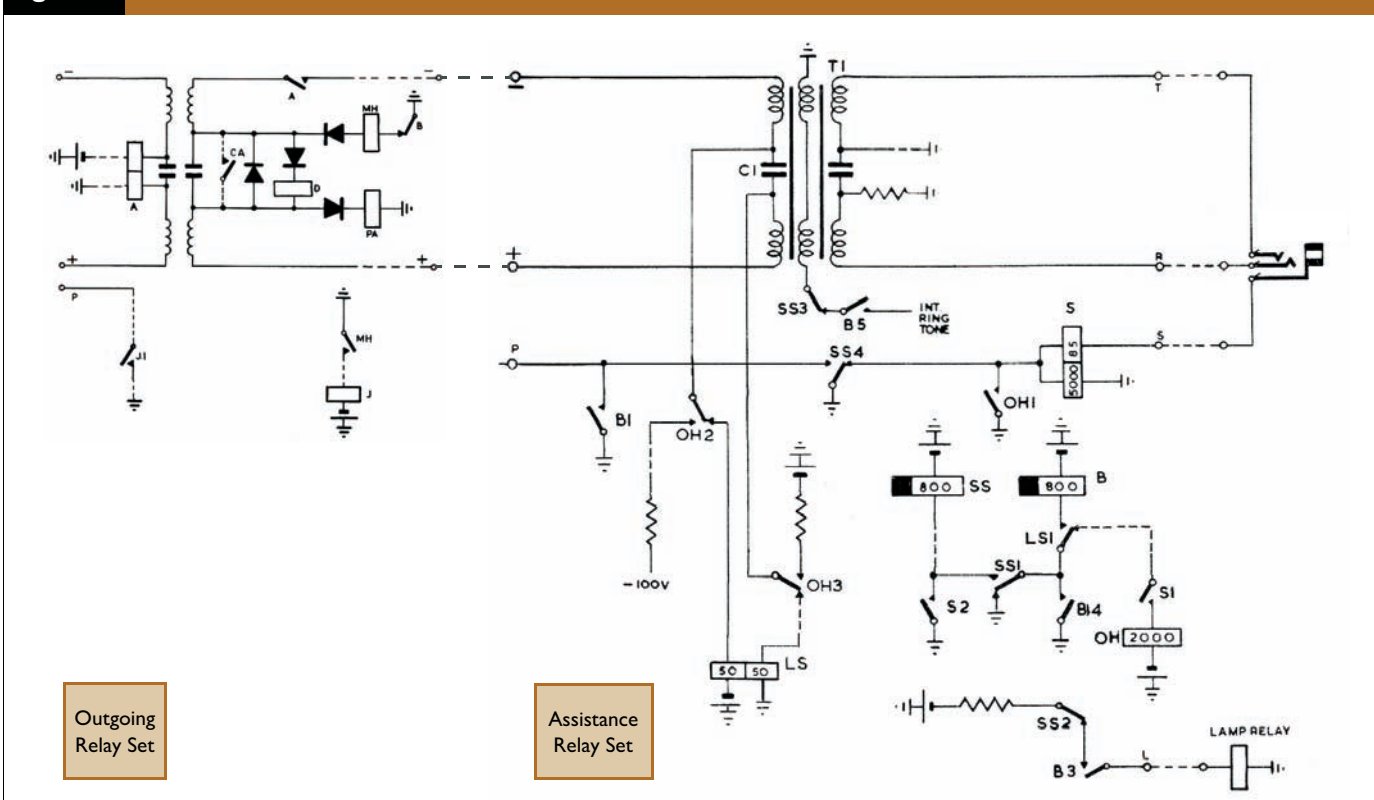
Emergency Calls at Manual Exchanges

One of the advantages of '999' is that emergency calls are immediately identifiable, and can be distinguished from other operator (e.g. 100) traffic. Though not strictly a Strowger facility, readers may be interested to know that a similar means of identifying emergency calls existed in pre-999 days in manual telephony, for calls from public call offices.

