The Post Office Electrical Engineers' Journal

VOL 70 PART 4 JANUARY 1978

THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL 70 PART 4 JANUARY 1978

Contents

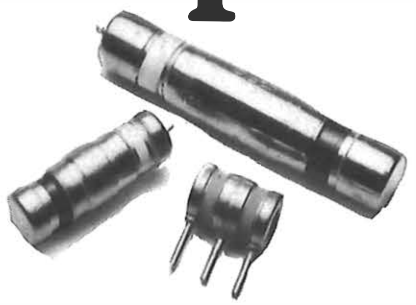
Published in April, July, October and January by *The Post Office Electrical Engineers' Journal*,
2–12 Gresham Street, London EC2V 7AG.

Price: 55p (80p including postage and packaging). Orders by post only.

Annual subscription (including postage and packaging): home and overseas £3·20.
(Canada and the USA $6·50.)

Price to British Post Office staff: 36p.

It only takes a little gas to put electricity in its place.



M-OV arresters provide complete protection against unexpected surges of voltage from lightning, accidental induction from power lines and a number of other sources.

Protection that is vital for not only communications, but for all forms of electronic equipment.

A telecommunications breakdown for example can be astronomically expensive.

Especially when compared with the modest cost of M-OV arresters.

If you add the fact that they also suppress interference that is very troublesome to sensitive equipment, you have a very compelling argument for investing in a little protection.

M-OV gas-filled surge arresters are designed to last for the lifetime of your equipment.

They will work first time, every time, even if they are activated after 20 dormant years.

And don't worry about the 'first-strike' effect. We've eliminated it.

The earlier protection is built into your equipment, the better. So take advantage of the complete M-OV service and seek our early advice on your protection problems.

Our brochure describes a wide range of applications and gives further details.

And remember, lightning needn't strike twice in the same place to be a costly disaster.

S5061

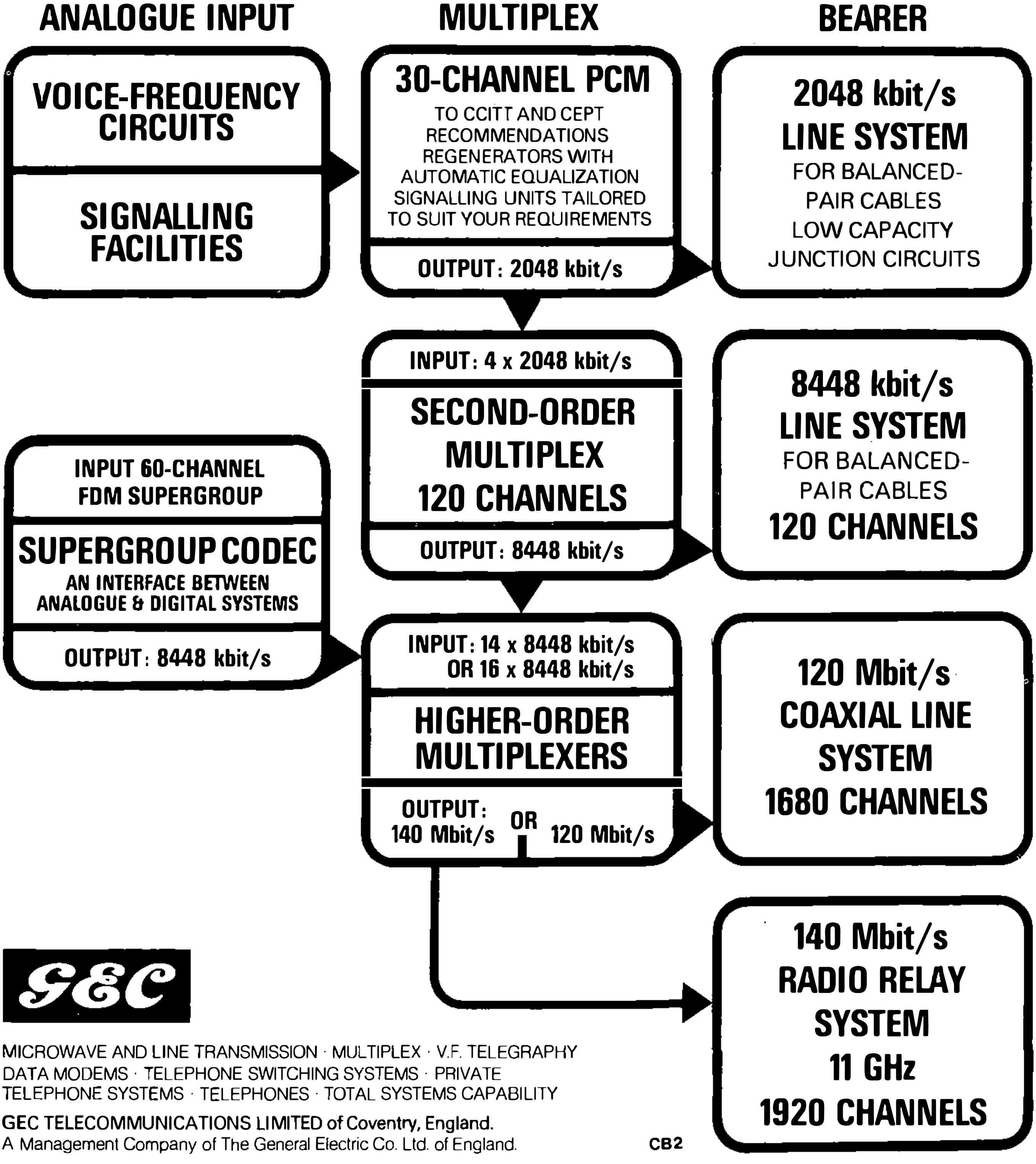
EEV/M-OV

Members of GEC - turnover £2054 million

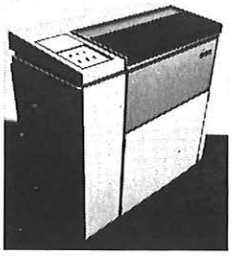
GEC

THE M-O VALVE CO LTD, HAMMERSMITH, LONDON, ENGLAND W6 7PE TEL 01-603 3431. TELEX 23435. GRAMS THERMIONIC LONDON

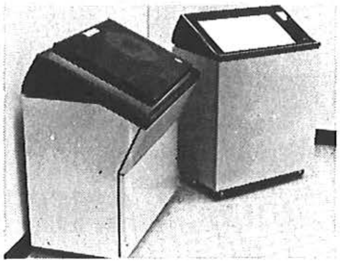

Our pad



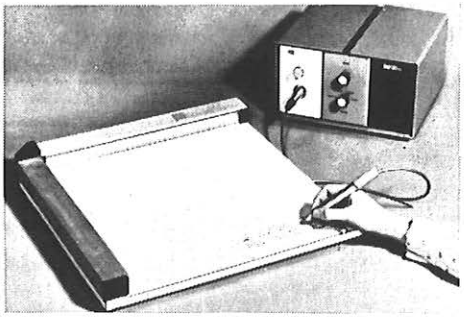
MINI-COMPUTER SYSTEMS AND PERIPHERALS



Line printer systems from 100 to 1800 lines per minute.

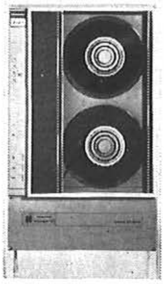


Electrostatic on line and off line printer/plotters.

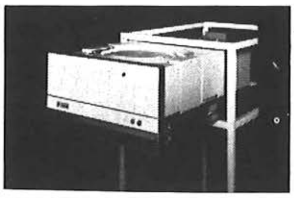


Data tablets for digitising and interactive graphics.

Magnetic cartridge memory system one to eight cartridge drives each storing 2 million 8 bit bytes.



Industry compatible magnetic tape units both synchronous and buffered.

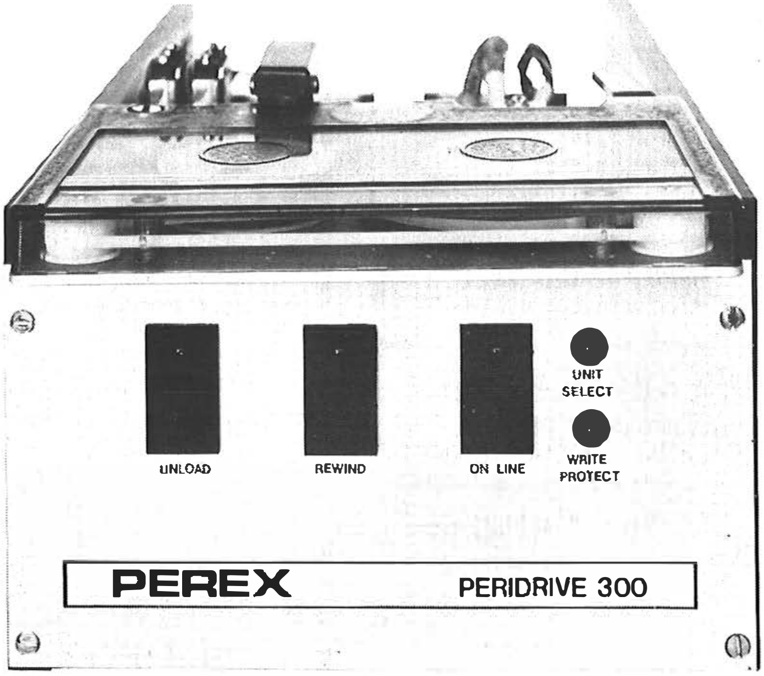


Moving head disc files capacity 12 million to 100 million bits using IBM type 2315 or 5440 disc packs.

PEREX LTD

PERIDRIVE

A cartridge recorder designed for truly reliable data recording at a low cost.



- Phase recording for large data capacity and error free recording with self clocking reading capability.
- Simple drive requirements due to unique isoelastic drive; no reel Servos are needed.
- Precision tape track location due to precision metal base plate of cartridge. All tape guides are within the cartridge.
- High Storage capability up to 16 million bits per cartridge.
- High speed capability.
- High transfer rate—40,000 bits/sec.

Available in 3 versions
  a) With full electronics.
  b) With read/write head.
  c) Motor chassis.

For further details contact Mrs Jay Dee

SINTROM ELECTRONICS LIMITED

SALES AND SERVICE THROUGHOUT EUROPE

Sintrom Electronics Limited, 14 Arkwright Road, Reading, Berks. RG2 0LS
Tel: Reading (0734) 85464 Telex: 847395 Cables: Sintrom Reading

The Post Office Electrical Engineers' Journal

EDITORIAL

A major change is taking place in formal education for technicians. The Technician Education Council (TEC) is assuming responsibility for technician education in England, Wales and Northern Ireland, and the Scottish Technical Education Council (SCOTEC) is assuming similar responsibilities in Scotland. Technician courses provided by these 2 bodies are now replacing those leading to City and Guilds of London Institute (CGLI) and National Certificate awards. The philosophy of the TEC, and the structure of its (and the SCOTEC's) courses, are described in this issue, with particular emphasis on the arrangements for British Post Office (BPO) students.

The TEC is introducing many progressive ideas, and the course it provides for technician-level BPO students (the Certificate in Telecommunications) has much to commend it. It is designed to be complementary to job training, and more importance is attached to establishing principles. TEC Certificate courses have been set up and are now running in many areas, and appear to be admirably suited to their purpose.

Much work has yet to be done, however, on the higher-level course (the Higher Certificate) intended to provide an award suitable for senior technicians. Concern is being expressed over some aspects of the Higher Certificate course which seem at present to limit the advantages of that course over those it will replace. A route to professional qualifications is not yet clearly established, and the broad approach that may be necessary endangers, to some extent, the advanced-level specialized courses that are catered for so well by the CGLI.

Many interested parties are watching the situation, and it may be expected that the efforts of all involved will be directed at ensuring that education at the higher level develops the standards aimed at by the TEC's Certificate-level course and will provide opportunity for further academic advancement.

The *POEEJ*'s model-answer *Supplement* has been published since 1931 and the Board of Editors intends that this service to students should continue. However, the form of the guidance material for students who follow TEC courses has yet to be decided. For some years ahead, the *Supplement* will probably be shared between coverage of TEC topics and model answers to CGLI examination questions.

The Telecommunications Network for EURONET

P. T. F. KELLY, B.SC.(ENG.), C.ENG., M.I.E.E., M.B.C.S., and E. J. B. LEE, B.SC.[†]

UDC 681.31 : 654

An international computer network is being developed under the auspices of the Commission of the European Economic Community (EEC). The network, to be known as EURONET, will enable people to gain access using their data-terminals to data bases holding a variety of information. The British Post Office and the Postal and Telecommunications Administrations of the other 8 EEC countries are now jointly involved in the provision of the telecommunications data network for EURONET. The network will operate in the packet mode of switching and transmission. This article describes the telecommunications network for EURONET, which will be brought into service at the end of 1978.

INTRODUCTION

EURONET[1] is the generic title for a European computer network which is being established by the Commission of the European Economic Community (EEC) to enable data terminals located in member countries to gain access to data bases holding specialized scientific, technical and socio-economic information. The telecommunications network to connect data terminals to any of the data bases is being provided jointly by the 9 Postal and Telecommunications Administrations (PTTs) of the EEC countries and will use packet-switching techniques.

Studies undertaken by the Commission in 1974 had shown that a single packet-switching network would cost one third to one tenth of the combined cost of several individual star-shaped networks (if such networks were established) each serving a single data base operator. At the end of 1975, the Commission of the EEC placed a contract with the PTTs for the supply of an international packet-switching network to be brought into operation at the end of 1978.

The agreement between the 9 PTTs of the EEC and the Commission of the EEC included the following significant provisions:

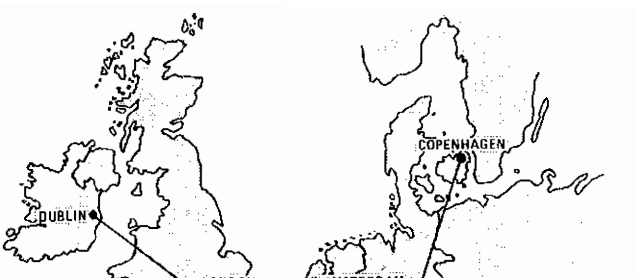
(*a*) The packet-switching network for EURONET would be implemented in accordance with Recommendations prepared by the CCITT[*] or CEPT[‡], in so far as they apply.

(*b*) Although EURONET is an international network to be established on behalf of the EEC Commission, and as such is a private network, the design of the network should be such that its reliability can be enhanced to that required for a public data network.

(*c*) Access to the international telecommunications network should be via national public data networks (PDNs) wherever such networks exist or as soon as they are provided.

(*d*) The design of the network should not preclude the carrying of non-EURONET traffic.

In June 1977, following the adjudication of international tenders, the French PTT, acting on behalf of the EEC PTTs, placed a contract for the development and supply of the packet-switching network to meet the needs of EURONET. The contract has been awarded to a multi-national consortium of software houses, one from each EEC country, which is headed by SESA[**] and Logica Ltd. The consortium will supply the switching and multiplexer equipment and the network management equipment, and the PTTs will provide the line plant, exchange and multiplexer accommodation and the national access facilities, including the customers' modems. Contracts have been placed on behalf of the EEC PTTs for the supply of the modems to be used within the network.



NMC—Network management centre

FIG. 1—The telecommunications network for EURONET at the opening date (end of 1978)

[†] Network Planning Department, Telecommunications Headquarters. Mr. Kelly is Chairman of the Technical Planning and Implementation Committee for EURONET, and Mr. Lee was, until recently, Secretary

[*] CCITT: International Telephone and Telegraph Consultative Committee

[‡] CEPT: Conference of European Postal and Telecommunications Administrations

[**] SESA: *Société d'Etudes des Systèmes d'Automation*

NETWORK PLAN

The network plan to meet the requirements of the Commission at the planned opening date (the end of 1978) is shown in Fig. 1. The network will consist of 4 switches, known as *packet switching exchanges* (PSEs), located at London, Frankfurt, Paris and Rome; remote-access facilities will be provided by multiplexers at Amsterdam, Brussels, Copenhagen, Dublin and Luxembourg. The design of the network will ensure that the facilities available to users connected via the multiplexers are identical to those for users who are connected to the PSEs. For example, the distance of a user from a PSE or multiplexer site will not prejudice the facilities or performance offered. A network management centre (NMC) will be located in London.

At the opening date of the network, some 27 computers offering about 100 data bases are planned to be connected to the network. More than 140 remotely-sited data terminals belonging to EURONET users in the 9 EEC countries will be able to gain access via the packet-switching network to these computers and their associated data bases. Among the data bases to be connected are those operated by: the Space Documentation Service of the European Space Agency in Frascati, Italy: the *Deutsches Institut für Medizinische Dokumentation und Information* at Cologne in the Federal Republic of Germany; and the Commission's economic and legislative data base at the Kirchberg Centre in Luxembourg. Within the UK, it is expected that data bases operated by the Computer Aided Design Centre in Cambridge, the National Computing Centre in Manchester, and the British Library and Institution of Electrical Engineers in London, will be connected to the network.

The computers will be connected to the packet-switching network by data terminal equipment operating in the synchronous packet-mode, at data signalling rates shown in Table 1. Data terminals belonging to users wishing to gain access to the computers will function in the start-stop character-mode, and will each operate at one of the data signalling rates given in Table 1.

The users' data terminals are planned to be of the teletypewriter type or terminals that are compatible with teletypewriter terminals. Some of these data terminals will be connected directly to the packet-switching network, but many character-mode terminals will be able to gain access to EURONET via public switched telephone networks (PSTNs). Thus, geographical coverage within each EEC country for EURONET will be increased. In addition, character-mode and packet-mode terminals will be able to have access to the international network via national PDNs, where these exist. All terminals will have connexions that provide the facility for duplex transmission to the packet-switching network, irrespective of their means of access.

TABLE 1

Methods of Access

Terminal Data Signalling Rate (bit/s)	Access Available		
	Direct	Public Switched Telephone Network	Public Data Network (Note 2)
Character-Mode Terminals			
110	No	Yes	Yes
200	No	Yes	Yes
300	No	Yes	Yes
600	Yes	No	No
1200	Yes	No	No
1200/75 (Note 1)	No	Yes	No
Packet-Mode Terminals			
2400	Yes	No	Yes
4800	Yes	No	Yes
9600	Yes	No	Yes
48 000	Yes	No	Yes

Notes 1. Transmission at 75 bit/s from a terminal to the network, and 1200 bit/s from the network to the terminal

2. Character-mode terminals may gain access through national circuit switched synchronous or asynchronous data networks, or via national packet-switched data networks. Packet-mode access via a PDN is possible only where national packet-switched PDNs exist

THE ORIGINS OF THE NETWORK

The concepts of the packet-mode of working were first demonstrated in a public network with the introduction in the UK of the British Post Office's (BPO) Experimental Packet-Switched Service (EPSS)[2-6], which was brought into full service early in 1977. There are, however, several private research networks, based on packet-switching techniques, which were brought into use in the early 1970s. The most well known of these are the Advanced Research Projects Agency Network (ARPANET)[7] of the USA's Department of Defense, the French PTT's *Réseau Commutation par Paquet* (RCP)[8], and the *European Informatics Network* (EIN)[9,10] which is one of the projects initiated by COST†. However, none of these networks, including the EPSS network, adopts internationally agreed standards for the connexion of terminals to packet-switching networks and, because of this, are generally incompatible. These networks have all, though, been significant in providing the opportunity of developing a comprehensive understanding of packet-switching technology. The experience and knowledge acquired from these earlier networks has influenced the design of networks which are compatible with agreed international recommendations. One such network is the French PTT's planned public packet-switching network, TRANSPAC[11], and it is on an adaptation of the system being developed for TRANSPAC that the packet-switching network for EURONET is being based.

FACILITIES OF THE NETWORK

The basic concepts and techniques of packet switching have been discussed in a number of previous *POEEJ* articles.[2,4-6] Some of the main features and the packet-switching methods of the EPSS are particularly relevant to EURONET; these are the type of call established to gain access to the network, control of the flow of packets, terminal-to-network interface procedures and error checking.

Virtual Calls

A user of the EURONET packet-switched network will be able to gain access to the computers containing the data bases in either of two ways. Either the network will establish, at a user's request, a communication path known as a *virtual call* between a user's terminal and any one of the computers, or a user may use a specially allocated route, called a *permanent virtual circuit*, through the network to a specific computer. The term, virtual call, is used because, although the call appears to provide a direct connexion between a user's terminal and a computer, transmission facilities within the packet-switching network are only assigned to the connexion when packets are being transferred over it. A permanent virtual circuit provides such a connexion on a permanent basis; it resembles a point-to-point private circuit in that it allows data transfer only between 2 predetermined terminals but, as for virtual calls, transmission capacity is allocated only when packets are being transmitted. A permanent virtual circuit, once established, has a fixed route through the net-

---

† COST: *Co-opération Européene dans le Domaine de la Recherche Scientifique et Technique*

work, whereas a virtual call is established between 2 terminals only for the duration of the call.

When a virtual call is made, the optimum routing of the packets through the packet-switching network is decided by the PSEs in accordance with routing tables, for a virtual call can be established over a choice of inter-PSE routes. Once the route is established, it is used for the duration of the call until completion, when it is cleared down. The routing tables are held in each PSE and can be changed by the NMC.

The system of fixed routing adopted for EURONET has certain advantages over the adaptive routing method used by most other packet-switching networks, including the EPSS. With the adaptive routing method, the PSEs choose the optimum route for each packet during a virtual call, thereby adapting the routing of the packets to a continually changing traffic situation. In an international network involving routings through several countries, the transit accounting arrangements of PTTs for transit virtual calls, each packet of which could take a different route, would present excessive network management overheads if adaptive routing of packets was adopted. EURONET, though, benefits from the fixed routing method which minimizes the network management overheads in this respect. With the fixed routing method, the PTTs' preferences for certain routes can be taken into account when the routing tables are programmed.

Over a physical link between a EURONET packet-mode terminal and its serving PSE, a number of virtual calls can be established simultaneously. To enable the terminal and the PSE to distinguish between packets associated with different virtual calls, a *logical channel number* is assigned to each virtual call when it is established; during the call, all packets carry this logical channel number. A permanent virtual circuit is also assigned a logical channel number, although this remains fixed as long as the permanent virtual circuit is established. Over a single physical link, both permanent virtual circuits and virtual calls can be continued simultaneously if required.

Flow Control

One of the advantages of the packet-mode of working is the network's ability to interconnect terminals having different data signalling rates. This requires that the network be able to control the flow of packets between the 2 terminals. The network acts as a temporary absorber (or buffer) of data.

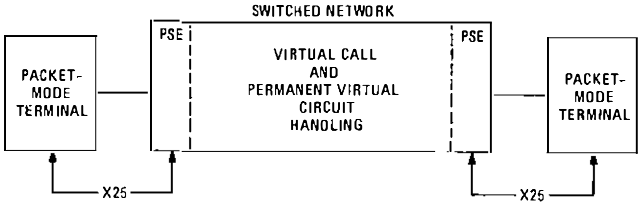
Depending on the degree of buffering available and the switching capability of the network, a limit on the data throughput transmitted by a terminal has to be imposed, and the maximum value allocated to a terminal is referred to as the *throughput class.*

Protocols

To establish communication between 2 terminals, it is necessary to set up a virtual call or use a permanent virtual circuit. This necessitates the adoption of specified terminal-to-network interface procedures, or *protocols* as they are known by users. Different protocols are used depending on whether the terminal operates in the packet or character mode.

Packet-Mode Protocols

The protocols for connecting packet-mode terminals to a packet-switching network will be in accordance with CCITT Recommendation X25†. The protocol given in CCITT Recommendation X25 and applicable to a EURONET user-to-network interface between a packet terminal and its parent PSE is shown in Fig. 2. There are 3 levels of control procedure applicable at the interface:



X25: CCITT Recommendation X25

FIG. 2—CCITT protocol X25 for packet-mode terminals

(*a*) Level 1—the physical, electrical, functional and procedural characteristics to establish, maintain and disconnect the physical link between the terminal and the network,

(*b*) Level 2—the link access procedure for data interchange across the link between the terminal and the network (recently the CCITT has proposed an alternative procedure and it is expected that this will also be offered on EURONET), and

(*c*) Level 3—the packet format and control procedures for the exchange of packets containing control information and user data between the terminal and the network.

The inter-PSE protocol to be adopted on the packet-switching network for EURONET will be that used on TRANSPAC, although it is expected that, in due course, this protocol will be modified to a proposed CCITT Recommendation in the X70 series which will enable the connexion of EURONET to national and international public packet-switching data networks.

Character-Mode Protocols

A small CEPT technical group defined the protocols for a start–stop character-mode terminal, which enable communications with the packet-assembly/disassembly facility (PAD) in the terminal's parent PSE, and which enable a packet-mode terminal to communicate with a character-mode terminal via the PAD facility. These protocols are incorporated in draft CCITT Recommendations X3*, X28‡ and X29**, which have been extended to meet EURONET needs for extra facilities and data signalling rates; the application of these protocols is illustrated in Fig. 3. A PAD whose parameters are defined in draft CCITT Recommendation X3 enables conversion facilities to be provided in a packet-switching network between start–stop character-mode terminals and packet-mode terminals. A PAD is an integral part of the network and one is implemented in each PSE, as shown in Fig. 3.

In addition to the protocols given in draft CCITT Recommendations X3, X28 and X29, one of the other protocols required for EURONET is a facility known as *network user identification.* This relates to the charging procedures adopted for virtual calls established when character-mode terminals gain access via the PSTN. Most users desire an option whereby they can elect either to pay for each virtual call themselves, or to have all charges billed to the called terminal. For calls established through a switched network to the EURONET packet-switching network, it is essential to be able to indentify the calling user. On EURONET, this is achieved by the user

---

† CCITT Recommendation X25 deals with the interface between data terminal equipment and data-circuit terminating equipment for terminals operating in the packet-mode on public data networks

* CCITT Recommendation X3 (Draft) deals with the PAD facility in a PDN

‡ CCITT Recommendation X28 (Draft) deals with the interface between data terminal equipment and data-circuit terminating equipment for terminals operating in the start-stop mode when accessing a PAD in a PDN

** CCITT Recommendation X29 (Draft) deals with the procedures for the exchange of control information and users' data between a data terminal operating in the packet mode and a PAD in a PDN

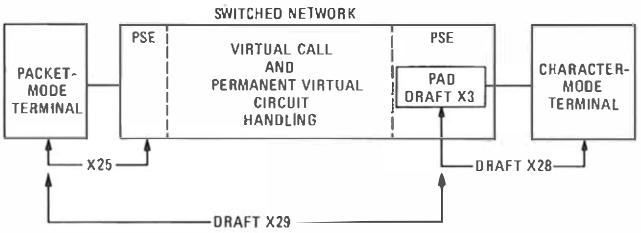


FIG. 3—CCITT protocols to enable communication between character-mode and packet-mode terminals

connecting to his allocated PAD and inserting a network-user identification (NUI) code. This is checked by the PSE against a table of NUIs, and a network-user address is passed to the NMC for charging purposes. For a subsequent virtual call, the user can opt to pay for all the packets, or request all charges to be made to the distant terminal if the distant terminal is prepared to accept the charge. This option will apply only for use of the packet-switching network; the user will be charged for using the PSTN or PDN according to national practice.

Error Checking

The network is able to provide an error-checking facility on a link-by-link basis. This detects transmission errors on inter-PSE trunks and on links between PSEs and packet terminals. If a frame (which may contain a packet) is corrupted during transmission over a link, the receiving PSE or packet-mode terminal requests the sending packet terminal or PSE on the other end of that link to re-transmit the frame. Once a frame has been satisfactorily received it is no longer retained at the sending end of the link. A frame can consist of an opening synchronization character (known as a *flag*), a frame *address* field, a frame *control* field, a packet, and a *frame check sequence* field. A frame containing an *information* field, which could be a packet containing user's data, is shown in Table 2.

TABLE 2

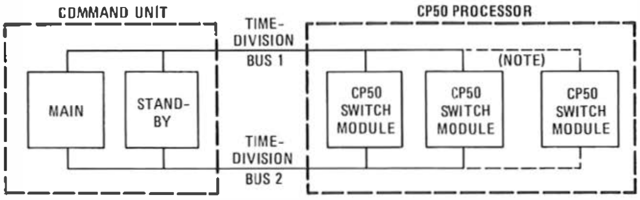
Format of a Frame Containing an Information Field

Flag	Address	Control	Information Field	Frame Check Sequence	Flag
0111 1110	8 bit	8 bit	N bit	16 bit	0111 1110

NETWORK HARDWARE

Many of the earlier types of packet-switching network used conventional minicomputers, programmed to perform packet switching; EURONET's packet-switching network will use purpose-designed hardware. Each PSE in the network will be based on 2 types of processor that have complementary functions. One, the CP50 processor, has been specially developed in France to perform the many repetitive functions involved in packet switching and is based on a number of microprocessors. The other type of processor, called the *Command Unit* (CU), is the Mitra 125, a general-purpose minicomputer of French manufacture. The CU controls the CP50 processor and is connected to it by a high-speed time-division bus (see Fig. 4); these 2 processors form the basis of a packet-switching exchange.

The performance of all the PSEs in the network will be monitored, and the overall control of the network, and the international accounting and charging information, will be managed by an NMC. A Mitra 125 processor will form the basis of the NMC equipment. As shown in Fig. 1, at the opening date of EURONET there will be a single NMC, located in London, which will control 4 PSEs.



Note: The CP50 processor can include several CP50 switch modules

FIG. 4—The CU and the CP50 processor of a PSE

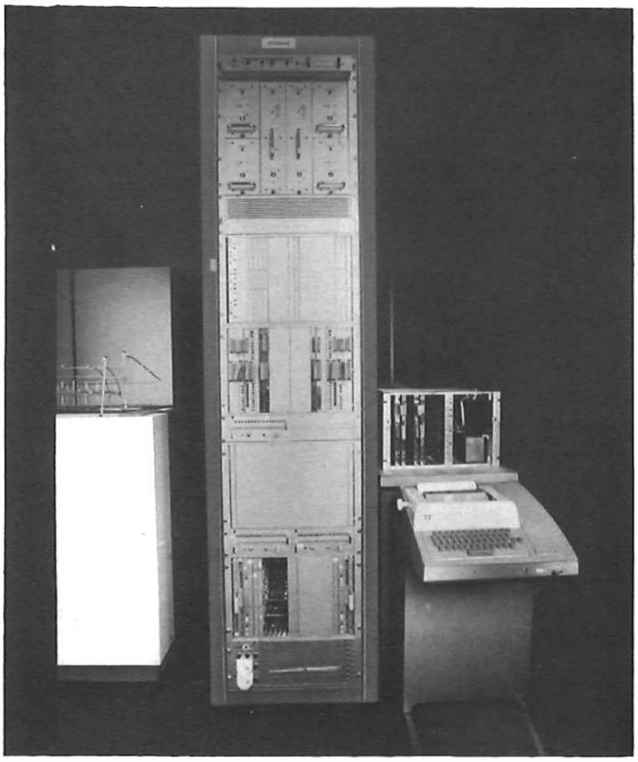


FIG. 5—The CP50 switch module
(By courtesy of SESA—photographer: B. Mandin)

In the interest of reliability, with the exception of a few sub-units in the CP50 switch modules and the NMC, all the processor equipment will be duplicated; in each PSE, the second CU and the duplicated parts of the CP50 processor will operate in a "hot stand-by" mode, ready to take over in case of failure of the operational equipment.

One of the features of the packet-switching equipment to be used for EURONET is its modular nature, enabling the expansion of a PSE in a number of steps by the addition of various modules. The CP50 processor is composed of one or more self-contained CP50 switch modules; each switch module occupies one equipment rack (see Fig. 5).

A CP50 switch module is built up of 3 types of unit, each based on the INTEL 80/10 microcomputer, which is a single-board computer driven by an INTEL 8080 microprocessor. The 3 units are the group unit (GU) which performs switching of packets, the synchronous line unit (SLU), and the asynchronous line unit (ALU). The SLU and ALU support synchronous-packet and asynchronous-character interfaces respectively. The synchronous-packet interfaces are implemented in synchronous line adapters (SLAs) which are

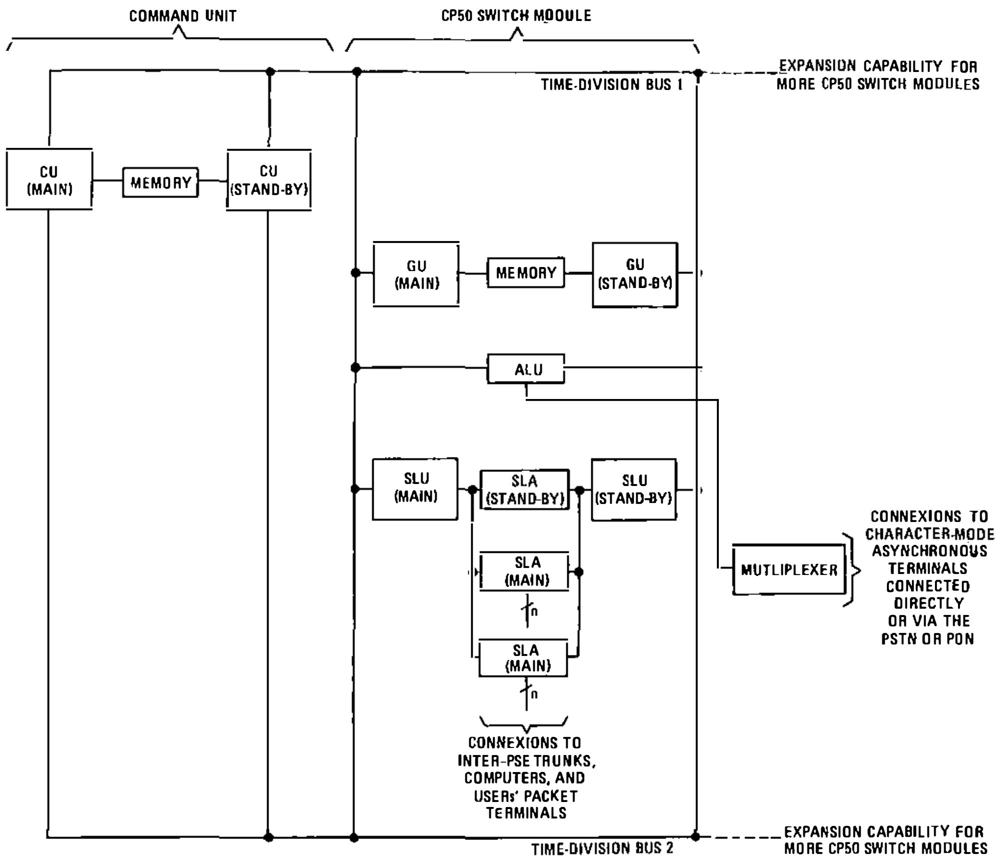


FIG. 6—Block diagram of a PSE

connected to the SLU, and the asynchronous-character interfaces are implemented in an asynchronous multiplexer connected to the ALU. In each CP50 switch module, the GU can be duplicated, and to each GU can be connected 2 SLUs which can also be duplicated for stand-by operation. Two ALUs can be installed in each switch module, but they cannot be duplicated. The interconnexion of these units in a CP50 switch module is illustrated in the block diagram of a PSE shown in Fig. 6.

Initially, the EURONET PSEs will each have only one CP50 switch module (with duplicated units, see Fig. 6) although the CU is capable of controlling several switch modules. The connexion of additional CP50 switch modules to the duplicated high-speed time-division bus will increase the number of interfaces available. Each CP50 switch module will provide up to 480 terminal interfaces. Of these, 240 will be for terminals operating in the synchronous packet-mode of transmission in accordance with CCITT Recommendation X25; some of the packet-mode interfaces will provide connexions for trunks to other PSEs. There will also be 240 interfaces for terminals operating in the asynchronous character-mode of transmission in accordance with draft CCITT Recommendation X28. Character-mode terminals will be connected either directly to the PSE, or via the PSTN or PDN.

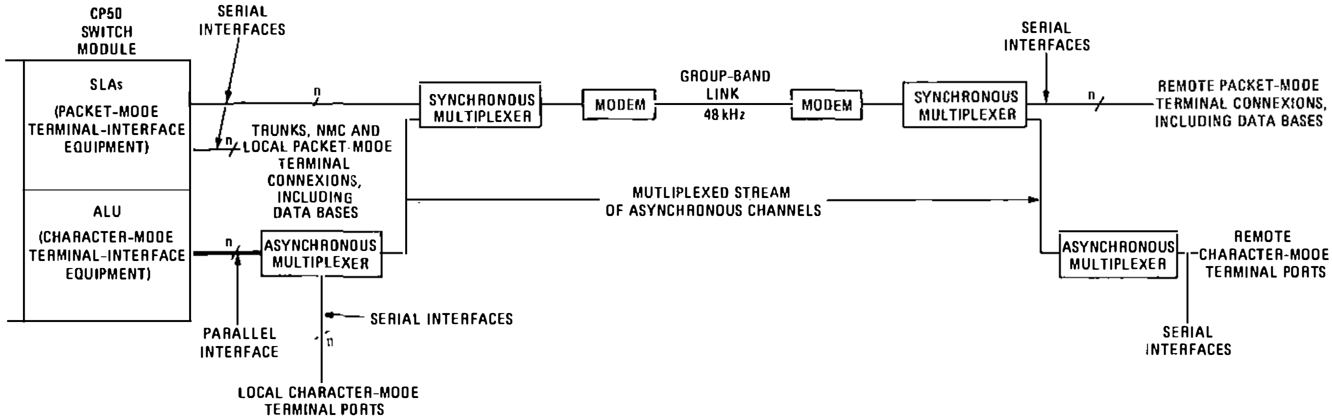
In addition to those interfaces catering for the connexion of users' terminal equipment, data bases, and inter-PSE trunks, the CP50 switch module interfaces in the London PSE will provide connexions for the NMC. The NMC, whose interface appears to the network as that of a standard packet-mode terminal in accordance with CCITT Recommendation X25, will have links to 2 synchronous packet-mode interfaces on the CP50 switch module.

All packet-mode data terminals will be connected directly over links to individual synchronous packet interfaces on a CP50 switch module. Where distances are considerable, use will be made of synchronous time-division multiplexers to economize on line plant. In this case, the distant packet-mode terminals will be directly connected over links to the input of a synchronous multiplexer at a location remote from the PSE. A synchronous multiplexer at the PSE will then provide individual demultiplexed links corresponding to those of the distant packet terminals, and these will be connected to individual synchronous packet interfaces on the CP50 switch module. Synchronous time-division multiplexers will be used to enable packet-mode terminals in Belgium, Denmark, Ireland, Luxembourg and the Netherlands to gain access to their parent PSEs.

Start-stop character-mode terminals will be connected in a different way. Terminals in countries having a PSE will be connected to an asynchronous time-division multiplexer, either directly or via the PSTN, or via a PDN if available. The multiplexed channels of the terminals will be connected by means of a parallel interface to an ALU in the CP50 switch module, as shown in Fig. 7. For terminals sited remotely from a PSE, access is available via an asynchronous time-division multiplexer whose aggregate bit stream from the terminals can be transmitted directly to the asynchronous multiplexer at the PSE. Alternatively, if there are remotely-sited packet-mode terminals connected via a synchronous time-division multiplexer to the PSE, the bit stream can be transmitted from the synchronous multiplexer. The asynchronous multiplexers are of the type used in the BPO's Dataplex service(12).

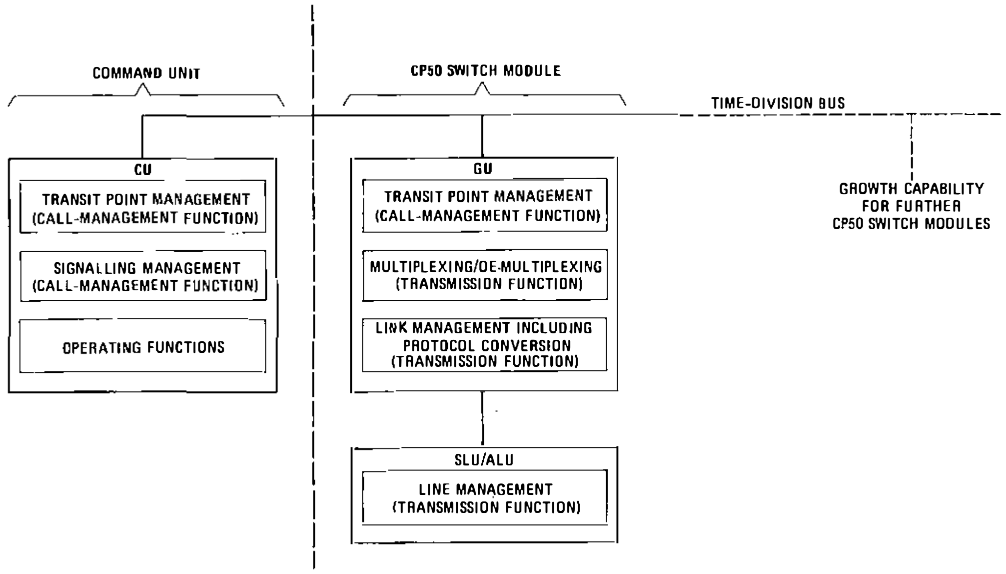
SYSTEM DESCRIPTION

Software for the Mitra 125 and CP50 processors for EURONET is based on that being developed by SESA for TRANSPAC. The production of software is being considered as a part of the development of the whole system rather than as



Note: Character-mode terminals can gain access either by direct connexion or via the PSTN

FIG. 7—Multiplexer access to the CP50 switch module



Note: The NMC, which is not shown in this diagram, performs operating functions

FIG. 8—System functions of a PSE

a separate entity. In this way, it is hoped to avoid any uncertainties of responsibilities at the boundary of analysis and programming. The system is taken to mean the techniques that constitute EURONET's particular packet-switching design and which provide the desired facilities. The system includes the implementation of these techniques as software together with the connexion of users and handling of their protocols. These will include the following: line and link level management, including packet-assembly/disassembly which will be performed by the CP50 switch modules; management at the packet level, which will be performed by the CUs and the CP50 switch modules; and the control of the network, which will be performed by CUs and the NMC.

The system functions to be implemented as software are shown in Fig. 8 and are classified as *transmission functions*, *call-management functions*, and *operating functions*.

Transmission Functions

The transmission functions, implemented specifically in the CP50 switch module, are known as the *line*, *link* and *multiplexing/demultiplexing* management functions; these functions handle characters from asynchronous start-stop mode terminals, and frames from packet-mode terminals and inter-PSE links. All line connexions to a PSE are made to the SLAs or asynchronous multiplexer of the CP50 switch module.

Line Management

The SLAs and asynchronous multiplexers provide the physical and electrical interface between the lines and the SLU and ALU line units.

The SLU will perform the following line-management functions:

(*a*) control of an SLA's acceptance and transmission of frames,

(*b*) frame synchronization,

(*c*) provide the GU with information on any change of state of the lines connected to the SLAs, and to change a line's state on command from the GU,

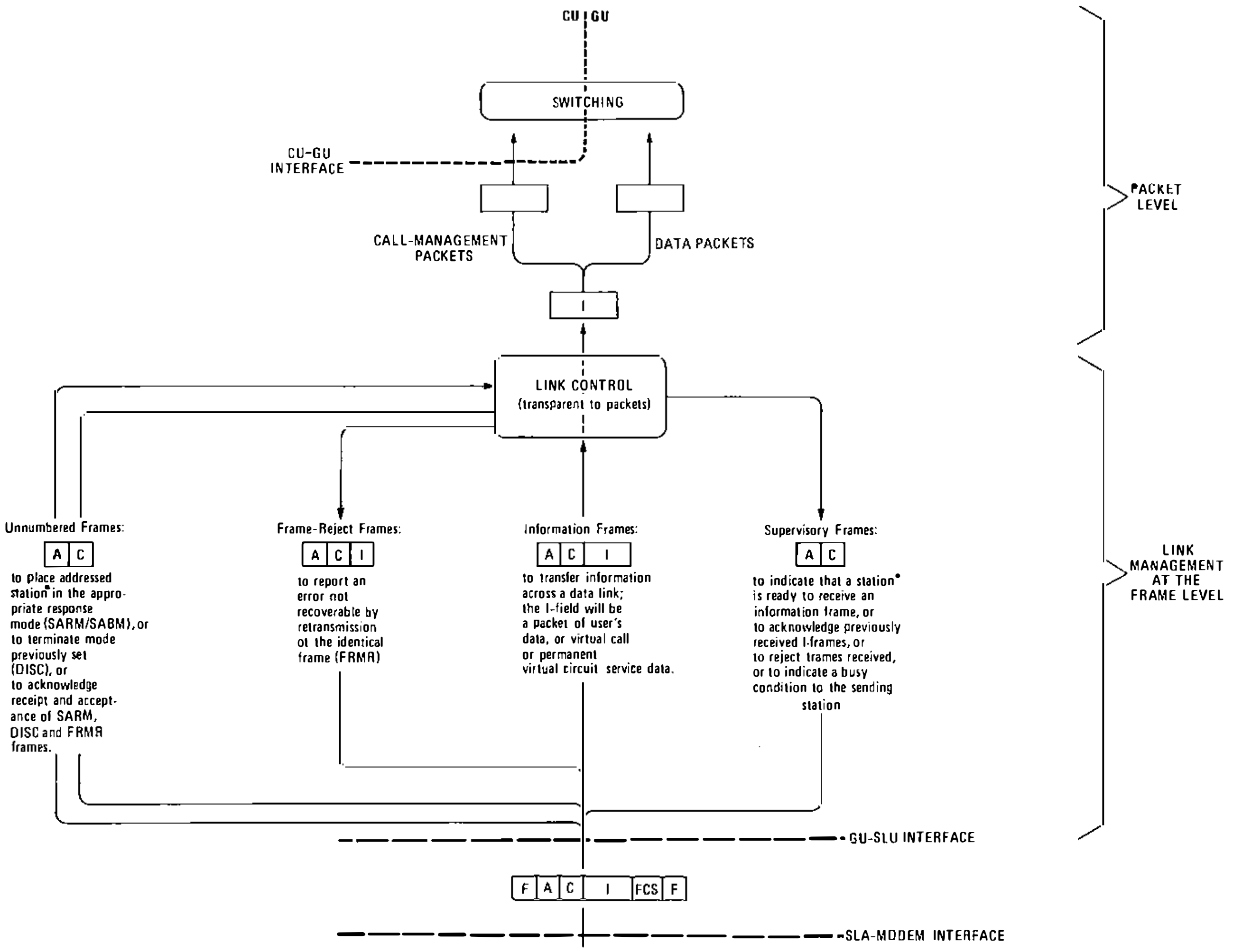
(*d*) parity checks, and

(*e*) cyclic redundancy checks (CRCs) for errors in the frames resulting from line transmission. (The SLU calculates the CRC division and inserts the frame check sequence (FCS) in frames being transmitted to line and, on reception, removes the FCS and uses it in the CRC to check for transmission errors in the frame.)

The ALU's functions are

(*a*) providing timing and control of reception and transmission of characters across the parallel interface with the asynchronous multiplexer,

(*b*) providing the GU with information on any change of



* In this case the station referred to is the GU

FIG. 9—A GU's link management for an X25 user calling a PSE

state of the lines connected to the multiplexer, and changing a line's state on command from the GU,

(*c*) parity checks,

(*d*) recognition of specific character sequences, and

(*e*) time-outs and severing of communication with a start-stop character-mode terminal if it delays transmission of characters for longer than a certain period.

Link Management

A link, as described here, is a line and its terminal devices considered at the frame level of transmission. In the case of a packet-mode terminal connected in accordance with X25 to a CP50 switch module, the link-management function consists of handling the remaining parts of the frame not handled by the line-transmission function; for example, the frame's address (A) field, the control (C) field and the information (I) field (if the frame contains one). The GU's management of frames on the link is shown in Fig. 9, which shows the case where the PSE is receiving a call from an X25 packet terminal. For the terminal to set up a link to the PSE it has to send a *set asynchronous response* (SARM) or *balanced mode* (SABM) unnumbered frame to the PSE; the PSE acknowledges this by returning another type of unnumbered frame. Set up of the virtual call can then begin; the packet terminal sends information frames, and the PSE acknowledges by returning supervisory frames. The I-field (the first one being a *call request packet*) of each frame is processed and switched, for example, to another packet-mode terminal via the GU's link control.

