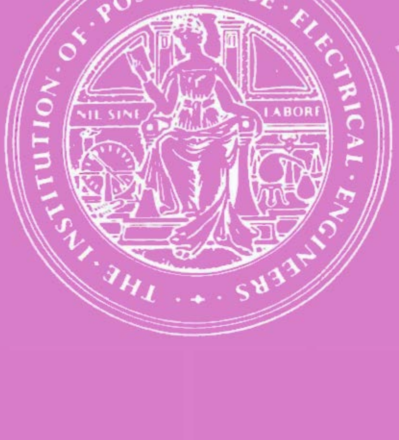
The Post Office Electrical Engineers' Journal

VOL 74 PART 1 APRIL 1981



THE POST OFFICE ELECTRICAL ENGINEERS' JOURNAL

VOL 74 PART 1 APRIL 1981

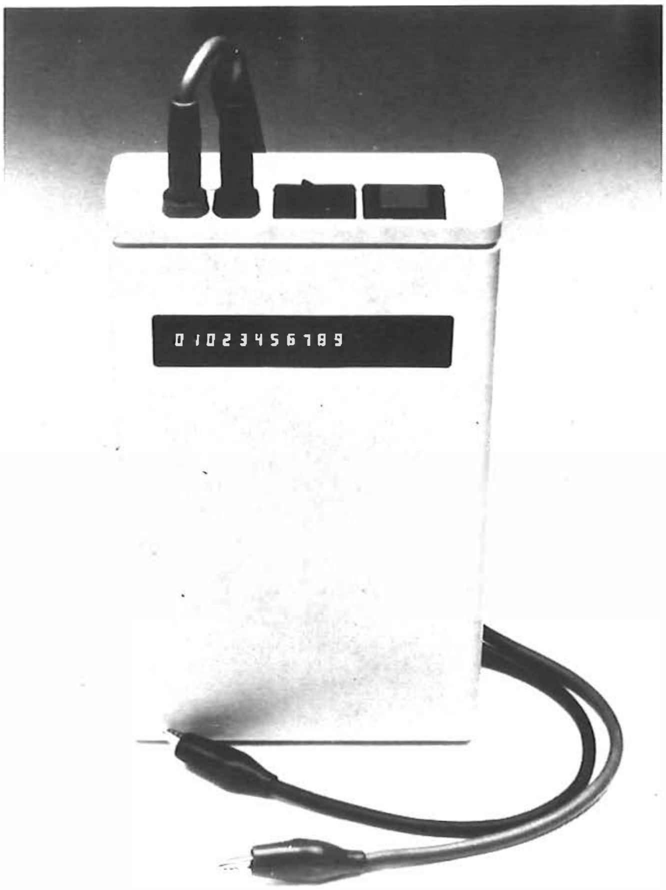
Contents

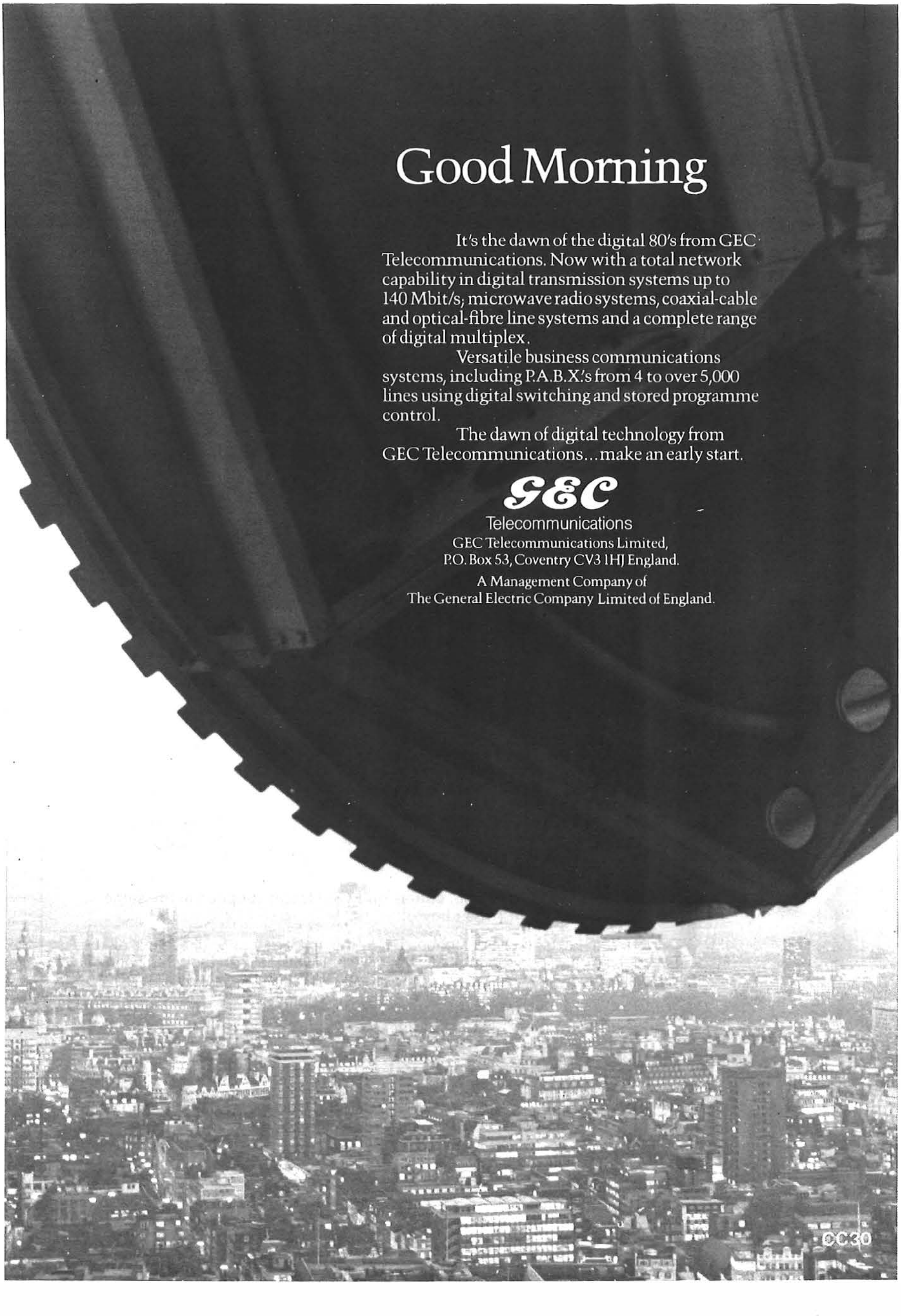
Published in April, July, October and January by *The Post Office Electrical Engineers' Journal*,
2–12 Gresham Street, London EC2V 7AG.

Price: 80p (£1.30p including postage and packaging). Orders by post only.

Annual subscription (including postage and packaging): home and overseas £5·20.
(Canada and the USA $12·00.)

Price to British Post Office staff: 48p.


0 1 0 2 3 4 5 6 7 8 9



The Post Office Electrical Engineers' Journal

EDITORIAL

Two years ago the *Journal* commenced a series of articles that described a family of digital-switching telephone exchanges (System X).

During this period of time, which has seen the introduction into service by the British Post Office (BPO) of the first System X exchange in Baynard House, London, a comprehensive coverage of the System X concept has been given in the *Journal*.