Pre-payment coinboxes

Coinboxes were 'pre-payment', requiring a minimum payment (typically four pence) for operator access, with the operator requesting the additional fee (sixpences and shillings) required on trunk calls. When the called customer answered, button 'A' on the coinbox was pressed, releasing the fee into

Figure 7 Circuit elements – manual hold



the cashbox, and opening the speech path. A second button 'B' was used to disconnect the line, and refund the fee, if contact with the called party could not be made. Figure 8 shows a pre-payment call box.

Obviously, it was desirable for emergency calls to be connected as speedily as possible, without waiting for a possibly fraught caller to search for the right change, and press the correct button, on connection. This was facilitated by the provision of an 'emergency call' button on the wallboard, which allowed the call to proceed without pre-payment.

Flashing calling signal

This button also had an important operational feature, which was that it caused the exchange switchboard calling lamp to flash, thus attracting the operator's

attention to the fact that this was an 'emergency' call.

Circuit details

For 'ordinary', i.e. non-emergency, calls, picking up the receiver connected an earth through one of the 500 Ω bell coils to the B-wire, thus providing a calling condition. This operated the L (line) relay at the exchange, which lit (via contact L1) the appropriate exchange calling lamp.

To allow emergency calling facilities at call offices, an additional E (emergency) relay was included in the line circuit, in series with relay L. Relay E was of the marginal type, and would not operate under normal calling conditions.

In the case of an emergency call, operation of the emergency call button put a 50 Ω earth on the B wire, in place of the normal 500 Ω earth calling condition. In this case the reduced resistance in the circuit allowed relay E to operate, changing over the feed to the calling lamp (at contact E1) from a straightforward earth (at L1) to 'interrupted earth', causing the calling lamp to flash, thus indicating an emergency call.

This is illustrated in Figure 9.

Postscript

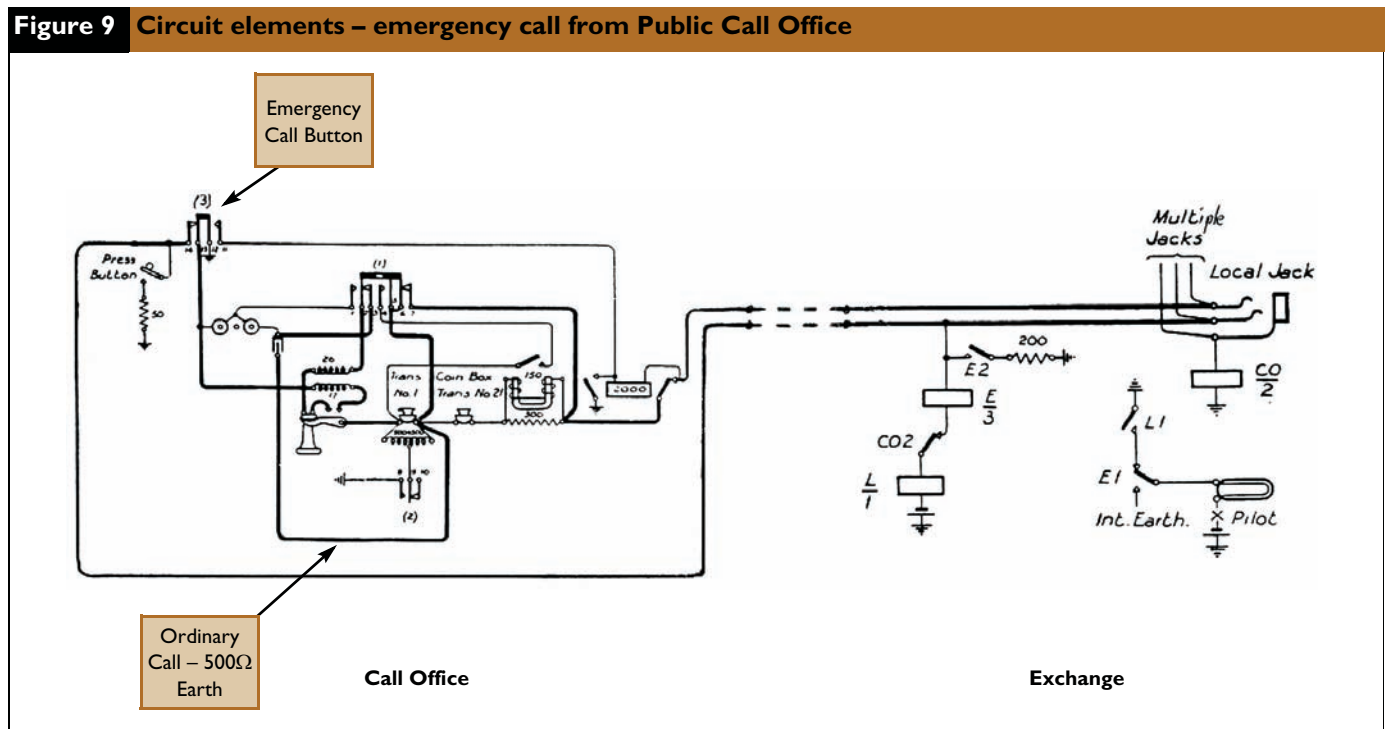
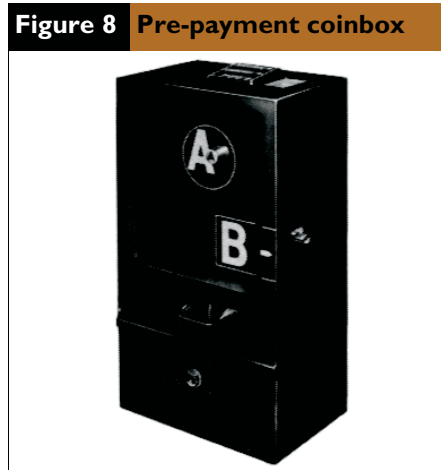
The emergency call button was obviously no longer needed in automatic telephony, and on conversion it was replaced with a metal framed emergency notice, giving the location of the call office, and explaining the availability of the 999 service – and it also conveniently covered the location of the button. However, for many years well into