In the case of a trunk connexion to another PSE, the link-management function is performed by the GU in accordance with the TRANSPAC trunk protocol.

For a start-stop character-mode terminal, the link-management function is performed by the GU in accordance with draft Recommendations X3, X28 and X29. The PAD facility is implemented in the GU.

The link-management function will also enable the use of a multi-line procedure between a packet terminal and a PSE, and between PSEs. The procedure allows a group of two or more lines to be used as one single link; this can improve reliability and the rate of flow of frames.

Multiplexing/De-Multiplexing

The third transmission function is the multiplexing/de-multiplexing by the GU of packets onto the appropriate logical channels that have been assigned to a virtual call; that is, incoming and outgoing paths of a virtual call. This multiplexing function by the GU can effectively be considered to be the switching of packets from a logical channel associated with one physical transmission link to a logical channel of another, where each physical link is a constituent part of a specific virtual call. The position where 2 logical channels meet is called a *transit point*, and this point is contained within the GU.

Call-Management Functions

There are 2 call-management functions, known as *transit-point management* and *signalling management*.

Transit-Point Management

When a virtual call is already established, data packets are switched directly by the multiplexing function of the GU. However, the routing of call set-up packets, which are used to set up a virtual call, is processed by the CU. To establish each transit point, a route is set up by the relevant PSEs' CUs and GUs; each GU is instructed, from data held within the CU, on the destination of the GU to which a packet is to be switched. The GU then transmits to the destination GU the number of the outgoing link, after modification at the transit point of the call's logical channel number contained within the packet.

Signalling Management

Signalling management is performed by the CU and involves processing *call set-up* packets, *call confirmation* packets, and *clear* and *clear confirmation* packets in accordance with the packet level procedures of X25. A CU does this among other things, to validify the packets and determine out-going routes from the GUs for the packets. The choice is made by means of a routing table held in every CU. Signalling between a PAD and an X25 terminal is managed in accordance with draft Recommendation X29.

Operating Functions

A CU performs a number of operating functions, nearly all of which involve interaction with the NMC (for example, accounting, remote-control and service functions).

The accounting function will relay traffic data from each PSE to the NMC to enable the NMC to assemble billing information for off-line processing. This information can be used to determine user charges.

A CU can receive remote-control functions from the NMC to be processed by that CU for transmission to an adjacent CU.

Other functions will enable the CU to monitor its configuration of CP50 switch modules. The CU monitors the state of its associated switch modules by collecting data at different points in the switch. In the case of signalling management, the CU sends signalling packets and commands to the GUs for data with which to update the CU's routing table, and for flow-control parameters. Inconsistencies and defects that occur will he reported by the CU to the NMC. The CU contains internal virtual terminals that perform services such as traffic generation and absorption when asked by the NMC. A virtual terminal, implemented in software in the CU, appears to exist as a packet-mode terminal to terminals outside the PSE. Network operating personnel and, for some services, users, will also be able to call these virtual terminals.

Because the CU will monitor the CP50 continuously, the CU has sufficient information for fault diagnostic purposes and, in the instance of hardware failure of a unit within a CP50 switch module, can re-configure the equipment (provided the faulty equipment is duplicated). During normal network operations, therefore, the whole PSE will be controlled by the CU, and the NMC plays a passive role. However, if the CU fails, a change-over to a stand-by CU occurs with no effect on any established virtual calls, since the stand-by unit is always updated by the operational CU. If the stand-by also fails, the NMC will initiate action to re-start the system by forcing a re-configuration in the network and remotely loading programs containing new routing information. The NMC is then able to execute partial reloads containing new programs, or test programs, on the switch that is faulty.

NETWORK ENHANCEMENT

On the opening date of the network at the end of 1978, EURONET will cater solely for the initial needs of the EEC Commission. It is expected, however, that extra terminal interfaces will be provided early in 1979 to cater not only for the additional requirements of the EEC Commission but also to meet requirements of possible non-EURONET users. One possibility is that the internodal links of the *European Informatics Network* may be replaced by permanent virtual circuits or virtual call facilities obtained from the EURONET packet-switching network. Tariffs are expected to be announced early in 1978 and, being based on the amount of data transmitted rather than on conventional time and distance parameters, they may attract non-EURONET users who currently use international Datel services on the PSTN or leased lines.

To meet the requirements of a public service, however, certain elements of the network may need to be enhanced. In particular a second NMC could be needed, and additional transmission links may be required to increase the network's availability to users. The EEC PTTs are also looking at other ways to enhance the network once it is in service. For example, the remote multiplexer sites could have switching equipment installed, thus providing PSEs in those countries which previously had none. Consideration is also being given within CEPT to the extent to which the network can be integrated within a European Data Network to provide an international packet-switching data service. Already some non-EEC countries have expressed an interest in joining the network, and it seems reasonable at this stage to envisage a phased expansion to meet user demand.

Once the CCITT has standardized the international interworking protocol between national packet-switching networks (such a protocol is currently heing developed and will be defined in the X70 series of CCITT Recommendations), the EURONET packet-switching network could be connected to other data networks in the world. However, while this will enable calls to be established, satisfactory communication can take place only if user-to-user protocols are developed and standardized. The EEC Commission has initiated development of EURONET data base access and retrieval protocols which, when available, will enable any user to use the same protocols to gain access to any of the available data bases connected to the network.

CONCLUSIONS

The planning and implementation of the EURONET packet-switching network has been a major task involving the close cooperation of the EEC PTTs and the EEC Commission. Although being set up initially as a private network, EURONET will have the capability to be expanded to meet not only the specific needs of the Commission but also those of commercial enterprises that wish to use international data transmission facilities.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the efforts of those people in the various PTTs who are jointly enabling a complex and novel international system to be implemented, and also to acknowledge the assistance of their colleagues in the departments of Telecommunications Headquarters for their help in the preparation of this article.

References

[1] Davies, G. W. P. The EURONET Project, *Proc. EUROCOMP*, p. 229, 1975.

[2] Belton, R. C., and Smith, M. A. Introduction to the British Post Office Experimental Packet-Switching Service (EPSS). *POEEJ*, Vol. 66, p. 216, Jan. 1974.

[3] Hadley, D. E., and Medcraft, D. W. F. Experimental Packet-Switched Data-Transmission Service: Network Design and Implementation. *POEEJ*, Vol. 67, p. 88, July 1974.

[4] Neil, W., Spooner, M. J., and Wilson, E. J. Experimental Packet-Switched Service: Procedures and Protocols, Parts 1, 2 and 3. *POEEJ*, Vol. 67, p. 232, Jan. 1975, Vol. 68, pp. 22 and 110, Apr. and July 1975.

[5] Gardner, A. J., and Sandum, K. N. Experimental Packet-Switched Service: Routing of Packets. *POEEJ*, Vol. 68, p. 235, Jan. 1976.

[6] Burgess, M. J., and Lockwood, J. A. Experimental Packet-Switched Service: The Customers and their Packet Terminals. *POEEJ*, Vol. 69, p. 122, July 1976.

[7] Roberts, L. G., *et al.* The ARPA Network. Computer Communications Networks, p. 485, Prentice Hall, 1973.

[8] Després, R. RCP: The Experimental Packet Switched Data Transmission Service of the French PTT. *Proc. ICCC*, p. 171, 1974.

[9] Poncet, F., *et al.* The Design of the Packet Switching Network for the EIN Project. *Proc. EUROCOMP*, p. 301, 1975.

[10] Barber, D. L. A. A European Informatics Network: Achievement and Prospects, *Proc. ICCC*, p. 44, 1976.

[11] Danet, A., *et al.* The French Public Packet Switching Service: The TRANSPAC Network. *Proc. ICCC*, p. 251, Aug. 1976.

[12] Murray, W. J., and Rimington, J. W. Dataplex Service 110: A New Service for Time-Sharing Computer Bureaux. *POEEJ*, Vol. 65, p. 68, July 1972.

Noise on Telephone Circuits

R. L. HOWIE†

UDC 621.395.7:621.391.822

This article describes experience in Wales and The Marches of interference effects in telephone circuits due to earth currents in electricity mains. In particular, problems caused by supplies using protective multiple earthing are described. Some remedial measures are discussed.

INTRODUCTION

During the investigation of noise troubles at Chester, Tarvin, Brecon, Monmouth and Whitchurch telephone exchanges, one of the causes was traced to a relatively new source: the effects of protective multiple earthing (PME), a system now being brought into more general use by supply authorities.

When connected to telephone exchanges, PME systems require that the neutral conductor of the supply authority's service cable be earthed at the interface between the service cable and exchange load. The screen of the service cable is also earthed at the interface, making the screen, neutral conductor and earth parallel connexions back to the supply point at the substation.

Some service cables have a sheath of solid aluminium or wave-wound aluminium wires around their live conductors; this sheath is used as the neutral conductor, and is earthed at the substation and exchange. The sheath is thus a combined neutral and earth (CNE) conductor.

Fig. 1 illustrates typical earthing arrangements for a supply using PME with a CNE conductor. The purpose of PME is to improve protection at consumers' premises. A side effect is the lowering of the impedance of the neutral connexion (due to the parallel earth-return path), giving some advantage to the supply authority in respect of voltage drop.

EARTH CURRENTS

Return currents in the neutral conductor produce potential differences across it, and these potentials also appear between the exchange and substation earths by virtue of the parallel path so provided.

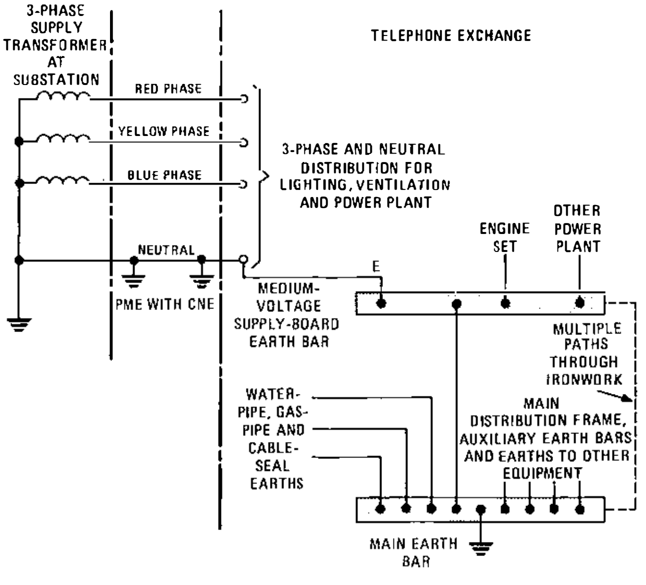


Fig. 1—Typical earthing arrangements

In the case of 3-phase supplies, a further effect is evident. Imbalance in the phase loading results in unequal currents in each phase, causing current to flow in the neutral conductor with the effect described above. However, any change in the load of any phase alters the imbalance, so that the potential difference between the exchange and substation earths varies as loads change in, say, adjacent buildings.

---

† Planning and Works Division, Wales and The Marches Telecommunications Board

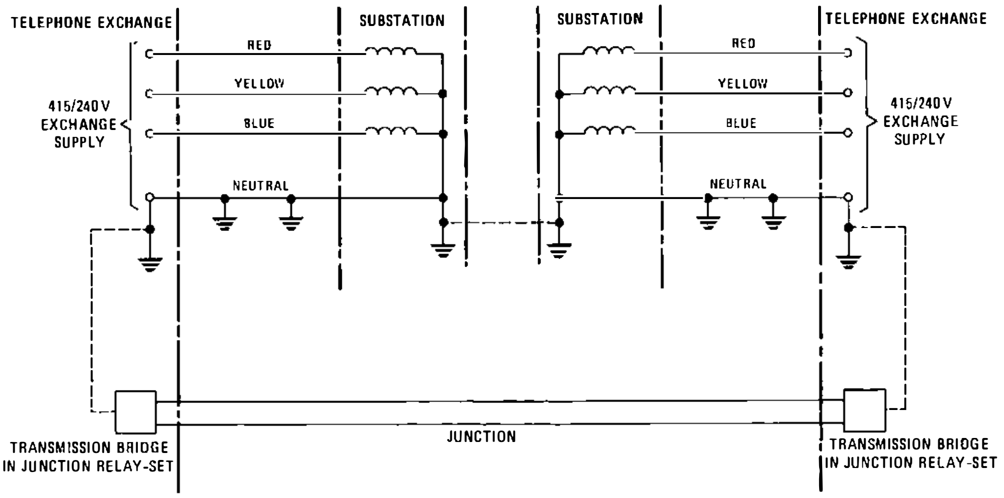


FIG. 2—Relation of earth potentials to a junction between 2 exchanges

The potential difference between the substation and exchange earths can have an RMS value of 5 V, or even more. For 2 exchanges such as those shown in Fig. 2, the total potential difference between the 2 exchange earths could have an RMS value as high as 10 V if the phases of the imbalance currents were vectorially additive.

EFFECT ON JUNCTION CIRCUITS

The effect on junction circuits can be assessed from Fig. 2. By virtue of the transmission bridges, junctions are referred to earth at each end. Thus, any differences between the earth potentials at each end are developed across the junction, so that the junction becomes yet another parallel path. The level of the resulting noise varies from the audible down to what is detectable only on a decibel meter or psophometer. Where signalling units have low input levels (such as the −22 dBm input to a Signalling System AC No. 11 receiver), the base noise level impairs adjustment of sensitive operating points. Carpenter relays, used in some signalling systems, are also adversely affected by a 50 Hz current. Junctions with capacitor-type transmission bridges are more susceptible than those with transformer-type bridges; both types are shown in Fig. 3.

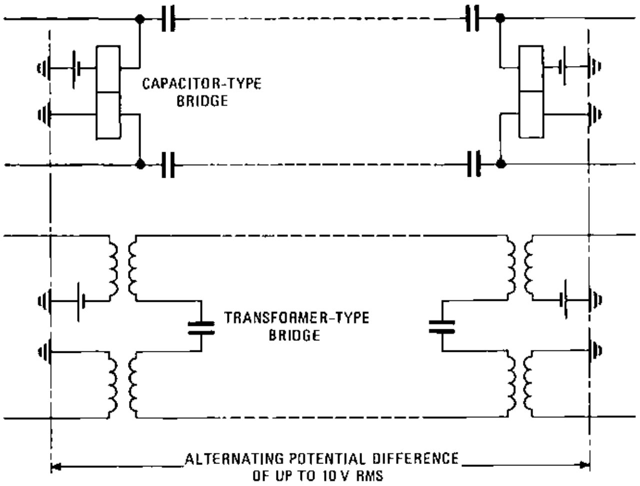


FIG. 3—Alternating potential differences across capacitor and transformer-type transmission bridges

EARTH CONNEXIONS

Earthing is generally poorer in those situations where service pipes into a building are plastic, and where telecommunication cables are plastic-sheathed. Where PME is used, the neutral conductor and substation earth are effectively in parallel with the exchange earth, making the exchange partly dependent on an earth connexion in which voltages are generated.

Camouflaging or aggravating the effects of PME with CNE cable is ineffective earthing of screens in plastic-sheathed junction cables, and ineffective through-connexions of screens from one cable to another. Poor earthing in this respect accentuates hum problems.

Because of the method used to earth the neutral conductor of the incoming supply, and due to the geography of exchanges, alternating currents flow to a greater or lesser extent in exchange ironwork (see Fig. 1). These currents appear on interconnexions between racks of equipment; in repeater stations, for instance, they appear on the screens of cables, causing interference.

DIAGNOSIS

A reliable pointer to PME troubles is given when reports show that own-exchange calls are quiet but junction calls are noisy. Using a clip-on ammeter, a check at the earth connexion adjacent to the supply (point E in Fig. 1) will show whether alternating current is flowing in the exchange earth; in bad cases, as much as 5–10 A may be detected. The clip-on ammeter can also show where the current is going; for example, to cable screens, water pipes or the main earth system. The currents are difficult to summate because of the element flowing in the ironwork.

For 3-phase systems, a situation can arise where imbalance in substation loads is matched by imbalance in the exchange load, so that no current flows in the neutral conductor. The exchange earth is then at the same potential as the substation earth, but a distant exchange may still be offset from the substation earth potential, giving the usual interference effect. This situation is not likely to persist, as loads are constantly changing. The state is readily identified using a clip-on ammeter, as there will be no current in the neutral conductor while currents in the 3 phases differ.

REMEDIES

Since PME troubles are usually associated with currents flowing from the mains CNE conductor into the exchange earth, an obvious remedy is to remove the connexion between them (strap E in Fig. 1). This is often effective, and is permitted by the rules for PME to which the supply authorities work. When it is done, however, it is essential that the following precautions are taken.

(*a*) All ironwork and all earth connexions must go to the exchange earth only; it is not permissible to connect some to the PME earth terminal and some to the exchange earth.

(*b*) The exchange earth must comply with the requirements of the IEE Wiring Regulations. In particular, it must be of sufficiently low resistance to ensure that the main fuse or circuit-breaker will operate in the event of a phase-to-earth fault within the exchange; alternatively, an earth-leakage circuit-breaker (ELCB) must be used. It will usually be found that an ELCB or equivalent out-of-balance tripping device is necessary since, for example, a 150 A main fuse requires an earth-fault resistance of 0·6 Ω or less to ensure that it blows.

Occasionally, removal of the PME-to-exchange-earth strap does not cure the trouble. This can occur when a nearby electricity earth connexion (for example, a substation transformer star-point) is carrying a heavy current and causing the earth potential of the whole neighbourhood, including that of the exchange earth, to rise.

Hum troubles due to PME have been found to be considerably more prevalent than suspected, although it is only when normal hum precautions fail that PME sources tend to be investigated. The first steps should usually be to check that the exchange earthing and screening arrangements are correct as set out in the Telecommunications Instructions, and that the mains system, if it is 3-phase, is balanced as well as is reasonably practicable. If the trouble persists, the supply authority should be asked to check and improve the balance of their system in the neighbourhood. If these attempts to remove the source of the trouble fail, consideration should be given to removing the PME-to-exchange-earth strap, as described above.

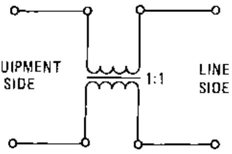


FIG. 4—Hum-bucker

If only a few circuits are affected, then a hum-bucker (see Fig. 4) in each circuit may be a satisfactory and economical cure. The 1 : 1 transformer presents a high impedance to currents flowing in the same direction, whereas speech currents, flowing as they do in opposite directions, are only slightly attenuated.

OTHER SOURCES

The preceding sections have been concerned with noise due only to PME troubles, but other sources, which were discovered in association with PME investigations, and which can be troublesome, are described below.

Fluorescent lighting superimposes fifth and seventh harmonics of 50 Hz on the supply and the earth connexion. Each lamp also passes about 1 mA AC to earth. In a large equipment room with 200 lamps, this current amounts to 200 mA finding its way through ironwork to the medium-voltage earth. The currents from these sources can be observed on an oscilloscope at point E in Fig. 1. The only practical remedy here is to ensure that lighting loads are as evenly dispersed as possible between phases.

DC-to-DC rack regulators have been found to feed back noise into 50 V DC supplies. The noise varies in frequency from 150 kHz to low audio frequencies. In all cases investigated so far, faulty components have been found. The noise was of such a level as to prevent proper adjustment of signalling equipment taking supplies from the same bus bars.

Pulses of current have been observed on supply lines from the voltage regulators of colour-television sets. As the regulator in one set works in unison with all other sets of the same general pattern, these pulses can be, when added together, comparable with or even higher than the base load on a supply line. Such pulses have been observed in exchange earths, and seem particularly irksome on loudspeaking telephones.

Earth cables taken from the nearest convenient point rather than being properly routed have caused noise transfer onto bus bars. The noise here is more of a random nature and can be a problem to locate when mixed with noise from other sources.

Where noise from more than one source is present, it becomes difficult to determine how far PME is involved, and care must be taken to ensure that earth currents are not merely due to miswiring of single-phase supplies, leaving earth and neutral supply connexions reversed to individual items of equipment. This can readily be checked by measuring live and neutral currents with a clip-on ammeter. The values should be the same.

CONCLUSION

This article is based on practical experience of the effects of PME on equipment in Wales and The Marches, and it is hoped that the foregoing will be helpful to others when unusual noise and signalling problems are encountered.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the assistance and co-operation of Mr. B. Nield of the Merseyside and North Wales Electricity Board in the investigation of cases of suspected mains interference, and to thank Mr. R. A. Crowther of the Planning and Works Division, Wales and The Marches Telecommunications Board, and Mr. J. O. Colyer of the Operational Programming Department, Telecommunications Headquarters, for encouragement and advice in the preparation of this article.

The Technician Education Council

H. BLAKEY and B. STAGG, C.ENG., M.I.E.E.†

UDC 374: 331.86

This academic year, most of the British Post Office's first-year apprentices are studying Technician Education Council (TEC) courses, rather than the more familiar City and Guilds and National Certificate courses. Eventually, the TEC's courses (and those of the equivalent body in Scotland: the Scottish Technical Education Council) will replace the other forms of technician education in technical colleges. This article explains briefly the origins and organization of the TEC, describes the structure and aims of its courses, and discusses the value of its awards against the background of comparable existing courses. The content of the telecommunications course is described and reference is made to this issue's Supplement, in which guidance is given on the use for revision purposes of model answers previously published in the POEEJ's Supplements and model-answer books.

ORIGINS OF THE TECHNICIAN EDUCATION COUNCIL

The City and Guilds of London Institute (CGLI) and National Certificate schemes have provided the main vehicle for technician education for many years, evolving to meet the changing requirements of industrial technology, and each oriented towards the needs of particular facets of industry. The contribution made by technicians to our economy, and to society, is enormous; the education of technicians is therefore important to us all. But the rigid division of technician education into 2 schemes is becoming less defensible. The risk in dividing students into 2 broad categories early in their careers is readily apparent, there being little opportunity to transfer from the craft-oriented CGLI courses to the professional route offered by National Certificate courses; many students are effectively excluded from degree courses because of this division. There is some scope for college education to be linked more closely with industrial training and the needs of industry. Combining resources into a single administration should make the development of common course material (where appropriate) less difficult. The multiplicity of qualifications available from the present systems is confusing to new students and to the public, hindering the well-deserved enhancement of the status of technicians.

The newly-created Technician Education Council (TEC) is charged with unifying and rationalizing technician education in England, Wales and Northern Ireland. It was established in 1973 by the then Secretary of State for Education and Science, following recommendations by the Haslegrave Committee on Technician Courses and Examinations, which reported in 1969. In broad terms, the TEC is concerned with the development of policy for technician education at all levels, and is responsible for devising or approving courses, maintaining standards and making appropriate awards. Its courses, aimed at meeting the personal and vocational needs of students as well as the requirements of industry, will supersede existing technician courses* over the next few years. Flexibility and equality of opportunity are important innovations, as is the modern outlook on methods of study adopted by the TEC.

STRUCTURE OF THE TEC

The TEC has established 3 *sector committees*, each with broad responsibility for an area of technician education. They advise on, interpret and implement the TEC's policies, oversee the work of organizing and running courses, and maintain relationships with other interested bodies. A number of *programme committees* has been set up under each sector, concerned with devising and approving course material (in conjunction with representatives from industry and the academic world) and giving guidance on such things as admission and assessment. Fig. 1 illustrates how the sector and programme committees are organized, with particular reference to the engineering disciplines.

THE TEC's AWARDS

The TEC makes 4 awards: the Certificate, the Higher Certificate, the Diploma and the Higher Diploma. The Certificate course (courses, in TEC terminology, are called *programmes*) normally consists of 3 years of study, although a well-qualified student may complete the programme in 2 years while another, taking one or two subjects at a time, may take considerably longer. For this reason, the programme is said to have 3 *levels*, rather than be a 3-year course.

Each level consists of a set of 4 or 5 *units*. Each unit comprises 75 h or 60 h of study time, and is normally devoted to one subject although, for flexibility, some subjects occupy only half a unit.

The Higher Certificate programme consists of 2 levels. The diplomas are of comparable academic standard to the certificates, but are broader in their coverage by virtue of containing extra units.

Because of the change in philosophy underlying the TEC's concepts, it is difficult to be precise about equivalents, but

---

† Mr. Blakey is Head of the Engineering Training and Technical Education Section of the Telecommunications Personnel Department, Telecommunications Headquarters, and Mr. Stagg is Assistant Editor, *POEEJ*, with special responsibility for the model-answer *Supplement*

* CGLI craft courses, such as those for electricians and motor mechanics, will still be held; only technician courses are to be superseded

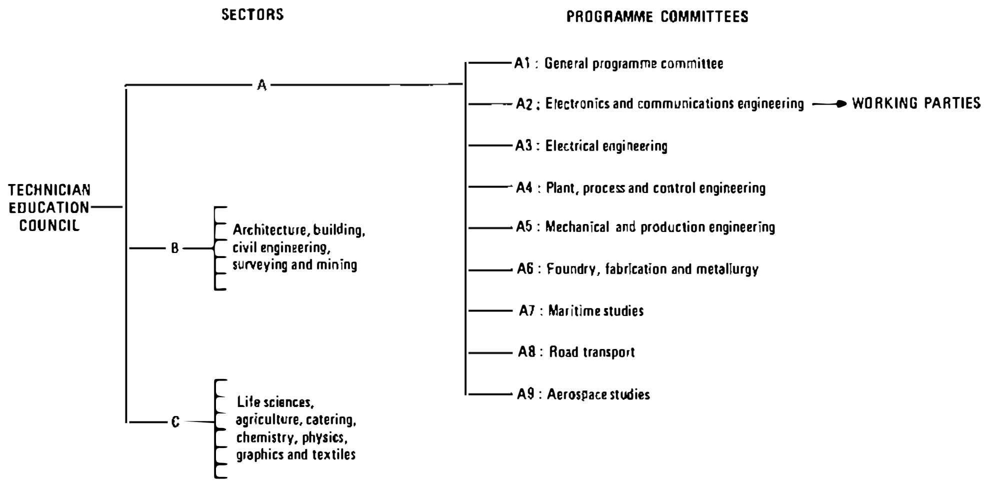


FIG. 1—Organization of sector and programme committees

TABLE 1

Approximate Levels of Comparability

National Certificates	TEC		CGLI	
	Programme	Level	Year	Part
Ordinary National Certificate	Certificate	1	T1 (Preliminary)	I
		2	T2 (A-year)	
		3	T3 (B-year)	
Higher National Certificate	Higher Certificate	4	T4 (C-year)	II
		5	T5 (Advanced)	III

Table 1 shows *very approximate* levels of comparability for TEC, CGLI and National Certificate courses. TEC Diploma and Higher Diploma programmes can be regarded as being *roughly* on a par with Ordinary and Higher National Diploma courses.

TEC awards are given titles according to the disciplines they cover; for example, "Certificate in Telecommunications" or "Certificate in Shipbuilding".

PHILOSOPHY AND METHODS OF STUDY

The TEC's policies can be interpreted as aiming to provide programmes of study that

(*a*) impart knowledge and skills that are relevant to the vocational needs of students,

(*b*) are acceptable to employers (by virtue of the facility for employers to take part in the design of programmes),

(*c*) encourage students to develop a mature attitude,

(*d*) give each student the same opportunity to progress in his academic studies,

(*e*) set standards acceptable to professional and other qualifying bodies, such as industrial training boards,

(*f*) enjoy full awareness and recognition of their value,

(*g*) ensure the progressive acquisition of knowledge and skills as the course proceeds, and

(*h*) lead to awards that are independent of the study route used.

The main features of the TEC's approach which provide for these objectives are described below.

Flexibility

The system of study units adopted by the TEC is very flexible; units can be assembled to form a Certificate programme or a Diploma programme, and a student can choose his own pace of working if he prefers not to equate levels with years of study. This structure caters for students of different abilities and academic goals. Various optional and supplementary units allow the more academic student to expand his educational base, while the basic TEC awards may be a final and completely appropriate qualification for those aiming at technician status.

Industrial Participation

TEC study units are designed by colleges (or by the appropriate programme committee) in association with local and national employers, so that courses reflect the needs of industry. (The extent of industrial participation for a particular industry may vary, depending on its organization.)

Where they fit local needs, standard units† can be adopted by colleges, and are particularly useful in common subjects such as mathematics and electronics. However, some specialized subjects, particularly in telecommunications, are also applicable nationally, and the British Post Office (BPO) has played a part in the design of standard units for telecommunications subjects.

The following example illustrates how colleges can offer variations of a standard programme to suit local needs. A communications course run by a college near an airport may offer radar and navigational aids as locally-designed specialisms (in addition to standard mathematics and electronics), while a college near a broadcasting studio may offer radio and television as specialist subjects in the same basic programme.

Liaison with industry also means that programmes can take account of formal training that students are receiving at work; in some instances, the TEC will allow exemptions on the strength of industrial training received.

Standards

The TEC is responsible for setting and unifying the standard of its courses. Although colleges may design them, programmes have to be approved by the TEC (a process known as *validation*), and the TEC also has to ensure that colleges

---

† A standard unit is one designed and published by the TEC

have the resources to run the programmes they wish to offer. Again, colleges will set examinations, but the TEC will ensure that the standards of its awards are being maintained by appointing moderators, who will check on the level of work being achieved and the methods of assessment. The TEC will work to ensure that its awards are widely understood and recognized.

Success Rates

The TEC takes the view that a student who is qualified to enter a course designed to meet his needs, and who works reasonably hard, has a right to expect an award. The TEC's aim is to protect standards by defining appropriate entry qualifications and by the quality of the course material, not by a high failure rate. End-of-course examinations will still be held, but more weight will be given to in-course assessments and to a student's coursework and homework, so that a lapse under examination conditions will not necessarily mean that the student fails the course.

TEC awards will not be graded overall, but a high standard of achievement in any unit will be recorded as a "pass with merit".

These concepts throw more responsibility on employers, universities and qualifying bodies to seek detailed information about a student's studies. The certificate awarded will, however, show the make-up of the programme followed and define any specialisms within the programme.

General and Communication Studies

Great emphasis is placed on general and communication studies, to the extent that this subject is assessed in a similar manner to the technical units. A broad outlook, and skill in communicating, are important assets to a technician, who may have to put across technical ideas, and implement them in a society governed by managerial, economic and legal considerations. General and communication studies at Certificate level will help to provide students with some of the basic skills involved.

Study Routes

TEC awards can be obtained by full-time, sandwich, block-release, day-release or evening study, or by a combination of these methods. Thus, particular awards are not tied to particular methods of study; for example, diplomas may be gained by part-time study. That the same award can be attained by various routes satisfies the TEC's policy that different combinations of knowledge and skills merit similar recognition.

THE BPO AND THE TEC

The BPO has had strong links with the CGLI for very many years and, when the opportunity to work with the TEC came along, careful thought was given to the areas where BPO help and influence would be of most value. It was immediately obvious that only a minority interest could be claimed in the work of some of the committees; the major interests were clearly telecommunications, electrical engineering, electronics and motor transport. A seat was gained on the A2 (Electronics and Communications Engineering) programme committee.†

When working parties (see Fig. 1) were established to deal with the structure and content of the various programmes, the BPO was able to play a major part in work on the electronics and telecommunications syllabi.

Much work, however, is being done at college level, and there are plenty of opportunities to maintain the traditional links with college staff. Evidence that BPO interest is welcome is not hard to find, even though BPO support, in terms of the actual number of students starting TEC studies in the current academic year, must be a disappointment to many colleges. It is the liaison between Regional and Area staff and the colleges that satisfies the TEC's requirement that there should be proper consultation with industry before programmes are offered for validation.

The burden of additional work has been spread fairly widely within the BPO, but this cannot be said of the colleges or the full-time staff of the TEC, where the pressures to formulate and validate several hundred programmes have been sharply felt. The extent of this disturbance to the smooth running of the colleges can be appreciated by an examination of the activities of the sector and programme committees shown in Fig. 1. These committees were set up to review the whole field of technical education and produce workable rules and acceptable programmes within a period of about 4 years.

ADMISSION AND EXEMPTIONS

The unit system allows credit to be given for previous attainment outside the TEC's programmes; that is, it is possible to gain exemption from a limited number of units by showing that the work has been covered by previous studies or experience. Thus, it is possible for students to enter TEC programmes at different starting points.

This facility is particularly important during the change-over years, when students may wish (or be obliged, due to closure of other courses) to change from CGLI and National Certificate courses to TEC courses.

Generally, the admission requirement for any level of a TEC programme is completion of appropriate units at the preceding level, or equivalent attainment and/or experience. For entry to level 1, completion of a 5-year secondary-school course is desired, with adequate attainment in appropriate subjects. Colleges may, at their own discretion, allow students without the minimum qualifications to be admitted, if special selection procedures indicate that such students are likely to complete the course successfully; this procedure is likely to apply in particular to mature students. Appropriate General Certificate of Education (GCE) O-level or Certificate of Secondary Education (CSE) grade-1 qualifications may give entry to level 2 of a TEC programme; that is, complete exemption from level 1. It is TEC policy that appropriate GCE A-level qualifications should give entry to the Higher Certificate (that is, complete exemption from the Certificate programme), but details have not yet been published.

During this first year of operation of TEC courses, the BPO is adopting a cautious attitude towards exemption, and most apprentices have commenced their studies at level 1. This policy will be reviewed, and perhaps modified, when training officers have seen the results of the first year's work.

ASSESSMENT

The traditional syllabus, which is rarely more than a topic list, gives little guidance to the lecturer about depth of treatment, and the student is obliged to reach his own conclusions by regular scrutiny of past examination questions. In effect, the examiner, rather than the college, interprets the syllabus. However, the topics covered by a TEC unit are defined in the form of minutely detailed objectives to be achieved by a student. For example, the student should be able to: "state the need for a carrier; describe modulation as the superimposition of information on a carrier by the technique of allowing some characteristics of the carrier wave to be varied by another wave; draw sine-wave amplitude-modulated waveforms; identify frequency-modulated carriers; and describe demodulation as the reverse process to modulation".

---

† The Post Office Engineering Union also gained a seat on the A2 committee, and its General Secretary was appointed to the main Council. The Society of Post Office Executives has a seat on the working party for electronics and telecommunications

The advantages of this form of presentation of syllabi are that teachers have a clear idea of the depth of treatment of each topic, employers know exactly what their technicians are studying, and students are aware of the criteria used when performance is being assessed. Externally-set examinations will not be a feature of TEC programmes, and lecturers will be able to use whatever teaching and assessment methods they wish to achieve the objectives, subject to the approval of the TEC.

The college *submission* to the TEC, which is the formal application for recognition of a programme leading to a TEC award, must include a full statement of the method of assessment, the parts of the syllabus which are subject to in-course (or *phased*) assessment, and those objectives which are assessed (or reassessed) at the end of the course. The TEC has not laid down a detailed pattern of assessment, but its published policies make it clear that coursework, homework and laboratory projects should all be given due weight in the decision to make an award.

The practical result of the TEC's approach is that most colleges seem to be devoting up to 10% of the course time to assessment; this will usually be allocated between coursework and phased tests, and terminal examinations, in the ratio 6 : 4. Although not all colleges are convinced of the need for traditional end-of-course examinations, they are in a small minority, and it is evident that there is a reluctance to depart from terminal examinations. Whether this is due to colleges' or employers' influence is hard to determine.

The TEC has appointed a number of external moderators, some being full-time but most being part-time. Their function is to provide a general oversight of the final standard of achievement, and they will therefore concern themselves with performance in only those units that are terminal; for instance, a level-4 unit may represent the final level of achievement in a particular specialism whereas, in others, a level-5 unit may be more appropriate.

VALUE OF AWARDS

Because of the broad levels of comparability shown in Table 1, it can be visualized that the TEC Certificate may acquire the same currency as the Ordinary National Certificate, and the Higher Certificate that of the Higher National Certificate. TEC qualifications are likely to be recognized for promotion purposes in the BPO, along with CGLI and National Certificate qualifications, but the details have yet to be worked out in consultation with the unions.

Part of the TEC's philosophy is that its awards should be acceptable to professional and other qualifying bodies concerned with the occupation the technician is following, and to degree-awarding bodies. Broadly, engineering education in Britain covers the needs of 4 groups: professional (chartered) engineers, technician engineers, technicians and craftsmen. With the exception of the first group, which has clearly defined qualifying requirements,† the groups are not clearly distinct from each other; Fig. 2 shows, very approximately, how the CGLI and National Certificate schemes cover the needs of the various groups.

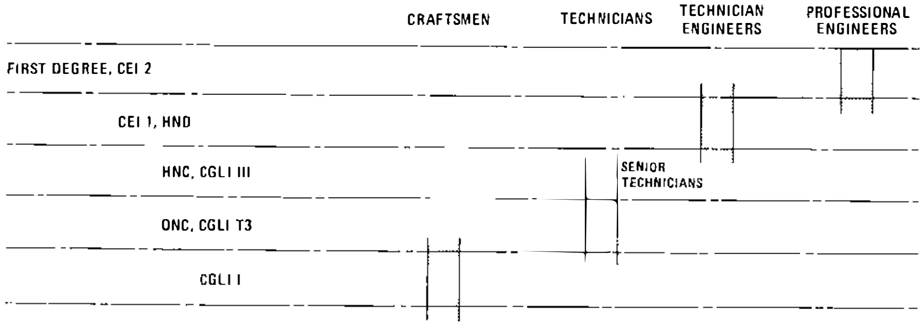
CGLI qualifications are evidence of craft or trade proficiency, with the higher years, by virtue of their academic content, being regarded as good technician (or even technician-engineer) qualifications. Parts of the National Certificate course (or, more realistically in recent years, the National Diploma course) have been accepted as equivalent to parts of the professional engineers' course; a good example is the Higher National Diploma, which gives complete exemption from part 1 of the Council of Engineering Institutions' examinations (CEI 1). Many students have progressed to chartered-engineer status by this route. Similar progression from CGLI courses is much more difficult, generally involving intensive part-time study for CEI 1 and CEI 2. The comparison in Table 1 suggests that the TEC Certificate is appropriate to technician level, while the Higher Certificate is appropriate to senior-technician level.

The unified and flexible structure of TEC courses allows all students to progress freely. The intention is that a student who sets out as a craftsman has the opportunity, at his own pace, to work his way up through the technician strata to professional status, and to transfer to a degree course if he has the ability and so wishes.

The qualifying bodies have yet to decide exactly what status they will allow TEC awards. Entry to university, for instance, will probably require high marks in most subjects (as is the case now) and additional mathematics units (a subject which is optional at the higher levels of TEC programmes). It is not yet known whether the TEC's Higher Diploma will have the same exempting status as the Higher National Diploma, and the Joint Committee for the Awards of Higher National Certificates and Diplomas has therefore decided to retain Higher National Diploma courses until the professional route so provided is adequately covered by TEC courses. Students aiming for professional status should ensure that any course on which they embark will lead to the exemptions they desire, and should make themselves aware of any extra studies that may be required. For instance, a full-time professional course could demand as an entry

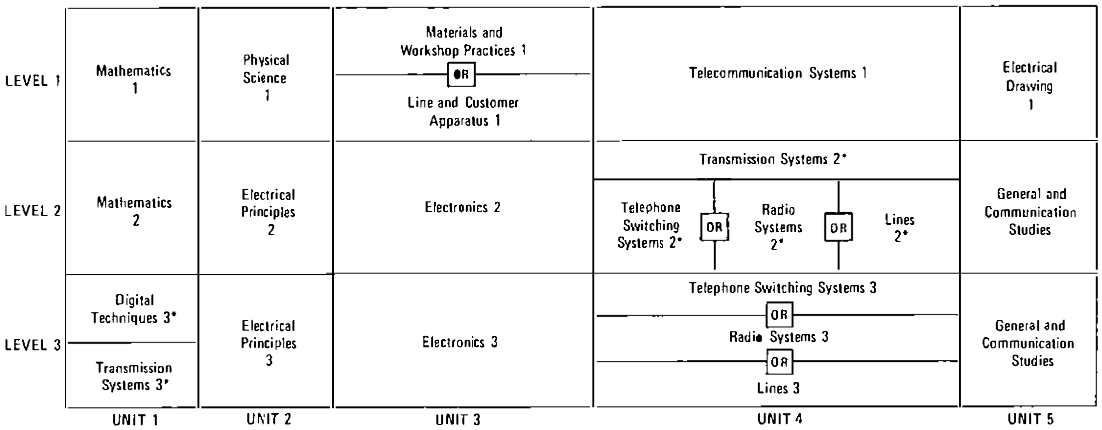
---

† It should be noted that there are many talented and innovative engineers who work in a professional capacity but do not possess the formal qualifications required to achieve chartered status



CEI 1, CEI 2: Parts 1 and 2 of the Council of Engineering Institutions' examinations
HND: Higher National Diploma
HNC: Higher National Certificate
ONC: Ordinary National Certificate

FIG. 2—Approximate relationship to technician hierarchy of CGLI and National Certificate schemes



LEVEL 1	Mathematics 1	Physical Science 1	Materials and Workshop Practices 1 OR Line and Customer Apparatus 1	Telecommunication Systems 1	Electrical Drawing 1
LEVEL 2	Mathematics 2	Electrical Principles 2	Electronics 2	Transmission Systems 2* Telephone Switching Systems 2* OR Radio Systems 2* OR Lines 2*	General and Communication Studies
LEVEL 3	Digital Techniques 3* Transmission Systems 3*	Electrical Principles 3	Electronics 3	Telephone Switching Systems 3 OR Radio Systems 3 OR Lines 3	General and Communication Studies
	UNIT 1	UNIT 2	UNIT 3	UNIT 4	UNIT 5

* Half-unit subjects

FIG. 3—Specimen TEC Certificate Programme in Telecommunications

requirement certain mechanical-engineering studies, in which a part-time preparatory course in electronics engineering may be deficient.

CERTIFICATE PROGRAMME IN TELECOMMUNICATIONS

For the Certificate Programme in Telecommunications, standard units have been designed, again in the form of minutely-detailed objectives, and the BPO has played a significant part in determining their content. For BPO students, it is expected that the standard units will be adopted in full.

The programme provides for 2 specialisms: radio systems and switching systems. There is a third variant, intended mainly for adult technicians, containing a line-plant specialism. The 3 programmes are illustrated in Fig. 3. Electronics and transmission are subjects common to all programmes; mathematics at level 3 is an optional subject. It is interesting to note that electronics is studied as a separate unit, as opposed to being included in a radio or computer specialism (as is the case with CGLI courses).

HIGHER CERTIFICATE

The 3 levels of study which lead to the award of a TEC Certificate will, for some students, prepare the way for entry to a Higher Certificate programme. In the electrical, electronics and telecommunications fields, the additional study time needed (600 h) will be made up of ten 60 h units: 5 units at each of the 2 additional levels. Other Higher Certificate programmes will involve the same number of additional hours, but the TEC's guidelines permit the introduction of programmes based on 8 units of 75 h each.

There will be fewer students at the higher levels and, in the interest of class size, colleges will be under some obligation to adopt more broadly-based programmes. It is BPO policy to ensure that adequate treatment of appropriate specialisms is provided in programmes which will be, to a very great extent, college-designed. How far this policy is successful will depend to some extent on the number of BPO students. Where specialisms are established to suit the special needs of industry, colleges will reasonably expect some support in the form of source material. The part which the BPO can play in this respect is evident.

NON-TELECOMMUNICATIONS STUDENTS

Colleges are free to replace units or design complete programmes to meet local needs (subject to approval by the TEC). In areas where sufficient numbers exist, the needs of minority groups of BPO staff (for example, postal engineers) will be met by this method. It seems likely, for instance, that postal and power engineering courses will be available in London and Birmingham, and perhaps other large centres.

The needs of mechanical-engineering, drawing-office and motor-transport staff are sufficiently in line with those of industry in general for the syllabi being offered to be acceptable; where necessary, the BPO may be able to assist in the design of these courses to ensure that basic BPO needs are being met. Similarly, the BPO will assist in the design of special units for staff engaged on duties such as quality assurance. Training officers will satisfy themselves that courses taken by laboratory staff, having a need for physics or chemistry specialisms, are suited to the duties on which those staff are engaged.

In areas where colleges do not run specialized courses, special provision could be made for external study.

EXTERNAL STUDENTS

In the TEC's policy statement† of 1974, particular mention was made of the needs of students who, for one reason or another, are unable to attend college for formal tuition. It is TEC policy that these needs be provided for, without undermining the position of colleges. The BPO has long experience, dating back as far as 1907, of providing and tutoring correspondence courses, and many tens of thousands of employees at all levels, relying wholly on this method of study, have undertaken CGLI examinations. Others, particularly in the motor-transport grades, have relied on commercial correspondence schools to provide their only contact with technical education.

The BPO therefore has a very keen interest in the future of a TEC-based external-student scheme. Considerable assistance has already been given in preparing a *learning package* for Telecommunication Systems 1; this package is now being used in the process of validation of self-tuition courses by a substantial number of colleges.

An acknowledged weakness of existing BPO correspondence-course schemes is the lack of student-to-tutor contact; this is only one aspect of package design which is being examined by course-writers, and improvements are likely. Other factors which perhaps contribute to the high drop-out rate are presentation, lack of variety and the sheer volume of reading matter needed to cover the subject. The course-

---

† Technician Education Council: Policy Statement. June 1974

writers have benefited from the advice of an educational technologist; much has been learned from working as a team on the Telecommunication Systems 1 package, and a more forward-looking approach will now be applied to other parts of the programme.

The TEC faces a major task in establishing an adequate study scheme for external students across the broad spectrum of technician education. Largely out of self-interest, the BPO has offered to prepare further learning packages at level 1, and this will ease pressure on the TEC, giving an opportunity for some of the administrative problems to be solved. When the TEC has established an adequate scheme, it will be the BPO's wish to relinquish control of level-1 tuition.

TIME SCALES

Of the colleges that will eventually be involved in TEC telecommunications programmes, more than half started level-1 studies in the autumn of 1977. Over the next few years, colleges will phase out CGLI technician and National Certificate courses. The CGLI itself may continue to offer its examinations for a little longer than some colleges offer its courses, but has issued a timetable of withdrawal of its examinations (see Table 2). BPO correspondence courses will continue to be available for CGLI examinations for the present, and the *POEEJ*'s model-answer service will also continue; the future of the model-answer service is examined in more detail in the Appendix to this article.

TABLE 2

Withdrawal of CGLI Telecommunications Examinations (Course Nos. 270/271)

Course	Last Normal Examination	Last Re-sit Examination
T1	1978	1979
T2	1979	1980
T3	1980	1981
T4	1981	1982
T5	1982	1983

Note The General Course in Engineering is also to be phased out in 1978 (last re-sit examination: 1979). This course has been widely used to extend basic secondary education for entry to CGLI or National Certificate courses. For as long as there are students offering it, suitable attainment in the General Course will be accepted as an admission qualification to TEC programmes

SCOTEC

The Scottish *Technical* Education Council (SCOTEC) is introducing in Scotland similar changes to those being made by the TEC in England, Wales and Northern Ireland. The SCOTEC's aims and philosophy are very similar to those of the TEC, but there are differences in its methods of operation.

Colleges and employers have again worked together to devise syllabi, and all SCOTEC programmes are standard. Levels are referred to as *stages*, and units retain their former name: subjects. The numbers of stages in the SCOTEC's Certificate and Higher Certificate programmes are the same as for the TEC's awards, but the examinations at stages 3 and 5 are controlled externally by the SCOTEC.

Fig. 4 shows a specimen Certificate Programme in Telecommunications. A minimum of 14 subjects must be taken for a Certificate award, 4 of which must be at stage 3, and all stage-3 subjects must also have been taken at stage 2. Students wishing to enter the Higher Certificate programme must pass stage-3 mathematics, although this subject is not necessary to qualify for the award of a Certificate. It is very desirable that SCOTEC awards should rank with those of the TEC for promotional opportunities in the BPO, although the situation is not yet clear.