The articles have included such topics as: the principles of System X—including aspects related to common channel signalling, and processor control; the architecture of System X—with a description of the structures of the different types of exchanges; the subsystems of System X; the hardware and software technology involved; and the design and support required by a modern switching system.

This issue of the *Journal* concludes this initial coverage of System X. It is hoped that these articles have contributed to a greater awareness and understanding of the system that is of immense importance to the future of telecommunications in the UK.

Since 1975, a computer aid to junction-network planning (CJP2) has been available to the BPO junction-network planner. With the introduction of digital switching into the UK telecommunications network, a complex network requiring skilful planning and utilization of resources will evolve. To meet this challenge an integrated series of computer based planning systems for the junction network is planned. These systems will assist both the network planner and the circuit-provision control duty in ensuring the efficient usage of the BPO junction network.

The first two of these computer systems, CJP3, which supersedes CJP2, and the junction network updating facility (JNUF) are covered in this *Journal*.

System X: Subsystems

Part 7—The Signalling Interworking and Analogue Line Terminating Subsystems

G. R. SMITH, B.ENG.†

UDC 621.395.345: 621.395.38

The signalling interworking and analogue line terminating subsystems (SIS/ALTS) provide the means by which System X exchanges communicate with an existing telephone network. This article describes the principal features of the SIS/ALTS; in particular, emphasis is placed on their application at the medium/large size System X exchanges.

INTRODUCTION

Historically, the UK public switched telephone network has evolved from a manually switched network, controlled by operators, through a semi-automatic phase to the present fully-automatic mode. During this period, the signalling used has varied from the manual generator type, with the operators conversing to set up the required connexion, through an era heavily based on the Strowger switch, needing decadic (10 pulses per second) signals, to the multi-frequency (MF) signalling used for some present-day calls. The exchanges installed during this period of change have all used analogue space-switching techniques, and the signalling for a particular circuit has, in most cases, been conveyed in the speech path.

In contrast, System X exchanges are based on digital switching techniques, with routes possessing dedicated signalling links for fast inter-exchange communication. The signalling interworking and analogue line terminating subsystems (SIS/ALTS) are provided in each System X exchange to translate the different transmission and signalling conditions encountered at the interface of the exchanges and the external network[1].

The System X family of exchanges caters for exchange systems ranging in size from large trunk/international units to small local exchange units[2-4]. The many types of signalling systems in the existing UK telephone network have resulted in the need to design a large number of signalling interfaces. This article concentrates on the SIS/ALTS used at medium/large exchanges; particular emphasis is given to the application at trunk exchanges, which have a traffic-carrying capacity of 200–20 000 erlangs.

SUMMARY OF PRINCIPAL ABBREVIATIONS USED IN THIS ARTICLE

ALTS	Analogue line terminating subsystem
AP	Application process
ASLT	Analogue signalling line termination
ATBA	Automatic test break access
Codec	Coder/decoder
CP	Common process
CPS	Call processing subsystem
DIO	Direct input/output
DSS	Digital switching subsystem
MCS	Maintenance control subsystem
MF	Multi-frequency
MOJ	Metering over junction
MUX	Multiplexor/demultiplexor
PCM	Pulse-code modulation
PUS	Processor utility subsystem
SCC	Signalling conversion circuit
SIS	Signalling interworking subsystem
TS16	Time-slot 16
VF	Voice frequency

INTERWORKING ARCHITECTURE

A block diagram of the SIS/ALTS medium/large trunk exchange architecture is shown in Fig. 1. The SIS/ALTS is centred on two of the other major System X subsystems: namely, the *digital switching subsystem* (DSS) and the *processor utility subsystem* (PUS)[5,6].

The signalling interworking subsystem (SIS) terminations on the DSS are standard 32 time-slot, high-density bipolar 3 (HDB3), 2·048 Mbit/s pulse-code modulation (PCM) transmission systems[7,8]. These systems are used primarily to terminate the digitally-encoded speech information for connecting calling and called customers. However, they are also used by the SIS as a flexibility point for the insertion or extraction of time-slot 16 (TS16) signalling information, or for the connexion of an MF register while a call is being established.

The PUS is a central processor in which application programs can be executed to perform specific functions; it also provides a means by which the SIS application programs can communicate either with other System X subsystems or with their associated SIS hardware by using a direct input/output (DIO) connexion path.

The SIS/ALTS handles the signalling from either analogue lines or PCM line systems with channel-associated TS16 signalling. The signalling can be contained either outside the speech band or within the voice-frequency (VF) spectrum. The line supervisory signals may be either decadic pulses (10 pulses per second) or fast MF tones. The SIS/ALTS also provides the facility to perform only analogue-to-digital conversion (that is, no signalling translations).

Decadic Signalling (Digital Lines)

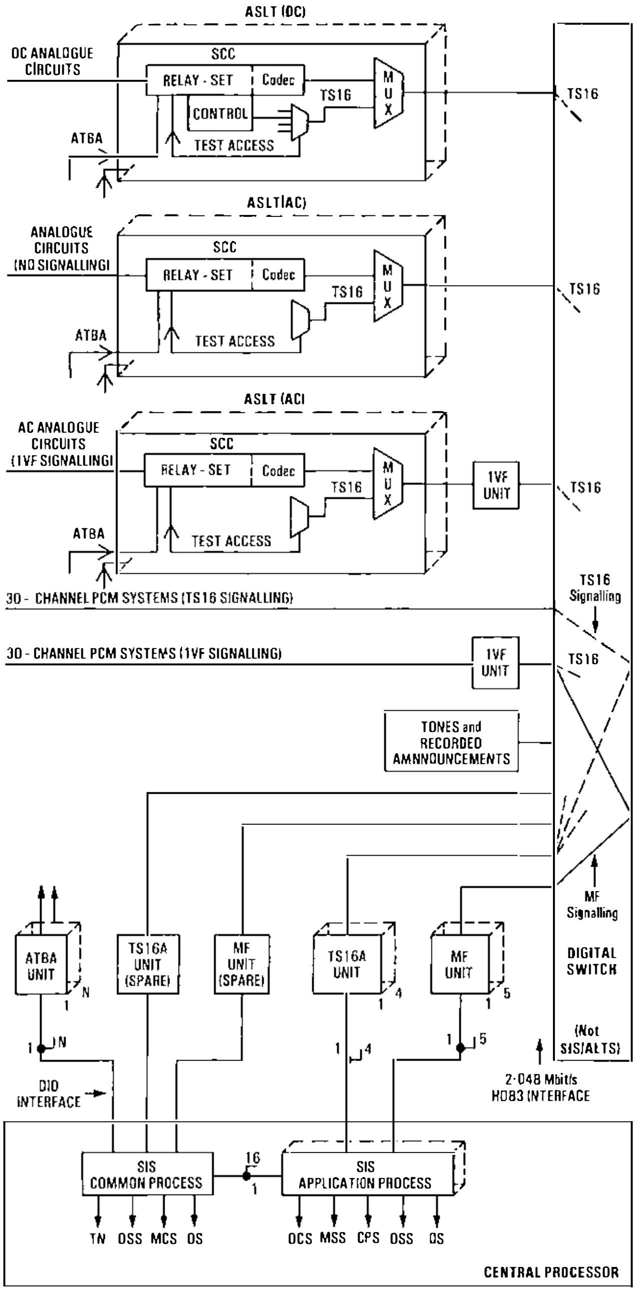
Digital 2·048 Mbit/s PCM systems from non-System X exchanges terminate directly on the DSS, and signalling information is contained in TS16. This signalling time-slot is semi-permanently connected across the DSS as a 64 kbit/s data channel, and is concentrated on a TS16A signalling unit with up to 29 similar data channels. The TS16A unit is connected to the DSS by a standard 2·048 Mbit/s HDB3 interface, but all the time-slots contain signalling information. Thus, the unit handles the signalling for up to 900 circuits simultaneously.