the 1970s, kiosk wallboards came pre-drilled with an aperture for an emergency call button. Figure 10 shows a PO kiosk No 6.

STD Trunk Transit Network Offload – C Digit Alignment

Subscriber trunk dialling (STD)

Strowger connectivity and functionality took a major step forward with the advent of subscriber trunk dialling (STD).



An inaugural call by the Queen on 5 December 1958 from Bristol telephone exchange (see Figure 11) was the start of a roll-out programme across the UK during the 1960s, with the last local exchange getting STD access in 1974, and with full end-to-end access by 1979.

STD involved the provision of electro-mechanical register translators (RTs) at some 370 group switching centres (GSCs).

Register translators

Registers stored the sequence of dialled digits, and subsequently retransmitted them. Translators 'translated' the ABC digits of the STD code into 'routing digits', which were used to operate the intermediate GSC switching stages. Digits D-J of the dialled sequence were then retransmitted to operate the switching stages at the distant GSC and local exchange. Figure 12 shows a register

translator, with the digit examination, translation, and re-transmission sequence.

In the early years of STD, a number of different types of register translator using different technologies were introduced. Type 1 equipment, designed for provincial use, employed cold cathode circuitry, which was electronic technology current at that time. Another type (Type 4) designed for use in large multi-exchange (director) areas, such as London, Manchester, etc, used magnetic drum storage, as this technique was suitable for large installations.

These represented an important first, being the earliest use of electronics for switching in the PO network. Other types of register translator (known as Types, 2, 3 and 5) used a conventional electro-mechanical approach².

Although all GSCs had RTs, translation was on a 'right through routing' basis, so that only the originating GSC brought RTs into play. The majority of traffic was routed over direct GSC-GSC links, or in some cases via an intermediate GSC, i.e. GSC-GSC-GSC links, known as 'two-link routings'³.

Routing limitations, and trunk transit network

However, a minority of traffic could not be routed in this way for technical reasons:

- the finite translation (TS) relay capacity at the originating GSC (generally a maximum of 300 TS relays were provided);
- absence of suitable GSC-GSC-GSC routings across the network;

- insufficient routing digits (a maximum of six digits could be generated) to reach the appropriate switching stage in the distant GSC.

In such cases this traffic was routed via the trunk transit network, a separate network with 37 transit switching centres, using crossbar (TXK4) 4-wire switching, with MF signalling⁴.