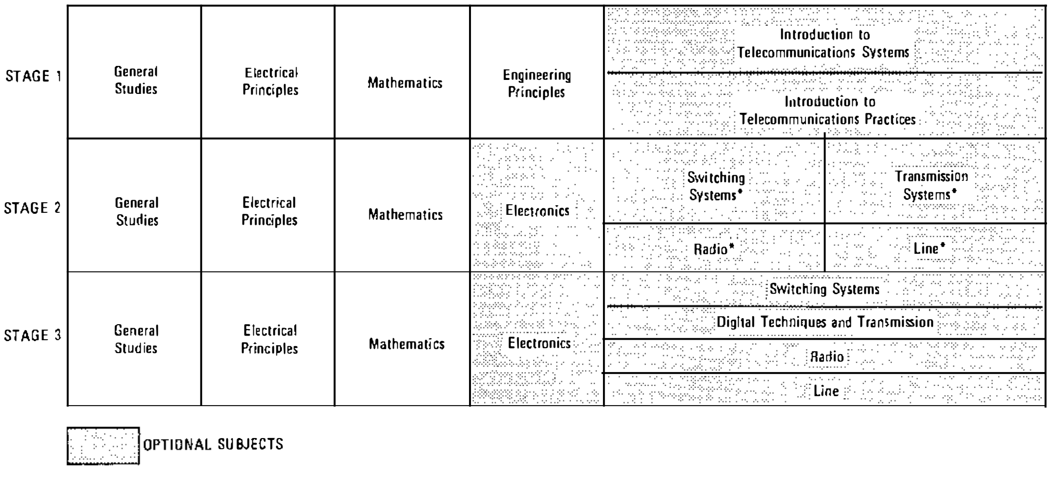
BUSINESS EDUCATION COUNCIL

The Business Education Council (BEC) has similar origins to the TEC, and similar aims, but operates in the fields of business and commerce. There will be cooperation between the TEC and the BEC where necessary but, in general, BPO technicians will not be involved in BEC courses.

CONCLUSION

An old-fashioned misconception of technical-college education is reflected in the epigram concerning the reaction of various types of student to a lecturer entering and saying, "Good morning". In a university, he is ignored; in a polytechnic, the students discuss it; in a technical college, they write it down.

The work of the TEC is the latest and most vigorous effort finally to banish old prejudices. The best features of the CGLI and National Certificate courses are being retained. The aim of every TEC programme is to develop a student's ability to do his own thinking, grasp ideas and communicate effectively, and to encourage personal qualities such as adaptability, curiosity and self-confidence; at the same time,



* Half-value subjects

FIG. 4—Specimen SCOTEC Certificate Programme in Telecommunications

the student will acquire knowledge and skills relevant to his vocation. The discovery and understanding of fundamental principles is as important in technical colleges as it is in universities.

During the transition period, BPO students will be studying National Certificate, CGLI, TEC and SCOTEC courses. All these are relevant to careers in the BPO, and no student need feel at a disadvantage through following a particular course of study. The value of National Certificate and CGLI qualifications is well established, and their recognition assured; after all, holders of these awards will be in the majority for many years to come. Those starting or transferring to TEC courses will be reassured by the efforts of the TEC to ensure widespread recognition of its awards, and by the mainly favourable reception given by industry to the progressive ideas of the TEC. It is possible, of course, that the reality could fall a little short of the ideal, and some deficiencies already apparent in the new schemes (in particular, the divergence of the TEC's and the SCOTEC's policies) are identified in this article. But the inherent flexibility of the schemes, and the continuing efforts of all those involved, will hopefully lead to the effective solution of any problems.

Many people in the BPO have been involved in the setting up of TEC and SCOTEC courses, and the situation will be reviewed continuously as implementation progresses. Front-line in safeguarding the interests of the BPO and its students are the training officers who, because of their involvement and experience in technical education, are in a good position to give advice.

The TEC is very young and its concepts are, to some extent, still developing. The information given in this article is the best available at the time of writing, and relevant changes will be recorded in the *POEEJ* as the TEC's operations evolve; the Telecommunications Personnel Department will circulate information in the BPO as necessary. More detailed information is given in the Appendix to this article on the help the *POEEJ* proposes to give to students following TEC courses, and the *Supplement* to this issue contains some pre-examination guidance for this year's level-1 students. The Appendix also contains some comments on the content of level-1 TEC units, compared with that of subjects in the T1-year of the CGLI course.

A self-disciplined approach to studying is more reliable than the whims of fortune but, nevertheless, the authors would like to wish all students good luck in their studies.

ACKNOWLEDGEMENT

Some of the statements made in this article are based on the many informative pamphlets produced by the TEC. The authors would like to acknowledge this source of information, and thank the staff of the TEC for their help and guidance.

APPENDIX

Service to Students

It was in 1931 that the *POEEJ*'s model-answer *Supplement* first appeared. It contained, in those early years, not only answers to CGLI examinations but also answers to the examinations of the Civil Service Commission. Indeed, the *Journal*'s tradition of giving guidance to examination candidates goes back much further. Model answers to the CGLI's Telegraphy and Honours Telephony examinations were given in the very first volume of the *POEEJ* in 1908.

The Board of Editors proposes to continue this long-standing service, and much thought is being given to how best the *POEEJ* can help students studying TEC and SCOTEC programmes. The TEC's courses introduce a number of novel aspects, and a degree of uncertainty surrounds the eventual form of examinations (which may evolve into the multiple-choice-answer style). The *Journal*'s approach, therefore, should be open to modification and development as implementation of the TEC's ideas proceeds and the corresponding needs of students become clearer.

The point has been made elsewhere in this article that, with examiner-interpreted syllabi, the student must rely heavily on model answers to questions actually set in past examinations to assess the standard expected of him. For TEC courses, however, detailed guidance is available on the topics and their depth of coverage, and the syllabi are effectively college-interpreted by virtue of there being no centrally-set examination.† This implies that model answers can no longer attempt the role of exemplifying the standard expected by the examiner, but rather should seek to reflect the type and standard of question being set. Further, the reduced emphasis placed on terminal examinations by the continuous-assessment concept tends to indicate that there could be other areas besides model answers in which help may be given to students.

The TEC scheme therefore offers some scope for flexibility in the presentation of guidance material for students. The possible spectrum ranges from model answers, through note-form revision packages with objective-style interrogative summaries, to full-blooded encyclopedic résumés of topics. It will be the *Journal*'s task to formulate and develop a presentation that makes the best use of the devices available. To aid progress towards establishing a helpful method of giving guidance to students, the Board of Editors would like to open the *Journal*'s correspondence columns to informed discussion on this subject.

The first TEC examinations in telecommunications will be held in the spring of 1978, and the *POEEJ* therefore expects to begin publishing guidance material in the winter of 1978–79. The *POEEJ* also intends to continue its present service to CGLI students as long as there is sufficient demand to justify doing so. The *Supplement* is likely, therefore, to be shared between the TEC and the CGLI for some years to come and, for the first time, will be catering for students who would perhaps have followed National Certificate courses under the previous schemes.

1977–78 Level-1 Students

Students already embarked on level 1 of TEC programmes cannot, of course, benefit from the proposal to publish guidance material from next winter. To ensure that some degree of help is

TABLE 3

Materials and Workshop Practices 1

1	Health and Safety at Work Act. Workshop hazards. Machine guards. Accident procedures. Dealing with injuries. Mouth-to-mouth resuscitation. Fire procedures
2	Hazards associated with electricity. Safety precautions and safe electrical practices. Dealing with cases of electric shock
3	Properties and uses of various metals, alloys, plastics etc. Solvent, welding, heat-bending and casting techniques for plastics. Hazards associated with adhesives, asbestos etc. Corrosion protection
4	Selection and use of hand tools and powered hand tools. Care of tools. Micrometers, Vernier principle and dial gauges. Marking out
5	Drilling machines, reamers, clamping and blind holes. Punch and die, cutters etc. Drilling in sheet metal and plastics
6	Use of guillotine, bending machine etc. in sheet-metal operations. Bending allowances. Working to diagrams
7	Components of machine tools. Cutting fluids and coolants. Effects of operating speeds. Milling and shaping machines. Use of centre-lathe. Grinding machines. Cutting angles
8	Screws, bolts, nuts and washers. Threads. Locking devices. Riveting. Adhesives
9	Electrical connexions using soldering, crimping and wrapping techniques. Plugs and sockets

---

† In some areas, groups of colleges may collaborate to compile *question banks*, from which they will extract examination material. To that extent, TEC examinations could be regarded as having an element of centralization

TABLE 4

Electrical Drawing 1

1	First and third-angle orthographic projection
2	Isometric and oblique pictorial projection
3	Hidden detail. Sectional views. Auxiliary views
4	Exploded and cut-away views
5	Dimensioning
6	British Standard symbols
7	Circuit diagrams
8	Design considerations

available to those students before the 1978 examinations, a section of the *Supplement* to this issue of the *POEEJ* is devoted to revision guidance for Physical Science I, Mathematics I and Telecommunication Systems I. This guidance takes the form of details of the topics covered in each of these units, together with references to previously-published answers to CGLI examination questions that most closely match the TEC syllabi. (Similar guidance for Line and Customer Apparatus I will be published in the April 1978 *Supplement*. Details of the topics covered in the Materials and Workshop Practices I and Electrical Drawing I units are given in Tables 3 and 4; there is no, or considerably less, coverage of these 2 subjects in recent issues of the *Supplement*, so that useful collections of references are not possible.)

Comparison of First-Year TEC and CGLI Subjects

For the T1-year of the CGLI course, the *POEEJ* publishes model answers to Engineering Science, Practical Mathematics and Elementary Telecommunication Practice (ETP).

Comparing the syllabi of Physical Science I and Engineering Science reveals a great similarity of coverage, although waves and sound are introduced in the former. The depth of treatment of some topics in Physical Science I is slightly less than in Engineering Science. Mathematics I is very similar to Practical Mathematics, although elementary statistics is a new topic here.

Telecommunication Systems I is entirely new. Much more emphasis is placed on establishing principles, and the approach is very much on a systems basis. This means that the unit covers a good deal of material previously found in Telephony and Telegraphy A and Radio and Line Transmission A (two of the subjects covered by the *POEEJ* at the T2-year of the CGLI course), as well as material from ETP. The detailed study of apparatus, which is a feature of ETP, is omitted, and this may throw more responsibility on employers to cover the work in on-the-job and off-the-job training.

The similarities described above enable model answers in past issues of the *Supplement* to be used to supply practice material for TEC students, and this feature has been exploited in the revision guides given in the *Supplement* to this issue.

Datel Modem No. 13A: A Simplified Modem for the Datel 200 Service

A. R. PUGH, B.SC.(ENG.), M.TECH., C.ENG., M.I.E.E., and B. M. GNANAPRAGASAM, M.SC.†

UDC 621.394.4:621.376.3:681.327.8

This article describes the Datel Modem No. 13A, which has been developed as a simplified, restricted-facility modem for operation at up to 300 bit/s on the Datel 200 service. An outline of the function of the modem is given, followed by a simplified description of its operation.

INTRODUCTION

Until recently, the only modem used to provide the Datel 200 service was the Datel Modem No. 2[1]. This modem provides all the interchange circuits recommended by CCITT* Recommendation V21. Market research by the British Post Office (BPO) Marketing Department showed that, for the simple dataprinter type of data terminal equipments, the number of interchange circuits provided was excessive. It was decided, therefore, that a new modem should be developed, specifically designed for operation with this type of data terminal equipment, with the emphasis on producing a low-cost modem.

BASIC REQUIREMENTS

The market research showed that most simple data terminal equipments could operate with a modem that provided only 4 interchange circuits. These circuits are detailed in Table 1. The channel-switching facility provided by the Datel Modem No. 2 was not included because most calls from this type of data terminal equipment are to computer bureaux or similar types of installation. The new modem, the Datel Modem No. 13A, was therefore required to transmit on the lower-frequency channel and to receive on the upper-frequency channel.

TABLE 1

Interchange Circuits Required

CCITT Circuit Number	Circuit Title
102	Common return
103	Transmitted data
104	Received data
109	Data channel received line signal detector

---

† Telecommunications Development Department, Telecommunications Headquarters

* CCITT: International Telegraph and Telephone Consultative Committee

FIG. 1—Datel Modem No. 13A fitted under a telephone instrument

The definitions and the method of use of the 2 frequency channels are contained in a previous article in this *Journal*[1]. The functions and electrical characteristics of the interchange circuits detailed in Table 1 have also been described previously.[2]

A further simplification was also possible by connecting the modem to line directly via key contacts on the associated telephone, instead of using a pair of contacts to operate a relay in the modem.

The considerable reduction in the number of interchange circuits reduced the overall power requirements, and powering the modem from the local telephone exchange became a possibility. Investigations showed that, if the power consumption was limited to a maximum of 435 mW, it would be possible to power the modem over the line on 90% of exchange lines in the UK. This limit on the power consumption ensured that the correct signalling conditions were maintained when the exchange battery voltage was on its minimum limit and the line resistance was on its maximum limit. In addition, a power consumption of this order enabled the modem to be constructed from relatively inexpensive components, thus maintaining the aim of producing a low-cost modem.

Where line-powering is not possible, a small external power unit will be used, the Power Unit No. 53A being a suitable item.

In view of the simplification outlined above, it was possible to reduce significantly the overall size of the modem compared with the Datel Modem No. 2; hence, it was decided that the modem should be suitable for direct attachment to the associated telephone, thereby giving a more compact installation. Therefore, the Datel Modem No. 13A was specified to be constructed in a moulding suitable for mounting directly under the telephone instrument, the appearance of the moulding being similar to that of the Plan Set N625, but with the overall height increased by approximately 10 mm, see Fig. 1.

With the recent advances in technology, simple data-printer types of data terminal equipments are now being

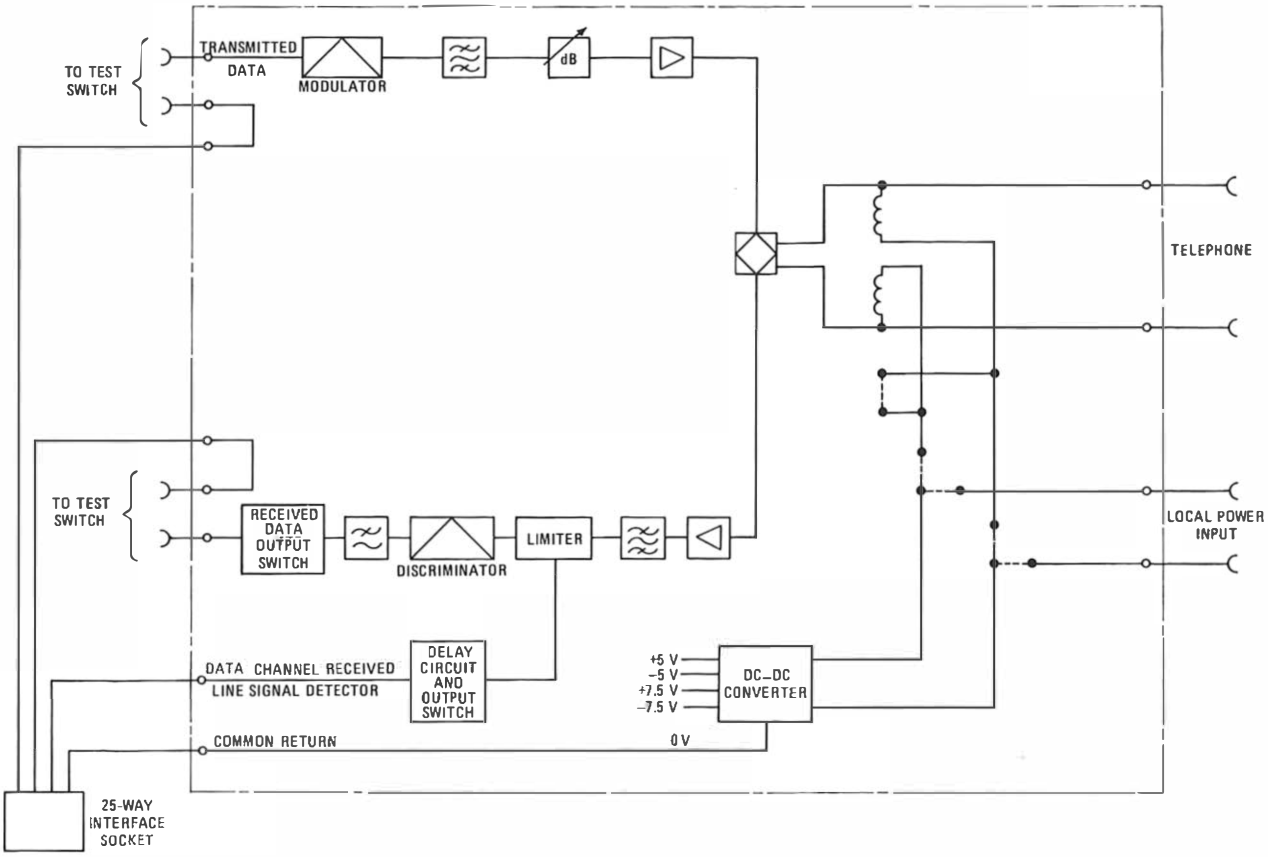


FIG. 2—Block diagram of Datel Modem No. 13A

designed to operate at up to 300 bit/s instead of 200 bit/s. The Datel Modem No. 13A was therefore specified to operate at up to 300 bit/s, thus allowing it to interwork with the Datel Modem No. 2 and also with the current development of the replacement modem for the Datel Modem No. 2, which has been specified to operate at 300 bit/s. The introduction of the Datel Modem No. 13A and this new modem will enable the BPO eventually to offer a guaranteed 300 bit/s service.

EQUIPMENT DEVELOPMENT

The design and development of the Datel Modem No. 13A was undertaken as a private venture by GEC Telecommunications Ltd. and, in April 1974, the GEC was awarded a production contract for 5000 units. The modem was officially introduced into service in September 1975.

SIMPLIFIED DESCRIPTION OF OPERATION

A block diagram of the modem is shown in Fig. 2. The 2 characteristic frequencies are derived from an inductance-capacitance oscillator by switching the number of turns on the inductor, under the control of the binary condition applied to the transmitted-data interchange circuit. The output of this modulator is fed via a band-pass filter and attenuator to the output amplifier. The attenuator enables the output level of the line signal to be adjusted over the range −1 dBm to −13 dBm† in 4 dB steps. The line signal is then fed to line through a line transformer.

The received line signal is passed through the line transformer to an input amplifier. The output of this amplifier is fed to the discriminator through a band-pass filter and 2-stage limiter. The discriminator[3] consists basically of an EXCLUSIVE-OR gate and a series tuned circuit. This is tuned such that, at the mid-band frequency, the phase lag is 90°; at the lower line frequency, the phase lag is less than 90° and, at the higher line frequency, the lag is greater than 90°. The output of the limiter and phase-separated output of the tuned circuit are fed to the inputs of the EXCLUSIVE-OR gate, the output of which is a square wave for mid-band frequency. At the lower line frequency, the output has an increased mark-to-space ratio and, at the higher line frequency, a decreased mark-to-space ratio. The output of the discriminator is fed into a post-discriminator filter and then to an output switch.

The output of the first stage of the limiter is also taken to the data channel received line signal detector circuit, which contains a delay circuit and output switch. The delay circuit ensures that the modem does not respond to short line breaks, nor to spurious pulses on the line. The output switch is provided to give nominally rectangular pulses to the data terminal equipment.

When the level of the received line signal is −43 dBm or higher, the output of the data channel received line signal detector circuit is at nominally +6 V. When the received line signal level is below −48 dBm, the output is nominally −6 V. In the latter condition, the received data circuit is clamped to binary state 1.

The power-supply rails are fed from a DC–DC converter, which is used for both the line and externally-powered modes. When operating in the line-powered mode, the modem presents an effective holding resistance of less than 650 Ω. This enables the modem to be line powered from exchange lines where the DC loop resistance is up to 650 Ω, assuming worst-case tolerances on exchange battery voltage and resistance. In the externally-powered mode, the maximum DC holding resistance is 150 Ω, thus enabling the modem to operate in this mode over lines of up to 1000 Ω loop resistance.

The connexions to the data terminal equipments are made using a standard 25-way socket. In this case, however, the socket is fitted to a 4-way cord, instead of the normal practice of directly terminating the cord on the modem. The cord is terminated in the modem using screw terminals.

REMOTE TESTING

In common with other BPO modems, remote-testing facilities are provided for the Datel Modem No. 13A. This is done by feeding the transmitted data and received data circuits via REMOTE TEST key contacts on the telephone. When a remote test is performed, the interface plug is removed from the 25-way socket and the REMOTE-TEST key is operated; this loops the transmitted data to the received data circuit.

ACKNOWLEDGEMENT

The authors wish to thank GEC Telecommunications Ltd. for their permission to publish Fig. 1 and the circuit description.

References

[1] SPANTON, J. C., and CONNELLAN, P. L. B. Modems for the Datel 200 Service. *POEEJ*, Vol. 62, p. 1, Apr. 1969.

[2] PUGH, A. R. The Latest Modem for the Datel 600 Service—Datel Modem No. 1F. *POEEJ*, Vol. 67, p. 95, July 1974.

[3] British Patent No. 1377362.

---

† dBm: decibels relative to 1 mW

POEEJ: SPECIAL ISSUES AND BACK NUMBERS

Copies of the April 1974 issue covering sector switching centres, and the October 1973 special issue on the 60 MHz transmission system, are still available.

Back numbers can be purchased, price 80p each (including postage and packaging), for all issues from April 1973 to date. Copies of the July and October 1970, and the April 1972, issues are also still available.

The July 1970 issue contains articles on the Post Office Technical Training College, transmission measurements in the switched telephone network, a transmission simulator for testing data-transmission systems, and a general survey of postal engineering. The October 1970 issue contains articles on gas turbines, monitoring the speed of engine-generator sets, control and supervisory systems for microwave radio-relay links, packets and parcels in postal engineering, and an anti-jamming device for conveyor-belt systems. The April 1972 issue contains articles on the Goonhilly aerials, the Leighton Buzzard TXE1/TXE2/TXE6 exchange, and humans in postal engineering.

Orders, by post only, should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2–12 Gresham Street, London EC2V 7AG. Cheques and postal orders, payable to "*The POEE Journal*", should be crossed "& Co." and enclosed with the order. Cash should not be sent through the post. A self-addressed label, accompanying the order, is helpful.

OCTOBER 1975 ISSUE

The editors would very much appreciate the return of spare and unwanted copies of the October 1975 issue of the *POEEJ* (Vol. 68, Part 3). Surplus copies, complete with the model-answer *Supplement*, should be returned to Mr. Hunwicks, Ground Floor Lobby, 2–12 Gresham Street, London EC2V 7AG.

A Computer System for the Routing and Design of Transmission Circuits in the London Junction Network

D. J. FRENCH, B.SC.[†]

UDC 681.31:621.315

This article describes aspects of the computer system recently introduced in the London Telecommunications Region to route and design speech-band transmission circuits. The routing and design techniques are outlined, and the principal results of the evaluation of the system are presented.

INTRODUCTION

It was recognized as long ago as 1966[1] that a computer could be programmed to determine the routing and engineering design requirements of audio circuits routed on telecommunication networks. Since then, computers have been used in the fields of circuit-provision record keeping and junction cable planning[2]. However, the availability of more-sophisticated computers has enabled the work to be advanced to find the cheapest circuit routing, consistent with the maintenance of required transmission performance standards.

Determination of the most economic routing for any circuit on the London junction network was a major problem because the network is so complex that it is commonplace for several-thousand different paths to exist between 2 stations. The computer system now in use supplies the basic data for the provision of all new junction, private and telegraph circuits on the London junction network. Using iterative matrix procedures, the computer first identifies a number of routes between specified terminal stations in order of length and then evaluates the availability, cost and transmission performance of the line plant on the selected routes (including the location of amplifiers if required). Finally, a skeletal circuit order form (Form A886) is produced that indicates the line plant and audio equipment to be used on the circuit routing chosen.

An extensive computer processing operation is required to analyse the alternative circuit routes on a network as complex as the London junction network, and it is being undertaken on an IBM 370/168 computer operated by the British Post Office Data Processing Service at the Harmondsworth computer centre.

SELECTION OF CONNEXION PATHS

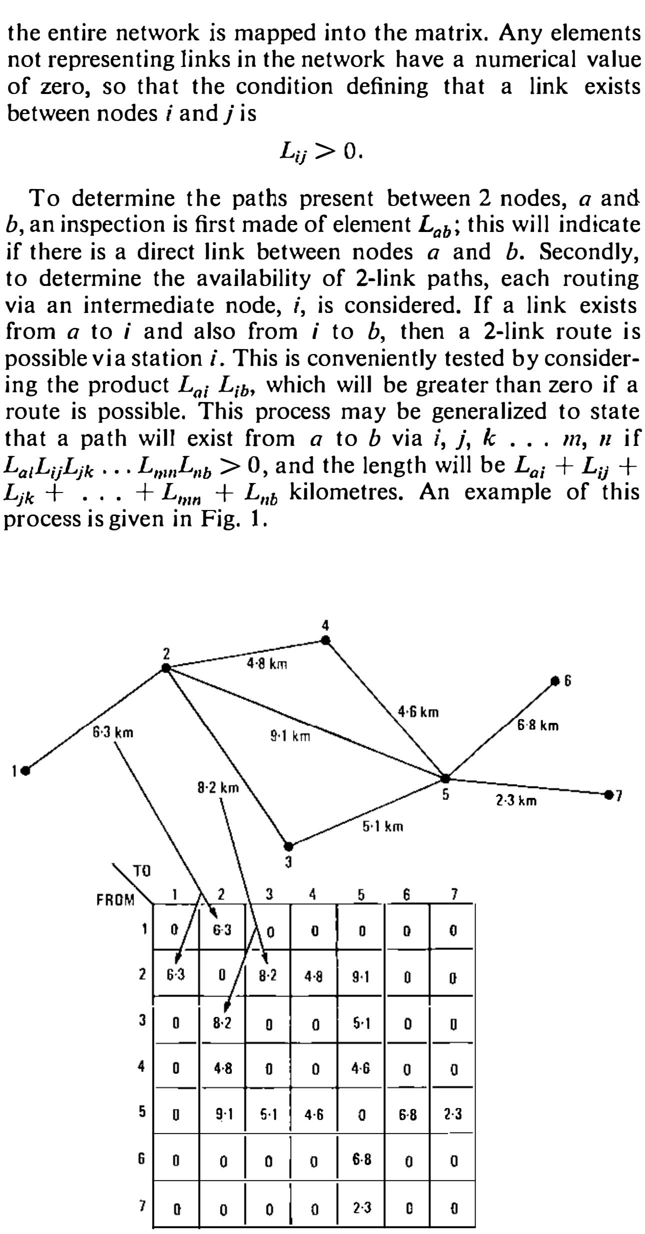
Basic Technique

There are several techniques within the scope of linear programming for the determination of the shortest path through a network but, in general, only one ideal solution is readily available, and to use such a method to find a series of best paths is an unwieldy operation. Therefore, the use of iterative methods was investigated and eventually adopted.

The first stage of the routing process involves an analysis of the network to assign a number to each terminal station node and to record the length (km) of each interconnexion link. Next, a 2-dimensional matrix (L) is constructed with N rows and N columns, where N is the number of nodes within the network. The matrix is used to describe the network by considering a link between 2 stations, say i and j, and the length of the link. The length of a link is inserted at the intersection of row i and column j. Proceeding in this fashion, the entire network is mapped into the matrix. Any elements not representing links in the network have a numerical value of zero, so that the condition defining that a link exists between nodes i and j is

$$L_{ij} > 0.$$

To determine the paths present between 2 nodes, a and b, an inspection is first made of element L_{ab}; this will indicate if there is a direct link between nodes a and b. Secondly, to determine the availability of 2-link paths, each routing via an intermediate node, i, is considered. If a link exists from a to i and also from i to b, then a 2-link route is possible via station i. This is conveniently tested by considering the product $L_{ai}\,L_{ib}$, which will be greater than zero if a route is possible. This process may be generalized to state that a path will exist from a to b via $i, j, k\ \ldots\ m, n$ if $L_{ai}L_{ij}L_{jk}\ldots L_{mn}L_{nb} > 0$, and the length will be $L_{ai} + L_{ij} + L_{jk} + \ldots + L_{mn} + L_{nb}$ kilometres. An example of this process is given in Fig. 1.



FROM \ TO	1	2	3	4	5	6	7
1	0	6·3	0	0	0	0	0
2	6·3	0	8·2	4·8	9·1	0	0
3	0	8·2	0	0	5·1	0	0
4	0	4·8	0	0	4·6	0	0
5	0	9·1	5·1	4·6	0	6·8	2·3
6	0	0	0	0	6·8	0	0
7	0	0	0	0	2·3	0	0

TO ROUTE FROM NODE 2 TO NODE 7

(*a*) Direct link possible if $L_{27} > 0$; no route is possible in this case
(*b*) Two-link route possible if $L_{2i}L_{i7} > 0$; true for $i = 5$. Therefore, one route is possible (2–5–7), length $= L_{25} + L_{57} = 9{\cdot}1 + 2{\cdot}3 = 11{\cdot}4$ km
(*c*) Three-link route possible if $L_{2i}L_{ij}L_{j7} > 0$; true for $i = 4$, $j = 5$ and $i = 3$, $j = 5$. Therefore, 2 routes are possible, (2–4–5–7) and (2–3–5–7), lengths are 11·7 km and 15·6 km respectively

FIG. 1—Example of using a matrix to determine routes

[†] Works Division, London Telecommunications Region

By permutating the possible combinations of intermediate stations, all the routes between specified terminals can be determined, and the lengths of the paths and the identities of the stations involved are stored. The routes are then sorted in order of length in readiness for more detailed examination.

Node Reduction

A significant feature affecting the size of the computing problem is the number of individual tests required to determine all the possible routings. It was decided that the system would need to identify routes of up to 4 links in tandem (that is, routed via 3 intermediate stations). For the London network, to account for all the permutations of 4-link routings would have required some 600^3 operations ($2 \cdot 16 \times 10^8$). This number of operations is too large for cost-effective implementation on present-day computers. Therefore, methods were considered for limiting the number of stations that would be used to determine a given routing path. It was necessary to ensure that the method of selection did not significantly degrade the efficiency of the routing process.

The method adopted was based on a particular property of an ellipse. If P is a point anywhere on the circumference of an ellipse, and points A and B are the foci of the ellipse (see Fig. 2), then the sum of the lengths AP and BP is a constant; thus,

$$\overline{AP} + \overline{PB} = k\,\overline{AB}, \text{ where } k \text{ is a constant.}$$

This property of an ellipse can be used when determining the best routes between 2 nodes, say A and B, for if an ellipse is drawn with nodes A and B as the foci, then any 2-link route via an intermediate station contained within the ellipse will be shorter than a route passing outside the circumference. Therefore, all the stations situated within the ellipse form the most effective part of the network for routing between nodes A and B.

The size of the ellipse drawn around the terminal stations at the foci can be varied to include a specified number of stations. The first step in sizing the ellipse is to consider the density of nodes in the area under consideration. To select M stations where the density of nodes is D nodes/km^2, then the area of the ellipse will be M/D km^2. Given the required area of the ellipse and the co-ordinates of the foci, the geometry of the ellipse can be explicitly determined, and the various stations within the ellipse can be listed. Unfortunately, the density of stations is far from uniform, and the number of nodes within the ellipse may be below that required to establish confidence in the result. However, it is possible to re-estimate the density of stations, based on the area of the ellipse constructed and the resultant number of nodes found within the ellipse. This revised estimate of density can then be used in a repeat performance of the procedure. Eventually, given sufficient iterations of the process, the required number of nodes is found within the ellipse. For the London junction network, it has been found that 70 stations selected from the total of 600 is adequate to determine efficient routing, so that the number of tests required to determine the 4-link routes is reduced from $2 \cdot 16 \times 10^8$ to a more realistic value of $3 \cdot 43 \times 10^5$. A simplified flowchart of the ellipse construction process is given in Fig. 3.

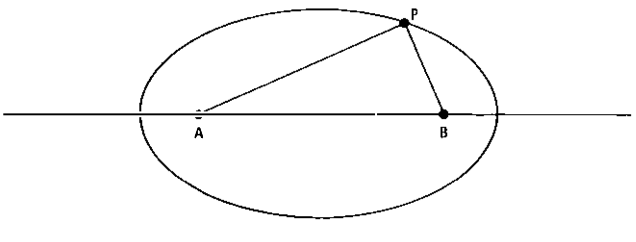


FIG. 2—Ellipse geometry

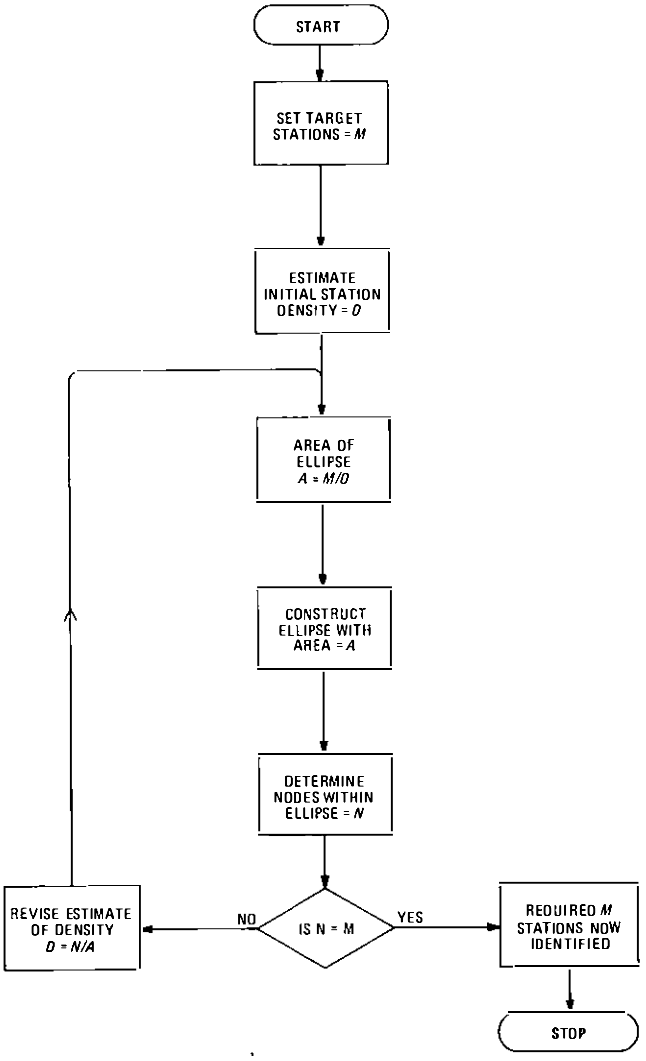


FIG. 3—Flowchart of ellipse construction process

NETWORK DATA FILES

Line Plant File

The line plant connecting 2 stations in the network is referred to as a *link*, and each link is given a unique reference number. A link may consist of one or more audio cables or other transmission media, and each distinguishable subset is known as an *arc*; each arc is allocated a reference number unique to a link. Any individual cable pair or channel in the network may be defined solely in terms of link and arc reference numbers and the physical pair or channel number.

The computer file contains a record of every arc in the network. There are some 13 000 arcs spread over 6600 links, including arcs that are awaiting completion. Each arc is divided into 2 parts: the first contains fixed parameters describing the physical and electrical characteristics of the arc, such as insertion loss, resistance, cable title and terminal stations; the second part contains information detailing the available spare pairs or channels.

In the case of audio-cable arcs, the number of spare cable pairs available could be as high as 1040; to retain the facility to process this number of possibilities would be wasteful of computer storage. Inspection of the network showed that approximately 80% of the audio cable arcs contained fewer than 15 spare pairs; thus, a method of storage of spare-pair numbers was evolved, devised around a stack principle where an ordered list of up to 15 spare-pair numbers is maintained for each arc. The allocation of cable pairs for new circuits causes the deletion of stored cable-pair numbers from the stack until a certain level is reached, when action is requested to replenish the limited store by manual inspection of the cable records.

Station Data File

The file describing the nodes forming the network is known as the *station file*. This file contains a record for every repeater station, telephone exchange and trunk unit in London and its environs. Each node record contains a number of data elements including the name of the station, its national grid reference and the availability of items of audio transmission equipment such as amplifiers. The grid reference information is required in the construction of the ellipse used in the node-reduction part of the routing process. The record of audio equipment availability is necessary to ensure that, if required by circuit design considerations, audio equipment will be specified only at stations where spare capacity is known to exist. When spare equipment is allocated for service, the station-file record of equipment availability is decreased accordingly.

CIRCUIT ENGINEERING

It has been explained that the routing process provides a list of the paths available to interconnect terminal stations sorted in order of length. An assessment must then be made of the ability of each circuit path to meet the performance standards required. The primary engineering performance requirements relate to insertion loss at 800 Hz, 1600 Hz and 3000 Hz, the resistance of the circuit path, and the suitability of conductor loading if the circuit is amplified.

The circuit design facility operates by selecting each path found by the routing process in turn, commencing with the shortest, and attempts to design each path in detail. There are several self-contained circuit-design sub systems that are used to determine the transmission performance of the circuit, locating suitable amplifying equipment if required. An outline of how the routing and design sub systems are co-ordinated is given in Fig. 4. The selected design components are costed using the prevailing annual charges for plant and equipment, and the costs are stored with the path details. The next path is then designed and costed. Proceeding in this fashion, further paths are processed until it is established that the costs of the designs are increasing to the extent that longer paths are unlikely to yield cheaper designs. The best path so far considered is then extracted and a circuit-order form is produced describing the line plant to be used and indicating the location of any audio transmission equipment required. An example of a circuit-order form produced by computer is given in Fig. 5. Finally, the main plant and station files are updated to reflect the use of plant and equipment on the circuit.

The detailed design of a circuit path is attempted in 3 fundamentally different ways, and the most suitable result, in terms of cost, is selected. A summary follows of the processes in the 3 methods.

Unamplified 2-Wire Circuit Design

In the simplest case, the circuit request may be met by designing a 2-wire circuit without any amplifying facilities, and this is the first design method attempted.

The first requirement is to assemble in the computer store all of the data for each arc on the various links forming the route under consideration. At this stage, any arcs with no spare pairs or channels available are rejected; any arcs with special usage restrictions are also eliminated, until the final assembly of arcs contains only useful arcs.

An iterative process is then started to select a permutation of one arc from each link on the path. The details of the selected arcs are extracted and assembled to represent a route between the terminal stations. The line losses and resistances of each arc are summed to assess the overall loss and resistance for the circuit. The results can then be tested against the permitted maxima and, if any limit is exceeded, this permutation is rejected and a new one considered. If the parameters are acceptable, the details are stored and the next permutation considered.

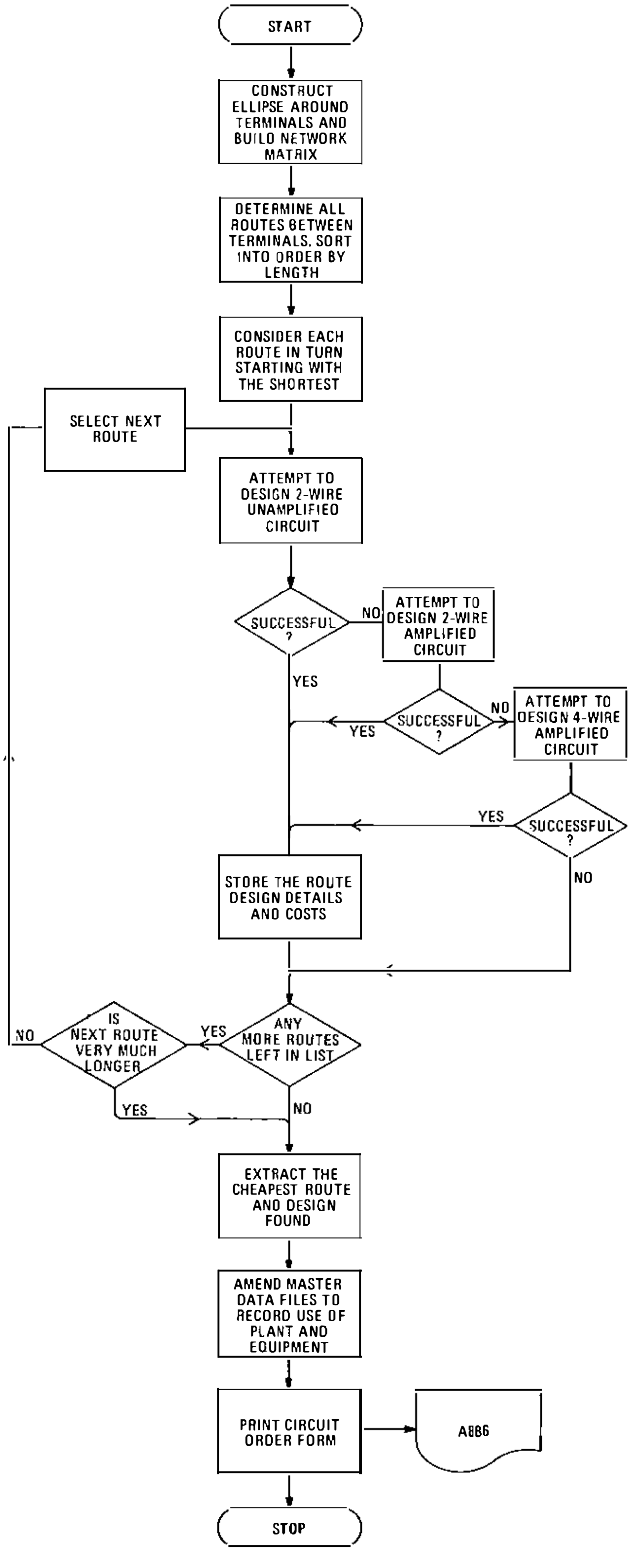


FIG. 4—Flowchart of complete computer process

When all possible permutations have been evaluated, the selected routes are compared. The most economical design that meets the transmission standards, making best use of

```
---------------------------------------------------------------------------------------------------
LTR886A                                 DRAFT                                            LTR886A
                             JUNCTION CIRCUIT ORDER FORM
                                                                         TASK 0287 IN RUN 1387
TARIFF/EPS. S3                                                                         USER 1500

MAX LOSS AT  800 HZ. =  3·0                                             SERIAL NO. CY/C 25478
MAX RESISTANCE     =  N/A                                            ------------------------
MAX LOSS/FREQ SPREAD =  3·0
                                                                         CIRCUIT    1 OF  1
---------------------------------------------------------------------------------------------------
 EQUIPMENT  : STATIONS :   CABLE   :      CABLE/SYSTEM       : CONDTR : KMS  : LINE : LINE
LOCAL : CODE :          :   PAIRS   :          CODE           :  DETS  :      : LOSS :  RES
-------:------:----------:-----------:-------------------------:--------:------:------:------
       :      :          :           :                         :        :      :      :
       :  T   :   RNTR   :           :                         :        :      :      :
       :      : L/NAT    :           :         4W LOCALS #     :        :      : 0·4  :    0
       :      : L/SE     : 1013 1014 : L/SE-L/NAT  NO 7        : 0·63U  : 1·8  : 1·7  :  196
       :      : L/3F     :           :         4W  TIES #      :        :      : 0·1  :   75
       :  AA  : BNJ      :         7 : BNJ-L/3F            950 :   HF   : 30·4 : 0·0  :    0
       :  T   :   RNTR   :           :         4W  LOCALS #    :        :      : 4·7  :    0
       :      :          :           :                         :        :      :      :
-------:------:----------:-----------:-------------------------:--------:------:------:------
                                                                        : 32·2 : 6·9  :  271
                                                                        :------:------:------

ALLOCATIONS
--------------:

LINK    ARC     CJ.       AREA    PAIR/CHS.

1282      2    CJ1215      CY     1013 / 1014     QUAD
5075    404                CY           7         CHAN
---------------------------------------------------------------------------------------------------
```

Fig. 5—Sample circuit-order form

lower-grade plant, is selected. A margin is incorporated in this procedure to prevent unnecessarily close approach to the maximum permitted loss, as it is occasionally found that measured losses of circuits exceed the theoretically predicted levels.

Finally, the selected arcs are costed using annual-charge tables stored within the system. If no successful design has been found, it is necessary to proceed to the next design method.

Amplified 2-Wire Circuit Design

This design facility tests the feasibility of using one amplifier only, either of the negative-impedance or hybrid type for use on a 2-wire circuit. As these amplifiers are not at present considered suitable for use on all types of private circuit this design method is confined to circuits being provided for the public switched telephone network.

As with the unamplified circuit-design arrangements, the arc data for the path are assembled and a permutation process initiated to select one arc from each link. The arcs selected are carefully checked for construction detail as only certain types of correctly-loaded cables can be used. An acceptable permutation will contain conductors with a loading of 88 mH spaced at 1·829 km.

The next process considers the possible locations for an amplifier. Each station is inspected until one with available amplifiers is found. The circuit lengths on each side of the amplifier are calculated and tested against a built-in table of maximum lengths. Restricting the cable lengths ensures that the circuit operates to the correct overall transmission loss without causing the limits for crosstalk on junction cables to be exceeded.

Amplified 4-Wire Circuit Design

This design method is primarily used to improve the transmission performance of private circuits. A permutation process similar to that for the 2-wire amplified design selects one arc from each link but, because the transmission path is 4-wire, a further test is required to ensure that a spare quad exists on each arc. If the arcs are acceptable, each station is considered as a possible site for a 4-wire amplifier. A wide range of tests, including assessment of circuit loss, resistance, insertion-loss/frequency distortion equalization and impedance matching requirements, are carried out to ensure that the various components of the circuit can meet the specified engineering criteria. The overall design is accepted and costed if the engineering tests are successful, and if spare 4-wire equipment is available at the station. Other possible design combinations are considered and similarly evaluated and the most economic design is ultimately selected.

EVALUATION

The initial 6 months of operation of the computer system was regarded as its trial, and all aspects of the system were closely monitored to assess engineering performance and financial viability. It was not practicable to run the computer system entirely in parallel with the existing manual procedures, as is the usual first step in implementation of a major computer system. Instead, a random sample of work passing through the system was extracted and reprocessed manually. The results obtained for the computer sample and by manual effort were then compared; particular attention was paid to the quantities of plant and equipment used.

A random sample was taken of circuits routed over the 5 years preceding the computer trial so that historical control results would be available. The principal results of the samples are given in Tables 1 and 2.

It was found that circuits routed by the computer were approximately 8% shorter than the corresponding results produced manually. There was, however, an increase in the number of pairs used on routings compiled by the computer,

TABLE 1

Plant Used for Public Traffic Circuits

	Historical Sample		Computer-Trial Evaluation		
	1971–1975	1975	Manual	Computer	Difference (%)
Mean Circuit Length (km)	11·60	14·88	10·30	9·55	7·26
Mean Pairs used per Circuit	1·64	1·68	2·09	2·14	−2·60

TABLE 2

Plant Used for Private Circuits

	Historical Sample		Computer-Trial Evaluation		
	1971–1975	1975	Manual	Computer	Difference (%)
Mean Circuit Length (km)	11·02	12·37	10·38	9·53	8·25
Mean Pairs used per Circuit	2·15	2·24	2·03	2·13	−5·00

by as much as 5%. As the cost of installing new junction cables is primarily a function of the length of the cable, the small increase in rate of use of pairs is not significant. However, it is an indication of the tendency to use less plant where a network comprises a large number of fairly short connexions, despite the attendant increase in the number of pairs used.

In London, the number of new circuits to be routed by the computer system in a year is expected to exceed 40 000. With a saving of approximately 8%, this would give an overall annual saving of 32 000 km of audio cable pairs to the credit of the computer system. The capital cost of providing this quantity of plant would exceed £1M.

CONCLUSIONS

This article has outlined the techniques of routing and design of junction circuits by computer. The system has been operating successfully in London since 1975.