The TS16A unit performs all the signal validation and decadic pulse-timing checks required by each of the signalling variants and converts them into messages for input to the processor.

Periodically, the SIS application process (AP), which runs in the processor, interrogates its TS16A unit input queues and extracts any waiting messages. The AP can accommodate up

---

† System X Development Department, Telecommunications Headquarters



ASLT: Analogue signalling line termination
ATBA: Automatic test break access
Codec: Coder/decoder
CPS: Call processing subsystem
DIO: Direct input/output
DSS: Digital switching subsystem
MCS: Maintenance control subsystem
MSS: Management statistics subsystem
MUX: Multiplexor/Demultiplexor
OCS: Overload control subsystem
OS: Operating system
PCM: Pulse-code modulation
SCC: Signalling conversion circuit
SIS: Signalling interworking subsystem
TS16: Time-slot 16

FIG. 1—Block diagram of the signalling interworking and analogue line terminating subsystem in a medium/large trunk exchange

to four TS16A equipments (3600 circuits); it decides the relevance of messages in a particular signalling protocol, and produces any required responses for either the call processing subsystem (CPS) or the TS16A hardware.

The above procedure is also operated in reverse by the SIS AP, which receives messages from the CPS, determines protocol and outputs instructions directly to the circuit concerned within the TS16A unit.

The SIS software in the main processor also contains a second type of process known as the *common process* (CP). The CP is not involved in normal call-handling procedures, but it contains all the maintenance, diagnostic and resource management procedures; it also enables more than one AP to be added to the subsystem when the number of junctions exceeds 3600.

Decadic Signalling (Analogue Lines)

Analogue circuits terminating on the exchange fall basically into 2 signalling categories: DC and AC types.

The DC category includes signalling systems, such as loop-disconnect signalling, in which DC line currents are used to convey signalling information. These lines terminate on analogue signalling line termination (ASLT) equipments that generate a standard 2·048 Mbit/s HDB3 output, with the signalling in TS16. The digital system terminates on the DSS and the signalling is handled in a similar manner to terminating 2·048 Mbit/s PCM systems. The AC signalling category is slightly different because any in-band signalling (for example, 2280 Hz) is treated as speech and is encoded in the PCM data of the appropriate speech time-slot.

All the analogue terminations provide test break access facilities for testing out to line or into the exchange.

1VF Signalling

Terminating channels that possess in-band signalling are handled by a digital 1VF unit, which is inserted into the 2·048 Mbit/s system before it terminates on the DSS. The 1VF unit monitors for the presence of signalling in the digital speech channels and converts such signals into equivalent *tone on/off* commands in TS16. These signals are then interpreted by the TS16A equipment, as outlined above.

Multi-Frequency Signalling

When fast inter-register signalling is required, an MF sender/receiver is connected during call set-up. Digital MF sender/receivers that terminate directly on the DSS in blocks of 30 sender/receivers are provided.

The normal line-seizure state is detected in the SIS AP and, if MF signalling is marked, the SIS AP selects a free MF sender/receiver channel.

The SIS AP instructs the DSS to connect a speech path between the appropriate speech circuit and the selected MF sender/receiver channel. The inter-register signals then pass into the SIS AP, which associates the register and line circuit identities and passes on information to the CPS. The sender/receiver channel is released at the end of the call set-up phase.

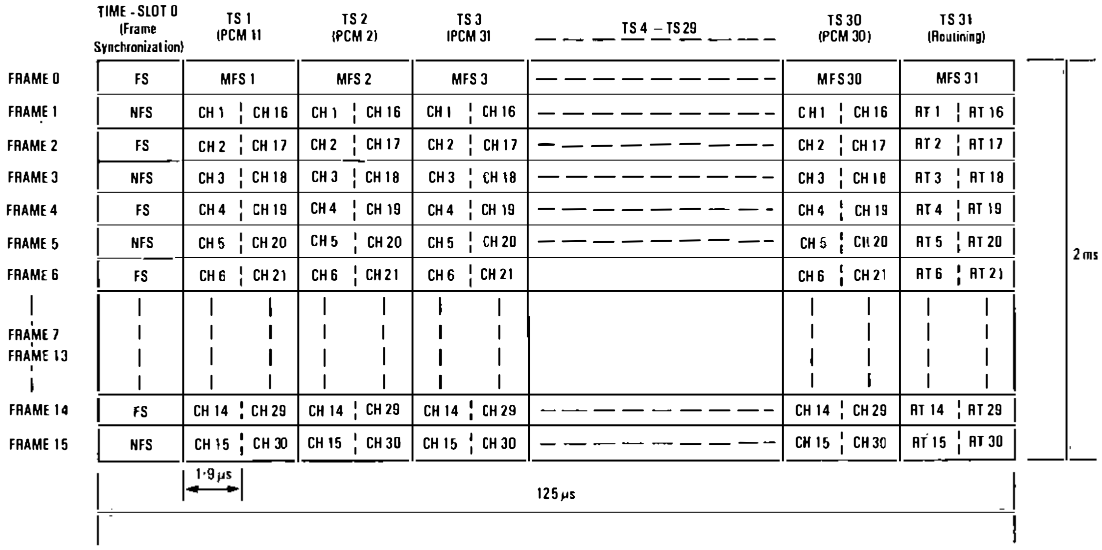
Full availability of all sender/receiver channels is given to any of the 3600 circuits controlled by each SIS AP. Additional 30-channel MF sender/receiver units can be allocated if warranted by the traffic demand.

SUBSYSTEM IMPLEMENTATION

The SIS/ALTS consists of several building blocks, which are often referred to as *functional entities*. Some of these functional entities exist at the periphery of the exchange to interface the analogue lines; others lie within the processor to interface with other System X subsystems. The following paragraphs describe the functioning of these separate entities. From a signalling viewpoint, the TS16A unit is the functional centre of the SIS. The concentration of subsystem resources centrally to within the TS16A unit enables the provision of relatively simple peripheral functional entities. Because of the importance of the TS16A unit operation and its interworking with other areas of the subsystem, a more detailed description of this unit is given.