Transit offload programme

During the 1960s and 1970s the growth in STD traffic had resulted in several extensions to the trunk transit network to increase its capacity. By the early 1980s, with the imminent advent of a System X-based digital trunk network, a transit offload programme was produced by the PO Telecommunications Headquarters Network Planning Division (THQ/NPD) in order to minimise the need for further investment in the trunk transit network by containing the traffic levels on the transit network, to avoid short-lived further TXK4 capacity being installed.

Generally this involved examining established transit routings to see if 'non-transit' routings were possible. However, a number of expedient options were also considered, such as increasing the number of TS relays in some GSCs.

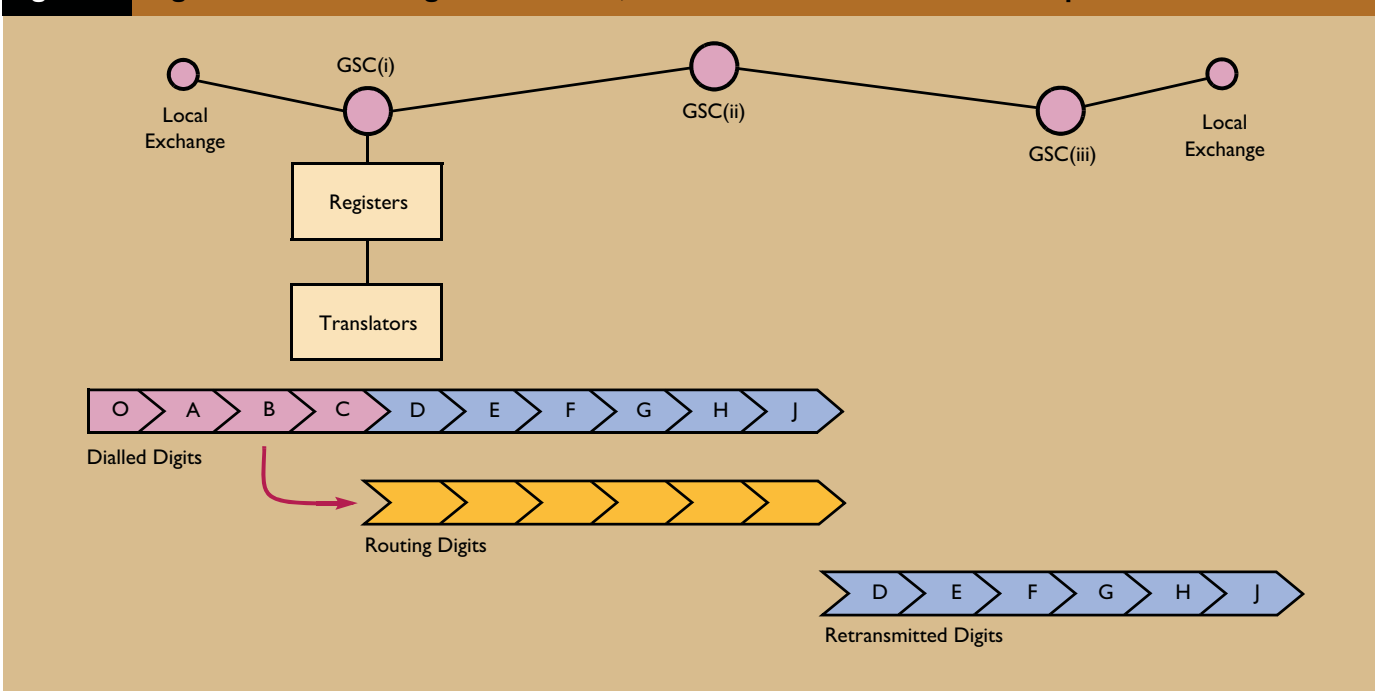
C digit alignment

An ingenious method, known as C digit alignment, devised by THQ/NPD, was considered in a number of GSCs in the former Wales and Marches Telecoms Region

Figure 11 The Queen makes the inaugural STD call, Bristol 1958



Figure 12 Register translator – digit examination, translation and re-transmission sequence



to overcome the routing digit limitation (i.e. only six routing digits available), which prevented 'non-transit' routings being used to access dependent charge groups – as many smaller GSCs in that region could only be reached by GSC-GSC-GSC routings, which therefore needed the maximum number of routing digits available⁵.