As the computer system has control of the use of the complex network of cables in London, it is essential that the system should be interrelated with the future planning of the network. To achieve this, the circuit routing system is designed to take data from the junction-cable-planning computer aids (known as *CJP2*) and, in turn, provide a feedback to the planning engineers of any problems found in following their specifications. Development is in hand to integrate further the planning and utilization computer systems.

References

[1] Cross, B. Using a Computer for Main-Line Planning and Circuit Provision. *POEEJ*, Vol. 58, p. 272, Jan. 1966.

[2] Cross, B. The Long Lines Computer Project. *POEEJ*, Vol. 63, p. 24, Apr. 1970.

Book Review

Principles of Digital Data Transmission. A. P. Clark, M.A., PH.D., D.I.C., C.ENG., M.I.E.R.E. Pentech Press. 256 pp. 80 ills. Cloth: £7·50; paperback: £4·25.

The first part of this book is an excellent qualitative review of the problems involved in digital-data transmission. It is refreshing to find a text which goes to such length to establish the scope of the subject before plunging into detailed theory.

The second part of the book concentrates on a theoretical analysis of the fundamentals of various types of signal used for digital-data transmission. Baseband and modulated-carrier signals are examined in some detail. Particular attention is paid to partial-response-coding techniques for baseband signals—techniques which are now popular for shaping the line spectrum of modulated-carrier signals. The theory of match-filter detection is also covered.

This book is intended for private study by students and practising engineers. The second part of the book assumes a basic understanding of Fourier transforms and modern probability and sampling theory as applied to signal processing.

The book should be of interest to those seeking an understanding of the principles of modern digital-data transmission theory, and the extensive list of references included should prove invaluable to those wishing to pursue the subject further.

D. G. H.

Programming and Microprogramming of Microprocessors

R. H. BENTON, M.SC., C.ENG., M.I.E.E., R. A. COWAN, M.A., M.SC.,
K. J. MAYNARD, B.SC.(ENG.), M.SC., A.C.G.I., C.ENG., M.I.E.E., and R. T. SCARFE, B.SC.†

UDC 681.31.181

A brief account is given of programming methods for use with microprocessors. The article begins with a description of fundamental hardware considerations, and progresses to programming in binary code, assembly language and high-level languages. A brief account of microprogramming is included, together with an introduction to software and hardware programming aids.

INTRODUCTION

The first article in this series[1] discussed the economic advantages of implementing various logic functions by using programmable logic. The meaning of programmable logic was widely interpreted, extending from the mask-programmable logic arrays (PLAs) and uncommitted logic arrays (ULAs) to the user-programmable single-chip processor.

In this article, the emphasis is placed on programming and microprogramming of microprocessors, which are subjects of considerable scope, drawing on the expertise gained from the design and programming of computers over the last 30 years.

At the outset, it is essential to understand the difference between a processor and a computer, although the difference may sometimes be elusive. A *processor* is primarily a controller of a memory, the combination of controller, memory and input/output channels being termed a *computer*. The prefix *micro* to the words computer and processor is not well defined. The only consistent definition appears to be based on physical size. The size of both microprocessors and microcomputers is likely to be between 1 cm^3 and 100 cm^3.

A processor of any size may be broadly identified as having a data path and a control path through it. The basic functional scheme of a processor is shown in Fig. 1; the upper block contains the registers and arithmetic logic unit (RALU), and the lower block contains a sequencer and control memory and the instruction decoder. In general, the microprocessors of today may be considered to contain the functions of Fig. 1 on one integrated-circuit chip. The control memory is likely to be a PLA within the chip and, therefore, cannot be programmed by the user.

This however is not true of *bit-slice* microprocessors. These are so called because each integrated circuit implements typically a 4 bit slice of the RALU, in which there are at least 4 RALU chips and at least one sequencing chip combined with a separate standard user-programmable read-only memory (ROM) array. The bit-slice microprocessor is therefore likely to be realized with about 10 chips for a typical 8 bit processor, but has the capability (in contrast to the single-chip microprocessor) to be programmed by the user to possess the characteristics required of a particular microprocessor. The process of programming the bit-slice microprocessor is known as *microprogramming*, and is not to be confused with programming for a single-chip microprocessor.

A programmer's view of a microcomputer is shown in Fig. 2. The programmer may write a program (that is, a sequence of instructions) directly as *ones* and *zeros* in the memory. This is known as *machine-code programming*, which is described in the following section. Later sections describe the greater flexibility achieved by assembly and high-level language programming, and are followed by a brief account of the diagnostic aids provided by simulators and development systems. Finally, details of the approach to microprogramming are given.

MACHINE-CODE PROGRAMMING

An unprogrammed microcomputer can be regarded as a set of interconnected digital control and data circuits. The control circuitry can perform specific tasks, such as data storage (memory), arithmetic and logic operations (arithmetic logic unit), decoding and sequencing (control unit), and provides an interface for input/output connexions. The constituent elements of a microcomputer are connected to each other by semiconductor gates and buses (one or more conductors connected to several signal sources and destinations). These gates and buses do nothing until controlled by a sequence of instructions. A sequence of instructions, stored in the memory as a program, controls the various gates of the microcomputer to make it perform the required function. The program effectively "rewires" the microcomputer from one instruction to the next. The address of the next instruction to be obeyed is stored in a program counter (PC). As a rule, a PC generates sequentially-increasing addresses to read instructions from the program store. There are 5 types of instruction which, when placed in a suitable sequence, produce a program; namely, data transfer, arithmetic and logic functions, processor-

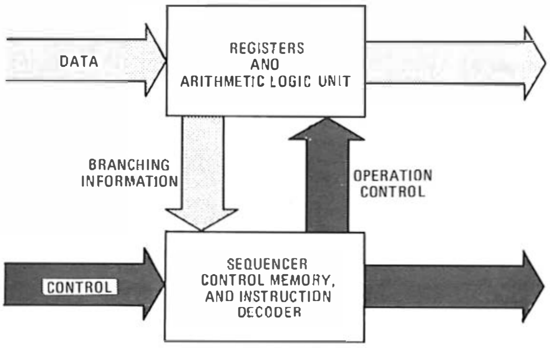


FIG. 1—Basic functional scheme of a processor

---

† Telecommunications Research Department, Telecommunications Headquarters

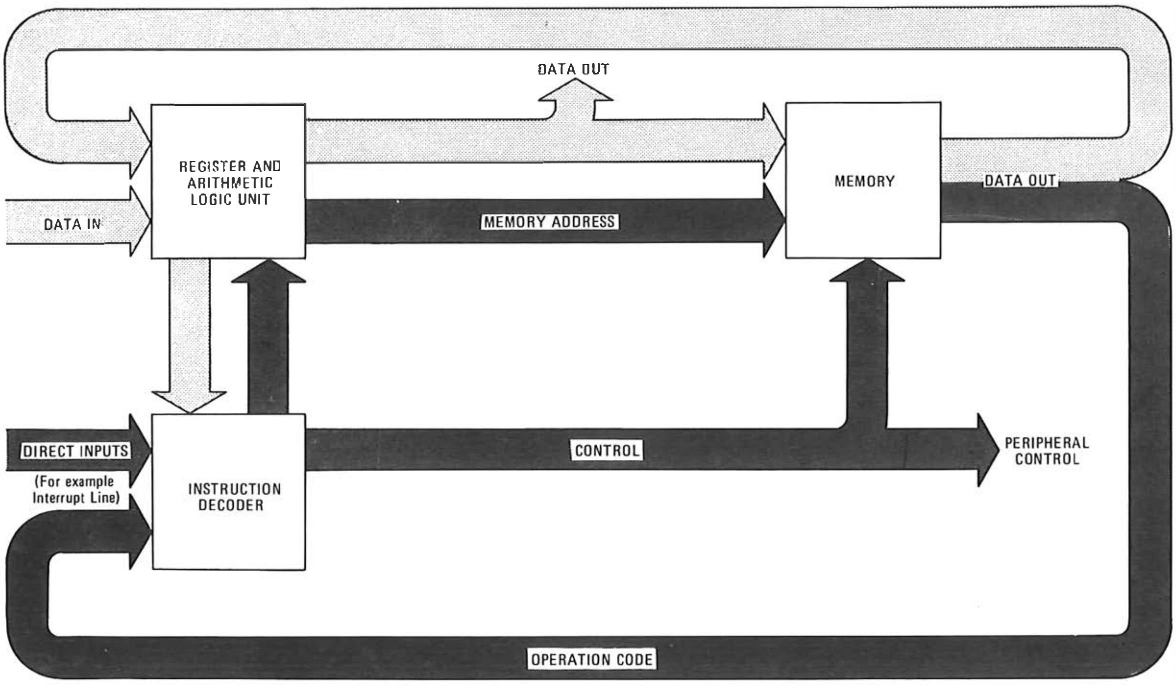


FIG. 2—Basic structure of a microcomputer

control, input/output and control transfers (that is, instructions which cause a non-sequential change to the PC). The 5 types of instruction are described in the following sections. The examples are taken from the INTEL 8080 machine-code architecture. The INTEL 8080 microprocessor has 7 general-purpose registers A, B, C, D, E, H and L, and various instruction lengths.

Data Transfer Instructions

Data transfer instructions move data from one location to another in the computer system. Examples of the instruction codes, the operand† and the resultant action of the data transfer instructions are given in Table 1.

TABLE 1

Examples of Data Transfer Instructions

Instruction Code	Operand	Action
01000001		Moves the contents of register C into register B
01111110		Moves the contents of the memory location whose address is in registers H and L into register A
00111110	00001011	Moves the decimal value 11 into register A

Arithmetic and Logic Instructions

Unlike the data transfer instructions, the arithmetic and logic instructions modify the contents and/or some associated condition flags* (for example, overflow) with an arithmetic or logic operation. These operations take data from one or more specified data sources, perform an operation on them, and place the result in a specified data location, as indicated by the examples given in Table 2.

TABLE 2

Examples of Arithmetic and Logic Instructions

Instruction Code	Operand	Action
10010011		Subtracts the contents of register E from the contents of register A, placing the result in register A
10110110		The contents of the memory location whose address is contained in registers H and L is associated in an inclusive- OR logic operation with the contents of register A, and the result is placed in register A
11000110	00001011	Adds decimal 11 to the contents of register A, placing the result in register A

Input/Output Instructions

To do useful work, a processor must perform input/output operations to communicate with devices connected to it. In the case of microprocessor applications, such interface devices will range from conventional computer peripherals (for example, teleprinter equipment) to more basic components such as relays, lamps, and switches; the programmer must have a detailed knowledge of the input/output interfaces. Broadly speaking, there are 2 mechanisms for conveying data to the input/output devices: by means of special input/output instructions, or by load-and-store operations to address the input/output ports as ordinary memory locations. The former approach completely separates input/output addresses from store addresses, while the latter necessitates

---

† An operand is a quantity on which an operation is to be performed

* A flag is an information binary digit used to indicate the boundary of an instruction or the end of a word. A condition flag indicates a particular state of operation of the computer

that areas of storage be dedicated as input/output ports and thus be unavailable as ordinary storage. Table 3 gives examples of input/output instructions.

TABLE 3

Examples of Input/Output Instructions

Instruction Code	Operand	Action
11010011	00000011	Output an 8 bit word to input/output port 3
11011011	00000100	Input an 8 bit word to input/output port 4

To facilitate communication with computer peripherals, separate *universal synchronous/asynchronous receiver/transmitter* (USART) chips are used. Such chips operate in several modes (such as synchronous or asynchronous operation, various word lengths, odd or even parity). Instructions in the program must preset the USART's mode of operation before input/output operations take place. For example, an instruction code of 11010110 sets the USART mode to: *2-digit binary stop code, enable parity, odd parity and low transmission speed.*

Processor Control Instructions

Processor control instructions are used for enabling or disabling all or part of the input/output structure (which conditions the computer's response to instructions to or from peripheral equipment). Examples of processor control instructions are given in Table 4.

TABLE 4

Examples of Processor Control Instructions

Instruction Code	Action
01111011	Enables interrupt instructions
11110011	Disables interrupt instructions
01110110	Halts the processor

Control Transfer Instructions

Control transfer instructions are used for control of the order of execution of the program by altering the contents of the PC, causing a *jump*. Such alterations may be *conditional* or *unconditional*, *returning* or *non-returning*. A conditional transfer checks the settings of the condition flags, set as a result of previous instructions. If a condition is set, then the PC is changed and a transfer of control effected; otherwise the PC proceeds to the next sequential instruction. An unconditional transfer permits control to be passed to a given location without constraint. A returning transfer saves the address from which it transfers, and a non-returning transfer does not save the address. (See also the section headed "Next Instruction" in the first article[1] of this series.)

In the examples given in Table 5, the instructions are all written in binary code (that is, to the base 2). Instructions may, for ease of reading, be written in octal (to the base 8) by grouping 3 binary digits together, or hexadecimal (to the base 16) by grouping 4 binary digits together. Table 6 shows the octal and hexadecimal values of the binary numbers from 0 to 1111.

TABLE 5

Examples of Control Transfer Instructions

Instruction Code	Operand	Action
11001010	01000011 00000011	If the zero flag is set, then the PC is set to the value in the contents of the address field; otherwise it is incremented
11000011	00011000 00000010	The PC is set unconditionally to the value in the address field, and execution continues from there
11001101	11100011 00000001	The contents of the PC are saved and the PC is set to the value in the address field

TABLE 6

Binary, Octal and Hexadecimal Equivalent Values

Binary	Octal	Hexadecimal
0000	0	0
0001	1	1
0010	2	2
0011	3	3
0100	4	4
0101	5	5
0110	6	6
0111	7	7
1000	10	8
1001	11	9
1010	12	A
1011	13	B
1100	14	C
1101	15	D
1110	16	E
1111	17	F

However, it is often appropriate to consider an instruction in its binary form because of the way in which the instruction is coded. For example, instruction

01 111 100

moves the contents of registers H and L to register A, and instruction

01 DDD SSS

denotes the instruction's general format. SSS denotes source register(s), and DDD denotes the destination register(s).

As these examples show, the instruction lengths vary according to their type. To evaluate the address of a destination of a transfer of control, not only must the start address of the program be known but, also, the intermediate distance must be calculated. This method of obtaining the required address is tedious for the programmer and is prone to coding errors. The need to calculate a destination address makes program alterations difficult. Each time a program change is made, all the jump destination addresses must be recalculated and changed appropriately. Writing machine-code programs has many practical problems: it is difficult to read, impossible to transport to a different computer, and very susceptible to programmer error. (The operation codes must be memorized, and it is necessary to calculate the destination address of transfers of control.)

ASSEMBLY-CODE PROGRAMMING

Assembler programs represent the lowest level of program development software. The assembler is a utility program which translates assembly code to machine code. Although an assembler performs only a few "book-keeping" functions, it allows a programmer to write complex routines more easily than is possible with machine code. In assembly language, each machine code instruction has a mnemonic assigned to it. For example, in mnemonic form, the instruction

01000001

is MOV B, C (move register C's contents to register B).

Mnemonics are far easier to remember than their corresponding codes. For instance, all transfer operations may be MOV instructions followed by the destination and source operands; address calculations may be replaced by addressing locations symbolically, and any address may be assigned a *label.* A particular address can be obtained by reference to its symbolic definition, thus avoiding the tedious calculations necessary in machine code. The assembly language statement is grouped into 4 fields, termed *LABEL, OPERATOR, OPERAND(s)* and *COMMENT.*

Each field is separated from the next by some form of delimiter, such as one or more spaces, a solidus or a comma. For example, the instruction

11000010 01000011 00000011

may be represented by JNZ LAB1 (jump if not zero to address LAB1).

If a program is changed, the addresses may alter. However, as such address references are specified symbolically by the programmer, the assembler is able to calculate the new addresses automatically, thereby relieving the programmer of a manual chore. The COMMENTS field is used primarily to explain the workings of the program, and is ignored by the assembler. Data forms other than binary may be used in an assembly program. If the programmer needs to specify a decimal number, the conversion to binary is both time-consuming and prone to error. Thus, 00111110 00001011 becomes

MVI A, 11D; (move decimal 11 to register A).

Variables may be assigned an area of memory and given initial values; for example,

MSTAK EQU $; (MSTAK = current value of PC),

ESAVE: DB 0; (ESAVE = a byte, initially valued at 0)

and

SSAVE: DW 0; (SSAVE = 2 bytes, initially valued at 0).

The assembly-code program, also referred to as a *source program*, is processed by an assembler to produce a corresponding list of binary numbers (binary or object program). Usually, one assembly language statement produces a single machine-code command. Each assembler (usually specific to one computer) has its own list of shorthand mnemonics for instructions. This list may be fixed or expandable, depending on the design of the assembler. The function of the assembler is to translate a series of mnemonics that are stored on an input medium (for example, paper tape) into a series of binary instructions on an output medium. The actual assembler need not operate on the target microprocessor on which the program is to run (see Fig. 3), but may reside on a different and larger computer. By running the assembler on a large host computer, all the facilities for editing and filing etc. on that computer become available to the assembly language programmer. The editor program of the host computer should make the creation and changing of a program far easier than on the microprocessor because many microprocessors have insufficient memory to run a sophisticated editor. When the assembler has produced the binary equivalent of the program, it may be output as a paper tape to load directly into the microprocessor's memory, or stored more permanently in a programmable read-only memory (PROM). At the time of assembly, the address at which the program is to be loaded may be known, and this information is passed to the assembler so it may generate the appropriate addresses; for example, ORG OH specifies the start of the program as address 0. From such a start address, all other addresses may be calculated absolutely.

FIG. 3—Use of PDP 11 minicomputer for cross-assembly

In some applications, no addresses are known at assembly time, but the assembler may still operate by assigning values to symbols relative to the start of the program and producing a symbol table of where these addresses occur. This method of addressing produces a *relocatable program*, which may be located at any address in the memory. Once the program has been assembled, the object code must be loaded into the microcomputer's memory to enable it to be run. To achieve this, either a *loader* or a *linking loader* may be used (the linking loader is able to link separately-assembled programs together). For an object program with absolute addresses, the loader places the program into the microprocessor's memory at the specified addresses. Where the addresses are relative, the loader must first be informed of the start address and then convert all relative addresses to absolute values before loading the program into memory.

Although use of assembly code makes reading and writing programs far easier than using binary code, assembly language is still far from being a natural language. By adding suitable comments to the program, the understanding of how the program works is increased; people other than the program's originator may understand how the program works. However, even use of assembly language does not improve program portability (the ability to use the same source program for more than one target processor). The reason is that the assembly code is generally specific to one microcomputer type only.

HIGH-LEVEL LANGUAGE PROGRAMMING

A different approach to the writing of programs lies in the use of a high-level language (HLL). An HLL is oriented essentially towards the problem to be solved rather than the computer hardware. A simple example will illustrate this. Suppose it is required that the sum of the contents of the memory locations, referred to symbolically as Q and R, is to be placed in location P. In a typical HLL, this would be coded

P = Q + R; (read as *P becomes Q plus R*).

The equivalent in assembly code for P = Q + R (in HLL) for the INTEL 8080 microprocessor is:

```
LDA   R
LXI   H, Q
ADD   M
STA   P
```

It is apparent that the HLL statement is closer to the way the programmer thinks of the problem than the assembler solution. In addition, the HLL statement is independent of the type of computer to be used. Ease of programming (as exemplified here) has a profoundly beneficial effect on both the productivity of a programmer, and on the correctness of his programs.

The HLL source program is translated into machine code by a utility program called a *compiler*. Although programs written in an HLL are independent of the machine on which they will run, a different compiler is required for each type of target microprocessor. Different compilers can be used to translate the same source code into machine code for different microprocessors. A compiler, like an assembler, need not necessarily run on the target machine.

The most common features used in HLLs are briefly described below by means of simple examples. Interested readers may refer to any HLL description[2,3,4] for more rigorous treatment.

Assignment Statements

Suppose P, Q and R are the names of variables (these names are analogous to the symbolic referencing of memory mentioned earlier). For example, considering

P = Q + R

the expression Q + R on the right-hand side of the assignment operator (=) is evaluated and the result is stored in the memory location referred to by the left-hand side (P). Expressions may generally contain operators for performing addition, subtraction, multiplication, division, and exponentiation. Brackets can be used to enforce evaluation of the expression in the required order.

Conditional Statements

An example of a conditional statement is **if** $X > Y$ **then** $A = X$; **else** $B = Y$.

The condition $(X > Y)$ is evaluated. If it is true, the assignment $A = X$ is performed; otherwise the assignment $B = Y$ is performed. In general, any statement (or group of statements) may appear in the positions occupied by the assignments in the example. Also, the condition may be any expression which yields the value "true" or "false" as a result.

Loops

It is often necessary to execute a group of statements repetitively until a certain condition obtains. An example is

```
do while (X>Y);
X = X + 1;
end;
```

Here, the variable X is incremented by 1 while the condition $X > Y$ holds. Other forms of looping are often provided; for example

```
do I = 2 by 2 to 10;
X = X + 1;
Y = Y + I;
end;
```

This form causes execution of the loop (bounded by **do** and **end**) 5 times, with I taking the values 2, 4, 6, 8 and 10 successively.

Procedures of Subroutines

A number of statements may be grouped together as a separate entity, and used to perform a specific function. The group of statements is called a *procedure*, or *subroutine*. To make the procedure have more general application, parameters may be passed between the main program and the procedure. For example: consider the following procedure:

```
double: proc (x);
X = X + X;
end;
```

This procedure may be invoked as follows:

```
A = 2;
call double (A);
```

The address of the memory location used for the variable called A is passed to the procedure named *double*. The value of the contents of A is doubled and stored back in the same memory location.

The above examples are all taken from the language PL/M[4], but similar features occur in CORAL[5] and other HLLs.

RELATIVE MERITS OF HLL AND ASSEMBLY CODE

The writing of programs in an HLL is quicker and easier than programming in assembly code; this helps in preventing coding errors. Furthermore, the meaning of an HLL program is more obvious than that of its assembly code counterpart, which aids correction and modification of programs.

This is not a case of getting something for nothing however. The machine code produced by an HLL source program is almost certain to be less efficient than that from an equivalent program written in assembly code. For example, a recent study of a typical HLL compiler has shown that the code produced occupies 1·6 times as much memory and takes 3·5 times as long to execute as an equivalent assembly-code program. In the future, with cheaper memories and more efficient compilers, this disadvantage may assume less importance. In summary, the decision of whether or not to use an HLL must be based on the benefits of decreased programming and maintenance costs against increased hardware cost, the latter being particularly important when many identical systems are being produced.

SIMULATORS

Because the available storage on a microcomputer is frequently limited, the assembly or compilation of a program may take place on a computer other than the microcomputer itself. The machine code from the host machine has to be transferred to the target machine before it can be run and tested. The source program then has to be modified to correct any errors, re-compiled on the host machine, and the resultant machine code transferred to the target machine once again; these steps are illustrated in Fig. 4.

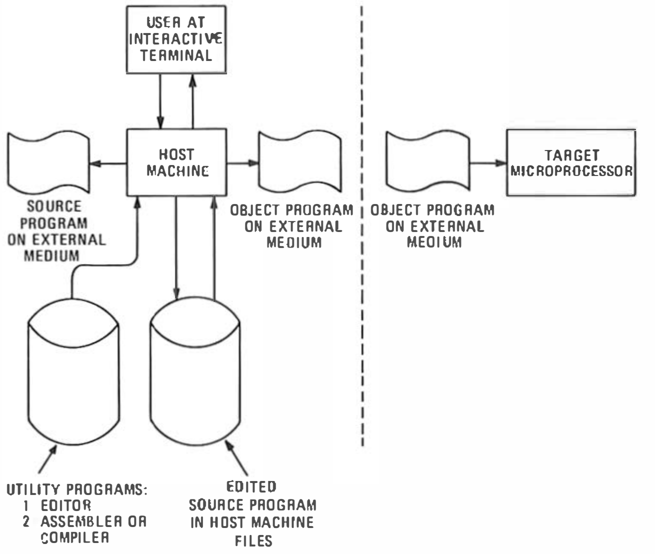


FIG. 4—Use of host computer to edit and assemble (compile) source programs

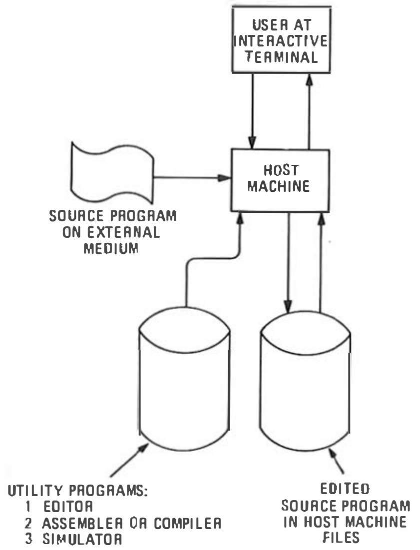


FIG. 5—Use of host computer to edit and assemble programs, and simulate microprocessor

While this procedure is perfectly feasible, the transferring of code from one machine to another is often difficult operationally. The problem can be alleviated in many respects by means of a *simulator*. The simulator is a program which runs on the host machine. Its function is to simulate the action of the target microprocessor. It does this by having software representations of the logic, arithmetic and memory functions of the microprocessor. The simulator interprets each machine instruction in the proper sequence, altering the software representations of the register contents, program counter etc. as appropriate. Fig. 5 illustrates how the external transfer of the object code is avoided.

Most simulators provide facilities (referred to as *debugging* aids) which aid the correction of logical errors in a program. For example, it is often possible to command the simulator to pause when the program counter reaches a particular value, or when a specified memory location is accessed. The status of the simulated microprocessor can then be examined; that is, register values, memory contents and so on can be displayed to the user. Thus, it is not necessary to have the target machine remove most program logic errors and, therefore, the program can be partially tested even before the microprocessor is delivered. The simulator can be used to judge the optimum instruction set for microprogrammed machines.

A simulator can be a valuable aid in removing logical errors in programs, but there are 2 important and fundamental drawbacks.

Firstly, simulation does not preserve the real-time environment of the microprocessor. Simulation proceeds (typically) 100 times slower than real time. This limitation has to be considered in process control, which includes many telephony applications. Simulators, then, are not suitable for diagnosing time-dependent faults.

Secondly, simulators cannot synthesize the action of peripherals accurately, although some rudimentary facilities are provided. For example, signals sent to the output bus may be typed as hexadecimal digits at a user's computer terminal. Input from a peripheral may be simulated by the user entering a representation of the data which would be present on the input highway. These methods, however, become unmanageable when large volumes of data must be handled. More sophisticated simulation of peripherals is sometimes provided. This usually involves writing a program that is individually tailored to simulate the action of the required peripheral. This program is called when an input or output instruction is encountered.

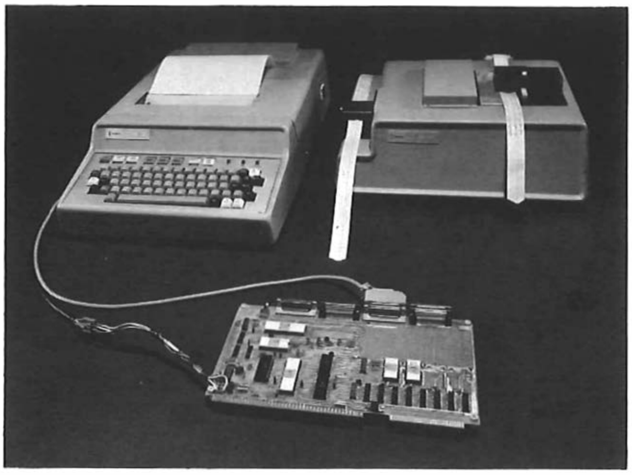


FIG. 6—A single-board computer supporting a printer, paper-tape reader and punch

Improved diagnostic facilities are provided by *in-circuit emulators*, which are described in the next section.

DEVELOPMENT SYSTEMS

An almost inevitable outcome of programming at any level is the presence of errors (often referred to as *bugs*) in the program. In a design using microcomputer control, it is possible that identification of an elusive bug could take days without the ability quickly to load a program into an alterable memory, make minor changes to the program and observe the behaviour of the microcomputer and controlled system. Microprocessor manufacturers and suppliers commonly provide *development systems* for their products that can reduce debugging time considerably.

Development systems can range from the very simple (see Fig. 6), which may incorporate just a hexadecimal keyboard and display, to the larger systems which are capable of supporting a range of peripheral devices such as program input and listing terminals (for example, printing terminals and visual display units) and program storage devices (for example, rotating magnetic memory discs, referred to as *floppy-disc units*, and digital cassette systems).

Most development systems have software (known as a *monitor*) to enable observation of programs in action. A monitor is usually provided with the following features.

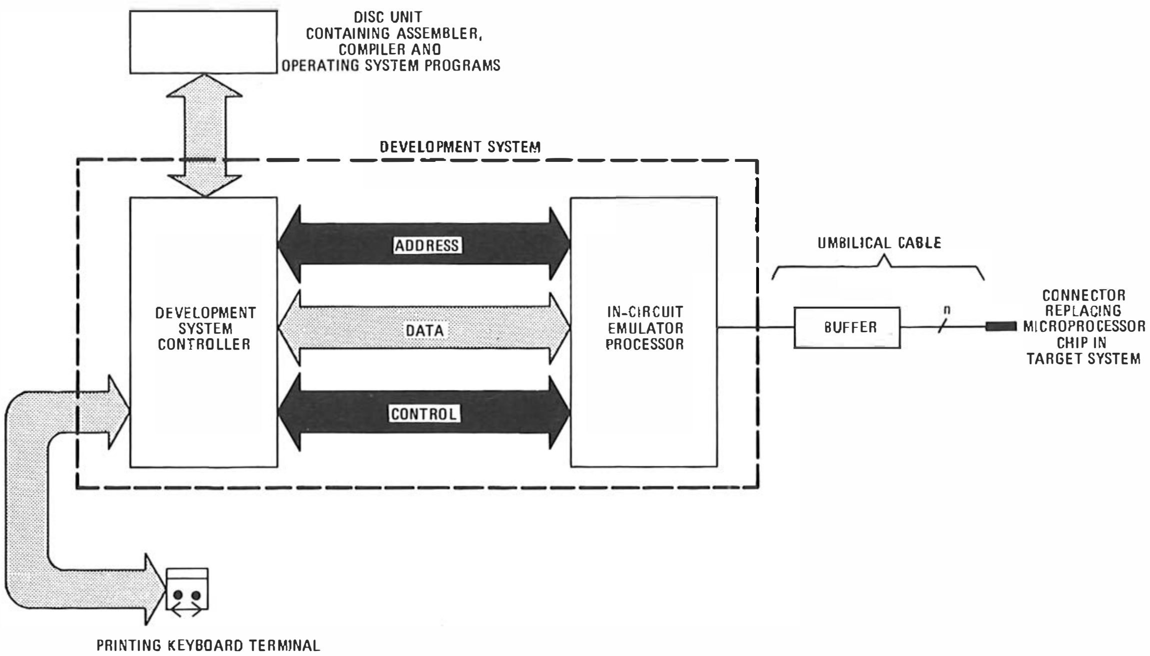


FIG. 7—A basic development system with in-circuit emulator

(*a*) *Memory Access.* A memory access facility allows the memory to be examined or modified. To this end, either a teleprinter or a medium of mass storage is used; for example, paper tape may be used to load a program into a microprocessor. (Paper tape may also be used to store data read from memory.)

(*b*) *Break Points.* An instruction may be inserted into a program to stop its execution at a specified point.

(*c*) *Register Access.* A register access facility permits a register's contents to be observed or altered.

(*d*) *Start Command.* A START command is given to start a program.

These features are the basic debugging tools that may be used to write a program into memory, start the program and check its operation (that is, note changes to memory locations and registers during the execution of the program). In addition, the programmer may provide special routines to display register or memory contents as the program runs. However, as with any software monitoring technique, the microprocessor is slowed down, or even stopped, when monitoring is in progress. Thus, such monitoring techniques are not practicable when timing is critical and, in these cases, special hardware aids must be used.

When operating at full speed, the same diagnostic capability can be accomplished by using an extra-fast microprocessor chip or chip set within a development system. This microprocessor is capable of providing the appearance, both physically and electrically, of the microprocessor to be used in the actual or target system, and is thus known as an *emulator*. The emulation is carried out in the circuit in which the normal-speed microprocessor will ultimately be used. For this reason, it is known as *in-circuit emulation* (ICE), the high speed processor in the development system being known as the *ICE processor*.

A block diagram of a development system with ICE is shown in Fig. 7. The ICE processor is controlled by the development system, and functions as an in-circuit emulator by means of an umbilical cable furnished with an integrated circuit connector which plugs into the target system's microprocessor socket.

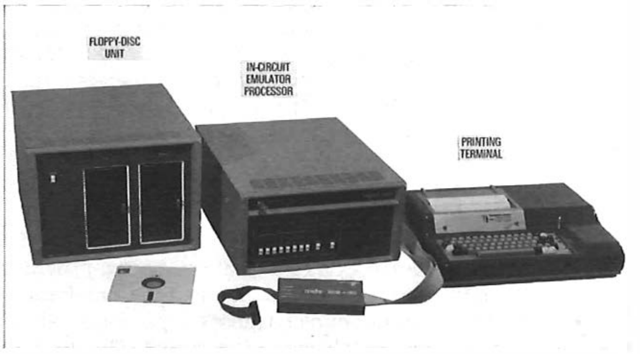


FIG. 8—A microprocessor development system

In earlier sections, it was shown how a larger computer could provide cross-assembly and cross-compilation facilities as well as being able to simulate a microcomputer for the purpose of verifying the correct operation of a program. However, it is natural to consider the use of the microcomputer itself for such functions as program editing, assembly and compilation. In fact, a large number of microprocessor development systems are now available using a microprocessor as a development system controller.

Fig. 8 shows some of the latest equipment to be used at the British Post Office (BPO) Research Centre, and illustrates a floppy-disc storage device, a development system with an ICE processor and a printing terminal.

MICROPROGRAMMING

In the introduction to microprogramming, mention was made of the facility of enabling the user to define the functioning of a processor. The concept of microprogramming is by no means new, and is normally attributed to Wilkes.[6] He introduced the concept as a systematic alternative to the usual *ad hoc* procedures used for designing the control section of a digital computer. Microprogramming has since evolved through several phases during the last 25 years, and has been closely associated with developments in control-memory technology. The relatively recent availability of user-microprogrammable bit-slice microprocessors is now

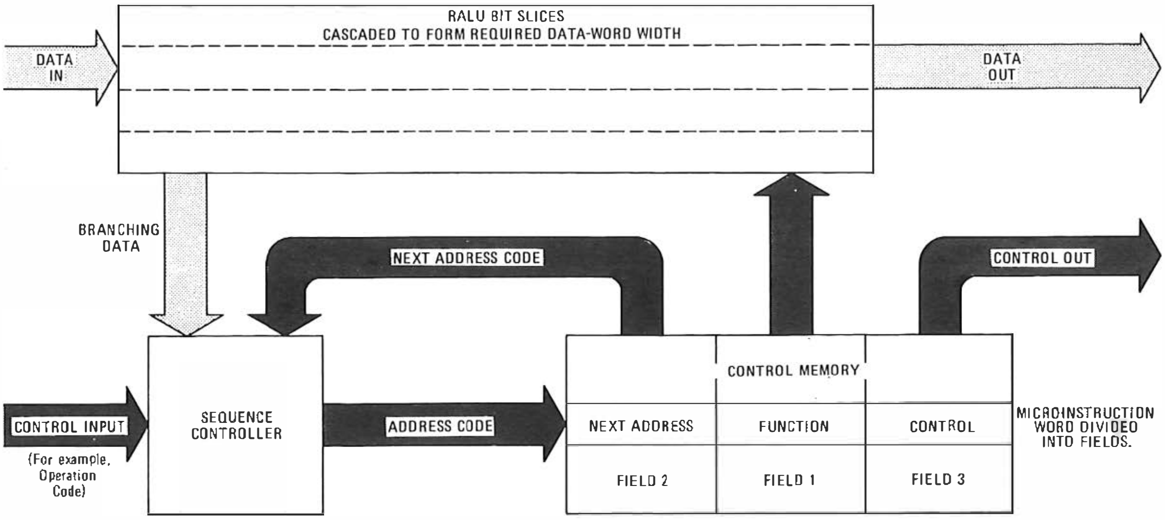


FIG. 9—Basic structure of a microprogrammed processor

focussing attention on user-programming of the control memory in processor and controller designs.

To appreciate the additional complexities involved in microprogramming, it is necessary to expand Fig. 1 to the much-simplified schematic diagram of a microprogrammed processor shown in Fig. 9, in which 3 principal elements can be identified:

(*a*) an RALU,
(*b*) a sequence controller, and
(*c*) a control memory.

These 3 elements are common to most microprogrammed processors and the existence of such structures was well established before the advent of microprocessors. Their function in the context of computers, which is to act as the interpreter of machine code applied to a control input, has necessarily meant that microprogrammed processors have been implemented in the faster bipolar technologies; for example, transistor-transistor logic and emitter-coupled logic. In the past, bipolar technologies, by nature of their lower gate-packing density compared with metal-oxide semiconductor construction, have not been capable of implementing a processor on a single chip. However, bipolar large-scale integration (LSI) is sufficiently advanced to implement major parts of the microprogrammed processor that have been identified above. A common feature of bipolar LSI processors is *bit slicing*, which enables an LSI element (for example, a 4 bit RALU slice) to be cascaded with similar devices to form an element of larger bit width.

At this stage, it should be appreciated that the 3 processor functions of an RALU, sequence controller and control memory each have their own element widths.

(*a*) The RALU slice, whose function is to act as an operator on input data, may be cascaded to form an RALU of the same word size as the input data. Although this is commonly 8 bit or 16 bit wide, it may be made much larger if the designer so wishes.

(*b*) The sequence controller functions principally as a micro-instruction address-code specifier from data and control inputs shown in Fig. 6. It is, therefore, the number of micro-instructions held in the control memory that defines the size of the sequence controller. Although some sequence controllers may be implemented from a number of slice elements, others are of fixed size, typically 9 bit wide. This enables 512 micro-instructions to be addressed directly.

(*c*) The control memory which holds the micro-instructions has a word width dependent on the type of RALU, sequence controller and the number of simultaneous control outputs which the designer requires during the execution of any one micro-instruction.

The micro-instructions held in the control memory of the microprogrammed processor (the microprogram) are structured in a completely different way from the instructions of assembler and higher-level instructions discussed earlier. Instead of data transfer, arithmetic and logic, processor control, input/output and control transfer instruction types of the assembly-level language being the alternatives for any one instruction, the micro-instruction contains basically 3 fields which simultaneously define the 5 different types of instruction required at microprogram level.

The logical and arithmetical transformation on the data input is determined by the central portion (field 1) of the current micro-instruction word. This can be between 5–9 bit wide in every micro-instruction (depending on the range of functions executable by the RALU). Instead of branching or jump information being coded as one of a sequence of operations held in the memory of non-microprogrammed processors, it is present as the *next-address field* (field 2), in parallel with the function field. The next-address field (typically 7 bit wide) is coded according to the kind of sequence options which are available from the sequence controller. The sequence controller can accept an assembly-level operation code from a higher-level memory (see Fig. 2). This will result in the execution of one or more micro-instructions. This sequence will thus define the type and order of RALU operations necessary to interpret the action of the operation code.

In addition, the control memory is capable of supplying a sequence of direct output control words from field 3. The width of this field is completely user-definable, in contrast to fields 1 and 2. These depend on the particular RALU and sequence controller chosen to implement the bit-slice microprocessor.

It can be seen from the foregoing that the word width of a control memory is likely to be large; it can be in the range 20–60 bit, and sometimes more, while the memory size is likely to be 512–1024 instructions.

What has been achieved in microprogramming is a tailor-made instruction set for the processor. This often means greater efficiency in the case of the RALU for particular user requirements, combined with greater operating speed. The overhead, of course, is the somewhat increased number of chips compared with the single-chip microprocessor, particularly in the control memory area, and the greater power dissipation associated with bit-slice processor elements (which are predominantly in a bipolar technology) The speed of operation is usually in the range 100–500 ns per instruction cycle.

FUTURE TRENDS AND CONCLUSIONS

Although the principles of computer programming had been evolving for many years before the advent of the microcomputer, it is generally recognized that the technological advances in microcomputer miniaturization are not being matched by advances in programming languages and their translation into machine code for microcomputers.

The trend towards the use of lower-cost memories results in the processing power of microcomputers being used to run assembler and compiler programs which generally take up more memory space than a typical applications program. This has resulted in a boom in the availability of development aids for microprocessor program development and diagnosis to meet the needs of the designer wishing to incorporate a microprocessor into his design. Although these aids are seen as a necessity at the present time, there are indications that the difference between microprocessor-based development systems and the actual target application systems will become less and less well-defined. For example, programmers for PROMs are in certain instances rendered redundant by the introduction of PROMs which can be programmed directly by the application microprocessor. Furthermore, bulky program-storage peripherals such as floppy-disc units are fast being approached in storage capacity and performance by single integrated-circuit packages containing large data stores and known as *bubble memories*.

Microprocessors in the future will support many of the facilities currently provided by host computers and development systems. Furthermore, the use of a compiler program to translate a source language into machine code is likely to be superseded by direct interpretation of the source language by the microcomputer. This would imply that, instead of compilers and assemblers existing as software, they would be implemented at the level of microcode within an integrated-circuit microprocessor. This leads to special classes of language known as *directly executable languages* which cannot be elaborated on here. The reader is referred to other literature.[7, 8]

What may be seen, however, as a more important subject for the immediate future of microprocessors is how programs affect the reliability of a microprocessor. It has been shown that the failure modes of microprocessors can depend on the programs which they run.[9]

ACKNOWLEDGEMENTS

The authors wish to thank their colleagues in the BPO Research Department for their help in the preparation of this article. They are especially grateful to Dr. T. F. Smith for his constructive criticism.

References

[1] TONGE, J. D., GAUNT, D. L., and KENDALL, J. P. Programmable Logic and Microprocessors. *POEEJ*, Vol. 70, p. 136, Oct. 1977.

[2] IBM Corporation. OS PL/1 Checkout and Optimizing Compilers Language Reference Manual. SC33-0009, 1970.

[3] BACKUS, J. W., *et al.* Revised Report on the Algorithmic Language ALGOL 60. International Federation for Information Processing, 1962.

[4] INTEL Corporation. 8008 and 8080 PL/M Programming Manual, 1975.

[5] WOODWARD, P. M., *et al.* Official Definition of CORAL 66. HMSO, 1970.

[6] WILKES, M. V. The best way to Design an Automatic Calculating Machine. Manchester University Computing Inaugural Conference, July 1951.

[7] NEMEC, J. A Primer in Bit-Slice Processors. *Electronics Design*, Vol. 25, No. 3, Feb. 1977.

[8] FLYNN, M. J. Microprogramming—Another Look at Internal Computer Control. *Proc. IEE*, Vol. 63, No. 11, Nov. 1975.

[9] HACKMEISTER, D., and CHIANG, A. C. L. Microprocessor Test Technique Reveals Pattern Sensitivity. *Computer Design*, Vol. 14, No. 12, p. 81, Dec. 1975.

Book Review

Efficient Electricity Use. Editor: C. B. Smith. Pergamon Press. xxvi + 960 pp. 130 ills. Hard cover: £22·50; flexible cover: £10·00.

The Americans appear to have given much study to the problems posed by the approaching end of the world's fossil-fuel stocks, and this book is the result of one such study initiated by the Electrical Power Research Institute of California.

A book on energy conservation, weighing 2 kg must raise the question, "Would it be better not to expend the energy used to produce it?" The editor answers this in a note at the beginning of the book, stating that the energy required to produce and distribute each copy totals about 0·2 GJ, and a case study later in the book shows how a typical American dwelling can reduce its annual energy consumption by 58 GJ. Even allowing for differences in energy usage in the 2 countries, the average British household should be able to reduce its annual energy consumption by 10 times that required to produce this book, merely by using the information contained in the chapter on residential energy use. In fairness, it must be said that most of the hard facts contained in this chapter have already been published, many in the series of free booklets produced by the Department of Energy.

The title is somewhat misleading, as the book deals with all forms of energy sources and their use. It studies methods of reducing total energy consumption over the whole lives of plant and buildings, including the energy used in construction and in the ultimate reduction to waste materials. In doing this, it covers an extremely wide field, from the energy flow of the planet earth, via the energy use of a prehistoric American cave-dwelling, to a suggestion for an underground city with buildings and utilities buried and the surface left free for parks, leisure activities and food production.

Telecommunications occupies only 15 pages, these being mainly concerned with comparing the relative merits of video telephones and personal travel. The book suffers slightly from being oriented to the US energy scene, but is worth looking at by anyone with an interest in energy conservation, and even those who think they have no such interest could well find useful information and ideas in its pages.

R. S.

Measurement and Analysis Centres

Part 1—System Concept and Equipment Description

B. G. SAPSFORD, B.SC., C.ENG., M.I.E.E.†

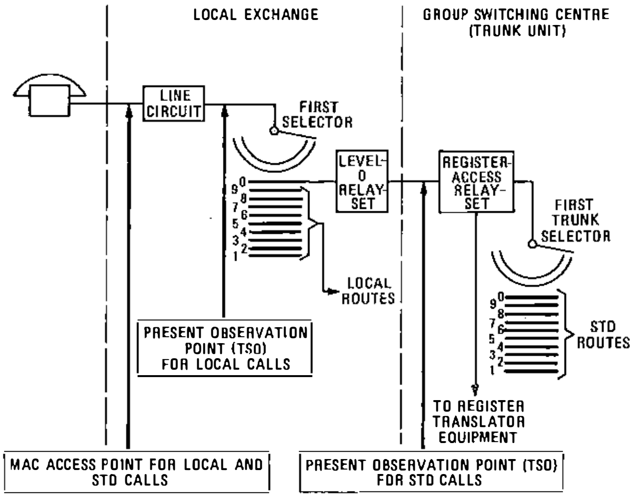
UDC 621.395.31: 621.395.36: 621.395.345

Measurement and analysis centres provide the facility to measure automatically the quality of service given by the British Post Office public switched telephone network. A series of test calls is sent over the network under the control of miniprocessors, and the performance of connexions is monitored. Part 1 of this article describes the system concept and the equipment used. Part 2 will describe the preparation and construction of test programs, and will include details of the management and operational aspects of the measurement and analysis centres.

INTRODUCTION

The UK inland public switched telephone network (PSTN) includes a variety of interworking switching systems; these are, Strowger, crossbar and electronic exchange types. Over the years, customer facilities have been enhanced to include full national dialling; international-dialling facilities have also been enhanced considerably. These developments, and a large growth in system size, have combined to produce a network of great complexity; diagnostic and measurement techniques have had to be improved to match the complexity of the network.

The measurement and analysis centre (MAC) scheme has been designed to provide continuous surveillance of the quality of service of the PSTN between 08.00–18.00 hours, and selected surveillance between 18.00–21.00 hours, Monday to Friday. The object is to achieve a performance measurement for every telephone exchange of 1000 lines and over, and every group switching centre (GSC), sector switching centre, central switching unit and director tandem exchange. This will be achieved by sending patterns of test calls over the network, under the control of miniprocessors. These miniprocessors will be located in centres to be provided, ultimately, on the basis of one per telephone area.



TSO: Telephone service observation

Note: With the present TSO arrangements, calls that are charged at the STD fee rate are rejected by observers at the local-exchange point of observation

FIG. 1—Service observation access points for existing and MAC monitoring facilities

PROBLEMS OF EXISTING METHODS OF MEASUREMENT

The present method of plant-performance measurement is based on the technique of manually sampling customer-originated traffic at the first switching point in the local and trunk switching units (see Fig. 1). The manual method is costly in terms of the number of observers required to obtain a significantly large sample, and has the following disadvantages from the day-to-day system-management point of view.

(*a*) It takes several months to find out if a change in maintenance methods is having the desired effect. The sample size of the present observations allows only long-term changes to be determined accurately.