TS16A Unit

The TS16A unit is terminated on the digital switch (DSS) by a standard 2·048 Mbit/s HDB3 interface. The information content of this interface is unique to the equipment, as all the time-slots (except TS0) contain 64 kbit/s TS16 signalling streams, enabling a maximum of 930 (30 × 31) channels to be



	TIME-SLOT 0 (Frame Synchronization)	TS 1 (PCM 1)	TS 2 (PCM 2)	TS 3 (PCM 3)	TS 4 – TS 29	TS 30 (PCM 30)	TS 31 (Routining)
FRAME 0	FS	MFS 1	MFS 2	MFS 3	— — — — — — — — — — —	MFS30	MFS 31
FRAME 1	NFS	CH 1 ¦ CH 16	CH 1 ¦ CH 16	CH 1 ¦ CH 16	— — — — — — — — — — —	CH 1 ¦ CH 16	RT 1 ¦ RT 16
FRAME 2	FS	CH 2 ¦ CH 17	CH 2 ¦ CH 17	CH 2 ¦ CH 17	— — — — — — — — — — —	CH 2 ¦ CH 17	RT 2 ¦ RT 17
FRAME 3	NFS	CH 3 ¦ CH 18	CH 3 ¦ CH 18	CH 3 ¦ CH 18	— — — — — — — — — — —	CH 3 ¦ CH 18	RT 3 ¦ RT 18
FRAME 4	FS	CH 4 ¦ CH 19	CH 4 ¦ CH 19	CH 4 ¦ CH 19	— — — — — — — — — — —	CH 4 ¦ CH 19	RT 4 ¦ RT 19
FRAME 5	NFS	CH 5 ¦ CH 20	CH 5 ¦ CH 20	CH 5 ¦ CH 20	— — — — — — — — — — —	CH 5 ¦ CH 20	RT 5 ¦ RT 20
FRAME 6	FS	CH 6 ¦ CH 21	CH 6 ¦ CH 21	CH 6 ¦ CH 21		CH 6 ¦ CH 21	RT 6 ¦ RT 21
FRAME 7 FRAME 13							
FRAME 14	FS	CH 14 ¦ CH 29	CH 14 ¦ CH 29	CH 14 ¦ CH 29	— — — — — — — — — — —	CH 14 ¦ CH 29	RT 14 ¦ RT 29
FRAME 15	NFS	CH 15 ¦ CH 30	CH 15 ¦ CH 30	CH 15 ¦ CH 30	— — — — — — — — — — —	CH 15 ¦ CH 30	RT 15 ¦ RT 30

TS: Time-slot
FS: Frame synchronization word
NFS: Not frame synchronization word

MFS: Multi-frame synchronization word
CH: Signalling channel number
RT: Routeing channel number

FIG. 2—Format of TS16A unit 2·048 Mbit/s transmit data

controlled. A transmitted multi-frame is shown in Fig. 2; all 31 PCM systems served receive their synchonization within the same 125 µs frame. However, in the receive direction, all the individual PCM systems have asynchronous multi-frames and, hence, 31 multi-frame synchronization counters are necessary. The thirty-first PCM system is reserved for routining functions and, hence, the maximum termination capacity is reduced to 900 circuits.

Individual channels possess a block of updatable random-access storage within the unit. When the exchange is brought into service, or after an in-service change-over, the SIS AP software loads the expected signalling type into each of the 930 locations. This action, typically, indicates whether a circuit is an incoming loop-disconnect (I/C LD) circuit or an outgoing 1VF circuit (each TS16A unit can accommodate up to 30 different types of signalling).

The next function to be loaded is the current signalling-state for each channel. This is normally set to the *idle* state when a new exchange is brought into service, but after an in-service change-over, the latest information is transferred from the SIS AP call states.

Finally, the metering charge-rate distribution (required for metering-over-junctions (MOJ)) applicable at that time of day is loaded into the charge-rate generators. Up to 60 separate distributions can be set to include all combinations of tariff groups (for example, ordinary or coin-collecting box) and charge bands (for example, local, trunk or international charge rates).

The TS16A unit is then started and, once the frame and multi-frame synchronization patterns have been located, signalling detection commences.

The synchronization counters produce a 10 bit circuit address (5 bit for frame and 5 bit for multi-frame) which is used to access the channel stores asynchronously. Each of the 930 channels is handled serially and, with a basic signal sampling rate of 2 ms, the time available for the unit to process the signalling for an individual channel is approximately 1·9 µs.

An outline of the operation of the TS16A unit is given in Figs. 3, 4 and 5, which show the signals received and sent by the unit, the receive-channel storage and the signalling program.

The TS16A unit signalling-type receive-channel store is set to *I/C LD signalling* and initially the *state-of-line* is set to the *idle* state (with reference to the signalling program). The *last code received* location holds the normal *idle* code, and the arrival of a new seizure is detected by comparison with this code. The new code is then loaded into the *last code received* location and the *persistence count* is incremented. This is repeated every 2 ms until the persistence-count value has indicated 3 consecutive new codes. The purpose of the 6 ms persistence check is to eliminate false signalling reports caused by minor disturbances to the line or slips in the synchronization. The persisted line code is then written into the *last code persisted* store, and a further validation check is performed using the *duration-count* store. This duration count can continue for up to 0·5 s but, in the case of a seizure, only 10 ms is indicated by the signalling program.

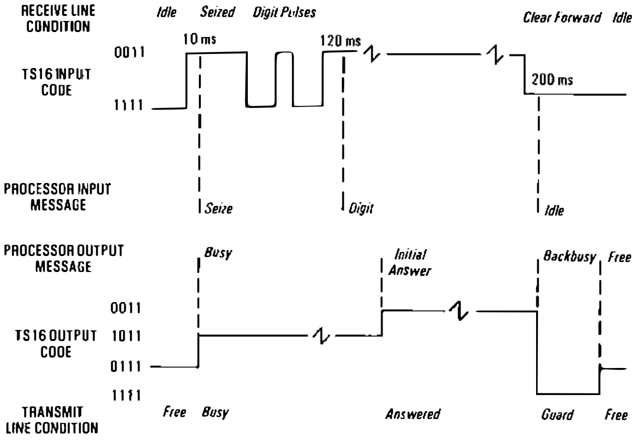


FIG. 3—TS16A unit interface signals (for incoming loop-disconnect signalling over analogue circuits)

A transition from the *idle* to the *seized* state is then performed: a *seize* message is sent to the processor and the *state-of-line* store is changed to the *seized* state. The remainder of the call continues in a similar manner except that, once seized, digits can be counted by incrementing the *digit-count* store after a valid *break* pulse followed by a subsequent *make* period. The digit value is sent to the processor after a validated inter-digit pause of 120 ms.

When a valid signalling event is detected by the unit, this condition is transferred into a processor input queue. The processor removes messages by using its DIO connexion; duplicated highways are used for the security of the DIO interface. The processor can also instruct the TS16A unit to output signals, as necessary.

The hardware–software boundary has been chosen to

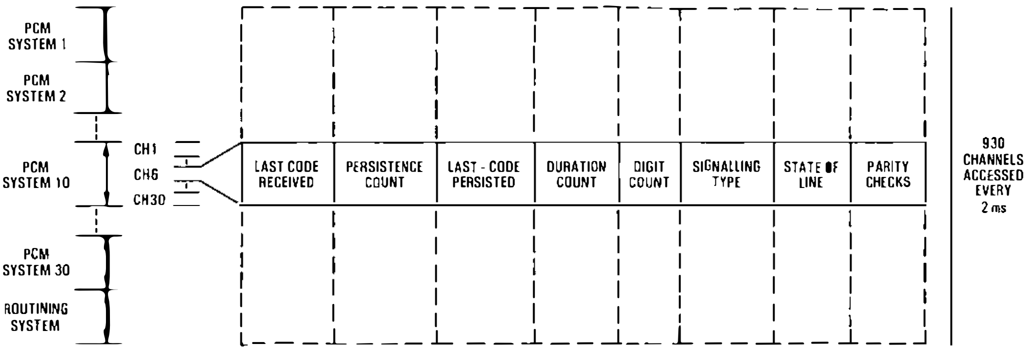
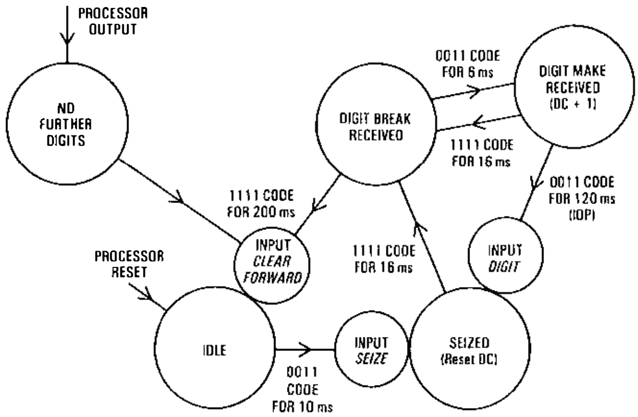