Dependent charge groups

Generally calls to dependent charge groups were arranged so that the final two routing digits provided by the originating GSC had the function of taking the call to the appropriate switching stage for the charge group concerned. This is illustrated in Figure 13 based on Haverfordwest GSC, where traffic to the Fishguard charge group exchanges (STD code 0348), terminated on level 93 selectors.

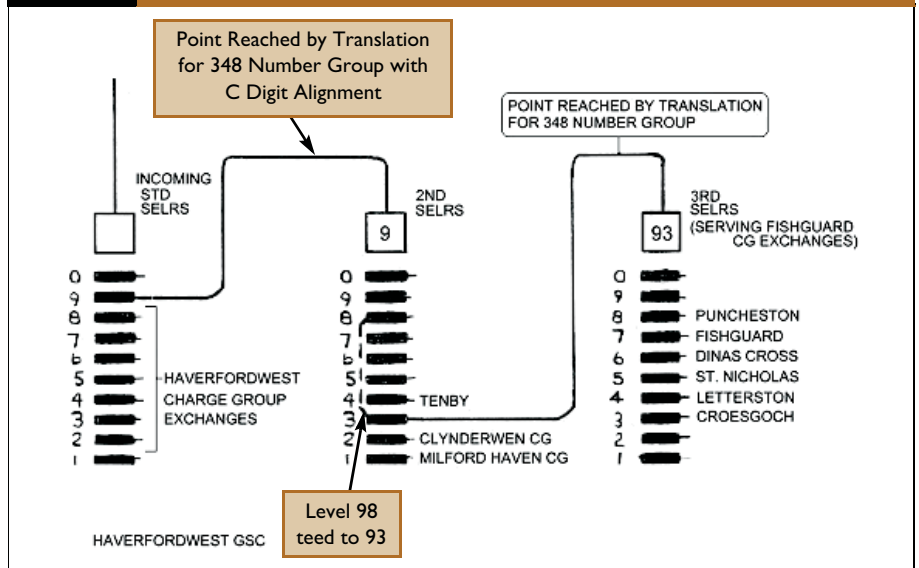
Implementation

As this meant that the final two routing digits (93) were used within Haverfordwest GSC, the expedient adopted was to align the C digit (8) of the STD code (0348) with the local access level, by 'teeing' the existing access level (93) to a spare level (98), thereby requiring only one routing digit to be used within Haverfordwest GSC.

Teeing the additional selector level, rather than changing the existing access level, meant that existing GSC-GSC routings, and also local dialling codes, were unaffected.

Because of the 'alignment' of the two codes, the C digit could now be used for the final stage of the routing within the distant GSC, taking advantage of the inherent register translator facilities to adjust their sending programme to re-transmit the stored C digit (as well as digits D-J), where

Figure 13 Trunking at Haverfordwest GSC, showing arrangements for C digit alignment



required. This meant, in effect, that seven routing digits were available for the GSC-GSC-GSC routing (instead of six), by using level 98 (instead of level 93), and also – though not illustrated in Figure 13 – for Milford Haven charge group (STD code 0646), access level 91, using (spare) level 96. Figure 14 shows the register translator, with the digit examination, translation, and re-transmission sequence.

Outcome

C digit alignment, as explained above, was introduced at a number of GSCs in the Wales and Marches region, and meant that the additional routing digit so derived was effective, in the case of many distant GSCs, in enabling possible GSC-GSC-GSC routings, rather than transit network routings, to be identified – thus helping reduce pressure on the trunk transit network in the run-up to

the full deployment of a System X-based digital trunk network in the 1980s.