(*b*) The performance of all equipment within an exchange, and its overall effectiveness as a switching unit, is not precisely indicated because the majority of calls observed terminate in other exchanges. This leads to conjecture on whether a poor result is due to the condition of the observed exchange or to the equipment at a distant exchange. For example, the performance of a common-control exchange, which should have a lower fault rate than surrounding Strowger exchanges, may be masked by the overall result.

(*c*) On STD and international direct-dialled (IDD)* calls, the performance of equipment in local exchanges, and of circuits to the serving GSCs, is not measured, mainly because of the high cost of obtaining a meaningful sample of such traffic.

(*d*) While the present manual method of measurement provides reasonably representative results for performance trends within the constraints already mentioned, it is essentially historical. Indeed, results are rarely available less than 2 weeks after the end of the month to which they relate.

Therefore, for the purpose of day-to-day management and control of network performance, the present method of measurement is considered to be of limited value. At telephone exchange and Area management level, a precise knowledge of exchange and circuit performance is an essential pre-requisite to improvement action.

---

† Service Department, Telecommunications Headquarters

* The terms *international subscriber dialling* (ISD) and *international direct dialling* (IDD) are synonymous

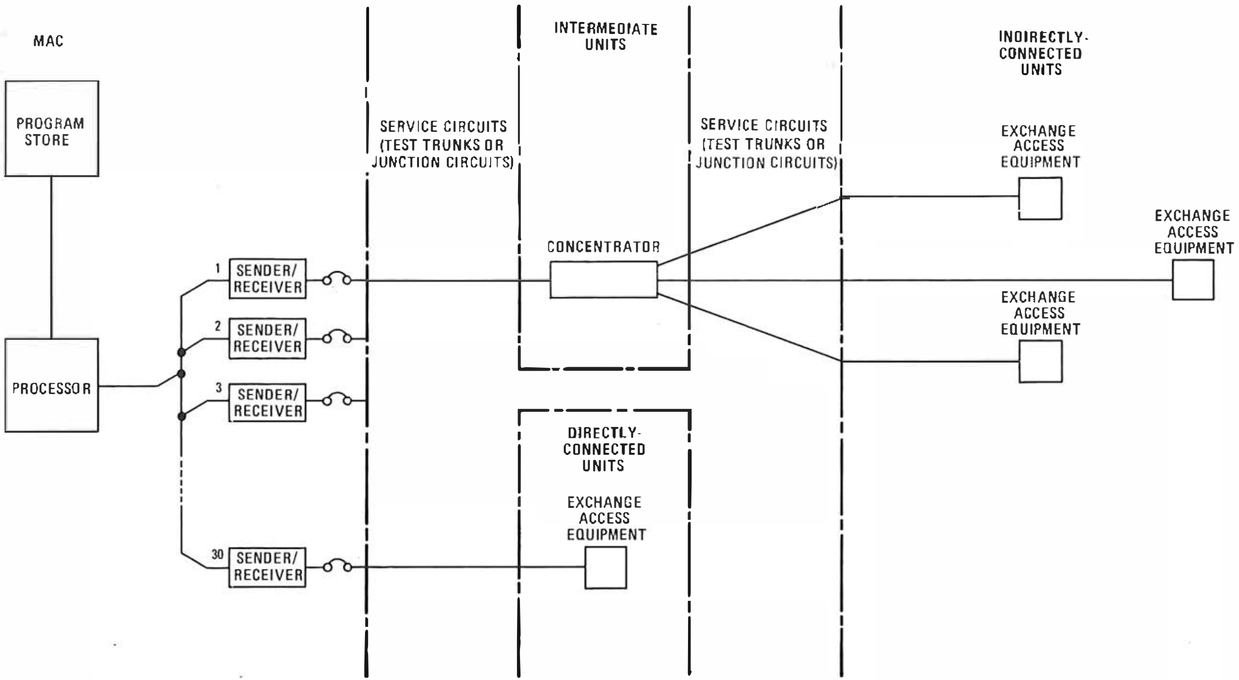


FIG. 2—Typical interconnexion arrangements of a MAC system

THE MAC CONCEPT

The MAC scheme was devised to overcome the problems of the manual method of assessment and to obtain the necessary sample sizes to give statistically-sound results, particularly on some large modern exchange units. Also, routings such as international and transit access need to be monitored.

The MAC concept is based on obtaining a rapid assessment of service quality and making immediate use of failure information to direct maintenance attention to points of high failure rate and to switching units that are performing unsatisfactorily. The MACs will serve as collecting points for call-failure information and will act as centres from which improvement action can be initiated.

A MAC will be equipped, staffed and organized to carry out the following tasks;

(*a*) to measure the quality of service as seen by the customer, with particular emphasis on own-exchange, local-dial area (LDA) and STD performance, using artificial test traffic,

(*b*) to carry out special surveillance measurements on sections of the network; for example,

(*i*) local-exchange access to a serving GSC, including a check of metering on all calls in that section,

(*ii*) incoming GSC circuits to dependent local-exchanges, and

(*iii*) transit and IDD access,

(*c*) to record the outcome of the test calls; for example, calls that were satisfactory, or calls failing to *number unobtainable tone*, *busy tone*, *ringing tone*, etc.,

(*d*) to collect any other call-failure information; for example, customer difficulties reported by telephone operators,

(*e*) to analyse all information received, and report areas of high plant-failure rates to the maintenance staff concerned, and

(*f*) to provide local management with up-to-date information on the performance of switching units and routes within the Telephone Area, and to apply such performance control limits as may be set by local management.

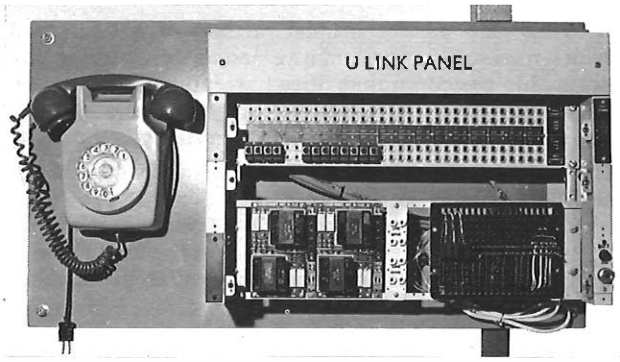


FIG. 3—U-link panel

EQUIPMENT IN A MAC AREA

Basic Area Plan

A typical interconnexion arrangement of a MAC system within a Telephone Area is shown in Fig. 2. Service circuits connect the MAC to the exchange access equipments, via concentrators where appropriate. The concentrators may be sited in any exchange, but will usually be in a GSC, depending upon the location of the exchanges to be measured and the local area cable-routes. A limit of 30 has been set on the number of service circuits which terminate directly at a MAC. Also, the maximum number of exchange units that can be connected to a concentrator has been set; this number is known as the *concentration ratio*. The concentration ratio has been fixed at 3 in a director area and 5 in a non-director area. However, at present, there is a limit of 90 exchange units that may be measured in any single MAC system. This number may be increased to 100 in the future.

Each service circuit connected to a MAC terminates on a U-link panel (see Fig. 3), which provides a testing/patching facility for fault location and temporary restoration of circuits. The U-link panel houses line-impedance matching transformers and attenuators.

A value of 8 dB loss and/or 2000 Ω loop resistance has been set as the maximum limit on any service circuit. Where a signalling system or amplifier is used to overcome these restrictions, normal test-jack-frame (TJF) facilities, as used on public traffic circuits, are provided to enable circuit line-up and faulting procedures to be implemented. It is expected that the majority of service circuits will be routed over 2-wire audio cables loaded with 88 mH coils spaced at 1·83 km.

Equipment Interworking

Each exchange unit to be measured will be fitted with an exchange access equipment, enabling test traffic to be connected to customers' line circuits, register-access relay-sets or incoming trunk-selectors (or the equivalent in TXK and TXE exchanges); inputs to these various equipment groups are termed *access circuits*. Traffic generated by a MAC will terminate at the objective exchange at specially-designed answering circuits or multi-metering-type test-number relay-sets.

In the MAC concept, a *measured unit* is defined as an exchange unit, or part of a large exchange or hybrid-exchange unit, where separate sequences of test calls will be injected. The functions of *sequencing*, *control* and *interpretation* of these test calls will be performed at the MAC.

Using data supplied by the local Service and Traffic Divisions, the MAC will initiate a test call to an exchange by passing routing information to a sender/receiver connected to the appropriate service circuit at the U-link panel. The sender is designed to transmit loop-disconnect pulses, and the first digits, known as *steering digits*, will be used to establish a path from the sender to an exchange access equipment at the designated exchange. If the exchange access equipment is linked directly to the MAC via a service circuit, 2 steering digits will be used by the access equipment to select one of a possible 100 access circuits. If the exchange access equipment is linked indirectly to the MAC via a concentrator, an initial steering digit will be used to set up the switching path through the concentrator. In the case of local-exchange switching units, the access circuits will have exclusive use of the customers' line circuits to which they are connected, and these are called *dedicated access circuits*. For other exchange switching-units, the access circuit will intercept existing traffic-carrying circuits during idle periods, and are, therefore, known as *working-circuit interception access circuits*.

The sender transmits further digits to route the test call either to a dedicated exchange-multiple number terminated by an answering circuit, or to a multi-metering test-number relay-set, depending upon the measurement sequence and the exchange unit to which the test call is routed. The results of the test calls will be analysed and recorded under the various failure categories appropriate to the type of sequence; these include *no dial tone*, *no tone*, *number unobtainable*, *wrong number*, *equipment engaged*, *congestion announcement* and *metering errors*. On certain test calls, the power level of the test tone returned to the MAC will be measured. During sending of the steering digits, the concentrator and the access equipment will transmit 400 Hz and 1000 Hz respectively to the MAC receiver until each has completed its task of establishing the connexion between the selected access-circuit and the sender/receiver. The 1000 Hz tone generated by the access equipment will be removed on detection of dial tone or when a working-circuit interception access circuit has been seized. When metering occurs, the access equipment will detect the condition and cause tone pulses of 2500 Hz to be transmitted to the MAC.

Another facility given by a MAC is *digit monitoring analysis* (DMA), the purpose of which is to collect traffic statistics to derive traffic weightings for routes used by the MAC. Periodically, between sending test calls, the MAC will select an access circuit which is connected to a DMA unit within the access equipment. The DMA unit may be cross-connected to monitor the calls at a switching stage or to monitor a main-network or junction circuit selected by the MAC staff. The DMA is capable of storing the first 5 digits sent during any call which takes place on the monitored circuit. The MAC will analyse the monitored calls to produce a print-out of the number of calls using each routing code. The results will be converted to traffic weightings for each routing code, and the test-call program may therefore be revised as necessary.

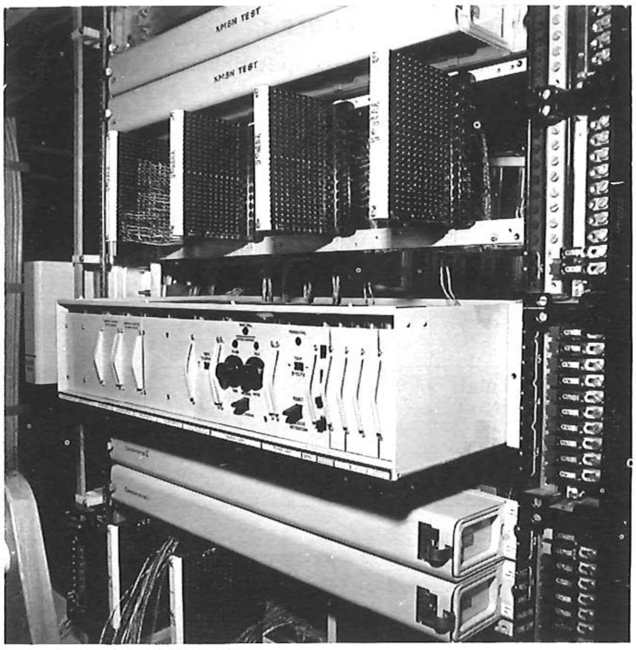


FIG. 4—Cable-termination tag blocks (top), exchange-access shelf unit with plug-in units (centre), and 2 concentrators (bottom)

The Concentrator

A method of concentrating was developed to reduce the number of service circuits needed to connect the measured exchanges to the MAC. Because of the various demands made upon the service circuits by the MAC in passing information to and from the access equipment, it was decided to adopt a concentration ratio of 3 for director areas and 5 for non-director areas.

A concentrator consists of a single 838 mm, 151-Type strip-mounted relay-set and is mounted on a miscellaneous apparatus rack (MAR). The circuitry which steers the test call to the desired outlet (1 of 6) includes Type-23 relays and strip-mounted discrete components. Two concentrators are shown in the bottom part of Fig. 4 (which also includes cable-termination tag blocks and an exchange access equipment shelf). The access shelf shown is served by one of the concentrators.

Exchange Access Equipment

The exchange access equipment is housed in one or two general-purpose shelves, which accept short 62-Type slide-in units, mounted on a suitable MAR. The exchange access equipment shown in the centre part of Fig. 4 is a single shelf unit for working circuit application only (installed at Aldershot, where the first MAC is situated). Tag blocks are provided with each shelf to ease exchange cabling problems. The shelf unit containing the exchange access equipment houses the control circuitry, test-number answering circuits and line-access units. Some of the constituent units of an exchange access equipment are shown in Fig. 5. Four types of shelf are

TABLE 1

Exchange-Access Equipment Shelves

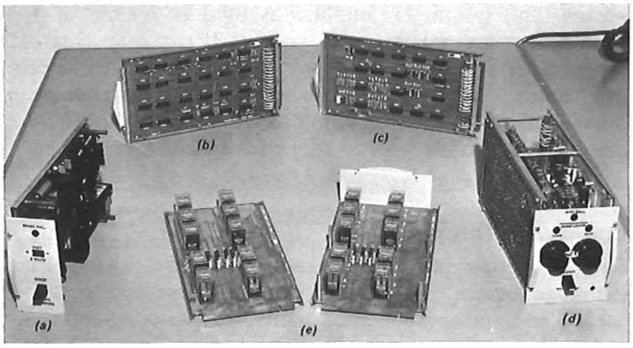
Access Type	Maximum Number of Access Points	Maximum Number of Test-Number Answering Circuits	Shelf-Unit Type
Dedicated and working-circuit	100	96 (Note 1)	Double
Dedicated only	100	96 (Note 1)	Double
Dedicated and working-circuit	40	48 (Note 2)	Single
Dedicated only	40	48 (Note 2)	Single

Notes: 1 Reduced to 56 in common-control exchanges
2 Reduced to 28 in common-control exchanges

to be provided to cater for variations in the quantities and designs of access units required, as indicated in Table 1.

A dedicated access position is connected to a customer's spare calling equipment to enable customer-originated calls to be simulated.

A working-circuit interception access facility is used to intercept the POSITIVE, NEGATIVE and P-wires (or the equivalent in a TXK unit) of an incoming first group-selector or a register-access relay-set in a GSC, or a first tandem-selector in a director tandem exchange to enable the results of test calls to facilitate network analysis.



(*a*) Power unit
(*b*) Steering-digit logic
(*c*) Seizure and metering logic
(*d*) Control unit
(*e*) Working-circuit access units for 10 circuits

FIG. 5—Some of the constituent units of an exchange access equipment

MAC EQUIPMENT

Basic Equipment

The MAC equipment is based on the GEC 2050 mini-processor, which interfaces with service circuits at the U-link panel. The computer has its main and backing stores housed in one cabinet, and the sender/receivers, transmission measuring unit and a data input/output cassette are housed in a second cabinet (see Figs. 6, 7 and 8, which show the equipment installed at Aldershot). Two Transtel keyboard printers are provided to enable additional instructions to be given to the processor and to enable information to be printed out. One keyboard printer is located with the computer, the other is located in an adjacent room where the day-to-day operational activities are carried out.

The physical interface between the sender/receivers and the service circuits (the U-link panel) permits a measure of flexibility to cross-connect sender/receivers or utilize spare units should this be necessary. The U-link panel will also be used as a test point from which the service circuits can be checked for correct operation, and will also provide an interface between the suppliers equipment and that of the BPO during acceptance testing.

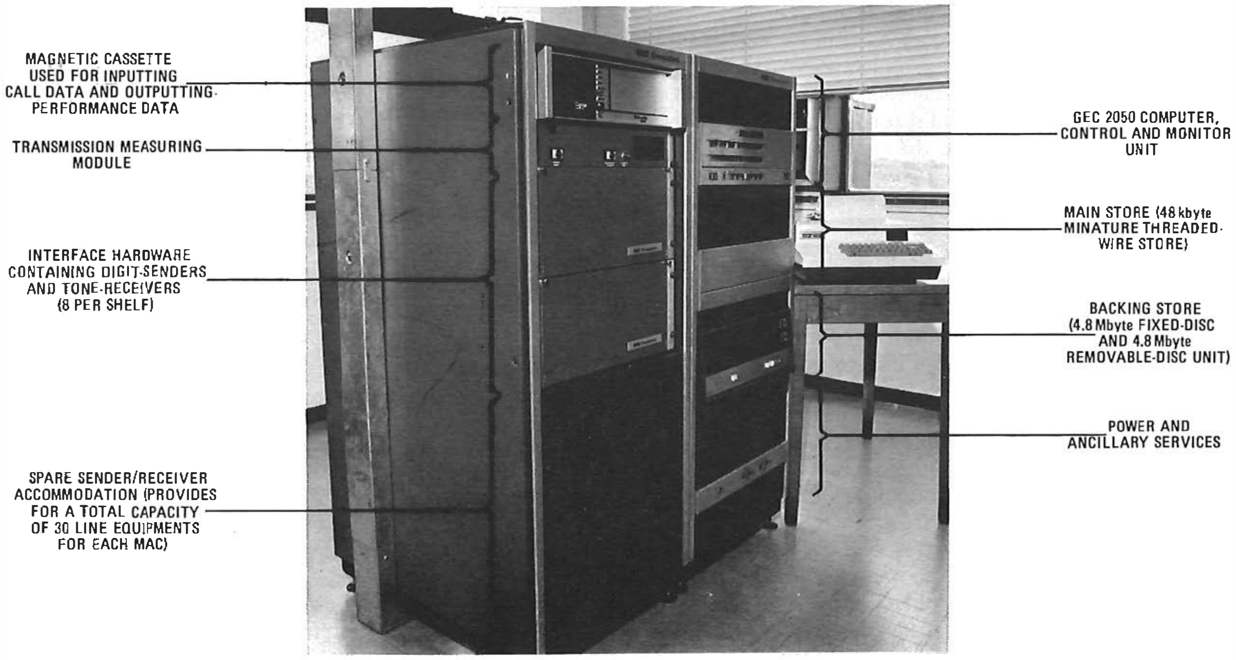


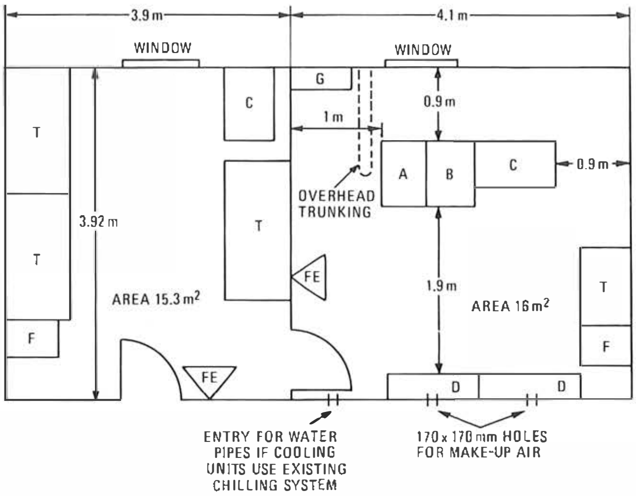
FIG 6—MAC equipment cubicles

FIG. 7—Sender/receiver cards and interface cards (8 sender/receivers and 2 control boards)

FIG. 8—Disc unit (removable disc in position)

Accommodation and Environment

A typical floor plan showing the position of the MAC equipment and operations accommodation is shown in Fig. 9.



A—Cubicle containing MAC sender/receivers, power supplies and cassette tape unit
B—Cubicle containing processor core store, controllers, disc unit and power supplies
C—Transtel keyboard printer
D—Cooling equipment
F—Filing cabinet
G—U-link panel
T—Table
FE—Fire extinguisher

FIG. 9—Typical floor plan of MAC

Two adjacent rooms are arranged so that the equipment room may be entered only from the operations room. This is necessary to allow for the smooth operation of the MAC, and as a physical security barrier to prevent unauthorized access and to ensure that the environmental conditions are maintained. The MAC equipment will operate in a temperature range of 10–35°C and, since it will radiate heat (some 4 kW, normally), it will be necessary to install a cooling plant. Also, the equipment should operate within the normal levels of relative humidity. Because the equipment is susceptible to high dust levels, it will be necessary to filter the incoming air. Fans and filters, which will pump filtered and cooled air into the equipment room, will be installed in the wall. The room will, therefore, be at a higher atmospheric pressure than the exchange-equipment room. The resulting flow of air back to the exchange, plus the equipment's own internal forced-air ventilation, will help to maintain the room at a reasonable temperature.

The day-to-day operations room will be at normal exchange environmental conditions.

SUMMARY

This part of the article has described the reasons for the introduction of MACs and the interdependence and basic functions of the equipment. Part 2 will describe how information is compiled to prepare the test programs, the construction of test programs, the test programs initiated by a MAC and the day-to-day activity concerning the operation of a MAC.

The TXK2 Switching System and Peripheral Equipment at Mondial International Telephone Services Centre

D. C. MODI, B.SC.(ELEC. ENG.), and K. W. YOUNG†

UDC 621.395.344.6: 654

This article describes how the TXK2 switching system, as used at Wood Street and De Havilland International Switching Centres, London, has been developed to provide additional facilities at the Mondial International Switching Centre, London. The article also includes a description of the peripheral equipment used at all TXK2 exchanges.

INTRODUCTION

Mondial is the third international switching centre (ISC) in the UK to be based on the Plessey 5005T 4-wire-switched crossbar system, and is scheduled to come into service in April 1978. With the exception of facilities related to the use of the International Telegraph and Telephone Consultative Committee No. R2 (CCITT R2)[1] signalling system, Mondial ISC's functions are, in most respects, similar to those provided at Wood Street and De Havilland ISCs[2]. However, there are some notable differences in the circuit designs used at Mondial ISCs, and these are explained in this article; also included is a description of the international maintenance centre (IMC).

ISC SIGNALLING

The signalling systems used at Mondial ISC are shown in Fig. 1. With the exception of the CCITT R2 signalling system, which will be described in a later issue of the *Journal*, all the signalling systems have been used in previous TXK2 installations. It should be noted that Mondial ISC does not have any co-located manual-board services and, consequently, DC coded signalling is not used. Subscriber-originated traffic from the London director area uses either Signalling System AC No. 11 (SSAC11) or SSDC3 with Signalling System Multi-Frequency No. 2 (SSMF2) inter-register signalling. Thus, there are only 4 basic register signalling systems appearing on the incoming side of the exchange.

The use of loop-disconnect signalling (LD4) on the outgoing side of the ISC is limited to those junctions directly serving the London local director exchanges, to which only the last 4 digits of a subscriber's number need be transmitted; the rest of the terminal calls to UK subscribers are completed using SSAC11/SSMF2 signalling.

ISC SWITCHBLOCK DESIGN

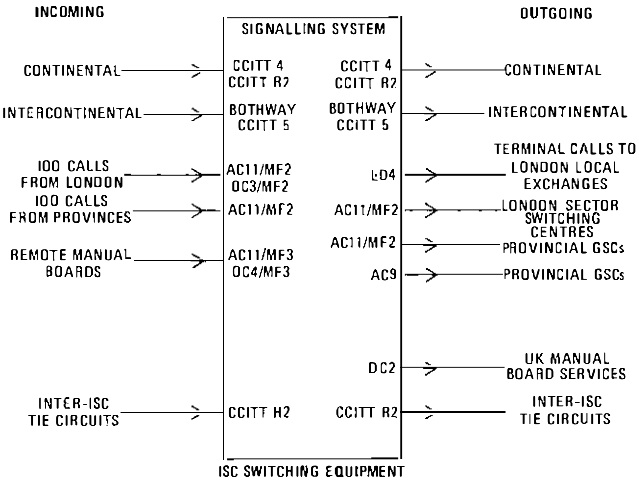
The switching capacity of the Mondial ISC will ultimately provide for approximately 5900 incoming circuits, 3400 bothway circuits and 6200 outgoing circuits. Thus, the switchblock is dimensioned to provide terminations for 10 000 incoming and 10 000 outgoing circuits, giving a busy-hour switching capacity of approximately 6000 erlangs. A simplified trunking diagram is shown in Fig. 2.

The formation of incoming routers, second-stage routers, outgoing routers and outgoing offices is similar to that at earlier TXK2 ISCs[2]. However, since the number of outgoing terminations is twice that of either the Wood Street ISC or the De Havilland ISC, there are 10 outgoing offices at Mondial ISC. To provide access to each of the outgoing offices from its corresponding second-stage router, it follows that each great router has to have 10 second-stage routers. Therefore, at Mondial ISC, a great router is formed by combining 10 incoming routers with 10 second-stage routers, such that any incoming router can access all the second-stage routers within its own great router.

The selection of an X or Y path[3] through the ISC, the marking of outgoing line relay-groups (LRGs) and the principles of self-steering[3] of marks through the route switches, are as for the Wood Street and De Havilland TXK2 ISCs.

ISC EQUIPMENT

The decision to adopt CCITT R2 signalling for European routes meant that changes were needed to the TXK2 equipment. Other contributory factors to the decision to revise the equipment design at Mondial TXK2 are



GSC: Group switching centre

FIG. 1—Signalling systems used at Mondial ISC

---

† Telecommunications Development Department, Telecommunications Headquarters

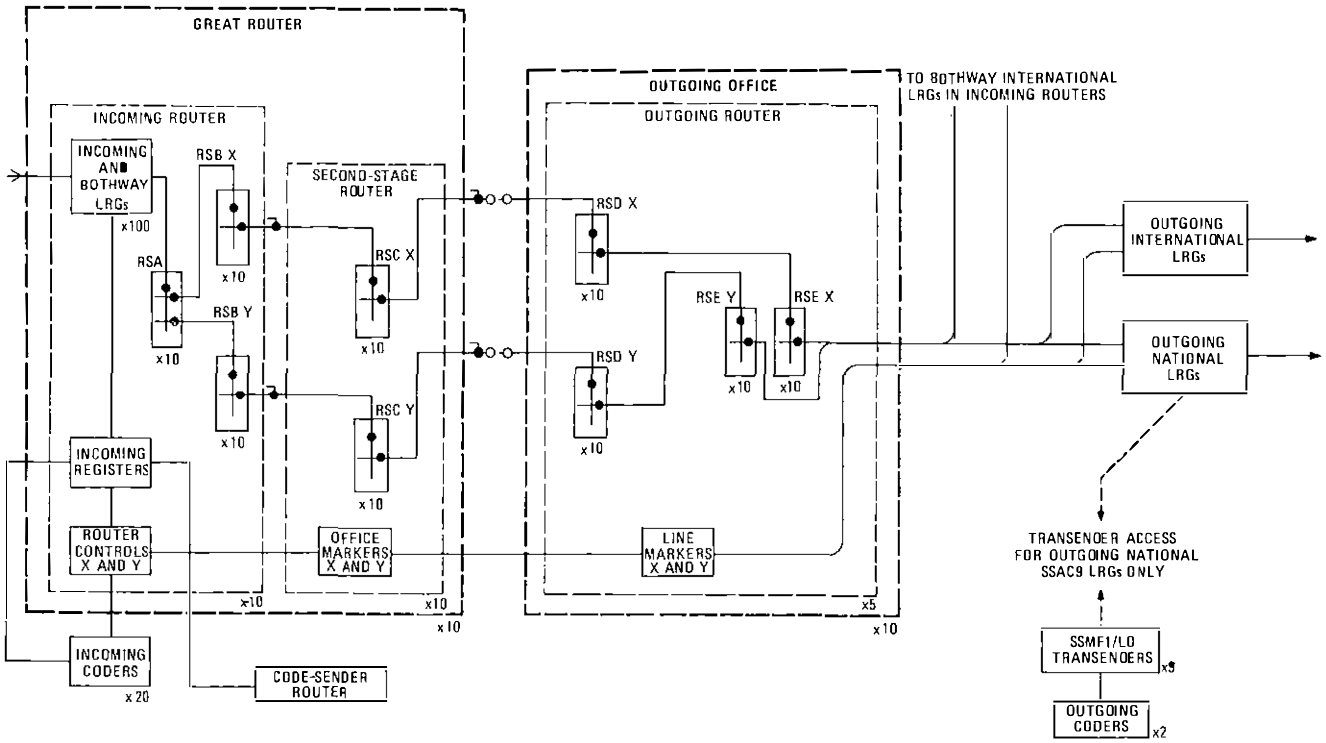


FIG. 2—Simplified trunking arrangements at Mondial ISC

(*a*) that Mondial ISC is required to act as an exchange of CT1[4] status,

(*b*) the need to provide operational flexibility for future changes in the calling rate owing to a reduction in call holding times, and

(*c*) the forecast increase in subscriber-dialled international calls and a consequent reduction in the number of calls set up by switchboard operators.

The opportunity was taken in the redesign of the equipment to increase reliability and to reduce maintenance effort. Six main areas of development are involved, and these are described in the following sections.

Introduction of CCITT R2 Signalling and CT1 Status for Mondial ISC

Various options for the introduction of CCITT R2 working in TXK2 equipment were considered.

To minimize equipment development, one possible way would have been merely to introduce newly designed CCITT R2 incoming and outgoing LRGs, incoming CCITT R2 registers and SSMF 1/CCITT R2 senders. The latter would be accessed via the outgoing CCITT R2 LRGs, thus retaining the trans-exchange SSMF 1† signalling feature provided at earlier TXK2 installations. However, adoption of this method would have severely curtailed the exchange of information possible on CCITT 4–CCITT R2 calls, SSMF 2–CCITT R2 calls or CCITT R2–SSMF 2 calls, because there are no backward signals available in CCITT 5 for the trans-exchange SSMF 1 signalling. Thus, Mondial ISC could not have fulfilled its role as a CT1 with ability to provide full interworking between signalling systems. Retention of the SSMF 1 link would also have nullified the advantages that can be obtained at a future date by the introduction of an enhanced register-signalling system in the British Post Office (BPO) national network.

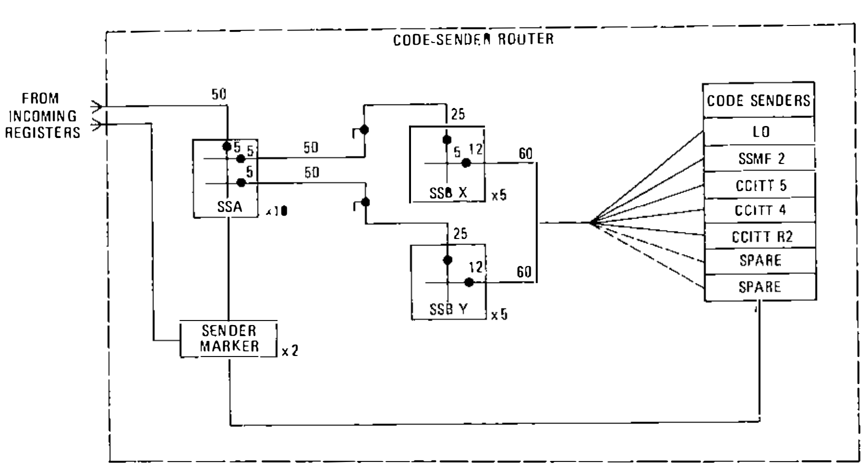
To obviate some of the interworking limitations, a second option was considered that would have introduced a CCITT R2 sending capability within each type of incoming register, and thereby remove the need for trans-exchange SSMF 1 signalling on outgoing CCITT R2 calls. However, the cost of providing built-in CCITT 4, CCITT 5 and CCITT R2 senders for each type of register would have been prohibitive, and would have resulted in the inefficient use of the built-in senders. It should be noted that CCITT R2 is an end-to-end signalling system as far as inter-register signalling is concerned, and that it can also be used as a national signalling system, thus permitting transparent working at the terminal ISC. In the latter case, the controlling register is required to remain associated with the call connexion until an *address complete* signal or a *busy* signal is received from the distant terminal national exchange.

Thus, to comply with the CCITT requirements for a CT1 ISC and to optimize the use of outgoing senders, it was decided to provide separate groups of CCITT 4, CCITT 5 and CCITT R2 senders, which could be accessed from the registers when required. This concept also favoured the inclusion of LD senders and SSMF 2 senders in the sender group because there are cost benefits to be obtained by eliminating the need for senders and transenders at the outgoing side of the exchange. Hence, at Mondial ISC, the only time the registers use trans-exchange SSMF 1 signalling is when calls are required to be routed to certain provincial centres using outgoing SSAC 9 LRGs. However, these LRGs and the associated small number of SSMF 1/LD transenders are expected to be recovered as soon as the exchanges concerned acquire the SSAC 11/SSMF 2 signalling capability that will permit either direct access, or access via the transit network[5].

The outgoing senders are called *code senders*. The access arrangement between the registers and the code senders, via 2 sets of crossbar switches designated *sender switches A* (SSA) and *sender switches B* (SSB), is shown in Fig. 3. Each of the sender switches is capable of switching 20 wires: 4 wires for outgoing transmit-pair and receive-pair signalling, and 16 wires for the exchange of DC signals between the register and the code sender.

---

† The register signalling part of CCITT 5 is known in the BPO as SSMF 1



Note: Three code-sender routers are provided for each great router

FIG. 3—Access arrangement for code senders

The 10 SSA and 10 SSB switches, in conjunction with a pair of sender-markers X and Y, form a code-sender router that gives access from up to 50 incoming registers to a maximum of 60 code senders. Three code-sender routers are provided for each great router at Mondial ISC. Since each great router contains 10 incoming routers, the access to a particular code-sender router is further limited to 3 or 4 incoming routers only within a great router.

The marking and selection of a code sender, when demanded by an incoming register, is the function of the sender marker. However, unlike the line marker, the sender marker uses *mass marking* of all code senders of the required type, as indicated by the calling register. Although, initially, there will be only 5 types of code sender provided at Mondial ISC, the sender marker can cater for up to 7 types of code sender to cope with future needs. The sender marker also contains timing elements for the supervision of code-sender marking, for the priming of SSAs, for receiving a mark, and for a continuity check of control wires through the sender switches. Facilities are also provided in the sender marker, when used by the register/code-sender routiner, for the selection of any particular code sender from a group.

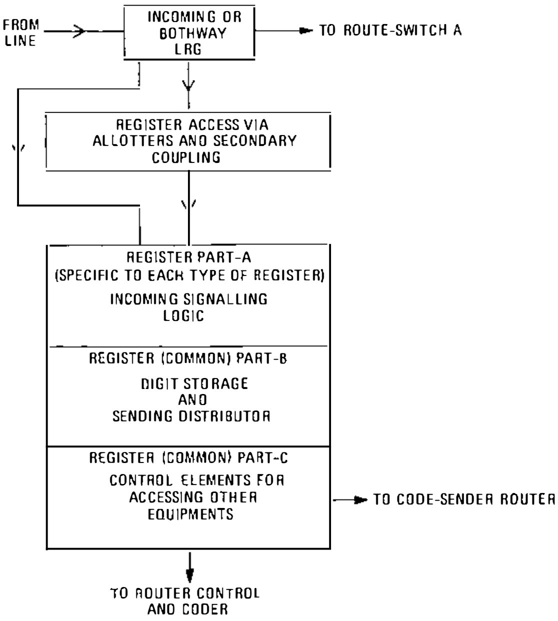


FIG. 4—Modular design of Mondial ISC registers

Modular Design of Incoming Registers

With the provision of separate code-sender routers, the register functions can be rationalized in that, with the exception of logic for incoming register signalling, all other functions, such as digit storage, interchange of information with common-control equipment (such as router control and coder) and DC control of onward transmission of digits through the code-senders, are applicable to all types of incoming register. Therefore, it has been possible to design the registers on a modular basis (see Fig. 4). The common functions applicable to all registers are contained in 2 shelves called the *register (common) part-B* and *register (common) part-C*. Register part-B provides the digit stores and the distributor for onward transmission of digits in accordance with the sending-program instructions given by the coder. Register part-C contains all the timing and control elements for accessing a router control, coder, sender marker and code sender. Register part-C also provides the control point for the exchange of information with part-B of the register and other associated equipments. The third part of the register, called *part-A*, caters for incoming register-signalling logic, and is different for each type of incoming register. Thus, it can be seen that the essential differences between the 4 types of register provided have been achieved in the design of only 6 register shelves. Furthermore, in the future, to cater for the addition of an enhanced signalling system in the national network will involve designing a shelf of equipment for register part-A only.

Line and Register Signalling Receivers

With the exception of CCITT R2 and SSMF 1 signalling receivers, all line and register signalling receivers used at Mondial ISC are BPO designs adapted for mounting on crossbar equipment. The SSMF 2, CCITT 4 and SSAC 10 (line signalling for CCITT 5) receivers use discrete silicon components and the SSAC 11 receivers use integrated circuits based on the miniaturized version of buffer-amplifier receiver used for SSAC 9. Opportunity was taken during the redesign of the SSMF 2 receiver to add the capability of signalling *called line busy*, *number unobtainable* and *early* or *late repeat attempt* in the backward direction. Thus, for interworking between SSMF 2 and CCITT R2, the incoming SSMF 2 register is capable of signalling the correct state of the called line to the originating UK national exchange, rather than merely signalling a *limited facilities—number received* signal followed by the return of *subscriber-busy* tone or *number-unobtainable* tone from the incoming LRG. The additional backward

SSMF 2 signals will enable the originating centres, whenever possible, to release the forward connexion to the ISC and to provide the appropriate tones locally. Receipt of a faulty incoming SSMF 2 digit at Mondial ISC results in the return of either an *early* or *late repeat-attempt* signal as appropriate, and this enables the SSMF 2 equipment at the originating centres to carry out automatically a repeat attempt to set up the call.

The CCITT R2 receiver and the SSMF 1 receiver are proprietary equipment designs manufactured by Plessey Telecommunications Limited. These use integrated circuits and discrete silicon components.

Register Access for Incoming LRGs

The prospect of increased register holding times on outgoing CCITT R2 calls, and a forecast increase in the calling rate on incoming LRGs owing to a reduction in average call holding times, influenced the decision to revise the register allotting arrangement for Mondial ISC. If the previous TXK2 concept of register allotting had been retained, it would not have been possible to optimize the use of the register groups. By introducing a further stage in register allotting, called the *secondary coupling circuit*, and revising the register group allotter design, the number of registers that an incoming LRG can gain access to has been increased from 5 to 15.

Each incoming LRG is provided with 5 register-access relays, designated *RA*, *RB*, *RC*, *RD* and *RE*. A demand for a register is made via the register group allotter, which is provided on the basis of one register group allotter per 10 incoming LRGs. On seizure, the register group allotter accesses the secondary coupling circuit where the 50 register-access *links* from the LRGs (5 per group of 10 LRGs × 10 group allotters) are grouped to access 5 *link controls*. Each of the link controls in the secondary coupling is capable of providing access to a maximum of 3 registers. Thus, each incoming LRG can access up to a maximum of 15 registers via its 5 register-access relays.

The revised allotter design also includes a facility to signal to incoming LRGs either to backward-busy the junctions or to prevent the return of a *release guard* signal should an ALLOTTER FAIL indication be encountered. This prevents further seizures of incoming circuits until the allotter fault has been cleared.

LRG Designs

Apart from the introduction of CCITT R2 incoming and outgoing LRGs, certain other types of LRG for Mondial ISC have either been completely redesigned or modified.

To provide operational flexibility for handling incoming national signalling (for example, changing SSAC 11 or SSDC 4 LRGs serving remote manual boards (RMBs) to SSAC 11 or SSDC 3 LRGs serving UK subscribers), an incoming multi-purpose LRG was designed which could be used in any one of these modes. The multi-purpose LRG incorporates an interface relay equipment for all standard functions such as register access, DC call supervisory conditions, force-release features and provision of tones. The SSAC 11, SSDC 3 and SSDC 4 signalling units are designed as 3 separate plug-in modules, any one of which can be connected to the interface equipment to form the required type of incoming LRG. The discrimination between RMB access and international direct dialling (IDD) class-of-service when using the SSAC 11 signalling module is obtained by appropriate positioning of wire straps in the main interface equipment.

Since the number of registers to which an incoming LRG has access has been increased from that provided previously, the incoming CCITT 4 and CCITT 5 LRG designs have been modified to provide the increased register identification needed when these are accessed either by the IMC or by the LRG routiners. Most of the outgoing national LRGs of previous design have also been modified to remove the SSMF 1/LD or SSMF 1/SSMF 2 sender-access relays which are now redundant.

The Mondial ISC transmission plan is different from that of earlier TXK2 installations, and this is reflected in changes to the value of the attenuators fitted in all LRGs.

Other Equipment Changes

Echo Suppressors

All incoming and outgoing LRGs serving international routes can have, if required, permanently-associated echo suppressors (ESs). However, the propagation delays on single-link calls, made over continental routes served by CCITT 4 LRGs and CCITT R2 LRGs, are such that ESs are not needed on a permanent basis. Permanently-associated ESs are therefore confined to CCITT 5 LRGs serving inter-continental routes only.

The small incidence of multi-link calls over continental routes for which ESs are required is catered for at Mondial ISC by routing these calls via re-entrant trunk (RET) LRGs that are equipped with ESs. Such calls pass through the ISC for a second time. Although the CCITT 4 and the CCITT R2 signalling systems include signals that can be used to control the insertion of an ES, the incoming coder circuit had to be modified to incorporate additional logic to decide whether or not the call should be routed to an RET LRG; the decision to route to an RET LRG is based on the receipt of information signals from the register and an indication within the coder of the ES switching capability of succeeding ISCs.

International Accounting and Traffic Analysis Equipment

The international accounting and traffic analysis equipment (IATAE)[6] is similar to that provided at the De Havilland TXK2 ISC, but it also includes facilities to record the call destination as *RET* when routing an ES-switched call for the first time; the IATAE then records the true destination (origin being *RET*) when the call is routed for the second time.

Testers

While the incoming and outgoing CCITT R2 LRG testers and the multi-purpose LRG tester are new designs, changes have been made to other LRG testers and routiners of earlier designs to reflect the modifications carried out on the LRGs described earlier. All register routiners have been modified to incorporate facilities for checking outgoing CCITT R2 signalling.

Equipment Monitor

The equipment monitor, which prints details of the ISC switching failures, has also been modified to obtain the identities of code-sender router equipment which was not provided in previous TXK2 installations.

The Routing of a Typical Call Through Mondial ISC

The way in which the designs of equipment have been integrated into the TXK2 system is clear from the block diagram of the Mondial ISC main equipment shown in Fig. 5 and from the following description of a typical call, which considers an incoming SSAC 11/SSMF 2 subscriber-dialled call requiring routing to a terminal ISC, using CCITT R2 signalling.

On seizure of an incoming multi-purpose-LRG fitted with an SSAC 11 (IDD) signalling module, the LRG seizes its register group allotter, which in turn seizes the main allotter and the secondary coupling circuit. Each of the 5 link controls in the secondary coupling will have been monitoring the state of 3 registers, and one of the free SSMF 2 registers is allotted to the LRG. On connexion of the register, the LRG

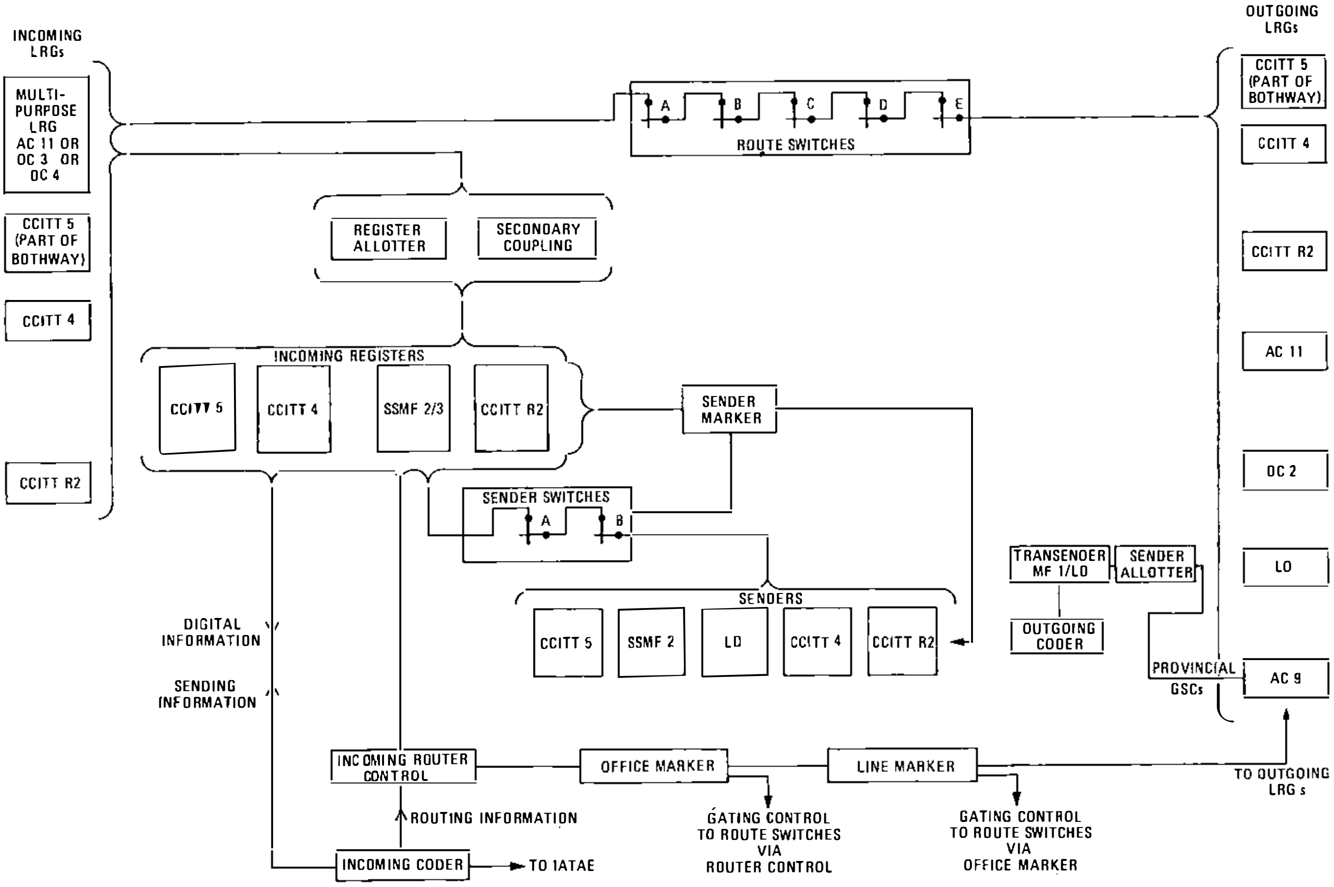


FIG. 5—Block diagram of Mondial ISC

indicates the path of entry (namely, a subscriber-dialled call) to the register, and SSMF 2 inter-register signalling takes place. Typically, the register receives C, C_1 C_2, AB, N_1 N_2 N_3 N_4 N_5, where the C is the subscriber's *class-of-service* digit, C_1C_2 is the 2-digit country code with digits AB representing the area code, and digits N_1 to N_5 indicating the called subscriber's number.

On receipt of digit B, the register initiates a demand for the router control (X or Y) which, when seized, associates with an incoming coder. The receipt of the sending and routing information from the incoming coder and the subsequent selection of the outgoing CCITT R2 LRG by the router control now proceeds in the same manner as that for a call to an outgoing SSAC 11 LRG, which has been described in a previous *Journal* article[1].