Fig. 4 Data fields in TS16A receive-channel storage



CSA: Called subscriber answer
DC: Digit count
IDP: Inter-digit pause

Fig. 5—Simplified TS16A receive-state transition diagram (for basic incoming, loop-disconnect signalling type)

minimize the number of signals transferred; this is achieved by timing the large majority of events within the TS16A hardware. In addition, the number of software signalling modules in the SIS AP is considerably reduced by having separate TS16A firmware programs; this removes the need for detailed software variations between signalling types.

Each TS16A equipment contains a duplicated charge-rate generator which produces charge-rate distributions applicable at a particular time of day.

When a chargeable *answer* signal is received by the SIS AP, (for example, when an incoming call requires MOJ), the SIS AP instructs the TS16A unit immediately to apply an initial *answer* signal and to continue metering at a periodic rate by pointing at one of the charge-rate distributions (for example, an *ordinary, trunk a* category). The unit then applies metering pulses appropriate to the signalling system until the calling customer clears.

If a particular call tranverses a charge-rate period when the rate of metering changes (for example, at 6 pm from standard to cheap rate), then the processor reloads all the amended charge-rate distributions. All calls pointing to an amended distribution are then correctly updated by a secure procedure which ensures that no overcharging occurs. The total update of all 930 channels takes less than 1 s, and the charge rate is always biased on the low side.

The MOJ generator is duplicated to facilitate immediate fault detection. If a discrepancy in the two outputs is detected, metering is immediately inhibited and the whole unit is taken out of service; in such cases, the circuits are transferred to a hot-standby TS16A unit.

MF Unit

A standard 2·048 Mbit/s HDB3 interface connects the MF unit to the DSS. Each time-slot (except TS0) contains an individual MF sender/receiver channel, to which an incoming or outgoing call requiring MF signalling can be connected during the set-up phase. One of the sender/receivers is reserved for routine testing (fault detection); therefore, a maximum capacity of 30 call set-ups can be accommodated simultaneously in each unit. A single MF unit can handle the MF signalling for several hundred terminating circuits, the actual number depending on the circuit occupancies, the signalling system and network environment.

When an exchange is switched into service, the MF unit is reset so that all its sender/receivers are set to send and receive a *silence* state. All the DSS connexions are cleared, and the input/output buffers are emptied.

If a unit becomes faulty while handling calls it is disconnected and a hot-standby spare unit reset and brought into service automatically.

Once the SIS AP decides that MF signalling is required, it connects a speech path across the DSS to the selected sender/receiver channel; it also instructs the MF unit to expect signalling of a specific type on the connected call.

The MF receivers are implemented by using digital filtering techniques, and 8 receivers are processed serially by the same circuitry. The logic is presented with a tone sample every 125 μs for each of the 8 receiver channels and it serially examines these for 6 possible tone frequencies (6 forward tones or 6 backward tones). Hence, the receiver has only just over 2 μs to process each tone sample.

The digital filters integrate the tone samples over approximately a 15 ms period and produce outputs which are examined by the microprocessor control logic. This checks that the required tone pairs have been correctly detected (for example, that 2-out-of-6 frequencies are present) and places validated signals in a processor input queue. The MF control logic also checks that the correct signalling prefixes have been exchanged, and transmits any prefix responses automatically.

The processor extracts the signalling events, and the SIS AP associates the line-circuit termination identity before forwarding any messages to the CPS.

If any transmitted signals are required, then the SIS AP loads these directly into the input queue of the microprocessor which will output the correct tone sequence when the protocol permits.

The transmitted tones are generated digitally by reading out stored tone-patterns from memory. Compression techniques are used to reduce the tone storage to an absolute minimum. The tone sender can handle all 31 channels serially because the tone-generation function is much more straightforward to implement.

Analogue Signalling Line Termination

Analogue circuits from either distant or collocated exchanges are terminated on the exchange MDF and then cabled across to the analogue signalling line termination (ASLT). The ALTS, which is incorporated in the signalling conversion circuits (SCCs), is an integral part of this entity, and provides the codec and MUX facilities.

The circuits with DC signalling are terminated on the SCCs, which provide a physical interface with the analogue lines and extract their signalling. The signalling is sampled every 2 ms and is converted into a 4 bit digital code; the speech is converted into A-law encoded PCM data. These outputs, for 30 circuits, are then multiplexed with the signalling in TS16 to produce a standard 2·048 Mbit/s HDB3 stream.

Each SCC handles 2 circuits, and any SCC position can be used for any DC signalling system. This facility ensures that the design is suitable for all exchange system applications.

Early SCC designs occupied 2 slide-in-units (SIUs) on which the signalling conversion relays (SCR) and the signalling conversion electronics (SCE) were separated; the codecs and filters were also mounted separately. A technology update has enabled the ASLT equipment to be reduced to half its original size and it now houses single unit SCCs, which incorporate the codecs and filters.

The AC termination units do not perform any signalling detection functions, but simply terminate the analogue lines and convert their speech into A-law encoded PCM. This practice enables a 30-circuit group to be accommodated in half the space of the DC termination.

Each SCC unit provides full test-access facilities (2-wire or 4-wire) to both the line and the exchange equipment. The control of the test-access relays is achieved by using bits in frame 0 of TS16, which indicates the channel to be connected to the selected test highway. The test highway can then be routed to either automatic test break access (ATBA) equipments or the test network for detailed examination.

1VF Signalling Unit

A block diagram of the 1VF signalling unit is shown in Fig. 6, which indicates the major functional components of the unit. The 1VF unit is designed so that it can intercept a 2·048 Mbit/s HDB3 PCM system. The HDB3 interfaces use circuitry common to that used in the ALTS multiplexor.

If any of the 30 receive channels contain in-band 2280 Hz signalling, the digital speech samples are diverted into a 2280 Hz digital filter. The filter consists of 2 main parts: a digital notch-filter, which has a strictly defined response to 2280 Hz; and a digital guard filter, which prevents false operation of the notch filter when a high level of interference is detected. A much more detailed description of such a digital filter, on which the fundamental design of the System X filter is based, is given elsewhere[9].

The tone-generation function is performed by reading out from memory stored digital samples that represent a sampled 2280 Hz signal. The channel concerned is intercepted and either a 2280 Hz sample or a *silence* signal is inserted.