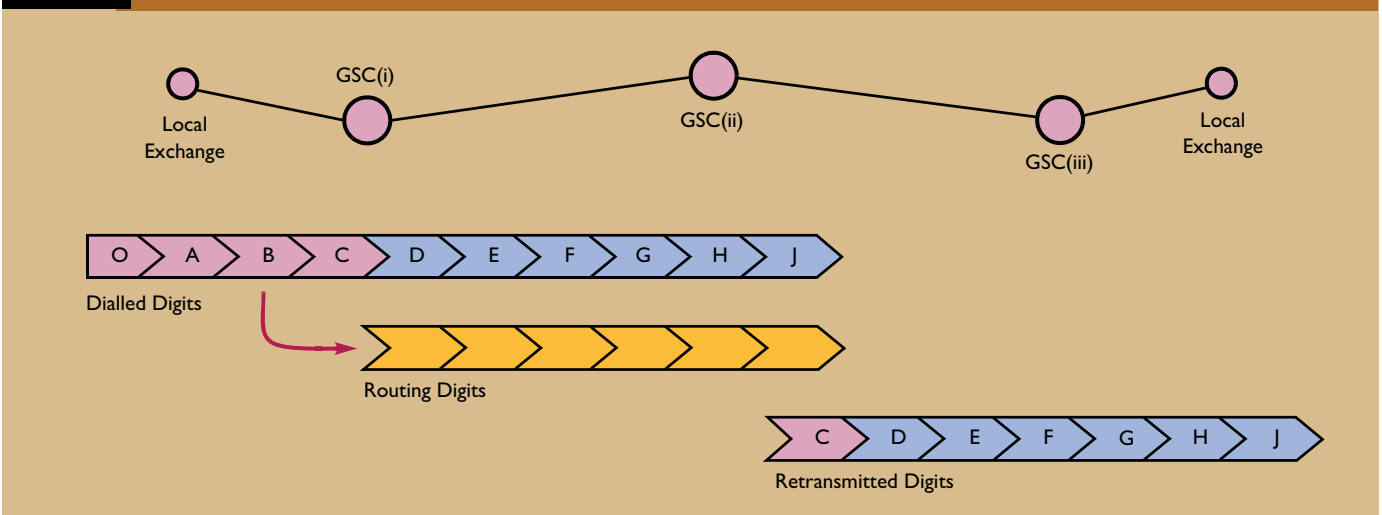
PABX – ‘Hold for Enquiry’

Strowger was also used for PABXs (private automatic branch exchanges). These ranged from small installations, such as the PABX No 1, with up to 10 exchange lines and 49 extensions, to larger installations such as the PABX No 4, with unlimited lines and extensions, and with, in some cases, DDI (direct dialling in) to extension numbers. Generally smaller installations were provided on rental terms, and the larger units were customer owned.

Hold for enquiry

One of the additional features required at a PABX was a 'hold for enquiry' or 'call transfer' facility. This recognised the

Figure 14 Register translator – digit examination, translation and re-transmission sequence, with C digit alignment



practical difficulty (which has survived the Strowger age) of being connected to the right department at the first attempt on incoming exchange line calls.

In essence, 'hold for enquiry' or 'call transfer' required a second switching sequence to be set up. This was initiated by pressing the recall button on the extension telephone. The extension user then received 'second dialling tone', and could contact the appropriate third party extension. Pressing the recall button a second time released the enquiry call.

In some PABXs (different PABX systems had differing facilities) where 'call transfer' was available, clear-down at this stage in effect transferred the call, and left the exchange line connection through to the third party extension.

Circuit details – differential relays again

Pressing the recall button applied an earth to the PABX extension loop circuit. This was detected in the exchange line relay set by relay D, which was differentially wound (see the description earlier of differential relays). Relay D operated (at contact D1) the ER relay, which in turn applied an earth (at contact ER2) to act as a start condition on the ST lead to the enquiry finder.

In the enquiry finder, which was essentially a uniselector, the ST relay activated the 'drive and search' circuit to 'find' the exchange line relay set – note that, for clarity, the 'drive and search' circuit has been omitted in Figure 15.