On release of the router control, the outgoing CCITT R2 LRG sends a *seizure* signal to line, and the SSMF 2 register takes over the control of the forward connexion and seizes the sender marker (X or Y). The latter receives an indication from the register that a CCITT R2 code sender is required. The sender marker *mass marks* all the free CCITT R2 code senders and then primes the SSA, the inlet of which is connected to the calling register. The free code senders initiate marks through SSB X (or SSB Y) and, on receipt of a mark in the primed SSA, the sender marker initiates the operation of the bridge magnets in the SSA and SSB X (or SSB Y), thus connecting the 20 wires from the register to the selected CCITT R2 code sender. When the continuity check of the control wires is successfully completed, the sender marker releases.

The SSMF 2 register then instructs the CCITT R2 code sender to send the first digit, which in this instance would be the *language* (*discriminating*) digit 0 because it is a subscriber-dialled terminal call. The CCITT R2 code sender then responds to signals from the distant ISC and further digits are sent forward on a compelled basis each time the code sender requests the SSMF 2 register to forward the next digit, thus stepping the digit-store distributor in the register. It should be noted that sending of the digits is supervised by a timing control in the register. This is necessary in case the onward sending catches up with the incoming SSMF 2 digits and further signalling has to be delayed. When the final digit, N_5, is received by the terminal ISC (or a terminal group switching centre if the CCITT R2 signalling also happens to be used as a national signalling system) and, provided that the call can be established, the CCITT R2 code sender receives a CCITT R2 $A6$† signal, which it conveys to the SSMF 2 register in DC form for transmission in the backward direction as an SSMF 2 *number-received* signal. The register in the originating national exchange and the SSMF 2 register and the CCITT R2 code sender then release, and the forward connexion through the ISC is held by the incoming multi-purpose LRG.

It should be noted that the registers do not initiate a demand for the appropriate code sender (loop-disconnect or SSMF 2 or CCITT R2 or CCITT 5) until the router control has successfully established the connexion through the ISC to the appropriate type of outgoing LRG. However, in the case of calls requiring outgoing sending in CCITT 4, the registers must initiate the demand for a CCITT 4 code sender as soon as the sending and routing program instructions are received from the coder. This is necessary to ensure that the register/CCITT 4 code-sender association is established by the time a *proceed-to-send* signal (pulsed) is received from the distant ISC in response to a *seize* signal sent from the outgoing CCITT 4 LRG.

---

† Address complete, set-up speech condition with call charging

INTERNATIONAL MAINTENANCE CENTRE

The complexity and variety of automatic switching and signalling equipment to be found in ISCs has necessitated the provision of specialized test and monitoring facilities in the associated IMCs.[7, 8] The facilities offered by the TXK2 IMC equipment are described below. However, it should be noted that some differences exist between the earlier IMC equipments and those provided at Mondial; in particular, changes associated with the addition of CCITT R2 signalling and changes in ISC equipment configuration have been made.

The basic functions of an IMC are

(*a*) to receive fault reports from the UK national centres and the international centres,

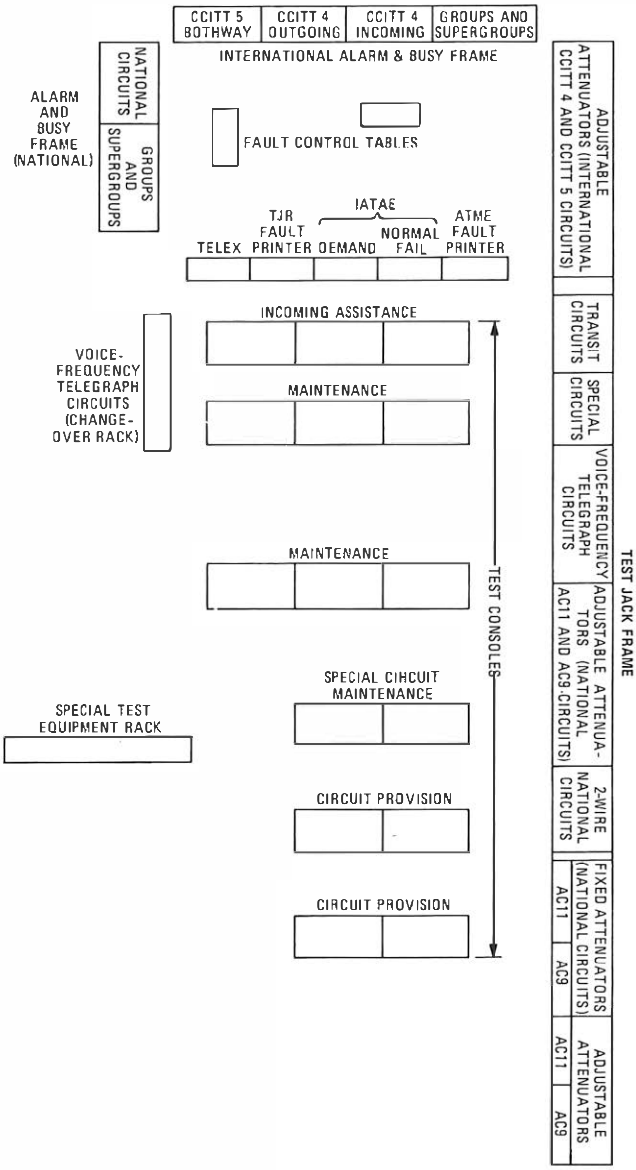
(*b*) to arrange for broad localization of faults in equipment categories such as signalling and transmission,

(*c*) to cooperate with other maintenance staff in the clearing of faults,

(*d*) to keep records of equipment faults and resulting out-of-service times, and

(*e*) to test new circuits for satisfactory operation prior to bringing them into service.

A typical layout of the equipment that comprises an IMC is shown in Fig. 6.



TJR: Trunk and junction routiner
ATME: Automatic transmission-measuring equipment

FIG. 6—Floor plan of typical IMC

Test Jack Frame

The test jack frame (TJF) provides line test-access points for circuits connected to the ISC, for through-connected circuits and for multi-channel voice-frequency telegraph circuits. The line test-access points can be patched via test extension circuits to test consoles, where the maintenance staff are able to monitor circuits or to intercept them and test to the external line or into the exchange. CALL-IN-PROGRESS lamps, which indicate the free or busy state of circuits connected to the ISC, are provided on the TJF. At earlier IMCs, variable attenuators for circuit-level adjustment were fitted on the TJF, these being in the repeater station at Mondial. Facilities also exist for connecting line-signal generators, known as *signal coders*, to the line test-access points to enable maintenance staff to check the line-signalling performance of international circuits, and to clear down locked-up circuits by injecting the appropriate signals.

Alarm and Busy Frames

The alarm and busy frames provide alarm indications relating to national and international circuits. Facilities are also incorporated for busying-out circuits, either as individual circuits or on a carrier-group basis. Alarm indications are also given of carrier group and supergroup failures.

Test Consoles and Access Arrangements

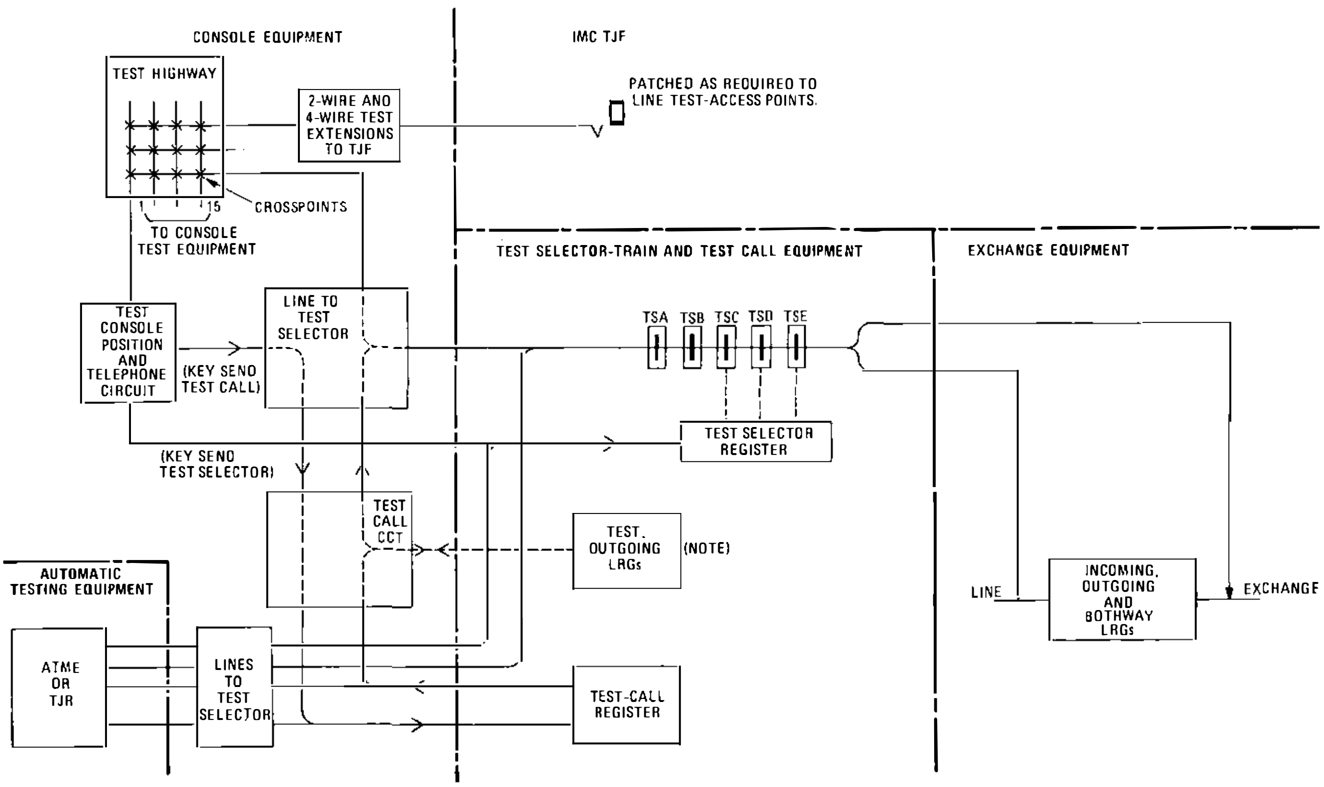
Cordless-type test desks (known as *test consoles*) are provided in TXK2 IMCs. From the test consoles (see Fig. 7), tests can be made on circuits that terminate at, or pass through, an international telephone services centre.

All consoles are universal in application and either contain, or have access to, test instruments such as an oscillator, transmission-level measuring set, frequency counter, loudspeaker amplifier and a psophometer. The facilities of a test console enable the maintenance staff to make transmission measurements, to monitor live traffic and to set up test calls. Call-progress indicators (CPIs), and DC testing and communication facilities are also provided. Test facilities of a specialized nature are also incorporated, but these require access to a special test-equipment rack.

The system arrangement for access between test consoles and circuits is shown in Fig. 8. Access to line test-points is

FIG. 7—TXK2 IMC test console

(By courtesy of Plessey Telecommunications Limited)



CCT: Circuit
TJR: Trunk and junction routiner
ATME: Automatic transmission-measuring equipment

Note. Test outgoing LRGs are automatically associated on testcalls via incoming LRGs

FIG. 8—IMC circuit testing arrangements

made via TJF test extensions whereas, to gain access to LRG exchange test points, the console uses a test-selector train. The latter consists of test-selector registers and 5 ranks of crossbar switches which are capable of switching 10-wire connexions.

Each of the LRGs in the ISC is given a unique 5-digit number for test-selection purposes. Receipt of this number from the test console enables the test-selector register to select the required path through test switches A to E to the LRG required for testing. The functions of the test-call register, which is accessed via the test-call circuit, are similar to those of the ISC registers, but it also has the ability to send the digits forward in any signalling-system mode to conform with the type of incoming or outgoing LRG being tested.

The console offers 3 basic modes for circuit transmission tests when used in association with the test-selector train: the testing officer can set up a parallel connexion on the line and exchange side of the LRG TRANSMIT and RECEIVE wires to monitor live traffic or carry out transmission measurements; he can back-busy the LRG, split the TRANSMIT and RECEIVE paths on the line and exchange side and carry out testing on the LRG in isolation, or he can make test calls using the exchange-side TRANSMIT and RECEIVE circuit paths. A test outgoing LRG of the appropriate type is automatically associated with the test-call circuit when test calls are made to incoming LRGs.

Call-Progress Indicators

CPIs decode and display signals transmitted on the circuit, and are an extremely valuable aid to maintenance staff in the localization of faults in signalling systems. The signal generating equipment, signal display panels and the equipment required for signal scanning are mounted on a rack in a room adjacent to the IMC. Each rack of CPI equipment deals with a specific national or international signalling system. The display panels are viewed by closed-circuit television cameras, any of which can be selected from the test consoles via a television switching matrix. A television monitor is provided on each of the consoles to display the decoded signals. Although the information relating to duration of signals is available only at the CPI rack, an indication is given at the test consoles if any of the signals are outside their predetermined limits. Digital signals are presented on the monitor as 1-out-of-15 characters, while supervisory signals appear as illuminated legends such as ANS (answer) or CLR (clear) or RLS (release).

At the end of the first call, the signal display on the test console television monitor is normally reset automatically by the start of the next call. However, if a faulty signal is detected, the automatic reset is inhibited, and the reset is under the control of the testing officer. Should it prove difficult to locate signalling faults by monitoring live traffic on a selected circuit, the signal-generating equipment (mounted on the CPI racks) provides facilities to inject appropriate line signals into the circuit under test. The CPI equipment is then used to check the circuit response.

Special Test-Equipment Rack

Test equipment not required for general testing and monitoring from test consoles is located on a special test-equipment rack. This includes such items as tape recorders, impulse-noise measuring sets, psophometer, group-delay measuring set and wave analyser. The test equipment is directly accessible from one or more consoles, and access from the other consoles is via the special test-rack jack-field, using patching cords.

Automatic Transmission-Measuring Equipment No. 2 and Trunk and Junction Routiner

To maintain a satisfactory transmission performance on all international and national outgoing circuits, it is planned to routine-test these circuits automatically by computer-controlled routiners, called automatic transmission-measuring equipment (*ATME No. 2*), and trunk and junction routiner (*TJR*). Both types of routiner obtain access to a circuit to be tested via the normal test-train access (see Fig. 8) provided for the test consoles.

The ATME No. 2, in conjunction with responding equipment (ATME responders) at distant ISCs, performs measurements in both directions of transmission for each of the international circuits under test. The tests include measurements of overall loss of the circuit at 800 Hz, the loss relative to 800 Hz at 400 Hz and 2400 Hz, and the noise present in the circuit. Additionally, the ATME No. 2 can check the signalling functions of the circuits.

The TJR can apply a single-frequency (800 Hz) transmission test tone to any of the outgoing national circuits to check the circuit loss or gain relative to the planned loss in the circuit under test. These tests require the national exchanges to be equipped with routiner-answering equipment.

Fault information derived from the ATME No. 2 and TJR tests is printed out on teleprinters located in the IMC.

CONCLUSIONS

The opening of Mondial ISC later this year will enable the BPO to provide CCITT R2 signalling facilities on minor continental routes. When the transfer is completed of minor-route (continental and intercontinental) traffic, which at present is being handled by other ISCs, Mondial will become the CT1 exchange in the UK.

ACKNOWLEDGEMENTS

The authors would like to thank their colleagues in the BPO and Plessey Telecommunications Limited for the help given in the preparation of this article.

References

[1] CCITT Green Book, Vol. VI-3.

[2] Modi, D. C., and Young, K. W. The TXK2 Switching System at Wood Street and De Havilland International Gateway Exchanges. *POEEJ*, Vol. 70, p. 86, July 1977.

[3] Corner, A. C. The 5005 Crossbar Telephone Exchange Switching System, Part 1—Trunking and Facilities. *POEEJ*, Vol. 59, p. 170, Oct. 1966.

[4] Mayne, R. T., Frame, P. B., and Young, K. W. The Development of International Telephone Switching Systems. *POEEJ*, Vol. 70, p. 81, July 1977.

[5] Tobin, W. J. E. The Signalling and Switching Aspects of the Trunk Transit Network. *POEEJ*, Vol. 60, p. 165, Oct. 1967.

[6] West, N. V., and Sylvester, D. J. A New Maintenance Aid for International Exchanges. *POEEJ*, Vol. 69, p. 191, Oct. 1976.

[7] Johnstone, E. C. De Havilland International Maintenance Centre. Introductory Handbook, ETE (ET 10.1.3), Oct. 1974.

[8] Walker, N., Blois, A. H., and Soames, S. T. Wood Street International Gateway Exchange and its Facilities. IPOEE Lecture Presentation Paper, 1970.

POEEJ: SUBSCRIPTION ORDER FORM

Those wishing to subscribe to *The Post Office Electrical Engineers' Journal* can do so by completing the relevant section of the order form below. British Post Office (BPO) staff should complete the upper section and send it to their local *POEEJ* agent or, in case of doubt, to the address shown; non-BPO staff should complete the lower section. A photocopy of this form is acceptable.

SUBSCRIPTION ORDER (BPO STAFF)

To: The Local Agent (*POEEJ*), or
The Post Office Electrical Engineers' Journal (Sales),
2–12 Gresham Street, London EC2V 7AG.

Please arrange for me to receive *The Post Office Electrical Engineers' Journal*. I have completed the form opposite authorizing deductions from pay to cover the special annual subscription of £1·44.

Date.................................. Signature..................................

Name and initials (in block capitals) .... Rank..................................

Official address ....

....

....

The Post Office Electrical Engineers' Journal: Authority for Deduction from Pay

I, ...

(name in full, surname first in block capitals), authorize the deduction from my salary or wages, until further notice, of the sum of 12p per month/3p per week for 48 weeks for payment to the Managing Editor, *The Post Office Electrical Engineers' Journal*, on my behalf.

Date.................................. Signature..................................

Official address ....

....

Rank.................................. Pay No..................................

Area/Dept. ....

YEARLY SUBSCRIPTION ORDER (NON-BPO STAFF)

To: *The Post Office Electrical Engineers' Journal* (Sales),
2–12 Gresham Street, London EC2V 7AG.

Please supply 4 quarterly issues of *The Post Office Electrical Engineers' Journal*. I enclose a cheque/postal order for the sum of £3·20 (Canada and the USA: $6·50) to cover the yearly subscription.

(Cheques and postal orders, payable to "*The POEE Journal*", should be crossed "& Co." and enclosed with the order. Cash should not be sent through the post.)

Name ....

Address ....

....

....

Please state with which issue you wish your subscription to commence (April, July, October or January)..................................

District Principal Exchange Working in the Leeds Charging Group

M. BENNETT†

UDC 621.395.31:621.395.34

This article describes a relief scheme in the Leeds charging group for the routing of local-fee traffic in an environment of common-control local telephone exchanges. The scheme provides a tandem switching capability at selected local exchanges sited on the periphery of the charging group.

INTRODUCTION

Tandem traffic is an ever-present problem in areas of high population density and high telephone penetration. Historically, tandem traffic is routed via large main telephone exchanges and is distributed over a radiating cable network. These large exchanges are, with only rare exceptions, located in city centres where building redevelopment and road traffic rearrangements often take place. These factors create a general disruption to city life and, combined with large volumes of vehicular movement, create practical problems and difficulties for telephone cable provision and rearrangement.

The replacement of Strowger telephone switching equipment by common-control systems, whether in modernization schemes or because of growth in traffic demand, has highlighted a need to review and analyse the methods currently adopted for the routing of local traffic.

The continued growth of the junction network, predetermined by historic number-oriented routes between Strowger exchanges, can lead to an uneconomical routing plan that negates many of the advantages of modern common-control telephone exchange systems. In Leeds, the choice of TXE4 to replace the centrally-sited main exchange has compounded the tandem traffic problem, in that the TXE4, at least in its early form, has a limited tandem traffic capability; a capability that in many cases cannot be exploited because capacity must be reserved for the use of existing and forecast direct-dialling-in facilities, a requirement more likely to be needed in city centres than elsewhere.

TO \ FROM	ADEL	ARTHINGTON	ARMLEY	BARWICK	CHAPELTOWN	CROSSGATES	DRIGHLINGTON
	%	%	%	%	%	%	%
ADEL	19·6	5·6	0·74	1·47	0·85	0·82	0·37
ARTHINGTON	1·24	9·2	0·09	0	0·07	0·06	0
ARMLEY	1·83	1·85	10·9	1·1	2·7	2·2	3·2
BARWICK	0·05	0	0·06	15·54	0·06	0·38	0
CHAPELTOWN	1·11	0·74	1·63	0·53	5·9	1·4	0·55
CROSSGATES	2·33	1·42	1·72	11·55	3·57	18·15	0
DRIGHLINGTON	0·04	0	0·14	0·06	0·05	0·02	
GARFORTH	0·46	0·25	0·73				

FIG. 1—Extract from a community-of-interest matrix

The foregoing outlines the situation that exists in the Leeds charging group, a charging group that contains one of the largest conurbations and possibly the largest non-director exchanges in the UK.

A small team, drawn from local Area and Regional staff having experience of modern systems and traffic routing, studied the many problems within the Leeds charging group. It was decided that the best of the many possible solutions to the local-traffic routing problems in the Leeds area was partly to remove the switching requirement from the one central unit and, where possible, effectively reduce the overall tandem needs. This rationalization of switching requirements was to be achieved by the following methods:

(*a*) by providing existing, suitably sited, peripheral telephone exchanges with a tandem switching capability to handle a portion of the charging-group tandem traffic within their own geographical *districts*, and

(*b*) by providing direct routes from terminal exchanges on a traffic justification basis, using modern-exchange discrimination facilities.

SELECTION OF PERIPHERAL TANDEM EXCHANGES AND DISTRICTS

The selection of exchanges for the district tandem function, although greatly influenced by traffic movements, was made with due consideration of the existing junction cable network and the present or proposed modern exchange system at each location.

The importance of accurate route-calls information, obtained from a *route-calls recorder*, cannot be over-emphasized. This information provided the basic planning data for the selection of the tandem exchanges and the geographical districts they were to serve. A movement away from the data being presented in a dialled-number form was achieved, and traffic quantities were presented as a percentage of the overall originating traffic at each exchange. Accuracy of results was assured by siting the route-call recorders at traffic sources rather than at existing tandem points, thus ensuring greater confidence in completed records. The resultant data identified all inter-exchange community interests, and was the fundamental basis for all decision making. An extract from a community-of-interest matrix is shown in Fig. 1.

The insertion of present and future traffic quantities, assessed from connexion and calling-rate forecasts and derived by use of the community-of-interest matrix, indicated that the optimum number of districts was 4; the geographical areas to be served by each of the district tandems was then decided. Consideration of exchange equipment use and the

---

† North Eastern Telecommunications Region

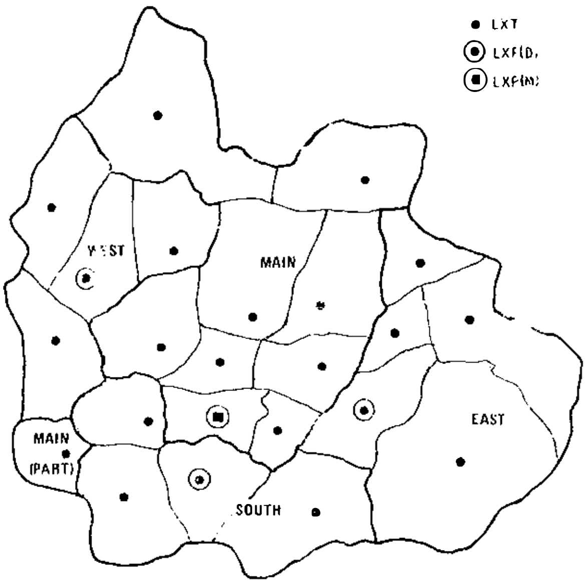


FIG. 2—District boundaries

availability of external plant resulted in the selection of 2 existing TXK1 exchanges to cover the south and west districts of the charging group. A new TXE4 exchange was proposed to cover the east district. The Leeds main exchange was retained to form a district tandem serving the historic satellite exchanges, and to act as a distributive tandem for exchanges not justifying access to the other district tandems.

The selected districts consist of 4 compact geographical areas, as shown in Fig. 2. One exchange has little interest either in traffic or line-plant terms with any of the selected districts; therefore, it was decided to retain this exchange within the main district.

EXCHANGE STATUS AND DISTRICT NOMENCLATURE

It became evident during the study that new nomenclature was required to supplement existing terminology. The following terms are now in use in the Leeds area.

District

A district is a geographical area within the charging group, and consists of a group of local exchanges, one of which is designated as a principal local exchange.

Main District

The main district contains, and immediately surrounds, the main principal local exchange.

Suburban District

A suburban district is outside the main district, but is within the charging-group boundary.

Home District

A district containing a specific local exchange is termed the home district when referring to the district containing that exchange.

Foreign District

A foreign district is outside a home district but is within the same charging group.

Terminal Local Exchange

A terminal local exchange (LXT) is an exchange that receives terminal traffic only.

Principal Local Exchange

A principal local exchange (LXP) is equipped to switch tandem traffic to all the exchanges in the home charging group.

District Principal Local Exchange

A district principal local exchange (LXP(D)) is equipped to provide a tandem capability to disperse traffic to a defined geographical area of the home charging group.

Main District Principal Local Exchange

A main district principal local exchange (LXP(M)) is situated within the main district and is provided with a tandem switching capability to disperse traffic to the whole charging group in addition to acting as the local tandem exchange for the main district.

MANDATORY JUNCTION ROUTES AND TANDEM-EXCHANGE TRAFFIC GROWTH

The LXP(D) and LXP(M) exchanges switch traffic from common-control exchanges only and, initially, will supplement the main exchange Strowger tandem unit. Under the impetus of modernization, a balance can be maintained such that further Strowger tandem growth will be curtailed. It was important, in view of the high traffic growth in the Leeds charging group, to avoid excessive central tandem requirements and to establish the LXP(D)s at an early date. The south and west LXP(D)s were of TXK1 design and were readily prepared. However, the east LXP(D) is not scheduled to achieve common-control status until the early 1980s; therefore, part of the Strowger local unit was trunked to give a common-control LXP(D) appearance in advance of the TXE4 installation; thus the east LXP(D) was created. The LXP(M) has been ordered as part of the modernization programme, and the initial unit of 8100 connexions has been provided with a tandem traffic capacity of 333 erlangs to cater for junction tandem growth within the 4-year design period of the initial installation. Extension to the LXP(M) is now planned and, as a direct result of the district principal scheme, no additional tandem capacity is required.

Provision of junction routes that are classified as *mandatory*

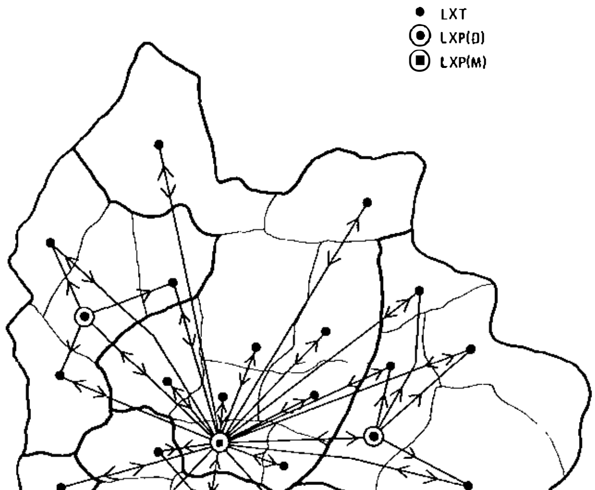


FIG. 3—Mandatory-route map

is in line with standard practice, in that the principal exchanges have outgoing routes to all exchanges which they serve; incoming mandatory routes are restricted to the LXP(M) exchange only. Traffic levels indicated that routes to home district LXP(D)s should be provided only where justified.

The mandatory routes have now been planned and the scheme is to be operational by late 1979. The mandatory-route map is shown in Fig. 3. The mandatory routes are

(*a*) LXP(M) to all LXTs in the charging group,
(*b*) LXP(M) to all LXP(D)s in the charging group,
(*c*) LXP(D)s to all LXTs in the home districts,
(*d*) all LXTs to the LXP(M), and
(*e*) all LXP(D)s to the LXP(M).

ROUTING DISCIPLINE AND JUSTIFICATION

Most routing plans suffer human interpretation, and traffic routing anomalies can arise. It was vital to establish a routing discipline encompassed by well defined rules, thus ensuring that traffic is routed (and routes are provided) on an economic basis. The type of routes to be justified fall into 6 categories:

(*a*) LXT to home district LXT,
(*b*) LXT to foreign district LXT,
(*c*) LXT to home district LXP(D),
(*d*) LXT to foreign district LXP(D),
(*e*) LXP(D) to foreign district LXT, and
(*f*) LXP(D) to foreign district LXP(D).

Discrimination facilities of a TXE2 exchange restrict its tandem access via the LXP(M) only.

In conjunction with the route-justification rules, the traffic levels assessed from the community-of-interest matrix were used to determine the routes that were required. Route justification was based on the following considerations:

(*a*) for LXT to LXT (home or foreign district) routes, by the amount of traffic generated by the originating LXT and destined for the objective LXT;

(*b*) for LXT to LXP(D) (home or foreign district) routes, by the sum of traffic quantities generated by the originating LXT and destined for the objective district exchanges not accessed via direct justified routes;

(*c*) for LXP(D) to LXT (foreign district) routes, by the amount of traffic generated by the LXP(D) only that is destined for the objective LXT; and

(*d*) for LXP(D) to LXP(D) (foreign district) routes, by the sum of traffic quantities generated by the originating LXP(D) only and destined for the objective district exchanges not accessed via direct justified routes.

Examples of justified routes from LXT and LXP(D) exchanges are shown in Fig. 4, which shows a typical plan of route provision.

To determine the most suitable routing of originating traffic, the justification rules and routing preferences were included in an algorithm that illustrated the thought processes. With knowledge of the originating and objective exchange status, combined with an understanding of the justification rules, use of the algorithm enables the most appropriate route to be selected (see Fig. 5).

FIG. 4—Justified-route map

TABLE 1

Digit-Sending Rules

Route	Number of Digits Sent
LXT to LXT (Note)	5 digits on one route; where objective exchange is TXE2, 4 digits are sent
LXT to LXP(D)	6 digits on one route; if the route carries no tandem traffic, then the LXP(D) assumes LXT status and 5 digits are sent (Note)
LXT to LXP(M)	6 digits on one route
LXP(D) to dependent LXT	4 digits (one route per 10 000 numbering range)
LXP(D) to foreign LXT (Note)	5 digits on one route
LXP(D) to LXP(D)	6 digits on one route; if the route carries no tandem traffic then the objective LXP(D) assumes LXT status and 5 digits are sent (Note)
LXP(D) to LXP(M)	6 digits on one route
LXP(M) to LXT	4 digits (one route per 10 000 numbering range)
LXP(M) to LXP(D)	4 digits (one route per 10 000 numbering range)

Note: Where the objective exchange is a TXE4 and is served by a numbering range having different D-digits, 6 digits are sent

TRAFFIC AND ENGINEERING DESIGN PROBLEMS

Extensions to common-control exchanges already encompassed in the district-tandem scheme are now in hand. A problem could arise at exchanges where the provision of additional direct routes lowers the traffic level on the objective LXP(D) route below a route-justification level. Therefore, to maintain a standard routing strategy, it was decided that the LXP(D) route should be ceased if the level of traffic did not rise to the justified level within the 5-year annual schedule of circuit estimates review period.

Another problem, relating to post-dialling delay, was anticipated with the use of TXK1 exchange systems at 2 LXP(D) locations. (The post-dialling delay on tandem calls was considered to be a service hazard.) It has been established therefore that all LXT exchanges served by LXP(D)s shall receive 4 digits on routes carrying tandem traffic and, to this end, one route per 10 000 numbering range has been provided; this reduces post-dialling delays in advance of the intro-

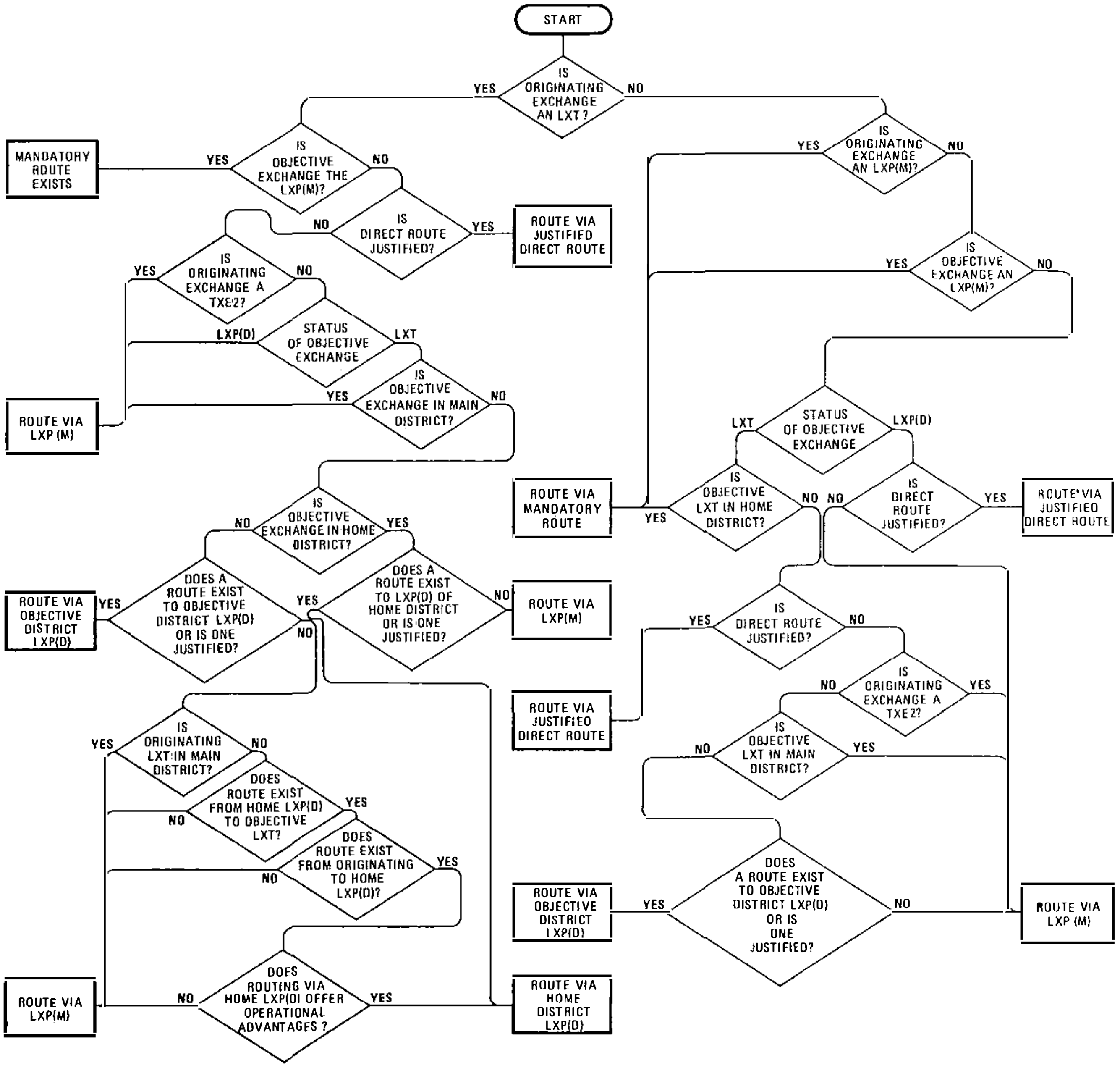


FIG. 5—Routing discipline for the switching of home charging-group traffic from common control exchanges using principal local exchanges

duction of multi-frequency high-speed signalling between common-control exchange systems.

A standard route-digit sending programme was derived to standardize engineering designs and reduce to a minimum the amount of restrapping of exchange registers and control equipment. All common-control engineering designs in the Leeds charging group are programmed within the digit-sending rules given in Table 1.

LONGER-TERM TANDEM-TRAFFIC FORECASTS

For a wholly common-control environment, the maximum tandem requirement forecast for each LXP(D) was assessed as being in the order of 100 erlangs; this was derived from average route-justification levels and maximum possible tandem-traffic requirements. The maximum tandem traffic to be switched by each LXP(D) is given by

$$EX(N-3) - EXG \text{ erlangs},$$

where E is the average route-justification level (erlangs), X is the number of LXT exchanges in the district served, N is the number of exchanges in the charging group, and G is the number of TXE2 exchanges in the charging group.

Using the above formula, for the west district where $E = 4$, $X = 3$, $N = 24$ and $G = 2$, a maximum tandem requirement of 228 erlangs is given.

From information derived from the community-of-interest matrix, some 60% of traffic for the west district will eventually be routed direct, giving a maximum tandem requirement of 100 erlangs. The situation at other suburban districts proved similar, and the overall result is the removal of 300 erlangs of tandem traffic from the main district tandem exchange, and a general reduction in overall tandem needs.

RATIONALIZATION OF INCOMING ADJACENT-CHARGING-GROUP TRAFFIC

The routing of traffic within a home charging group on a justfication basis under the district principal scheme is seen as an acceptable strategy in compliance with long-term plans and modern exchange system facilities. Investigation showed,

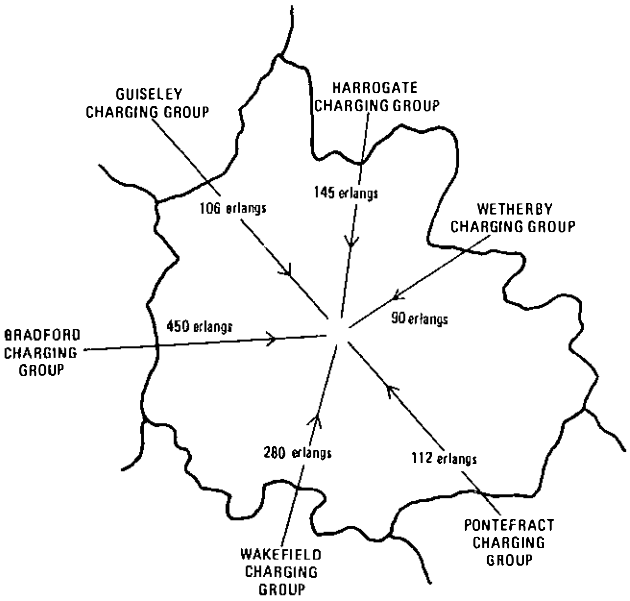


FIG. 6—Incoming adjacent-charging-group traffic forecast for 1979

however, that although the removal of quantities of home charging-group tandem traffic outside the central complex greatly eased the problems associated with the routing of tandem traffic via the traditional central tandem, it by no means removed it entirely.

Assessment of short-term forecasts indicated that, by 1979, traffic originating in adjacent charging groups and destined for Leeds exchanges would be approximately 1200 erlangs (see Fig. 6), and a high growth rate was expected. To accommodate the expected growth in traffic in the traditional manner would require substantial amounts of additional local-exchange equipment and incur, unnecessarily, double, and in some instances treble, switching costs.

The establishment of the district principal exchange scheme offered an opportunity to adopt a similar method of reducing and removing incoming adjacent-charging-group tandem growth away from the central area; a method adopted to comply with the aims of national number dialling.†

Incoming non-director adjacent-exchange equipment and non-director adjacent-charging-group traffic growth will be met by the provision of justified routes from adjacent-charging-group common-control sources to the Leeds LXT and LXP(D) units. The method of route justification by community-of-interest matrices, connexion and calling-rate forecasts and modernization programmes are all used to identify future junction network requirements.

The incoming adjacent-charging-group routes are all provided from common-control sources on traffic-level justification; for this purpose, all originating exchanges are considered to have LXT status. Three types of route are provided where justified, but technical limitations restrict the provision at TXE2 exchanges to a route to the LXP(M) only.

The 3 types of route and the route-justification rules for each case are:

(*a*) LXT to LXT, justified by the amount of traffic generated by the originating LXT and destined for the objective LXT;

(*b*) LXT to LXP(D), justified by the sum of traffic quantities generated by the originating LXT and destined for the objective district exchanges not accessed via direct justified routes; and

(*c*) LXT to LXP(M), justified by the sum of traffic quantities generated by the originating LXT and destined for the objective-charging-group exchanges not accessed direct or via LXP(D)s.

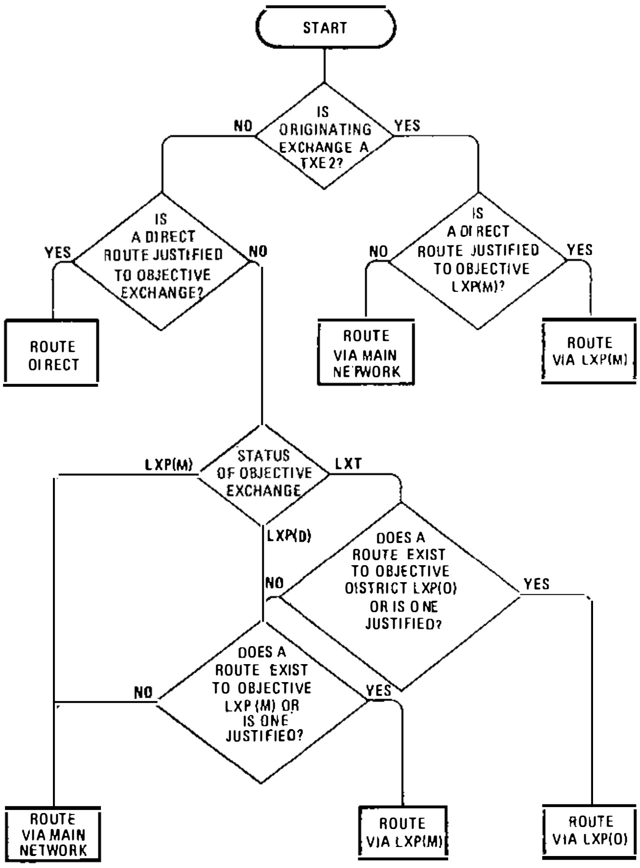


FIG. 7—Routing discipline for the switching of traffic under national number dialling from adjacent-charging-group common-control exchanges to a home charging group using district principal local exchanges

A simple algorithm was produced (see Fig. 7) showing the routing discipline for the switching of traffic under national number dialling from adjacent-charging-group common-control exchanges to a home charging group using district principal local exchanges. The algorithm has exchange system limitations and routing preferences built in, the final choice being to route via the main network. In the short term, prior to national number dialling, this traffic is switched via the Strowger level-9 junction tandem selectors at group switching centres.

CONCLUSION

The district principal scheme is seen as a rational solution to local routing problems in a common-control environment within the Leeds charging group. The scheme, encompassed by well defined rules, has introduced a standard approach to local traffic routings, and given greater confidence in traffic and engineering designs. Annual updates of the community-of-interest matrices will keep pace with any change to the overall routing strategy and should foster confidence in future planning levels.

---

† National number dialling is one of the long-term aims of the British Post Office. The abolition of local code dialling and its replacement by a 2-part dialling procedure will be achieved after completion of all national number group linked-numbering schemes. The 2-part procedure will consist of a first-part national number group code and a second-part subscriber's linked-numbering scheme identity; for example, 0532 371941

Optical-Fibre Transmission Systems: The 140 Mbit/s Feasibility Trial

R. W. BERRY, B.SC.(ENG.), A.C.G.I., and I. A. RAVENSCROFT, C.ENG., M.I.E.E.†

UDC 621.391.63: 666.2

This article describes the feasibility trial of an optical-fibre transmission system operating at 140 Mbit/s, which has potential for main-network use. The system has been developed by British Post Office (BPO) Research Department staff. The route over which the system is being evaluated initially is between the BPO Research Centre at Martlesham Heath, and Kesgrave, a distance of 5·75 km.

INTRODUCTION

The development of a multimode graded-index type of optical fibre has progressed rapidly over the past few years, to the extent that optical fibre now has the potential for main-network as well as for junction-network applications. The performance of this type of fibre depends largely upon maintaining control of the index profile in the core, but considerable strides in fibre-drawing processes have improved the available tolerances in the product. The Martlesham–Ipswich feasibility trial of an optical-fibre transmission system, planned for the junction system and operating at 8·448 Mbit/s, developed into a natural test-bed for experiments at 140 Mbit/s. Exploratory system measurements[1] at the higher bit-rate were made shortly after the initial installation in February 1977 of the Martlesham–Kesgrave section of the link. The detailed performance of the fibre will be recorded in a future article to be published in this *Journal*. In brief, the loss over the 5·75 km section of optical-fibre cable installed between Martlesham Heath and Kesgrave was measured as about 25 dB with an electrical bandwidth of 160 MHz. This indicates a transmission capacity of at least 300 Mbit/s, which is a substantial margin over the requirements for 140 Mbit/s operation. Therefore, the cable was extended to 8 km to provide a more realistic assessment of the system capability.

In outline, the equipment requirements for 140 Mbit/s operation are the same as for 8·448 Mbit/s. The essential differences are that, for high speed of operation, the effects of material dispersion in the fibre in the spectral window of 800–850 nm, plus the reduced sensitivity of the receiver, prohibit the use of light-emitting diodes (LEDs). Therefore, a laser is used to achieve suitable section lengths. Switch-on delay in a laser, however, becomes significant at high bit-rates, and special level-control circuits are necessary to reduce this delay to acceptable limits, and to maintain a suitable pulse format to line. Bandwidth limitations in the fibre also begin to take effect at 140 Mbit/s as the section length is increased, and a small measure of equalization is therefore required in the receiver to obtain optimum overall performance.

High-speed operation demands precise timing information in the digital system, and necessitates the use of emitter-coupled logic. This adds to the problems of achieving low power consumption in repeaters required for main network applications where remote power-feeding will be used, as in the present-day coaxial-cable systems. Repeater spacings are not critical, provided they are below the maximum required for adequate transmission performance, and repeaters can therefore be housed in established duct and manhole installations. A repeater which incorporates automatic gain control (AGC) to accommodate a substantial range of input signals removes constraints which may otherwise be applied to the repeater spacings. In other respects, the optical-fibre medium is stable, and is not subject to variations caused by, for example, temperature changes, so that continuously compensating equalizers are not necessary.

The basic repeater in an optical-fibre transmission system (see Fig. 1) consists, in the receiving module, of an opto-electronic transducer (avalanche photodiode) which converts the incoming optical impulses into their electrical equivalent, a low-noise amplifier, equalizer, AGC amplifier and finally a regenerator. The transmitting module incorporates the laser with its drive and bias-control circuits. Power supplies for repeaters are derived from DC–DC converters, driven from a standard 50 mA constant-current source.

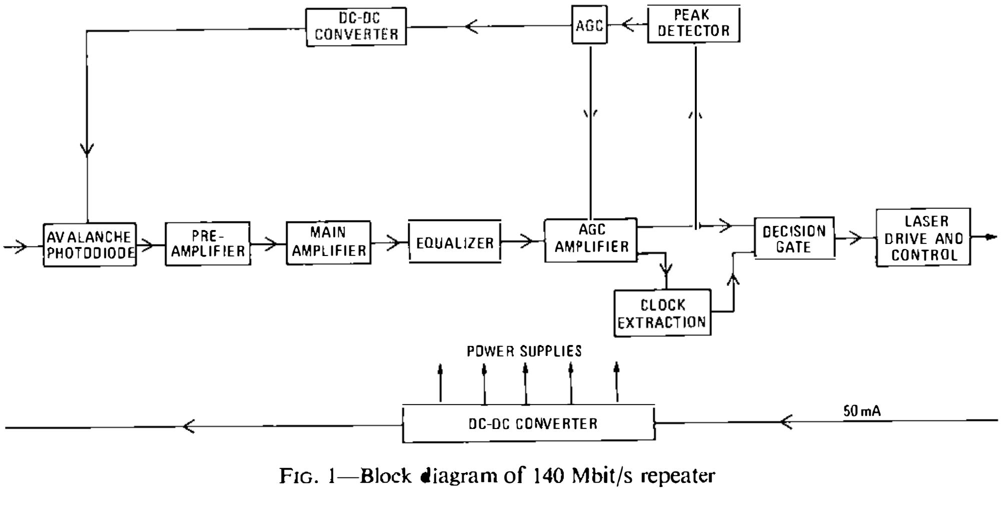


FIG. 1—Block diagram of 140 Mbit/s repeater

---

† Research Department, Telecommunications Headquarters

FEASIBILITY TRIAL ARRANGEMENTS

The feasibility trial has been planned in 2 stages. Under stage 1, bothway terminals are to be installed at the British Post Office (BPO) Research Centre, Martlesham Heath, and the Kesgrave telephone exchange, and satisfactory system performance and margins will be established over the 6 km (approximately) route. For stage 2, the cable route is to be extended as far as practicable, and a buried repeater will be installed in a footway box to provide a repeatered loop between send and receive terminals at the BPO Research Centre. Installation and measurement of the cable was completed during May 1977, and stage 1 is well in hand; buried repeater construction is under way, and stage 2 is expected to commence soon.