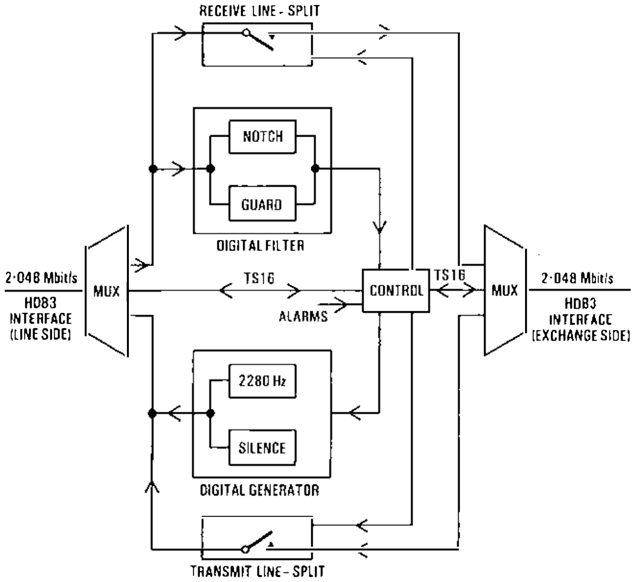


FIG. 6—Block diagram of the IVF signalling unit

An integral part of the tone filter and generator is a line-split facility, which can break either the receive path or the transmit path, or both. The line-split facility can be applied

(*a*) immediately a tone is detected from line,
(*b*) after a delay of 20–35 ms, or
(*c*) continuously (no tone present).

This function is required to prevent spillover of pulses from one link to the next and to prevent fraudulent operation.

The control section analyses outputs from the received digital filter and converts these into TS16 codes to indicate either *tone on* or *tone off* conditions. These codes are over-written into the TS16 signalling slots of the channel concerned. In the return direction, the TS16 codes are monitored by the control logic and converted into *tone on* or *tone off* instructions for the tone generator. Several *tone off* TS16 codes are used to control the line-splitting logic.

If some of the channels do not possess in-band signalling, their speech and TS16 data channels are simply passed transparently through the unit. This enables in-band and out-band signalling to be mixed in the 30 channels of the terminating PCM system.

Automatic Test Break Access Unit

All the analogue SCCs described so far have the option of providing 2-wire or 4-wire test-access facilities.

The test-access relays in each SCC unit are controlled from the SIS AP via TS16. The selected channel is diverted from its normal straight-through mode via one of two 8-wire test-access highways, which are cabled to each ASLT module. The highway can then be further switched to either the test network or to an automatic test break access unit (ATBA).

The ATBA unit has signalling auxiliaries for each of the signalling systems and is capable of performing detailed signalling tests into the exchange or limited DC tests on the junction or trunk circuit. For example, the maintenance engineer (using the MCS) can initiate a test of the SCC concerned, and all the associated circuit equipment between the SCC and the processor. This action can be achieved by operating the test-access relays in the SCC and by sending a *seize* signal, followed by a digit if necessary. The SIS AP marks the circuit under test, and the incoming signals are diverted to special test software. Similarly, the maintenance engineer can send signals via the SIS AP to the SCC concerned, which can be diverted to the ATBA unit for analysis.

Tones and Recorded Announcements

The SIS generates tones digitally by storing A-law encoded PCM samples of the appropriate tone frequency. The tone cadences are also stored in memory, and the cadence outputs are used to switch the tone frequencies at the desired on-off rate. The cadence switches also enable more than one tone, or different levels of the same tone, to be serially switched (for example, *equipment engaged* tone). The design caters for any tone which is a multiple of 10 Hz to be generated, and cadences are variable in 0·025 s steps up to 6·4 s. This flexibility allows the design to be easily modified for export applications.

The recorded announcements are generated by using adaptive differential PCM (ADPCM), which is a method of reducing storage requirements while retaining an acceptable signal-to-noise ratio. Each announcement is generated for 8 s, with a 2 s period of silence between cycles.

In the medium/large trunk exchange, up to 8 different tones and 3 recorded announcements are multiplexed together and fed into the DSS in a standard 2·048 Mbit/s HDB3 stream. The tones are selected by the call processing subsystem (CPS) when an invalid routeing has been dialled, and a path is set across the DSS from the incoming channel to the selected tone. The DSS can copy the same tone source to large numbers of incoming calls because, unlike analogue tones, there is no fan-out degradation of signal level[8].

Software Application Process

The SIS application process (AP) is responsible for the normal call-handling protocols required between the SIS hardware and the CPS.

The SIS AP is a periodic process activated by the processor operating system every 10 ms. In the interval between periodic activations, the SIS AP:

(*a*) increments its internal timers,

(*b*) extracts and processes messages from the CPS and the DSS software,

(*c*) extracts and processes messages from the TS16A unit and MF hardware, and

(*d*) processes any internal timeouts that have expired.

If any events have occurred in (*b*), (*c*) or (*d*) above, the appropriate software signalling module is invoked to process the event. The consequences of the processing may be either to transmit a message into the hardware, the CPS or the DSS, or simply to update the software circuit storage awaiting a further event.

Software Common Process

The prime function of the SIS common process (CP) is to interface with the MCS, to allow circuits, PCM systems and SIS hardware to be brought into or taken out of service. The CP co-ordinates the SIS AP replications that enable the subsystem to be extended in multiples of 3600 circuits.

The CP is also responsible for monitoring fault reports from the SIS APs. These reports can arise because of hardware faults arising from equipment malfunctions or simply because of the receipt of unexpected messages. The CP can set threshold counts on the individual fault categories so that equipment or circuits are not removed from service owing to transient reports. If a threshold count is exceeded, a fault report is sent to the MCS, and immediate action is taken to by-pass the affected area.

In a trunk exchange, another function of the SIS CP is to hold the tariff programs for MOJ. The SIS CP determines when the tariffs being applied in the TS16A hardware require updating and instructs each SIS AP to amend its TS16A hardware accordingly.

RELIABILITY AND MAINTAINABILITY

The adoption of high-technology integrated circuits, coupled with strict System X standards, has led to a very-low fault rate throughout the SIS/ALTS. However, were a fault ever to occur, its effect would potentially be very serious, especially in the common-control hardware, which can be processing several hundred calls simultaneously. Failure-detection mechanisms have been incorporated to isolate malfunctions in their infancy. These include:

(*a*) extensive hardware parity generation and detection,
(*b*) synchronization checks,
(*c*) the cycling of tone-loops through digital filters,
(*d*) the provision of watchdog alarms for microprocessors,
(*e*) synchronous duplication,
(*f*) continuous routines (using spare DSS channels),
(*g*) power supply and fuse alarms,
(*h*) cumulative sum checks on stored data,
(*i*) the detection of out-of-sequence signalling events,
(*j*) overnight routining of hardware fault-detectors,
(*k*) short-holding-time call detection, and
(*l*) trunk and junction routining.

When a fault has been confirmed, a report is immediately passed to the MCS, which initiates 2 important actions. Firstly, any dependent resources are immediately taken out of service; for example, if a 1VF unit fails, all the outgoing circuits are busied-out to prevent further call loss. Secondly, a fault report is issued to inform the maintenance staff of the faulty unit.

Critical areas of the subsystem, in particular the TS16A unit and the MF equipments, are replaced automatically by hot-standby spare units. The SIS CP allocates a spare TS16A or MF unit to the SIS AP which has reported the malfunction and removes the failed unit from service. The MF unit is relatively straightforward to replace, as new calls can simply be diverted to the new working unit. The change-over of TS16A equipments, however, is more complicated because each unit is semi-permanently allocated. The change-over is achieved by loading the signalling types and call states into all 900 channels of the new unit and then diverting the thirty TS16 connexions across the DSS. Some call loss would occur during these emergency change-overs, but the mean time between failure of the equipments concerned is over 10 000 hours, and only a small portion of calls are lost in the few seconds taken to complete a change-over.