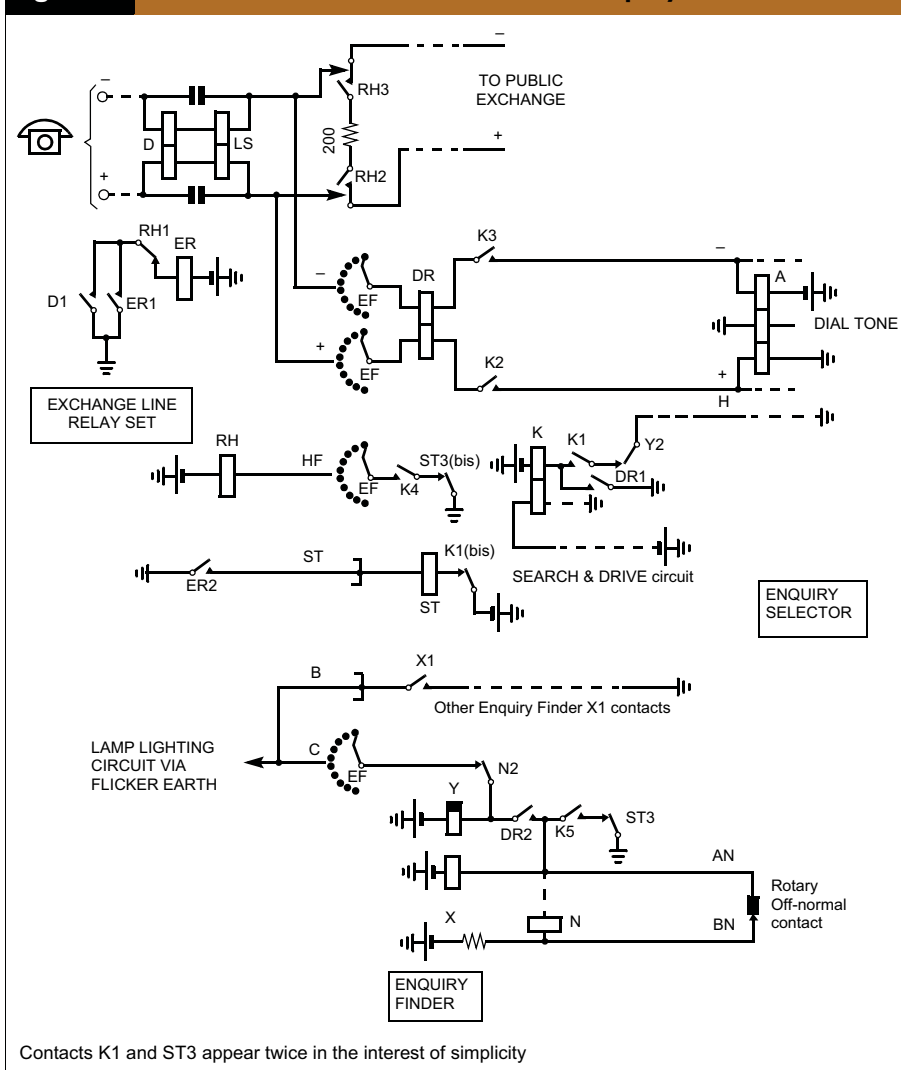
Enquiry finder operation

Once the enquiry finder had found the exchange line relay set, relay K operated via the 'drive and search' circuit. This in turn operated (at contact K4) the RH relay in the exchange line relay set, which (at contacts RH2 and RH3) held the exchange call, and extended the extension user to the enquiry finder. The PABX extension user then received second dial tone from the associated enquiry selector, and was able to establish an enquiry call to another PABX extension.

Completion of enquiry

On completion of the enquiry, the recall button was pressed again. This time the earthed loop operated the differentially wound DR relay in the enquiry finder, which (at contact DR2) operated the Y relay, releasing relay K (at contact Y2), which in turn released (at contact K4) the RH relay in the exchange line relay set, returning the connection to the exchange call.

Figure 15 Circuit elements – PABX 'Hold for Enquiry' call



Interaction between contact Y2 and DR1 (which would have kept the K relay operated) was avoided by making the Y relay 'slow-to-release', thus ensuring that the enquiry finder was released successfully.

All enquiry finders engaged

Where this occurred, the X1 contacts in the enquiry finders, which were connected in series, formed a 'chain', and extended an earth condition on the B wire to the exchange line relay set. This had the effect of diverting the call to the PABX operator. In the circuit illustrated, based on the PABX No 3, this was effected by operating the exchange line calling signal in a flashing sequence. An equivalent alternative condition was provided in cordless systems, such as the PABX No 4.

Operator recall

The circuit also provided operator recall by double depression of the recall button. In this case the second depression again operated the DR relay, which (at contact DR2) extended an earth (at contact N2) to the C wire, to provide a flashing calling

signal (in a similar way to the case of 'all enquiry finders engaged'), and also released the enquiry finder, which was at that stage no longer required.