TERMINAL EQUIPMENT

The terminals have been constructed in 62-type equipment practice. At Martlesham, 2 equipment racks have been provided; one rack contains power supplies, fuse alarms, and other common services for up to 3 experimental transmission systems, and the second rack is used for test and ancillary equipment. Similar, but reduced, rack accommodation is provided at the Kesgrave telephone exchange.

The 140 Mbit/s transmission equipment is mounted on one 62-type equipment shelf; the 2-fibre cable terminates in a jointing box on the back of the equipment rack, and 2 single-fibre cables extend the optical paths to half-couplers[2,3] mounted at the back of the equipment shelf. The transmit and the receive/regenerator units have half-couplers mounted at the rear to complete the optical paths when inserted in the shelf.

A block diagram of the 62-type equipment shelf layout is shown in Fig. 2. Data and clock inputs and outputs are taken to a cross-connexion panel to provide flexibility. In the present design, on the transmit side of the shelf, data and clock inputs at 139·264 Mbit/s are taken to the encoder; the scrambler unit will be incorporated in later tests. The encoded outputs, at 159·159 Mbit/s, are extended to the transmit unit. In the transmit unit, the data signal is converted into a current drive for direct modulation of the semiconductor laser, which is mounted in the half-coupler at the rear of the unit. The optical output of the laser is coupled directly into the fibre via a lens-coupler, and a take-off port in the laser half-coupler provides a subsidiary output which is used for automatic level control of the optical signal. Access is provided to the electrical control signals for monitoring purposes.

On the receive side of the shelf, the optical input signal is coupled, via the lens-coupler, directly to the detector, which is an avalanche photodiode (APD). The detected signal is amplified and equalized, and a clock signal is recovered from the data stream. Clock and data signals are passed to a decision gate, where the 159·159 Mbit/s data signal is regenerated. Optical and electrical AGC is provided, and access to the control signals is given for monitoring purposes. Data and clock outputs are extended to the decoder unit for translation to the required 139·264 Mbit/s output. The decoder also provides error-detection and re-alignment facilities; the error-detection output is used for monitoring and to provide PROMPT and URGENT alarm indications.

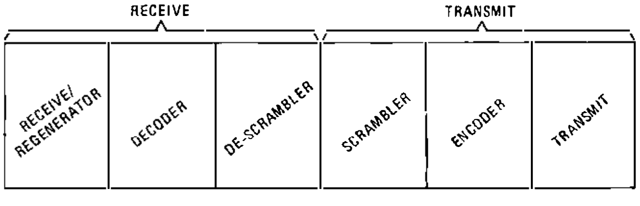


FIG. 2—62-type equipment shelf layout for 140 Mbit/s system

CODING ARRANGEMENTS

Coding requirements for digital line systems are well known[4] and apply, in principle, to optical-fibre transmission systems. At the time when the Transmission and Data Systems Division of the BPO Research Department was requested to design and develop suitable coding arrangements for the present 140 Mbit/s systems, it had been decided that binary modulation of the laser would be adopted, that the line rate should not be greatly in excess of the information rate (although the fibre bandwidth was not then known), and that the line code should permit relatively straightforward repeater design. With these restrictions, the 7B–8B *balanced disparity code* was developed for current use.

The design of the balanced-disparity code allows for the use of the output code word 01010101, or its inverse, for an *alarm inhibit* signal, and code words with more than 3 like digits at the beginning or end of the word are rejected. The resultant coding table uses 67 zero-disparity words, 48 words with disparity ±2, and 13 words with disparity ±4.

Timing information in the line code is adequate, low-frequency variations in the mean DC level are small, and the limiting of any sequence to a maximum of 6 *ones* and 6 *zeros* ensures that there are no dynamic-range problems in the integrating receive amplifier. Error detection and re-alignment in the decoder are achieved by monitoring end-of-word disparity for violation of the coding rules.

For a given fibre loss and bandwidth, and for given device speeds and efficiencies, a particular coding method should exist to give the optimum economic advantage. The 7B–8B code requires relatively complex terminal equipment, and allows the use of relatively simple repeater equipment at a penalty of increasing the line rate by approximately 14% to 159·159 Mbit/s. For the present experimental system, the fibre bandwidth is about 160 MHz, and no significant performance reduction is incurred. Work is continuing to investigate the economics of other forms of coding so that optimum rules for future system use can be defined.

TRANSMIT UNIT

The data output from the encoder is fed to the transmit unit, which contains the laser pulse drive and automatic level-control circuitry. The laser, manufactured by STL, provides an optical output of a wavelength of approximately 840 nm, and has a threshold current of the order of 150 mA at room temperature and a slope efficiency of, for example, 0·3 W/A; once threshold is reached, a drive current pulse of as little as 10 mA peak may be sufficient to produce the recommended peak optical output power of 3 mW.

However, if a current pulse of 160 mA (threshold plus pulse-current) is applied directly to such a laser at room temperature, a finite time is required (in this example, approxi-

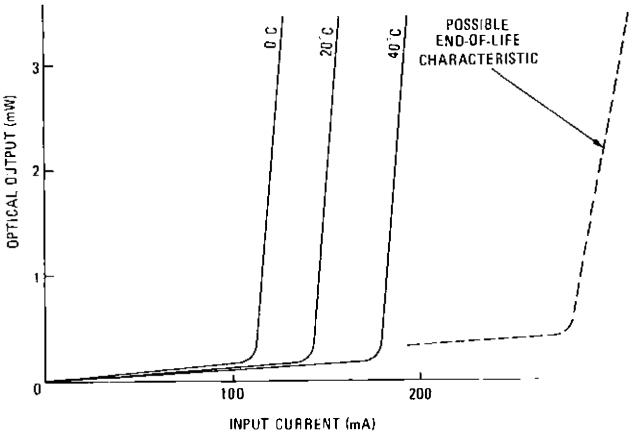


FIG. 3—Typical laser transfer characteristic

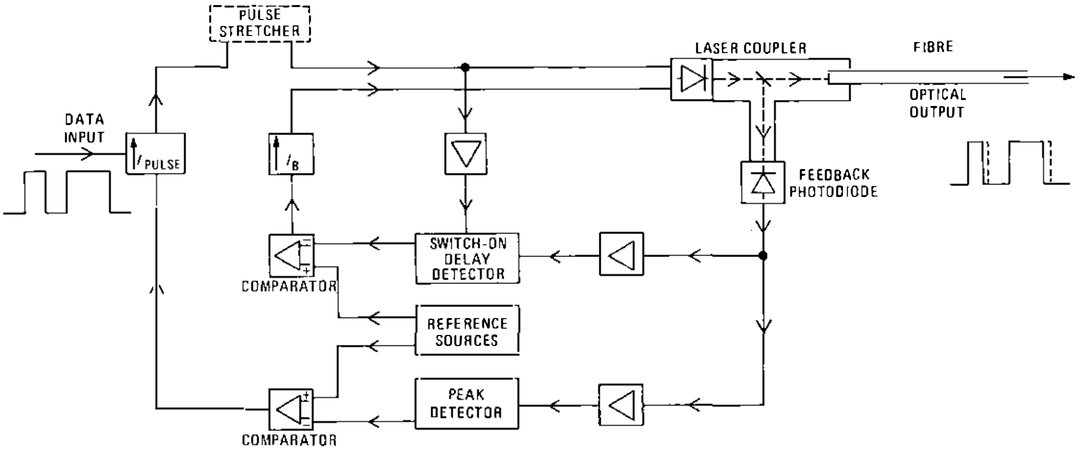


FIG. 4—Block diagram of transmit unit

mately 10 ns) before laser action is initiated. This switch-on delay is much too long for operation at 140 Mbit/s, and it is necessary to apply a bias current to lasers having such values of threshold current to obtain satisfactory system operation. To a lesser extent, the switch-on delay is also dependent on operating temperature, introducing a possibility of variation in optical pulse width with temperature. Optical pulse amplitude could also be affected by changes in threshold current and slope efficiency with temperature, and also with ageing in state-of-the-art devices (see Fig. 3).

It was important that the design philosophy adopted for the laser control circuit should ensure satisfactory operation over the expected range of working conditions. At the design stage, it was considered that, irrespective of temperature and ageing effects on laser performance, the optical output to line should remain constant until the end of the life of the laser; the present level-control circuit design meets this requirement. In addition, although the switch-on delay problem could have been avoided by running the laser biased above threshold, there is a significant power penalty paid at the receiver under this condition, due to the increase in level-dependent noise. Because the present 140 Mbit/s system uses non-return-to-zero (NRZ) pulses of pulse width 6·28 ns, a variation of even 1 ns in switch-on delay could cause a significant percentage change in pulse width, and it was therefore decided to use constant switch-on delay as a criterion in the control circuit.

For a double-heterostructure single-injection laser of the type used, switch-on delay, t_D, is given by

$$t_D = \tau \log_e \left\{ \frac{I_{PULSE}}{I_B - (I_Q - I_{PULSE})} \right\},$$

where τ is the carrier lifetime (approximately 3·5 ns), I_Q is the laser threshold current, I_B is the laser bias current, and I_{PULSE} is the pulse current (superimposed on the bias current).

For $$t_D = 1 \text{ ns},$$

$$\frac{I_B - I_Q}{I_{PULSE}} \approx -0{\cdot}25,$$

so that, for a pulse current of 10 mA, I_B must stay 2·5 mA below threshold and track the threshold current as it varies.

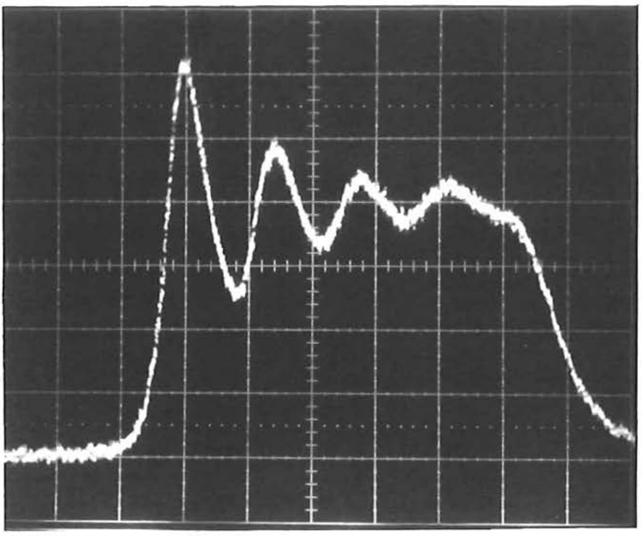
A block diagram of the transmit unit is shown in Fig. 4. A small fraction (approximately 15%) of the total optical output power is detected by a fast-operating photodiode, and the amplified pulse-train output is fed to a circuit where it is compared with a pulse train derived from the drive current. The output voltage is proportional to the switch-on delay. This voltage is compared with a reference voltage, and the difference is used to control the bias current to the laser, so as to maintain a constant switch-on delay. In the present system, NRZ pulses are used and, in a stream of digital *ones*, therefore, only the first pulse in the train suffers delay and produces an output from the delay-detection circuit. To avoid undue dependence of the control voltage on the pulse pattern, the output is integrated and smoothed prior to comparison with the reference source, so that it is the mean switch-on delay which is used as a control. Tests using a 2^{10}-1 pseudo-random sequence have shown that, over a temperature range of 40°C, a mean switch-on delay of 600 ps can be maintained, with maximum excursions during the sequence of not more than 300 ps, which is adequate in system applications. It is believed that part of the variation is due to pulse-train patterning effects on laser operation, and this is to be investigated further.

Control of the peak pulse output-power level is effected in a similar fashion by peak-detecting the fast-operating photodiode output, comparing it with a reference source, and controlling the drive-current amplitude accordingly.

Protection circuits have been incorporated to ensure that, under fault conditions, the laser cannot be overdriven either by the bias current or the pulse current.

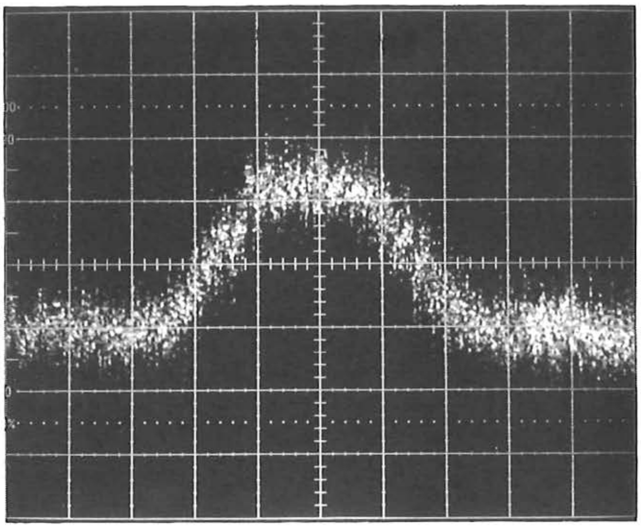
When operating below threshold, as in the digital *zero* condition, laser emission is spontaneous, and radiation is emitted over a wide angle. The lens-coupler has a limited acceptance angle and does not focus all the emitted power on to the fibre, so that approximately only 100 μW is launched into the fibre. This value remains sensibly constant during operation. Above threshold, light is emitted over a reduced angular range and, at the peak level (digital *one*), most of the laser light emitted is launched into the fibre. With the present system, the laser is slightly under-run and provides a peak power output of approximately 1 mW into the fibre. The ratio of launched power at the *zero* level to that of the peak *one* level is termed the *extinction ratio* and, in this system, has a value of 0·1 approximately. The effect of extinction ratio is discussed later in this article.

Present lasers produce a transient oscillation at switch-on, with a period of approximately 1–2 ns. The output optical signal has this oscillation superimposed upon it (see Fig. 5). At switch-on, the rise time of the optical pulse is controlled by this transient condition but, at switch-off, the fall-time of the pulse follows closely the current-pulse shape. To ensure that the transient oscillation does not prolong the line pulse, undershoot in the current waveform is provided to give fast switch-off action. The current drive and optical-output wave-



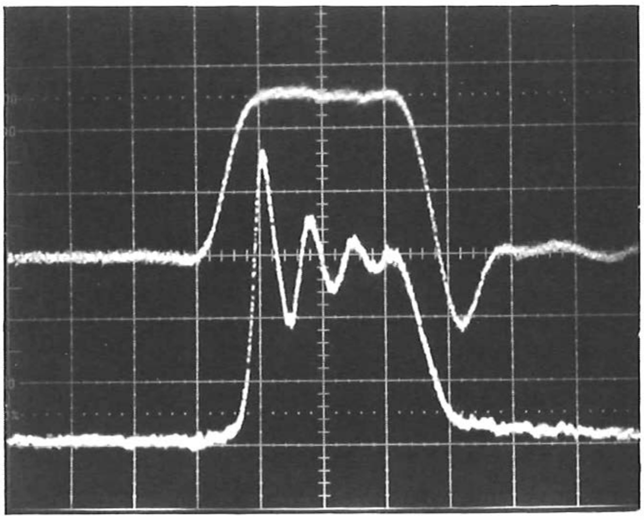
Time scale: 1 ns per division

FIG. 5—Laser output pulse waveform



Time scale: 2 ns per division

FIG. 7—Optical pulse waveform at the end of 5·75 km of fibre



Time scale: 2 ns per division

FIG. 6—Current-drive and optical-output waveforms, showing switch-on delay

forms applied to the switch-on delay detector are shown in Fig. 6. The trailing edges of the pulses are aligned, and the switch-on delay at the leading edge can be clearly seen.

In a practical circuit, the presence of switch-on delay on only the first pulse in any sequence of digital *ones* could introduce undesirable effects at the timing-recovery circuit in the receiver. To avoid such effects, a pulse stretcher (see Fig. 4) extends each sequence of digital *ones* by the amount of switch-on delay, so that the line pulses are all of the correct width; that is, 6·28 ns.

TRANSMISSION MEDIUM

Details of the fibre and cable used in the system will be given in later issues of the *Journal*. It is, perhaps, sufficiently informative to record here that the 25 dB optical loss of the 5·75 km section is due mainly to absorption and scattering centres in the fibre-core material; fibre joints contribute, on average, approximately 0·2 dB per joint, and there are other small losses due to launch conditions, in that some of the energy launched cannot be contained within the fibre. It must be stressed that these losses affect the optical carrier only, and are not a function of the imposed modulating frequencies. However, the launched modes have different velocities of propagation and, hence, different arrival times; the graded-index fibre used in the system greatly reduces these differences, but the multi-path dispersion introduced is still significant over the section length used. In addition, because the velocity of propagation is a function of wavelength, the line-width of emission of the laser gives rise to pulse broadening from the material dispersion, so that the differences in arrival times of the various modes are increased further. The total dispersion over the 5·75 km section is approximately 2·5 ns; that is, if an impulse is launched into the fibre, the received pulse will have, approximately, a Gaussian shape, with a width of 2·5 ns at the $1/\epsilon$ point (0·37 of the pulse height). By Fourier transform, the pulse dispersion can also be expressed as a 3 dB fibre bandwidth. This may be given as an optical bandwidth, derived from 10 times the logarithm to base 10 of the optical output-power ratio which, in this instance, would be approximately 210 MHz. It is now more common to use the electrical bandwidth (20 times the logarithm to base 10 of the current ratio produced in a linear photodiode), which, for the present system, has a value of 160 MHz approximately. Since the total pulse energy remains constant (apart from the reduction due to fibre loss), the net effect of fibre dispersion is a reduction in the relative pulse height at the receiver. Fig. 7 shows a received pulse (transmitted as in Fig. 5, and measured with the same photodiode) at the end of the fibre section of 5·75 km. The peak optical received power is approximately 3 μW, and the noise present is due mainly to subsequent amplification and the sampling oscilloscope used, but the action of the fibre characteristics in damping the laser transient oscillation and broadening the pulse waveform can be seen clearly.

RECEIVE/REGENERATOR UNIT

A block diagram of the receive/regenerator unit is shown in Fig. 8. The optical output from the fibre is focused via a lens-coupler on to an APD. The type of APD used in the system is an RCA C30817 reach-through device having good high-frequency quantum efficiency. The DC quantum efficiency

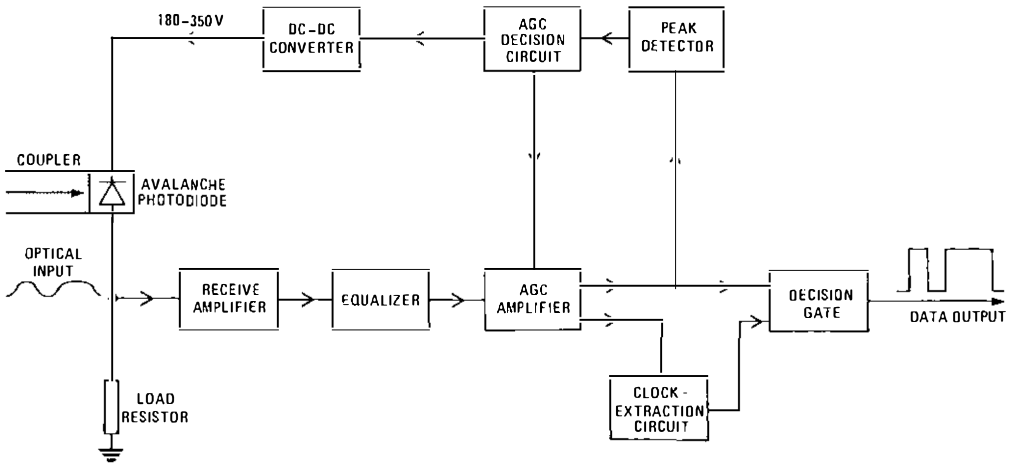


FIG. 8—Block diagram of receive/regenerator unit

(that is, the conversion efficiency from optical power to electrical current) is 0·54 A/W, falling to 0·27 A/W at 280 MHz (approximately). Since the device acts effectively as a constant-current generator (because of its high series resistance when reverse biased), it should preferably be terminated in a large value of bias resistance to develop the maximum output voltage. However, the device also develops quantum noise (due to the uncertainty in the time of arrival of each input photon) and avalanche noise (due to the uncertainties of the avalanche process). These noise processes in the detector result in an output noise signal which is dependent on the level of the incoming optical signal which, in addition to the usual thermal and receiver noises, imposes certain limitations on receiver design. These effects are discussed later.

The reverse-bias voltage required for the photodiode must lie approximately between 340 V (breakdown voltage) and 180 V (the minimum reach-through voltage, below which the electric field across the device is insufficient for correct operation). The maximum current flow is small (less than 2 μA), and it is therefore convenient to use a DC–DC converter to supply the required bias voltage. By varying the mark-to-space ratio of the multivibrator which drives the DC–DC converter, the output voltage can be controlled. This principle is used to advantage to provide part of the AGC.

The output signal from the photodiode is fed directly to a low-capacitance, low-noise pre-amplifier, which uses a Plessey GaAs field-effect transistor (GAT 1). The input capacitance of the amplifier is approximately 4 pF and, with the 2 pF of the photodiode, presents a total capacitance of 6 pF across the 10 kΩ load resistor. (The input resistance of the amplifier is high, and can be neglected.) The input time constant is therefore 60 ns, so that, with a nominal pulse-width input of 6 ns or so, the pre-amplifier acts as an integrating circuit. The following main amplifier, having a nominal voltage gain of 40 dB and a 3 dB bandwidth of 280 MHz, incorporates a feedback stage that provides the inverse of the integrating characteristic (differentiation) to restore the input-pulse shape. This combination, curious though it may appear at first sight, leads to the best noise performance.

The signal waveform at the output of the main amplifier includes noise components generated at various parts of the circuit. An equivalent noise circuit is shown in Fig. 9. The current generator, I_S, represents the level-dependent noise source due to the quantum and avalanche noise processes in the photodiode. The current generator, I_D, represents the noise source due to the photodiode dark current; that is, the noise produced in the absence of any optical input. In a reach-through device, such as is used in the present system, this noise is not level-dependent. Thermal noise due to the photodiode load resistor, R_B, is represented by the current source, I_B, and the 2 equivalent noise sources due to the amplifier are represented by current generator I_A and voltage generator E_A.

Resistance R_A and capacitance C_A represent the input impedance of the amplifier, and capacitance C_D is the photodiode capacitance. It can be seen that the noise voltage from all the current sources is developed across the parallel combination of R_A and R_B and C_A and C_D (amounting to 10 kΩ and 6 pF in the present system), so that, as for the signal waveform, a falling frequency characteristic results. The voltage generator, E_A is, of course, not affected by the time constant of the input circuit and, over the range of interest, the frequency spectrum of this noise source can be assumed constant. However, to restore the signal waveform, the frequency characteristic imposed on the main amplifier also restores the frequency characteristic of the noise spectra due to the current generators, and introduces a rising characteristic to the noise spectrum due to the voltage generator, E_A. At the output of the main amplifier, therefore, the noise components of the signal waveform can be characterized under 3 headings:

(*a*) level-dependent and photodiode gain-dependent noise, due to current I_S, with an approximately constant spectrum,

(*b*) thermal and dark-current noise, due to currents I_D, I_B and I_A, also with an approximately constant spectrum, and

(*c*) thermal noise due to E_A, with an approximately triangular spectrum.

It is the summation of these 3 characteristics that determines the overall signal-to-noise ratio at the decision gate, and hence the achievable error rate. The factors which affect the various sources must, therefore, be examined carefully to

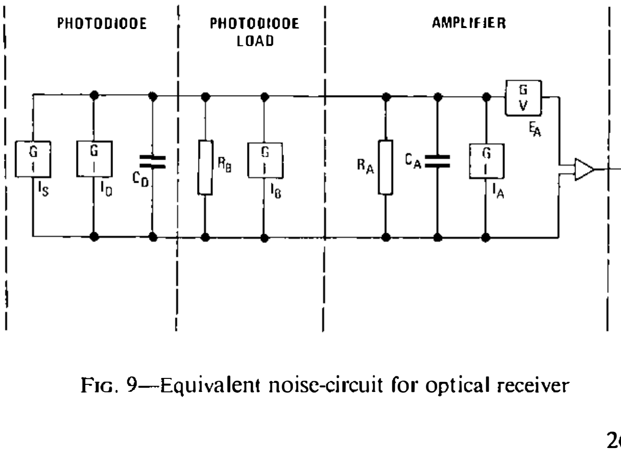


FIG. 9—Equivalent noise-circuit for optical receiver

decide on the optimum design and construction requirements. A further condition to be considered is that of extinction ratio; that is, the ratio of signal power in the digital *zero* condition to that in the digital *one* condition. The higher the value of extinction ratio, the higher will be the level of level-dependent noise in the *zero* condition, and the greater the difficulty in distinguishing between a *zero* and a *one*.

Studies, by Personick[5] and others, have shown that, for given receiver design characteristics and a given input-pulse shape, there are particular values of avalanche gain, M, and load resistor, R_B, which produce the optimum receiver sensitivity. For the receiver design and input conditions in the present system, under conditions of minimum received optical power, the value of M is 80 and the value of R_B is 10 kΩ.

To minimize inter-symbol interference, the signal output from the main amplifier is equalized to produce a full raised-cosine output in the frequency domain. The equalizer also reduces the noise bandwidth though, if significant pulse-broadening has occurred, the level-dependent noise due to the input signal will still affect the signal-to-noise ratio after equalization. In the present system design, the equalization is provided by 3 bridged-T sections and, because of the large fibre-bandwidth available, the main function lies in the reduction of noise bandwidth.

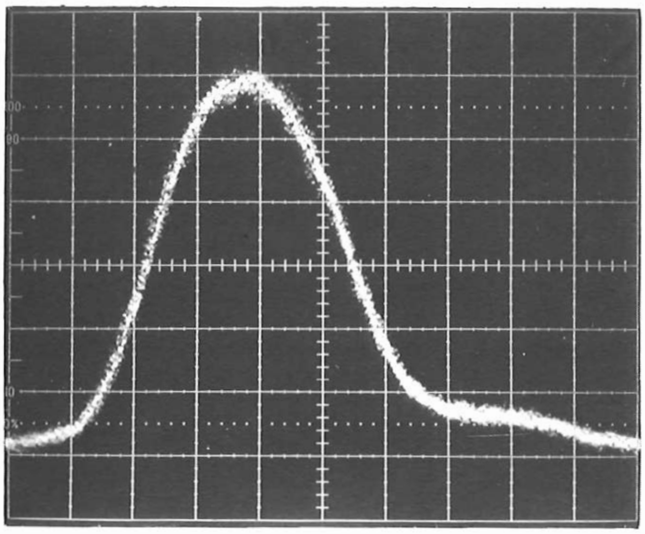
The equalized signal from the main amplifier passes to an AGC amplifier, which has 2 outputs. One output drives a peak detector which provides an AGC signal. If the receiver is operating at maximum sensitivity, and the input optical signal increases above the minimum received power, the AGC signal is used to control the bias voltage of the photodiode to reduce the avalanche gain. When the voltage is reduced to approximately 180 V, no further reduction can be made, for the photodiode would be biased into a non-linear, and excessively noisy, region of operation. The avalanche gain has then been reduced from 80 to 14, approximately, and the output voltage of the AGC amplifier has remained constant over a range of optical input power that would otherwise have caused an output voltage increase of approximately 15 dB. If the input increases still further, the output voltage is allowed to increase by about 0·5 dB. The AGC voltage is then switched to control the gain of the AGC amplifier while maintaining the photodiode bias voltage at its low level. The AGC amplifier gain can be controlled over a further range of 20 dB, giving a total AGC range of about 30 dB.

The output of the AGC amplifier is also fed to the decision gate and to the clock-extraction circuit. The latter circuit is relatively conventional in that, after initial slicing at mid-height, the signal is passed to a tuned circuit with a Q-factor of about 60, followed by a zero-crossing detector. The resultant clock signal is passed to the decision gate via a short length of coaxial cable to delay the leading edge so that it falls in the centre of the signal-eye opening.

Because of level-dependent noise, and because the data *zero* level is not a true zero, there is an optimum threshold level at the decision gate which will ensure that, for minimum received-power conditions, the tails of the 2 noise distributions (together with residual inter-symbol interference) will give equal probability of decision errors at both the *one* and *zero* data levels. The decision gate is an MECL 3 D-type bistable, in which edge-triggering by the clock signal gives an effective sampling interval of the data signal of approximately 1 ns duration. The regenerated data and clock signals are fed via coaxial connexions at the rear of the unit to the decoder unit.

SYSTEM PERFORMANCE

For the present trial, the available drive current in the transmit unit is limited, and the peak optical output power launched into the fibre is 850 μW, about 2 dB below that



Time scale: 2 ns per division

FIG. 10—Received pulse after 6 km of fibre and prior to equalization

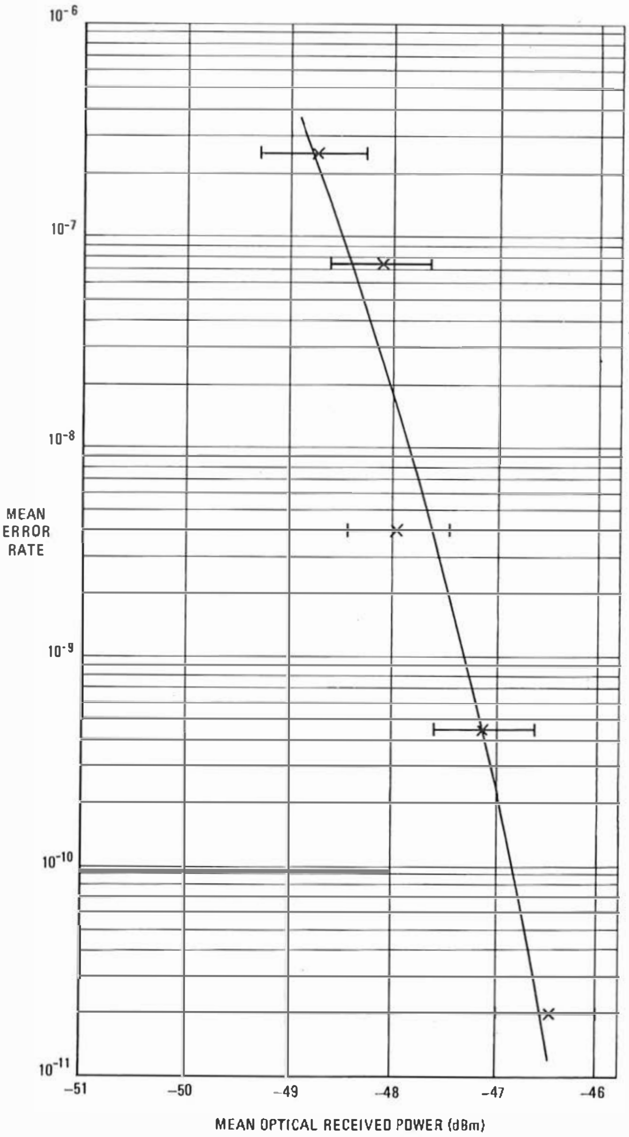
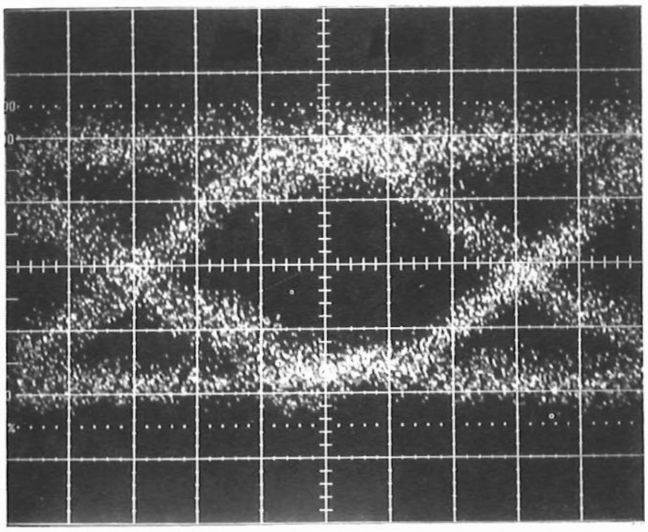
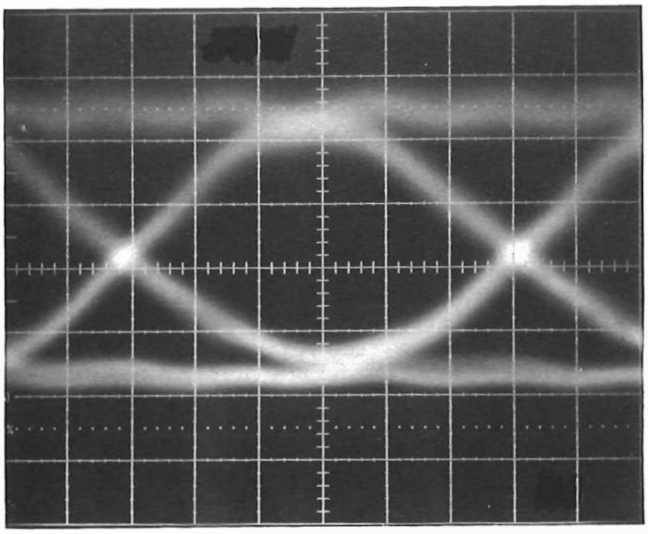


FIG. 11—Error-rate characteristic for 6 km section



Time scale: 1 ns per division

FIG. 12—Eye diagram for 6 km section



Time scale: 1 ns per division

FIG. 13—Eye diagram for 8 km section

attainable with full drive. Launched power in the digital *zero* condition is 70 μW, giving an extinction ratio of 0·08 and a mean launched optical power of 460 μW (−3·4 dBm). The mean received power is 1·4 μW (−28·5 dBm), agreeing with the fibre attenuation measured by other methods.

Performance of the 2-stage AGC has been verified over an optical input-power range of −49 dBm to −29 dBm. Characteristics of a single pulse (see Fig. 10) at the equalizer input point have been measured and are being used to construct an equalizer which should produce optimum performance. The equalizer at present in the system is not of optimum design and appears to have a power penalty of the order of 2 dB. Preliminary tests using a 2^6–1 pseudo-random sequence at 159·159 Mbit/s (that is, without the encoder and decoder units) have given the error-rate results shown in Fig. 11. It can be seen that an error rate of 2 in 10^{10} (the system design criterion) was obtained at a mean received optical power of −47 dBm. An eye diagram for the equalized pulse train is shown in Fig. 12.

The power margin (that is, the difference between received and required powers for the system error rate) is 18 dB, and

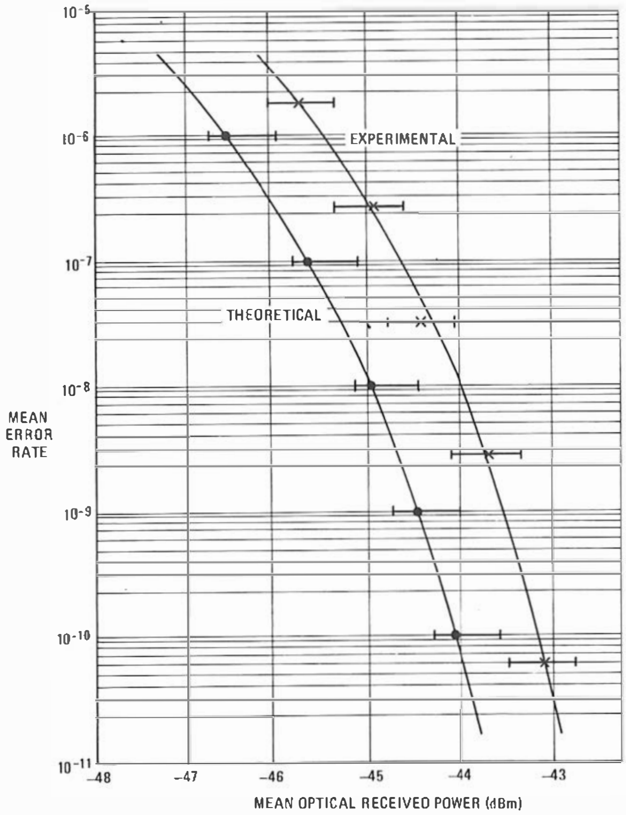


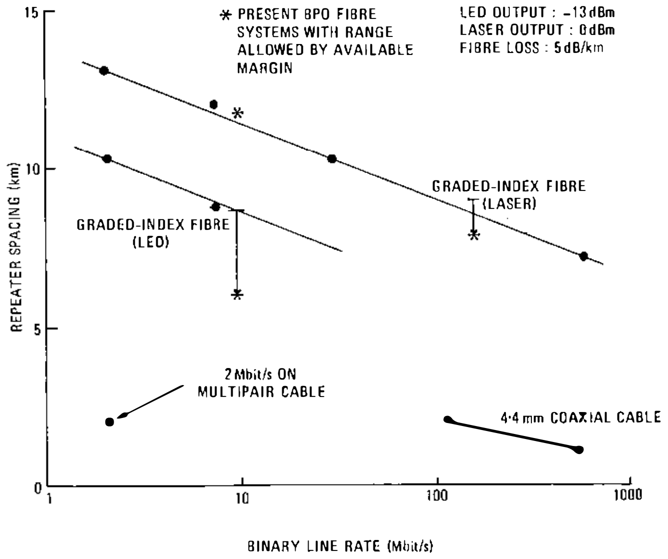
FIG. 14—Error-rate characteristic for 8 km section

it was therefore decided to extend the section length by the addition of further cable. An additional 2 km of fibre cable was inserted at the receive terminal, and the error-rate tests repeated, using the same equalizer as before. The eye diagram and error-rate curve are shown in Figs. 13 and 14 respectively. In Fig. 14, the theoretical error-rate curve, which allows for the mis-equalization present, is also plotted and is in good agreement with the experimental curve. The theoretical power margin (that is, with full transmitted power and with correct equalization) is estimated at approximately 9 dB—a more than adequate margin for system operation.

CONCLUSIONS

The feasibility trial has developed rapidly from the first considerations of a strictly bandwidth-limited system; repeater spacings have been extended and equalization requirements are moderate. The maximum repeater spacing possible with the present 140 Mbit/s system is about 9 km, assuming 1 mW optical power into the fibre. On the basis of similar repeater-unit costs, this indicates that the optical-fibre system can provide equipment which is below one third of the equivalent coaxial system costs. With experience to date of the optical system, a trend line can be drawn (see Fig. 15) showing the maximum repeater spacing as a function of the line rate. Extending this beyond 140 Mbit/s, the repeater spacing is expected to reduce to 7 km at 600 Mbit/s, which is a small penalty for quadrupling the capacity of the system, and is very attractive compared with a coaxial-cable system having equivalent capacity.

The power consumption of a bothway repeater of the present design is about 15 W. Thus, if the existing type of power-feeding system is used (250 V–0–250 V, deriving 50 mA at each power-feeding station), 3 dependent 2-way repeaters spaced 8 km apart can be powered between power-feeding stations spaced at 32 km. Good prospects of reducing



LED: Light-emitting diode

FIG. 15—Repeater spacing for optical-fibre system

repeater power consumption to about half that used at present offer an attractive improvement over existing systems, which require power feeding at 30 km intervals.

Reliability is a major consideration in the design of transmission equipment and, although the majority of components in an optical-fibre system are well-tried conventional devices, the 2 opto-electronic devices, the laser and the photodiode, are as yet unproved. At the present time, a system involving a state-of-the-art laser could not be guaranteed to provide an adequately low failure rate to meet a mean-time-between-failures of not less than 20 years/100 km. Nevertheless, taking into consideration the unique degradation characteristics of the laser, it is possible to envisage a selection process, based on the rate of change of the laser threshold with time, that enables the probable working lives of lasers suitable for system use to be predicted. A laser, whose threshold point is increasing at a rate of a few per cent per 1000 h, would provide a working life of about 5 years, assuming a threshold operating range of 160–400 mA of the control circuit. A maintenance schedule involving the supervision of laser threshold levels with BIAS-CONTROL-LIMIT PROXIMITY alarms could ensure rapid replacement before actual failure occurs, and an adequately low repair time could be achieved to meet the availability requirements.

Improvements in the fabrication technology will inevitably be made to meet the long-life requirements of the system. One development in hand involves the reduction of threshold level[6], which can provide an effective means of switching the laser directly from zero to peak-level output. This would have the immediate effect of halving the time that a laser is switched on.

The feasibility trial so far has demonstrated the possibility of introducing optical-fibre systems into the main network. Operation at 140 Mbit/s provides a sound basic starting point for the introduction of optical-fibre systems, and allows consideration of possible future expansion as techniques and technologies develop.

ACKNOWLEDGEMENTS

The authors acknowledge the work of their colleagues, in particular, that of R. C. Hooper, B. R. White and T. G. Hodgkinson, who were largely responsible for the success of the exercise.

References

[1] BERRY, R. W., HOOPER, R. C., and WHITE, B. R. Preliminary Test Results on a 140 Mbit/s Experimental Optical-Fibre Transmission System. *Electronics Letters*, Vol. 13, No. 12, pp. 358–360, 9 June 1977.

[2] HENSEL, P., North, J. C., and STEWART, J. H. Connecting Optical Fibres. *Electronics and Power*, Feb. 1977.

[3] BRACE, D. J., and RAVENSCROFT, I. A. Optical-Fibre Transmission Systems: The 8·448 Mbit/s Feasibility Trial. *POEEJ*, Vol. 70, p. 146, Oct. 1977.

[4] BYLANSKI, P., and INGRAM, D. W. Coding for Digital Line Systems. Digital Transmission Studies, Chapter 11, *Publisher* Peter Peregrinus.

[5] PERSONICK, S. D. Receiver Design for Digital Fiber-Optic Communication Systems, Parts 1 and 2. *BSTJ*, Vol. 52, pp. 843–886, 1973.

[6] STEVENTON, A. G., FIDDYMENT, P., NEWMAN, D. H., and TINKLER, J. M. Low Threshold Current Proton Isolated (GaAl)As DH Lasers. Proceedings, Third European Conference on Optical Communication, Munich, pp. 126–128, 14–16 Sept. 1977.

Book Review

SI Units in Engineering Technology. S. H. Qasim, B.SC.(ENG.), PH.D. Pergamon Press. 64 pp. £2·50.

According to the preface, this book is intended to promote a better understanding of the SI system in education and industry, and to serve as a quick reference for conversion from imperial to SI units. It is unlikely to achieve the first objective, however, since the 3 chapters devoted to the SI system total only 10 pages. Several of these are used to reproduce definitions, to list letter symbols for quantities (values of which need not necessarily be stated in SI units), or to table signs and symbols used in mathematics. Those explanations which are provided are not well expressed, and the text suffers from the fact that English is not the author's mother tongue. Of more importance, however, are mistakes such as the use of quantities when units are intended, and the confusion between scales and degrees in the section on temperature.

Chapters 4 and 5 list conversion factors by subject and alphabetically. The second list contains a number of entries of rather doubtful value, such as those illustrated in the table.

Unit	SI Equivalent
ampere, A kilowatt, kW	1 A 1 kW

The final chapter includes 12 conversion tables for quantities such as length, mass and temperature. The tables all provide for the conversion of values from imperial to SI units, and some have been constructed so that they may be used in the reverse sense also. Only a selection of units is covered for a given quantity. For length, for example, one table covers conversions from inches to millimetres, a second from miles to kilometres, while a third bidirectional table also deals with inches and millimetres. The procedure recommended for the conversion of a value is to break it down into convenient parts, obtain the equivalent values of those parts from the tables, and sum them to obtain the final answer. Such a procedure can easily lead to a result which is not as accurate as the number of decimal places would suggest, since the equivalent figures in the various parts of the tables are not all to the same degree of accuracy. Moreover, the addition of 2 numbers accurate to a given number of decimal places can well yield a sum which is not as accurate as its constituent parts. At least 3 of the worked examples in the text suffer from this fault and a fourth is incorrect—probably due to a printing error.

The subject of quantities and units demands a painstaking approach and careful attention to detail. Unfortunately, it cannot really be said that this book satisfies the requirement.

S. J. A.

Copperas Hill Mechanized Letter Office

K. S. J. WEBB and W. DICKIE, C.ENG., M.I.E.E.†

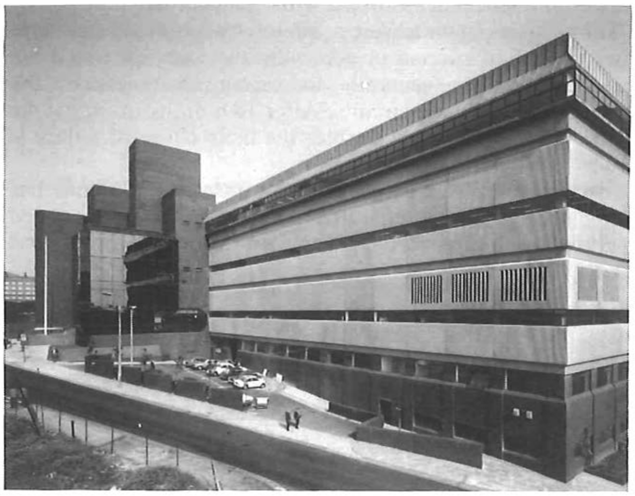
Over 80 years of British Post Office history came to a close in Liverpool during the August bank holiday of 1977, when the operational transfer to the new Head Post Office and mechanized letter office (MLO) at Copperas Hill took place.

The new £10M MLO, built under the design-and-construct principle and controlled during the planning and construction stages by the Postal Mechanization and Buildings Department, Postal Headquarters, was brought into full operation by Tuesday 30 August. The building replaces the Victoria Street Head Post Office, which was opened in 1899, and whose varied history includes being partially destroyed by enemy action during the Second World War. Other outstationed sections (except for an independent parcel office) were also replaced by the newly commissioned building.

The accommodation was initially handed over by the contractors in March 1977, but further specialist work on the mechanization aspects had to be completed before the final transfer could be arranged. Equipment and systems trials were also necessary, and many of these were carried out during the summer months, using live mail traffic whenever circumstances, resources and quality of service permitted.

Accommodation not affected by the post-contract work was progressively occupied from the date of handing over. Engineering, postal and administrative sections moved into the office on a phased basis, backed up as required by welfare, catering and accommodation services. The first live operational work—foreign-letter sorting—was transferred to the building as early as 23 April 1977.

The final phase concerned the large and important operational sections of the outward and inward letter office and the city delivery office (Liverpool districts 1–3); the remaining administrative sections with specific links with the letter office were also involved. These formed the first stage of the bank-holiday-weekend transfer, which was completed well before noon on the Saturday. Meanwhile, the Saturday collections were processed in the old accommodation. Following the appropriate letter dispatches, all outstanding work (both inward and outward) was transferred to the new accommodation. Delivery work operated from Copperas Hill on the Tuesday morning, and the first full collections were processed later the same day.



Copperas Hill MLO

(By courtesy of the Group Communications Department, The IDC Group Ltd., Stratford-upon-Avon)

The office is linked by tunnel with Lime Street station. Inward and outward mail began to be conveyed over this link on conclusion of the transfer, thereby reducing by a significant amount the road traffic involved on station services. A new railway-station terminal provides for the segregation of all mails, both for dispatch and on receipt.