SUMMARY AND CONCLUSIONS

The extremely broad specification for interworking has resulted in a highly-modular distributed design for the SIS/ALTS. The basic aim has been to keep the analogue termination equipment as simple as possible, and to perform the more complex timing and interactive functions in either shared hardware or in the processing units. This approach has resulted in a lower cost, highly-reliable design, which retains the flexibility required to meet a wide variety of signalling requirements.

The SIS/ALTS gives the System X exchange the ability to interwork with a large number of different types of signalling systems. This allows the System X exchanges to be gradually incorporated into the UK telephone network without any restrictions being imposed by the signalling requirements of the existing network or of System X itself. Thus a smooth transition to the fully integrated digital switching, signalling and transmission network can be achieved.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues in the System X Development Department and also within Plessey Telecommunications Ltd. for the provision of information contained in this article.

References

[1] Harris, L. R. F., and Davis, E. System X and the Evolving UK Telecommunications Network. *POEEJ*, Vol. 72, p. 2, Apr. 1979.

[2] Tippler, J. Architecture of System X, Part 1—Introduction to the System X Family. *POEEJ*, Vol. 72, p. 138, Oct. 1979.

[3] Vanner, N. J. Architecture of System X, Part 2—Digital Trunk Exchange. *POEEJ*, Vol. 72, p. 142, Oct. 1979.

[4] Oliver, G. P. Architecture of System X, Part 3—Local Exchanges. *POEEJ*, Vol. 73, p. 27, Apr. 1980.

[5] Risbridger, J. N. A. System X: Subsystems, Part 1—Digital Switching Subsystem. *POEEJ*, Vol. 73, p. 19, Apr. 1980.

[6] Belton, R. C. System X: Subsystems, Part 3—Processor Utility Subsystem. *POEEJ*, Vol. 73, p. 158, Oct. 1980.

[7] Vogel, E. C., and McLintock, R. W. 30-Channel Pulse-Code Modulation System, Part 1—Multiplex Equipment. *POEEJ*, Vol. 71, p. 5, Apr. 1978.

[8] Turvey, K. J. 30-Channel Pulse-Code Modulation System, Part 3—Signalling Units. *POEEJ*, Vol. 71, p. 225, Jan. 1979.

[9] Welsh, E. J., and Adams, P. F. New Digital 1VF Signalling Unit. *POEEJ*, Vol. 72, p. 108, July 1979.

Computer-Aided Design and Engineering of System X Exchanges

K. J. DIVER and D. W. SWAN, B.SC.†

UDC 621.395.345: 681.31

This article describes the computer support facilities that the British Post Office and the UK Telecommunications Industry are developing for the design and engineering of System X exchange installations.

INTRODUCTION

The process of converting basic traffic data for an exchange or an exchange extension into documentation to support the various requirements of a telephone administration and of the equipment supplier is known as *exchange design and engineering*. Computer-aided design (CAD) facilities to assist the engineers engaged in this task have been established for many exchange systems and similar facilities for System X are now being jointly developed by the British Post Office (BPO) and the UK Telecommunications Industry. The main objectives are to provide coherent computer support that:

(*a*) is standard for use throughout the industry,

(*b*) is capable of processing both home and export market orders,

(*c*) can rapidly accept design changes and enhancements, and

(*d*) will interface to other computer systems used by the administration and supplier.

For System X, two complementary systems are being developed. The first, covering the hardware aspects of design and engineering and known as the *Exchange Design CAD* (EDCAD) system, is the subject of this article. The second, covering the exchange data aspects and known as the *Data Management System*, will be the subject of a later article.

The main benefits of computer assistance to the design and engineering process are

(*a*) an increase in productivity contributing to a reduction in lead-times,

(*b*) a closer adherence to standards,

(*c*) an elimination of tedious and error prone schedule preparation,

(*d*) a consistency in both quality and format of derived documents, and

(*e*) the transfer of data between processes as computer files, thus eliminating transcription errors.

OVERVIEW OF THE DESIGN AND ENGINEERING PROCESS

The design and engineering process encompasses numerous activities ranging from the collection of basic traffic data by the administration to the provision of documentation to meet the requirements of the administration and supplier. The process can be divided into 6 major areas of activity.

(*a*) Dimensioning—converting the basic traffic data into equipment quantities.

(*b*) Placement—determining the location of this equipment within the exchange building.

(*c*) Allocation—determining the interconnexion of particular equipment where system design permits flexibility, and assigning external circuits to the appropriate type of terminating equipment.

(*d*) Cabling—identifying all cables and their routeing through the cable support structures.

(*e*) Software data build—converting data (for example, that established in the allocation process) into a format suitable for loading on the exchange processor; this activity is relevant only to stored-program controlled (SPC) exchanges.

(*f*) Documentation—recording the information established by the foregoing activities in a format suitable for its purpose; for example, installation instructions, exchange management records, etc.

For System X, the computer support facilities broadly follow the above pattern. The external circuit allocation and software data build activities are incorporated into the data management system, the remaining activities being included in the EDCAD system.

THE EDCAD SYSTEM ARCHITECTURE

The EDCAD system, which will generally give interactive support for the various design and engineering functions, is designed to operate on computers which are local to their users. Although many of the processes are automated, the system does not remove from the design engineers the ultimate responsibility for ensuring that exchanges are adequately designed and engineered. The principal components of the system (see Fig. 1) are:

(*a*) main program suites covering the activities of dimensioning, placement, internal allocations and cabling,

(*b*) standards data files which provide the system design data for the programs to use,

(*c*) exchange data files which are the outputs of program runs and serve both as master records of the exchange and as interfaces between the programs, and

(*d*) documentation production programs which produce from the exchange data files the various man-readable reports and schedules needed to support the realization of the design.

MAIN PROGRAM SUITES

Dimensioning Program Suite

The main responsibilities of this suite are to

(*a*) vet the exchange traffic data,

(*b*) convert the exchange traffic data into equipment quantities,

(*c*) identify the *software suite* that will be used when the exchange is brought into service, and

(*d*) produce estimates of the cost and of the DC power requirements of the exchange.