Rotary off-normal contacts

An ingenious method was employed to distinguish between the depression of the recall button at the end of a normal enquiry call, and a double depression, to call in the operator. This involved the enquiry selector rotary off-normal contacts, which were closed prior to the operation of the selector (or strictly speaking, prior to its rotary operation).

These contacts short circuited relay N, inhibiting its operation, and leaving the connection to the C wire in place. Once the enquiry selector had operated, relay N (at contact N2) disconnected the C wire, preventing unintentional operator recall at the end of a straightforward enquiry call.

Outcome

So a useful facility, enabling PABX users to pause an existing call, and initiate an enquiry call – which was taken for granted

Strowger at its best – Faultsman’s Ringback provided a ready means of testing a telephone line’s incoming connectivity or simply adjusting the bell

by most PABX users – was provided by making use of a combination of Strowger techniques, such as differential relays, and selector rotary off-normal contacts.

Faultsman’s Ringback

Lastly, one circuit illustrates Strowger at its best – providing a useful facility, simply and effectively. The same facility still exists today, but with solid-state technology.

Faultsman’s Ringback (FRB) provided a ready means of testing a telephone line’s incoming connectivity, or simply adjusting the bell. In explaining the need for such a circuit, the POEEJ related, by way of comparison, ‘it is difficult to tune-in a radio receiver to a station, unless signals are being transmitted from that station’⁶.

The circuit is illustrated in Figure 16, taken from the POEEJ article in question – readers should note the earlier symbol for the 0.5 μ F capacitor.

The key to the circuit is relay B and relay H. The customer loop on the incoming call operated relay L, which (at contact L1) operated relay B, where contact B2 prepared a circuit for relay H. The testing engineer received NU (number unobtainable) tone of 400 Hz (at contact H1), and then replaced the receiver. This released relay L, which, in releasing, operated relay H (at contact L1), and ringing current was then applied (contacts H1 and H2) to the line.

Once testing and/or bell adjustment had been completed, the receiver was picked up, operating relay F, which (at contact F1) then

released the connection, and restored the line to normal use.

Conclusions

Strowger technology disappeared from the PSTN in 1995, with the completion of the BT local exchange modernisation programme. In looking back at some of its features, I hope it has been interesting to consider some of the ways in which Strowger handled ‘value-add’ facilities, some of which live on, in their digital counterparts today.

Strowger had many, many other facilities and features as well – 2/10 PBX groups, 11/- switches, shared service, international direct dialling, SVI/CNI, gradings, metering-over-junctions, VF signalling, keysenders, motor-driven uniselectors – and I hope this article has stirred other readers’ recollections [*and might prompt future articles – Ed*], as well.

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Biography



**Michael
Clemitson**
BT

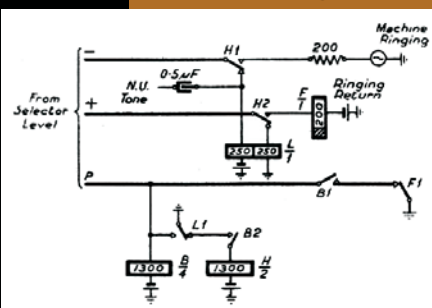
Belfast-born Michael Clemitson joined the GPO (as it was then) in 1968 as a direct management entrant.

Based originally in Preston Telephone Area, he was employed on exchange design work, and customer service work. Moving to Cardiff on promotion in 1980, he had operational service responsibility for the Wales and Marches Regional Prestel Centre, later moving to the regional planning division, and on the District reorganisation following BT privatisation, he was responsible for the Local Exchange Modernisation Programme, and subsequently following a later reorganisation, the Wales and West Zone Internal Works Control (IWC), and Customer Wideband Circuit Provision (CWPC) functions.

Prior to moving to BT Exact, he was the project manager for the extensive exchange clearance work needed for the building of the Cardiff Millennium Stadium for the 1999 Rugby World Cup. Moving to BT Exact in 1998 to join the Year 2000 (y2k) Readiness Review group, Michael, a Member of the Association of Project Management (APM), is currently responsible for the Network Engineering Journey 21CN delivery programme.

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Figure 16 Circuit elements –
Faultsman Ringback



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