Copperas Hill is fully mechanized. Special training was given to more than 1800 members of staff before the building was occupied. The main sorting hall is large enough to provide turn-round space for the installation of coding and sorting equipment. The initial installation and commissioning of 24 coding desks, 2 pre-sorters and 4 automatic sorting machines was completed late in 1977, the work being carried out by engineering staff on a direct-labour basis.

The transfer demanded cooperation between all disciplines, not least of all between the engineering and postal operational staffs. The successful outcome does credit to the close relationships at every level that have been a feature of the whole commissioning exercise.

---

† Mr. Webb is the Headpostmaster, Liverpool, and Mr. Dickie is the Regional Engineer, North Western Postal Board

---

Line-Only Private-Circuit Identification

I. M. ROSS, B.SC.†

When a line-only private circuit has been provided for a customer, there is no way of positively indicating to installation and maintenance field staff (prior to the connexion of the customer's terminal equipment) that the underground pair is allocated. An earth or loop on the line are forms of indicators, but they cannot be differentiated from fault conditions.

A suggestion was made to the Area Engineering Productivity Committee that an astable multivibrator (Buzzer No. 33A and battery) should be connected to the line to give an audible tone that would identify the pair as being in service.

The circuit of the Buzzer No. 33A was redesigned to give a suitable tone when powered by a 9 V dry-cell battery (PP3). Buzzer, battery and a connector are encapsulated in a 51 mm × 51 mm × 25 mm cuboid of clear resin (Plasticraft resin). Encapsulation is carried out in stages due to the danger of destroying the transistors by the heat generated during the exothermic hardening reaction. To prolong the life of the battery, the circuit is designed so that the multivibrator functions only when the output terminals are looped. The tone is therefore heard when a handset is connected across a line to which the unit is attached. The circuit diagram of the unit is shown in the sketch.

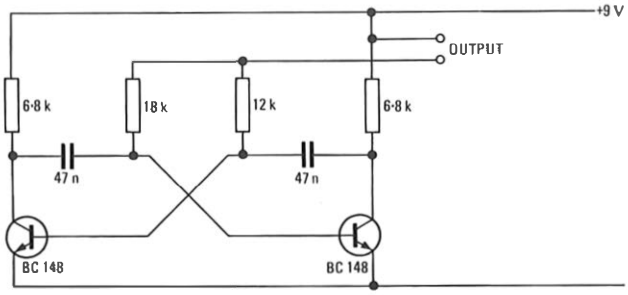
---

† Work Study and Installation Efficiency Group, Glasgow Telephone Area

Consideration was given to whether the units should be provided at the exchange, cabinet or customer's premises. The last of these was chosen because of the convenience of removing the unit when the customer's terminal apparatus is connected. To enable the customer to advise the Telephone Area office that this has been done, a telephone number is shown on a label encapsulated with the identifier unit.

Thirty-five such units were produced by the local workshop. They have had success in achieving their object, and have played a part in generally increasing awareness of the importance of private circuits. After 18 months of use, some of the units are still serviceable; the main cause of failure is battery exhaustion.

In view of the successful result, an order for 100 units has been placed with a manufacturer. The unit has been redesigned to allow the battery to be replaced, but the overall dimensions have been increased only marginally. The manufactured units have a more professional finish and are cheaper than the locally-produced items.



SCEPTRE: A Portable Electronic Traffic Recorder

B. F. PODMORE†

Traffic-recording methods have been modified in recent years in an endeavour to obtain accurate information for dimensioning both existing and new telephone exchanges. However, the principle remains the same: some form of electromechanical scanning equipment is used and, ultimately, there are meters that need to be read, often before as well as at the completion of a record. Now, a portable recorder using entirely different principles is becoming available, known as the software-controlled electronic-processing traffic-recording equipment (SCEPTRE).

The SCEPTRE has become a reality thanks to the interest, resources and technical assistance of the Exchange Computer Projects group, Network Planning Department, Telecommunications Headquarters. Development started early in 1976, with microprocessor technology being used as the basis of the SCEPTRE. By September of that year, the design was at a stage where the construction of a field-trial recorder could commence. The Plymouth Telephone Area completed its model in May 1977, and this device is now undergoing trial in the Area.

The prototype recorder comprises 2 units. The main unit houses the display and programming arrangements, and the circuit cards for the processor, memory and interface elements. The second and smaller unit is the power supply, which is fed from the −50 V exchange battery.

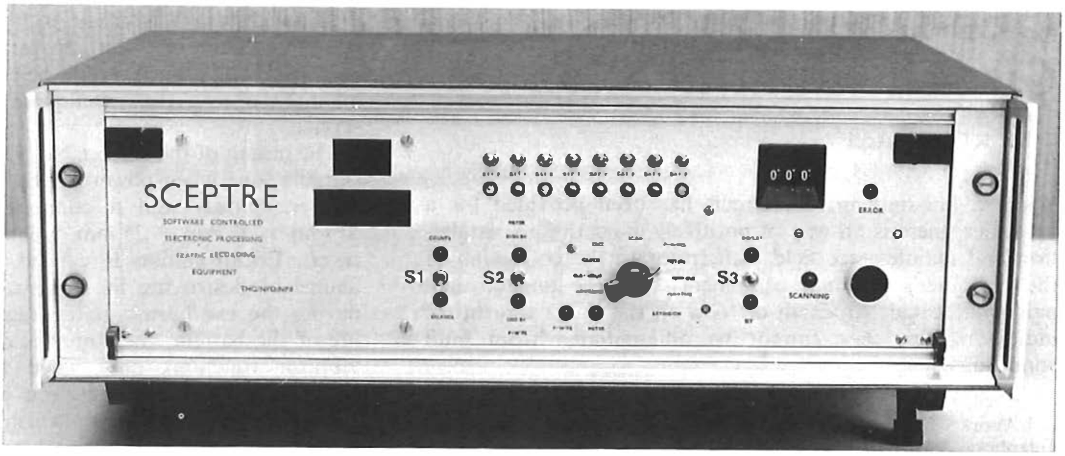
The recorder has a maximum capacity of 256 P-wires, which have complete flexibility of access to 256 "meters", the meters being in data-store form. Traffic recording is possible for 2 busy hours per day for up to an 8 d cycle, with a scan period of 18 s. A very useful additional facility is an arrangement for checking for any permanently free or permanently engaged circuits that may occur during the period of the record. The output is given directly in erlangs or in call-count form on a 7-segment numerical display panel.

To date, the recorder has been used to prove grading unbalance in a large group switching centre, and to provide complete day and evening simultaneous time-consistent busy-hour traffic records at unit automatic exchanges No. 13 (UAX 13s) due for conversion to TXE2s. The results so far obtained have been consistently accurate, even from an exchange known to have induction problems from a Central Electricity Generating Board grid line. The greater accuracy of records obtained at UAX 13s will ultimately be reflected in better and more economical TXE2 designs.

It is hoped that some production models of the SCEPTRE with capacities of up to 960 circuits may be available in kit form in the near future. These recorders will have a number of additional facilities, including an improved arrangement for programming the recorder using a combined key pad and alpha-numeric display unit. A recording output in the form of a small printer may be available.

---

† Internal Planning Division, Plymouth Telephone Area



Prototype SCEPTRE

Bridging the River Lea

C. A. WITT, A. SILWOOD and C. W. INETT†

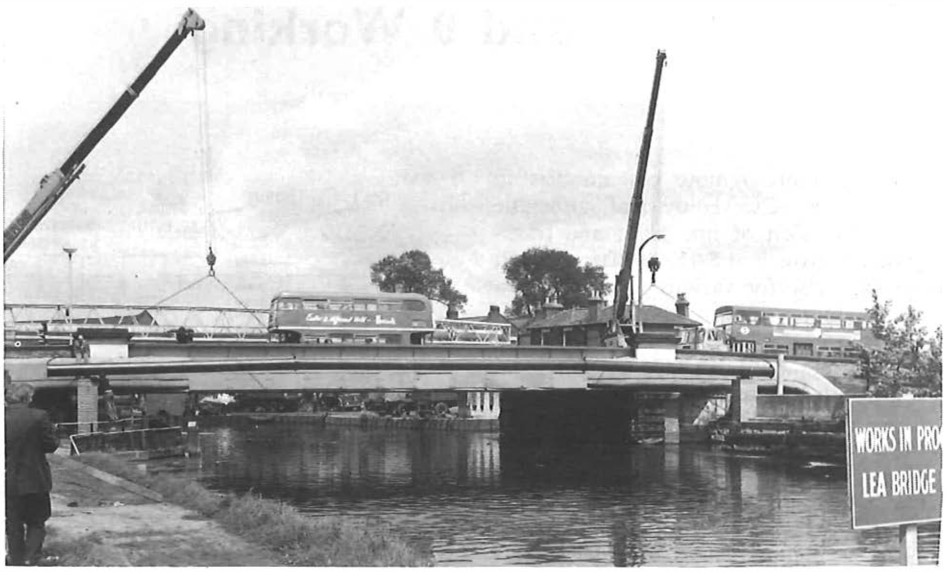


FIG. 1—The main span over the River Lea

The external planners of the East Telephone Area, London Telecommunications Region, had known for many years that the provision of additional ductways over the River Lea at Lea Bridge Road, Hackney, would present them with a major problem. The project became a firm commitment when the need finally arose to provide 12 ducts across the river to meet the forecast demand for main-network and junction cables.

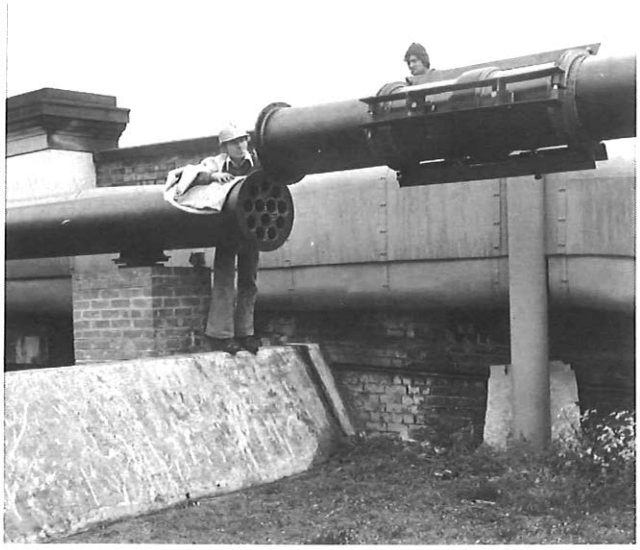


FIG. 2—Pipe-work at the eastern end of the bridge, showing the bellows section

The usual arrangement of placing ducts within the service bays of the bridge structure was not possible, due to lack of space. Boring below the canal bed was considered, as were the provision of a separate bridge to support the pipes or, perhaps, attaching the pipes to the side of the existing bridge. But, for various reasons, these schemes were found to be impracticable.

Eventually, after protracted negotiations with the British Waterways Board, the Lea Conservancy, the Thames Water Authority, the London Borough of Hackney and our Regional Headquarters colleagues, it was agreed that the most suitable scheme would be a steel tube containing 12 PVC ducts, spanning the river adjacent to the south side of the existing bridge and freely supported on brick piers on each bank of the river. Fig. 1 is a general view of the site during the construction work.

The project design was prepared by the Area planning and drawing offices in conjunction with the Works Division at Regional Headquarters. By competitive tendering, the job was let to a pipe-work specialist for manufacture and erection.

The tube, of 4 mm thick steel, having an outside diameter of 457 mm, was constructed in 7 separate sections which could be bolted together to give an overall length of 67 m. This prefabrication was necessary to allow transportation to the site.

Expansion problems were overcome by fitting to the piers bearing plates having longitudinal slots to allow movement, and also by the inclusion of a bellows in one section of the tube. Fig. 2 shows the bellows section and the bearing plate on one of the piers.

It was proposed to position the PVC ducts (Ducts No. 54) in the tube by means of steel templates tack-welded to the bolt flanges at each end of the sections, but it was found that additional support within the tube was required. This was accomplished by packing 3 m lengths of PVC Duct No. 56 in the interstitial spaces. The whole assembly within the tube

---

† East Telephone Area, London Telecommunications Region

was maintained in position by the injection of polyurethane foam to fill the voids. Ducts protruding from the template were cut flush and, to ensure that the butt joints between sections lined up accurately, holes were drilled in the bolt flanges so that steel locating pins could be inserted prior to the final assembly on site.

In view of the obstruction which would be caused to road traffic during a normal weekday, it was necessary to carry out the operation of lowering the sections of tube into position, using 2 mobile cranes, in one weekend. In fact, the whole operation was successfully completed within a period of just 7 h on Saturday 11 June 1977.

Combined Level 1, 9 and 0 Working

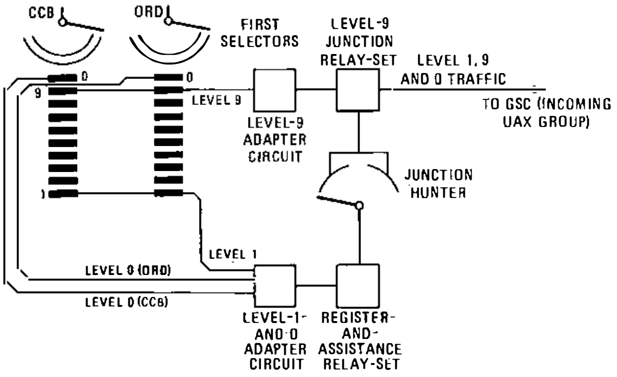
D. C. JEFFREY†

Many of the smaller and more remote communities in Scotland West Telephone Area are served by small automatic exchanges (SAXs). The provision of line plant and transmission systems for junction growth at SAXs is often difficult and expensive. Delays can arise for various reasons, and a means was therefore sought to improve the utilization of existing line plant.

Outgoing traffic from a standard SAX is carried by 4 separate outgoing routes to the parent group switching centre (GSC): level 1 (assistance services), level 9 (GSC access and emergency services), level-0 (ordinary) and level-0 (coin-collecting box) STD access. Each of the routes is small and, often, the individual route busy-hours do not coincide. The total outgoing circuit requirement can be reduced considerably by combining access from levels 1, 9 and 0 over a single route to the GSC.

Combined level 1, 9 and 0 working can be achieved by the use of standard unit-automatic-exchange (UAX) outgoing-junction relay-sets, connected via adaptor circuits to the selector levels at the SAX. The incoming terminations at the GSC are transferred from the non-director group to the UAX group. The trunking diagram illustrates the arrangements.

The adaptor circuits were derived from standard circuit elements, and the components were strip-mounted. One 20-way mounting plate accommodates 10 level-9 adaptor circuits, or 4 level-1-and-0 adaptor circuits. Relay-sets were available from a recovered UAX 14.



CCB: Coin-collecting-box subscribers
ORD: Ordinary subscribers

Combined level 1, 9 and 0 working at an SAX

The scheme was used to give junction relief at an SAX early in 1977, and has operated without service difficulty. The modification is also applicable to mobile non-director exchanges, permitting their use as direct UAX replacements either in an emergency or to allow the turn-round of equipment in an existing building.

---

† Head of Internal Planning and Works, Scotland West Telephone Area

---

Institution of Post Office Electrical Engineers

IPOEE CENTRAL LIBRARY

The books listed on the next page have been added to the IPOEE library since the publication of the 1974 Library Catalogue. Any member who does not have a copy of the catalogue can obtain one from the Librarian, IPOEE, 2–12 Gresham Street, London EC2V 7AG. Library requisition forms are also available from the Librarian, from honorary local-centre secretaries, and from Associate Section centre secretaries and representatives.

Alternatively, the form opposite, or a photocopy, can be used (only by members) to borrow any book listed in the catalogue or in the updating lists published in recent issues of the *POEEJ*.

The form should be sent to The Librarian, IPOEE, 2–12 Gresham Street, London EC2V 7AG. A self-addressed label must be enclosed.

IPOEE Central Library

LIBRARY REQUISITION FORM

For use only by members of the Institution of Post Office Electrical Engineers

Author ....

Title ....

....

Catalogue No. .... Date ....

Name ....

Official Address ....

....

....

5216 *Handbook of Data Communications* (1975)

Produced by the British Post Office (BPO) in conjunction with the National Computing Centre Ltd., this book is based on BPO data-communications courses. The subjects covered are those which have been found to be the ones most needed by the average student.

5217 *Electrical Installation: Questions and Answers.* M. Neidle (1975)

A question-and-answer form of coverage is given of basic wiring systems, types of cable and installation accessories, with special treatment of safety and testing.

5218 *Electrical Installations and Regulations.* M. Neidle (1975)

This book is designed for students taking the City and Guilds of London Institute's Electrical Installation B course (Course No. 231). Many worked examples are included, as well as unworked problems, with answers.

5219 *Semiconductor Circuit Elements.* T. D. Towers (1975)

The author's approach is a single-volume coverage of all commercially available semiconductor devices. The aim is to help readers find out what devices are available, how they work, how they are used in circuits, and where to look for more detailed information.

EAST MIDLANDS CENTRE PROGRAMME, 1978

1 February (Nottingham University, 14.00 hours): *Total Energy* by A. W. Mealing.

1 March (Leicester University, 19.00 hours): *Technical Aspects of the Post Office Viewdata Service* by K. E. Clarke. (Combined meeting with the Associate Section and the IEETE.)

20 April (Peterborough Technical College, 14.00 hours): *Development in PABXs and PMBXs* by R. C. Gibbs.

SOUTH-EASTERN CENTRE PROGRAMME, 1978

Meetings will be held at: the conference room, 46 Holland Road, Hove; St. Saviours Church Hall, Leas Road, Guildford; or the Social Centre, Culverden Park Road, Tunbridge Wells. All meetings start at 14.00 hours.

1 February (Tunbridge Wells): *Repair Service Controls* by M. Bayley.

1 March (Hove): *Test-Equipment Designing in the SETR* by B. H. House, E. Hall and E. E. J. Huggins.

15 March (Tunbridge Wells): *The Increasing Importance of Power Plants for Telecommunications Systems* by D. G. Cooke.

12 April (Guildford): *Optical-Fibre Transmission* by I. A. Ravenscroft and D. J. Brace.

19 April (Hove): *Optical-Fibre Transmission* by I. A. Ravenscroft and D. J. Brace.

LOCAL-CENTRE SECRETARIES

The following is a list of local-centre secretaries, to whom inquiries about the Institution may be addressed. It would be particularly useful if members would notify any change in their own address to the appropriate secretary.

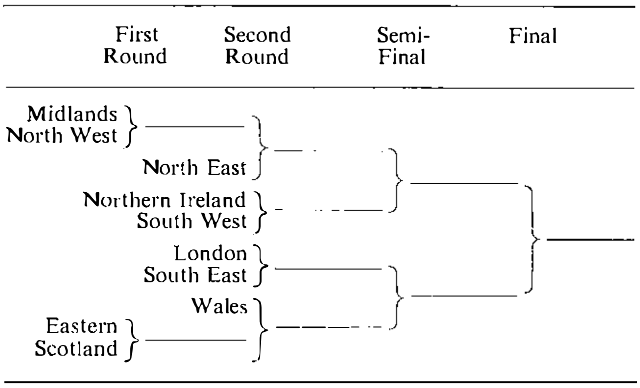
Centre	*Local Secretary*	*Address*
Birmingham	Mr. D. F. Ashmore	General Manager's Office, ED3/7, 84 Newhall Street, Birmingham B3 1EA.
Eastern (Bletchley)	Mr. D. R. Norman	Telephone House, ED9/3, 25–27 St. John's Street, Bedford MK42 0BA.
Eastern (Colchester)	Mr. P. M. Cholerton	Eastern Telecommunications Region, Planning Division, St. Peter's House, St. Peter's Street, Colchester CO1 1ET.
East Midlands	Mr. D. W. Sharman	General Manager's Office, Room 1301, 200 Charles Street, Leicester LE1 1BB.
London	Mr. M. S. Armitage	City Telephone Area, ESS1, Telephone House, 8–18 London Bridge Street, London SE1 9SH.
North Eastern	Mr. D. Spencer	North East Telecommunications Region, Service Division, Darley House, 79 St. Paul's Street, Leeds LS1 4LW.
Northern	Mr. L. G. Farmer	Telephone Area Office, Swann House, 157 Pilgrim Street, Newcastle-upon-Tyne NE1 1BA.
Northern Ireland	Mr. W. H. Tolerton	Belfast Telephone Area, GM/IM2, 55-61 Donegall House, Donegall Square, Belfast BT1 5DR.
North Western (Manchester and Liverpool)	Mr. W. Edwards	North West Telecommunications Board, Planning Division, Bridgewater House, 60 Whitworth Street, Manchester M60 1DP.
North Western (Preston)	Mr. J. Allison	Post Office Telephones, Clifton Road Depot, Marton, Blackpool FY4 4QD.
Scotland East	Mr. W. L. Smith	Scottish Telecommunications Board, Planning Division, Canning House, 19 Canning Street, Edinburgh EH3 8TH.
Scotland West	Mr. G. A. Dobbie	Telephone House, 65–95 Pitt Street, Glasgow G2 6AH.
South Eastern	Mr. J. M. Smith	South Eastern Telecommunications Region, Planning Division, Grenville House, 52 Churchill Square, Brighton BN1 2ER.
South Western	Mr. R. C. Willis	South Western Telecommunications Region, Planning Division, Mercury House, Bond Street, Bristol BS1 3TD.
Stone/Stoke	Mr. K. A. Priddey	Post Office Technical Training College, Stone ST15 0NQ.
Wales and the Marches	Mr. D. A. Randles	Wales and the Marches Telecommunications Board, Planning and Works Division, 25 Pendwyallt Road, Coryton, Cardiff CF4 7YR.

A. B. Wherry
Secretary

The Associate Section National Committee Report

NATIONAL TECHNICAL QUIZ COMPETITION

The draw for the 1977–78 National Technical Quiz took place at the Technical Training College, Stone, on Friday 30 September 1977, during a General Purposes and Finance Committee meeting. The National Quiz Organizer, Mr. K. Marden, was in charge of the proceedings. The result of the draw is shown in the table.



The first round should have been played by the end of 1977, the second round by 14 February 1978, and the semi-final by 25 March. The final will be held at the Institution of Electrical Engineers, Savoy Place, London, on Friday 28 April, with Mr. J. F. P. Thomas, Chairman of the IPOEE, in the chair.

NATIONAL PROJECT COMPETITION

Details of the National Project Competition for 1978–79 are being published separately. The subject is a novel application of alternative energy sources for use in the British Post Office using non-fossil fuels; for example, solar, wind, geothermal or tidal power. An essay, drawing or model is required.

Names of entrants must be in by the end of January 1978, and entries must be submitted by the end of November 1978. Judging will take place during February 1979, and the trophy will be presented at the National Technical Quiz final in 1979.

INSURANCE COVER

From 1 June 1977, all members of centres affiliated to the National Committee were covered by a personal-accident insurance policy. Details of the cover are being circulated to all centres concerned. All claims against this policy must be made via the secretary or treasurer of the National Committee.

NATIONAL NEWS

There will shortly be another issue of the *National News*, the previous 2 issues having been well received by members. The editor, Mr. B. Harlow, is setting up a national network of reporters; he now has reporters in most Regions.

Any member who has an article or item of interest he would like printed in the *National News* should contact his local reporter, or the editor himself on 0742 732575.

M. E. Dibden
General Secretary

Associate Section Notes

NOTTINGHAM CENTRE

The early months of 1977 saw a large amount of Centre activity, which included 2 papers read by Telecommunications Headquarters staff: *An Introduction to TXE4*, given in January by Mr. A. M. Belenkin, and *Local Distribution—A time for Change*, given in March by Mr. S. H. Grainger. Both items were enjoyed by those who attended, and discussions continued afterwards in a local hostelry.

A film evening was presented in February, when 22 members saw a selection of 16 mm films which included *Whatsoever is Rightly Done*—the manufacture of the Rolls-Royce Corniche, and *Darien Conquest*—the British transamerican expedition in 1972 from Alaska to Cape Horn.

On 6 April, a dual visit was arranged. Members visited the Reliant Motor Co., Tamworth, in the morning, and saw a sharp contrast between the Robin and Scimitar models, while the afternoon was spent at the Donnington Park Motor Museum where a bygone era was widely represented.

The annual general meeting was held on 28 April, and the following officers and committee were elected.

Chairman: B. M. Smith.
Secretary: M. Rush.
Treasurer: L. E. Smith.
Assistant Secretary: R. H. Marsh.
Librarian: P. Birchmore.
Quiz Secretary: J. D. Liley.
Committee: R. Taylor, B. F. Miller, M. P. Melbourne and G. Fotheringham.

Mr K. Chandler again agreed to be our President.

The Centre was again involved in the Midlands Regional technical quiz and, after successfully meeting the challenge of Evesham and Birmingham, we sat opposite Stone in the final, held at Leicester on 1 June. This was the end of the competition for us, however; we were eliminated, 37 points to 35. Our Trainee Technician (Apprentice) quiz team was more successful when it met Derby and achieved a win with a margin of 2½ points. Prizes were awarded to both our teams by Mr. A. Hancock, Deputy General Manager, Nottingham Telephone Area.

Two events took place in August and September which attracted a high degree of interest. The first was a visit to the Sandstone Caves in Peel Street, Nottingham, and a tour of the caves beneath the Salutation Inn. It is said that this inn was used by Charles I, and that men were recruited there by Oliver Cromwell. In September, 2 coaches took us to visit the Science Museum and City of London.

A new venture by the Centre took place in late August when a series of gliding evenings was arranged with a local gliding club. This also proved to be a popular event, and we hope to be able to repeat it.

Items left on the programme at the time of writing are talks on home winemaking and the Main Line Steam Trust, and a visit to the East Midlands Airport. The annual general meeting and a film evening will be held on 25 April 1978.

M. Rush

SALISBURY CENTRE

Salisbury Associate Section members were made aware of the importance of the communications services they provide when we visited 2 of the users during the year: the London air-traffic control centre at West Drayton, and Calshot Spit coastguard station. The latter visit was timed to coincide with the dispersal of Her Majesty the Queen's Spithead review.

Further trips later in the year concentrated on the pleasures of the flesh, when we enjoyed the hospitality in particular of Messrs. Guinness at Port Royal, London, and W. D. and H. O. Wills at Somerton.

Members' hobbies are to be catered for by visits to Kodak Ltd. and the Whitefriars glassworks and, at home, a members' film evening.

D. J. Todd

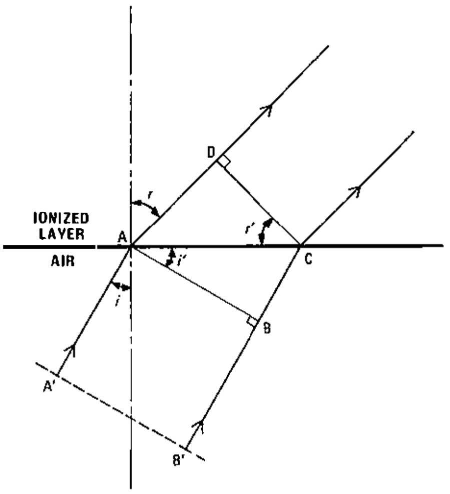
Notes and Comments

CORRESPONDENCE

Dear Sir,

As an examiner and author of model answers, I would like to comment on the answer to Q1, Communication Radio C 1976 (on p. 93 of the January 1978 *Supplement*).

While the reference given provides an adequate answer to the question, there is a degree of confusion among students concerning the mechanism of refraction at an air–ionosphere boundary. This is because the effect is opposite to that at an air–glass interface; that is, the refraction is away from the normal instead of towards the normal. Since some students endeavour to use the air–glass situation to explain ionospheric refraction (no doubt because it is taught universally in schools), they are then at a loss to relate the effect to the propagation of waves through the ionosphere. I believe the following explanation will help to clarify the situation.



The sketch shows a wavefront, A'B', propagating through air and being refracted at the interface between the air and an ionized layer.

From Snell's law,

$$\frac{\sin i}{\sin r} = \mu,$$

where μ is the refractive index (and is a constant), i is the angle of incidence, and r is the angle of refraction.

Using geometrical methods, it can be shown that $i = i'$ and $r = r'$.

$$\therefore \quad \frac{\sin i}{\sin r} = \frac{\sin i'}{\sin r'} = \frac{BC/AC}{AD/AC} = \frac{BC}{AD}. \qquad \ldots\ldots(1)$$

If the wavefront at point B moves to point C in time t with the velocity of light, c, the distance travelled is given by $BC = ct$. During this time, the wavefront at point A moves to point D with velocity v, so that $AD = vt$. Hence, from equation (1),

$$\frac{\sin i}{\sin r} = \frac{ct}{vt} = \frac{c}{v} = \mu. \qquad \ldots\ldots(2)$$

At the interface between the air and the ionosphere, the measure of refraction is given by $\sin r = \sin i/\mu$ and, for the wavefront to move away from the normal, μ must be smaller than unity.

Since, from equation (2), $\mu = c/v$, this implies that v is greater than c. However, this does not conflict with the principle of relativity because the velocity concerned, v, is the *phase velocity*. No physical material moves at the phase velocity, for it is the velocity of a point of intersection of the wavefront and a line drawn in some given direction: in this case, line AC.

An analogy to this phenomenon is the wavefront produced by an ocean wave striking a sea wall at an angle other than 90°. The wave velocity does not change, but the progress of a wavefront along the sea wall occurs at a higher velocity.

D. J. B.

Publication of Correspondence

The Board of Editors would like to publish correspondence on engineering, technical or other aspects of articles published in the *Journal*, or on related topics. Letters of sufficient interest will be published under Notes and Comments.

Letters intended for publication should be sent to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NP 9.3.4, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY.

PRICE OF THE JOURNAL TO NON-BPO READERS

The Board of Editors regrets that, with effect from this issue, the price of the *Journal* to non-British Post Office readers is increased to 55p (80p including postage and packaging; annual subscription: £3·20; Canada and the USA: $6·50).

SHORT CONTRIBUTIONS

The interesting and varied short articles being contributed, of which there are several examples in this issue, are welcomed by the Board of Editors. These short contributions, especially those from Regions and Areas, help to lend balance to the *Journal*'s coverage and can, as in the article on interference from protective multiple earthing (on p. 216), give useful information in advance of a possible future full-length report.

Anyone who feels that he or she could contribute an interesting short article or, indeed, full-length article is invited to contact the Managing Editor at the address given below. The editors will always be pleased to give advice and try to arrange for help with the preparation of an article, if needed.

GUIDANCE FOR AUTHORS

Some guiding notes are available to authors to help them prepare manuscripts of *Journal* articles in a way that will assist in securing uniformity of presentation, simplify the work of the *Journal*'s editors, printer and illustrators, and help ensure that authors' wishes are easily interpreted. Any author preparing an article is invited to write to the Managing Editor, at the address given below, to obtain a copy.

All contributions to the *Journal*, including those for Associate Section Notes, must be typed, with double spacing between lines, on one side only of each sheet of paper.

As a guide, there are about 750 words to a page, allowing for illustrations, and the average length of an article is about 6 pages, although shorter articles are welcome. Contributions should preferably be illustrated by photographs, diagrams or sketches. Each circuit diagram or sketch should be drawn on a separate sheet of paper; neat sketches are all that is required. Photographs should be clear and sharply focused. Prints should preferably be glossy and should be unmounted, any notes or captions being written on a separate sheet of paper. Good colour prints and slides can be accepted for black-and-white reproduction. Negatives are not required.

It is important that approval for publication is given at organizational level 5 (that is, at General Manager/Regional Controller/THQ Head of Division level), and authors should seek approval, through supervising officers if appropriate, before submitting manuscripts.

Contributions should be sent to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NP 9.3.4, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY.

Post Office Press Notice

SYSTEM-X CONTRACTS

Contracts worth £20M have been placed by the British Post Office (BPO) with British telecommunications manufacturers as part of the System-X project—the biggest telecommunications development ever undertaken in Britain. They cover the design of main-network, tandem and small-to-medium capacity local-exchange equipment. The contracts have gone to the General Electric Co. Ltd. (GEC), the Plessey Co. Ltd. and Standard Telephones and Cables Ltd. (STC).

Based on electronic and computer-like control technologies, System X represents a new generation of technically-advanced exchange equipment which will carry the BPO's telephone system into the twenty-first century.

The new equipment is expected to hold down plant and operational costs through the 1980s and 1990s, and lay the foundations for an expanding range of customer services and facilities. Export as well as BPO requirements are being taken into account in the development programme. A great deal of preparatory work has already been carried out jointly by the BPO, GEC, Plessey and STC, and the new contracts carry the work into the next phase.

Already, some 500 engineers are involved in the System-X development. It is expected to cost more than £100M before the full range of applications is in service. These development costs are justified by the very large supply programme envisaged in the 1980s and 1990s, and the boost System X is expected to give to exports.

System X is based on digital, microelectronic and software technologies, and is being designed to meet a wide range of applications. It uses a family of modular "building blocks" (called subsystems) that can be adapted to meet an expanding range of service and network requirements at home and overseas.

The applications envisaged for System X include local exchanges of various capacities, and a family of main-network exchanges. The subsystems include

(*a*) stored-program-control processors, which store and manipulate information required to control the setting-up and progress of telephone calls,

(*b*) digital-switching subsystems, which interconnect, as required, digital circuits connected to the switch,

(*c*) signal-interworking subsystems, which are used on calls to and from existing exchanges,

(*d*) analogue-to-digital-conversion subsystems, which are used to convert analogue transmission signals into digital form and vice versa, and

(*e*) message-transmission subsystems, which are used to transmit control and management information between stored-program-control processors in different exchanges.

To simplify production, planning and operational problems, the subsystems are being designed to common equipment, documentation and other standards, including a standard equipment practice.

System X builds upon experience gained with earlier systems, including the reed-relay electronic systems TXE2 and TXE4, and digital transmission systems, and upon the private development undertaken by firms in recent years.

INDEX TO ADVERTISERS

Cole Electronics	6
Communications 78	6
GEC Telecommunications	3
M-O Valve Co. (GEC)	1
Northeast Electronics	8
Sintrom Electronics	4
Standard Telephones & Cables	2
TCL	5
Thorn Ericsson	7

Advertisements

Communications, advertisement copy, etc.
should be addressed to The Kemps Group Ltd., 1-5 Bath Street, London EC1V 9QA. Telephone: 01-253 5314/3871

No responsibility is accepted by the POEEJ *for any of the private or trade advertisements included in this publication.*

Copyright

The entire contents of this *Journal* are covered by general copyright, and special permission is necessary for reprinting long extracts, but editors are welcome to use not more than one-third of any article, provided that credit is given at the beginning or end, thus: "From *The Post Office Electrical Engineers' Journal.*"

The Board of Editors is not responsible for the statements made nor the opinions expressed in any of the articles or correspondence in this *Journal*, unless any such statement is made specifically by the Board.

Subscriptions and Back Numbers

The *Journal* is published quarterly in April, July, October and January, at 55p per copy, 80p per copy including postage and packaging. Annual subscription: £3·20; Canada and the USA: $6·50.

The price to British Post Office staff is 36p per copy.

Back numbers will be supplied if available, price 55p (80p including postage and packaging). At present, copies are available of all issues from April 1973 to date; copies of the July 1970, October 1970 and April 1972 issues are also still available.

Orders, by post only, should be addressed to *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG.

Employees of the British Post Office can obtain the *Journal* through local agents.

Binding

Readers can have their copies bound at a cost of £4·25, including return postage, by sending the complete set of parts, with a remittance, to Press Binders Ltd., 4 Iliffe Yard, London SE17 3QA.

Remittances

Remittances for all items (except binding) should be made payable to "*The POEE Journal*" and should be crossed "& Co."

Advertisements

All correspondence relating to advertisement space reservations, copy, proofs etc., should be addressed to Paul M. Johnstone, Advertisement Manager, The Kemps Group, 1–5 Bath Street, London EC1V 9QA (telephone: 01-253 5314 or 01-253 3871).

Distribution and Sales

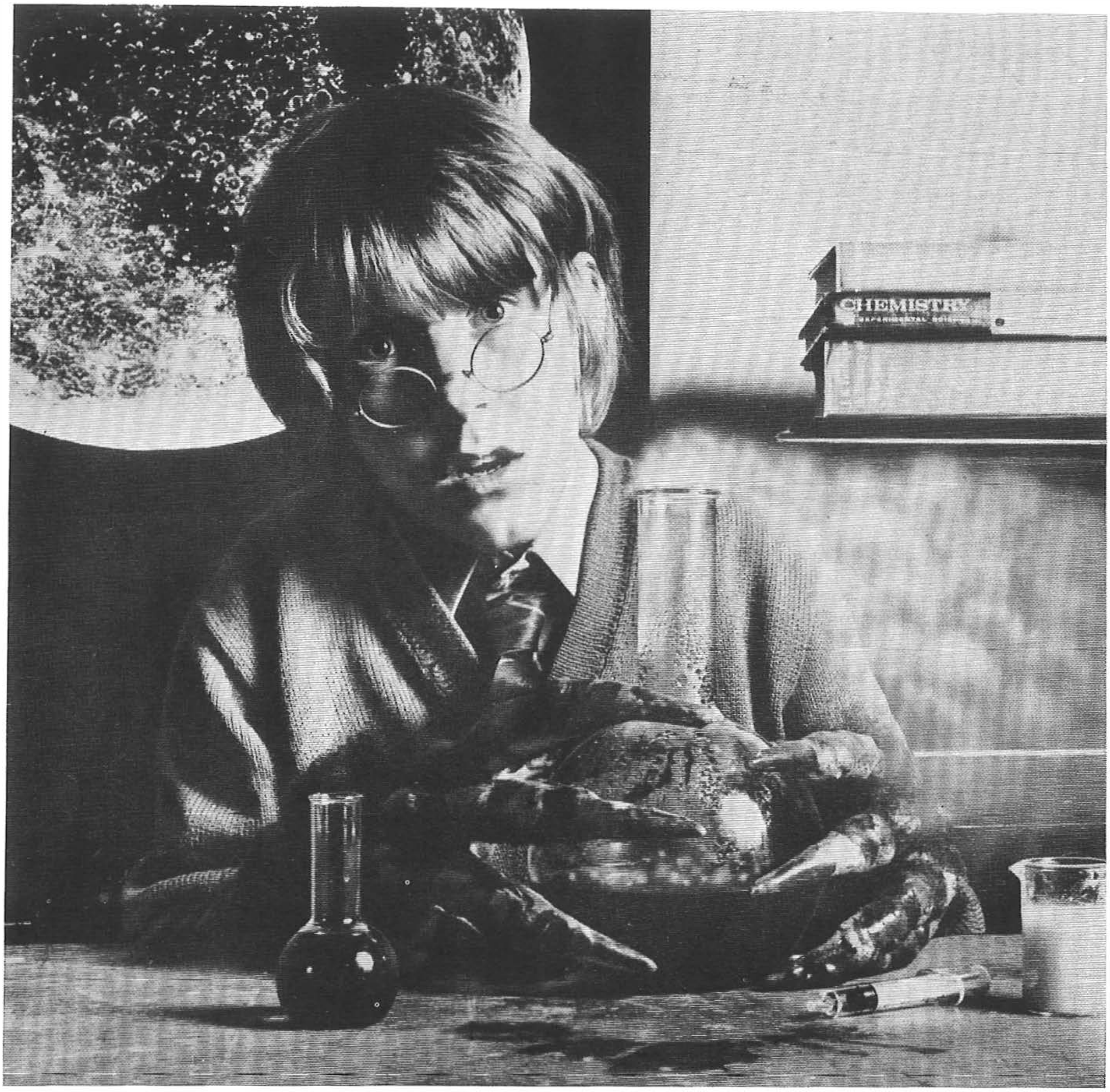
Correspondence relating to the distribution and sale of the *Journal* should be addressed to *The Post Office Electrical Engineers' Journal* (Sales), 2–12 Gresham Street, London EC2V 7AG.

Communications

With the exceptions indicated above, all communications should be addressed to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NP 9.3.4, Room S 08, River Plate House, Finsbury Circus, London EC2M 7LY.

Model Answer Books

Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Details of the books available are given at the end of the Supplement to the *Journal*. Copies of the syllabi and question papers are not sold by *The Post Office Electrical Engineers' Journal*, but may be purchased from the Department of Technology, City and Guilds of London Institute, 76 Portland Place, London W1N 4AA.


CHEMISTRY

Communications 78
Communications Equipment and Systems

National Exhibition Centre, Birmingham, England.
Tuesday 4-Friday 7 April 1978

You are invited to Communications 78

Communications 78 is the world's leading exposition for selling communications equipment and systems, providing an international focal point for the latest technological advances in the fields of PTT telecommunications, fixed and mobile radio communications and defence communications.

Active backing

Trebled in size since the last event in 1976, Communications 78 is being supported by more than 200 international exhibitors and has the active backing of the International Telecommunication Union (ITU), representing the interests of 153 governments; the British government through the Ministry of Defence, the Home Office and the British Overseas Trade Board; Post Office Telecommunications; the Electronic Engineering Association (EEA) and the Telecommunication Engineering and Manufacturing Association (TEMA).

Integral conference

The integral conference is being organised by The Institution of Electrical Engineers (IEE) in association with the Institution of Electronic and Radio Engineers (IERE), the UKRI section of the Institute of Electrical and Electronics Engineers (IEEE) and the IEEE Communications Society.

Communications 78 is being held for the first time at the National Exhibition Centre, Birmingham-the UK's premier exhibition complex-from Tuesday 4 April to Friday 7 April 1978. The exhibition will be open daily from 09.30 - 18.00 hrs. (17.00 hrs. on last day).

Admission to the exhibition is free to bona fide users and specifiers of communications equipment and systems. The coupon below may be presented as an admission ticket to Communications 78 or, if you require more detailed information, please complete and send it to: Tony Davies Communications, c/o Industrial and Trade Fairs Ltd., Radcliffe House, Blenheim Court, Solihull, West Midlands B91 2BG, England.

Please send me details of

the exposition ☐
the conference ☐

Name ____________________

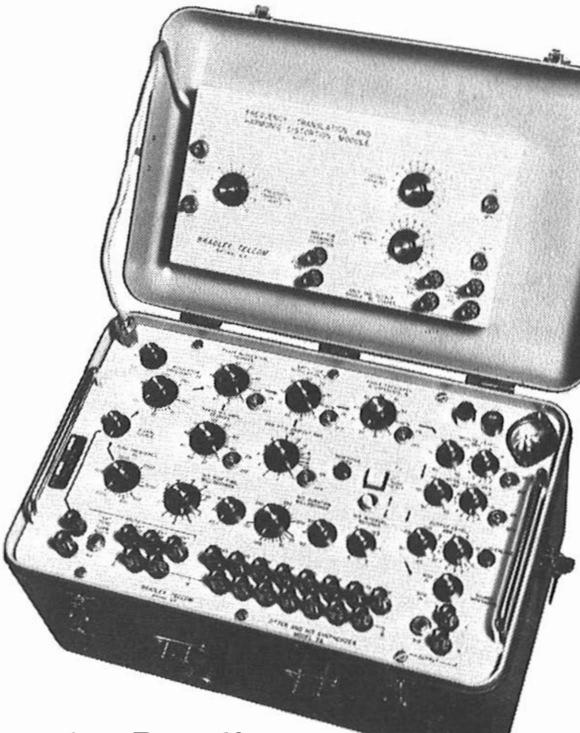
Position ____________________

Company ____________________

Address ____________________

36

THE UNIQUE SIMULATOR OF NON-TARIFFED DISTURBANCES



..the Bradley Telcom Model 2A/2B Line Impairment Generator

No other instrument in the world includes all these simulation facilities of non-tariffed disturbances: amplitude jitter/gain phenomenon, single-frequency interference, realistic hit capacity, continuously variable jitter frequency, internal tone oscillator, and impulse simulation repeatable from unit to unit.

With the Bradley Telcom Model 2A/2B, you also get these advantages: 'pure' or othogonal impairments (a phase hit that does not include a gain hit), continuous variability in all parameters, and accurate settings by calibrated panel dials.

You can have the Model 2A/2B in a single, portable box, or in a rack-mounted configuration. Versions available for 100, 115 or 230 volts, 50 or 60Hz.

For more information, contact Cole, the company advancing data communication in the U.K.

cole

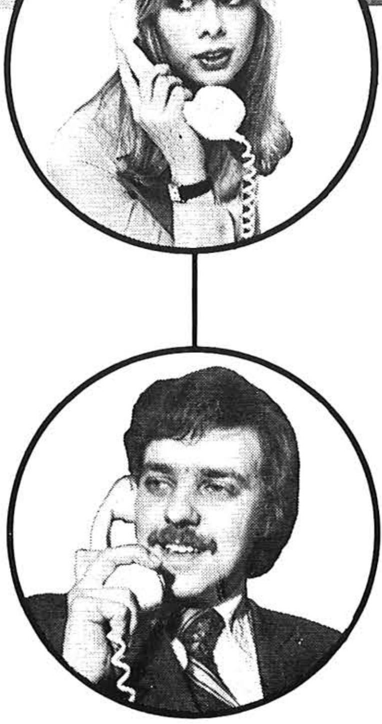
Advance Data Communications

Cole Electronics Limited,
33-35 Lower Coombe Street, Croydon, CR0 1AA
Telephone: 01-688 6822   Telex: 946847

A Thorn Ericsson PABX can provide over twenty aids ✱
to efficient communications. Here is one of them

Automatic Transfer

After an incoming call has been routed to an extension by the operator, the extension can transfer the call automatically to another extension by use of the service button on the instrument. To avoid a 'lost' call, special safeguards have been built into the system.



A Thorn Ericsson PABX can be built up with extra lines, extensions or facilities as traffic needs increase.

Planning ahead with a Thorn Ericsson 561 or 562 PABX will give you that efficiency and flexibility that is a real investment.

Contact: PABX Division, Thorn Ericsson Telecommunications (Sales) Ltd., Viking House, Foundry Lane, Horsham, Sussex. Telephone Horsham 64166.

✱ *Other facilities available include: Barred Extensions (stops unauthorised calls), Hold for Enquiry, Repeated Enquiry, Camp-on Busy, Call Announcing, Trunk Offering, Parking Incoming calls, Automatic Transfer, Call overlapping, Night Service (Three methods), Inter PABX connexion (Private wires), Group Calling, Direct Dialling-in, Automatic Call Back and many more*

SAVE TIME. Simply clip this coupon to your letter heading and send to **Thorn Ericsson, Freepost, Horsham, Sussex.**

No stamp needed

Name

Please arrange for me to have:
details of PABX's ☐
A technical adviser (appointment) ☐
A Demonstration of PABX ☐

THORN ERICSSON

Published by *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG
and printed in Great Britain by Unwin Brothers Limited, Old Woking, Surrey

The new, intelligent Model 2760 by Northeast Electronics is a signalling problem-solver that locates trouble areas quickly to keep revenue-producing telephone systems operating efficiently with minimum downtime. It has the brains to detect, store and display full sequences of digits and codes for register and line signalling, in both forward and reverse directions. This compact, easy-to-operate instrument is so versatile it outperforms anything else available today.

The genius has a built-in memory, a microprocessor and the ability to perform a broad range of test functions. It has plug-in capability and can handle many signalling systems including **R2/MFC, MF2, E & M or Loop DP, AC9, AC11, 3825 Hz SF.** Model 2760 is modularly expandable and future plug-ins for R1/CCITT 5, Touch-Tone® plus other signalling systems will include programmable senders and receivers.

A dual display shows as many as 16 digits/codes and up to 240 digits/codes per call can be captured in memory and recalled for use. The instrument can be bridged anywhere on 2, 4, or 6-wire circuits without disturbing normal service.

In addition to routine maintenance and service observing functions, the 2760 can be used to detect fraudulent use of the telephone network and to test systems to their marginal limits.

The genius is ready to go to work for you and help improve toll call completion, increase revenue, and make maintenance easier and faster. For full details, call or write today:

A. W. Hart, Eurep Ltd., P. O. Box 1,
Chepstow, Gwent NP6 5XQ, UK,
Tel. Chepstow 5614/5870,
Telex 49280 Severn Chepstow.

NORTHEAST ELECTRONICS
Division of nt northern telecom

The genius can solve your toughest signalling problems.