---

† System X Launch Department, Telecommunications Headquarters

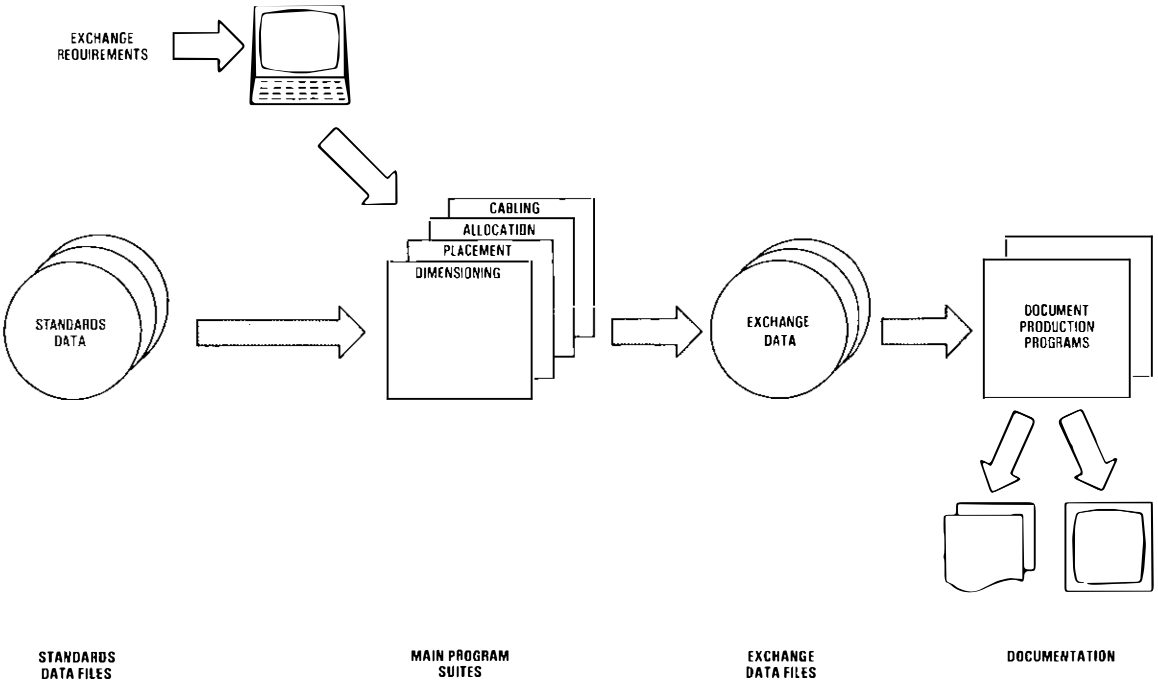


FIG. 1—EDCAD system architecture

The user may modify the results of the dimensioning process in order to cater for special requirements.

Placement Program Suite

This suite consists of two parts: *placement part 1* which positions the items identified by the dimensioning process; and *placement part 2* which identifies and positions the remaining hardware that will be necessary to build the installation. Placement part 1 comprises several programs which are run in sequence to

(*a*) position the slide-in units within shelf groups,

(*b*) position the shelf groups on rack frameworks (standard rack configurations being used wherever applicable),

(*c*) position the racks and distribution frames on to the exchange apparatus floor taking into account the building constraints (preferred exchange layouts being used wherever applicable), and

(*d*) designate the various racks, shelf groups, etc.

Placement part 2 is run at a later stage and identifies and positions the remaining hardware which comprises:

(*a*) power conductors and supports (from the power room to the main fuse panels),

(*b*) overhead ironwork arrangements,

(*c*) cable trays and grid mesh, and

(*d*) suite lighting.

An interactive graphics system is an integral feature of the program suite and allows plan-type information to be displayed and modified on a graphics display terminal. The system stores this information on a *layered* basis; different layers being used to hold the building outline, racks and frames, dimensions, overhead ironwork, etc. It can be used to display, process and output individual layers or combination of layers as required.

Internal Allocations Program Suite

The main responsibilities of this suite are to

(*a*) determine the interconnexion of those items within the exchange where the system design permits flexibility, and

(*b*) determine the grouping and addresses of equipment on the various highways.

Cabling Program Suite

The main responsibilities of this suite are to

(*a*) identify all plug-ended cables and their routeing,

(*b*) identify all bulk-supplied cables including individual length and routeing,

(*c*) monitor the fill of cable trays; re-routeing non critical length cables if appropriate,

(*d*) produce a cable running-out list, and cable identification labels for use by the installation team, and

(*e*) produce a plug-up schedule showing the termination address of each plug-ended cable.

Specification Production

The specification is a contractual document which is particular to an individual order and its content is, therefore, dependent upon the agreed division between the administration and supplier of the responsibility for the design and engineering of the installation.

For BPO contracts with the UK industry, a specification computer program exists and is run after the dimensioning, placement part 1 and internal allocations programs, deriving inputs from all of them.

STANDARDS DATA FILES

The EDCAD system requires information relating to all the exchange types for which it will be used. This information is recorded in a number of standards data files which are accessed during the running of the programs. The files are structured in a manner that enables any change in design rules to be rapidly accommodated by replacing the appropriate file with a new version.

An outline of typical files is given below; it is not a comprehensive list but is intended to give an indication of their scope.

(*a*) The *dimensioning rules*, which are a set of algorithms to convert the traffic data into equipment quantities.

(*b*) The *costs and power data*, which are used to produce cost and power estimates.

(*c*) The *graphics symbols library*, which contains the picture elements used by the placement programs to prepare the plan type documentation.

(*d*) The *placement constraints*, which are a set of rules constraining the relative positions of items.

(*e*) The *standard rack layouts*, which are pre-determined groupings of shelf groups on rack frameworks; ensuring consistency for similar types of exchange.

(*f*) The *preferred floor layouts*, which are pre-determined groupings of standard racks that will be selected by the placement programs if the building constraints permit.

(*g*) The *cable connexions files*, which are records of local and distant termination addresses for each shelf group together with cable type and any constraints; for example, maximum cable length.

(*h*) The *available cables file*, which are records of the range of plug-ended cables from which the cabling program makes its selection.

EXCHANGE DATA FILES

The process of using the EDCAD system creates a set of exchange data files, each recording particular aspects of the installation. These are the master records from which all documentation relating to the exchange is produced; they also serve as the interface between the processes. The major files are as follows:

(*a*) The *equipment quantities file*, which is output from the dimensioning program and lists the items of equipment required for the exchange installation.

(*b*) The *exchange parts file*, which is output by the placement programs and contains the identity and location of each item of hardware in the exchange.

(*c*) The *exchange graphics file*, which is output by the placement programs and identifies each symbol required on the exchange floor plan or related drawings, and includes the position and orientation of each symbol.

(*d*) The *exchange cabling file*, which contains a list of all cables required for the exchange together with the termination addresses, routeing and length of each run.

(*e*) The *exchange allocation file*, which defines particular equipment interconnexions and highway addresses.

DOCUMENTATION PRODUCTION

The exchange data files are the source of the documentation that is required for the varied aspects of planning, manufacturing, installation and management of the exchange. This documentation falls into two broad categories:

(*a*) *transient*, relating to information which is not required after the exchange has been installed, and

(*b*) *permanent*, relating to information which may be required at any time during the life of the exchange.

During the running of the various programs, error and analysis reports are produced to monitor progress; remedial action being taken as appropriate to ensure the accuracy of the exchange data files. These files in their final form are the master records of the exchange installation and are the sole source of the permanent documentation.

Programs will exist to access the files and process the data into formats suitable for reproduction on hard-copy printers and for display on visual display terminals.

OUTLINE OF USE OF THE SYSTEM

A broad outline of how the system is used to design and engineer a new exchange is given below. Extensions are handled in a similar manner with the exception that the existing exchange data files are input to the appropriate programs and in the process updated files are created.

To keep the description concise, standard files are not mentioned although they will be accessed by all the programs (see Fig. 2).

Dimensioning

The design engineer, having gathered traffic, connexion and other information, enters the data into the system via an interactive visual display terminal. The dimensioning program then calculates the equipment quantities (racks, shelf groups, slide-in-units) needed to meet this traffic data, and records these totals in the equipment quantities files. At this stage, the calculated equipment quantities will not in all respects be precise; for example, some equipment quantities are dependent upon the equipment layout—a factor which is not considered by this program.

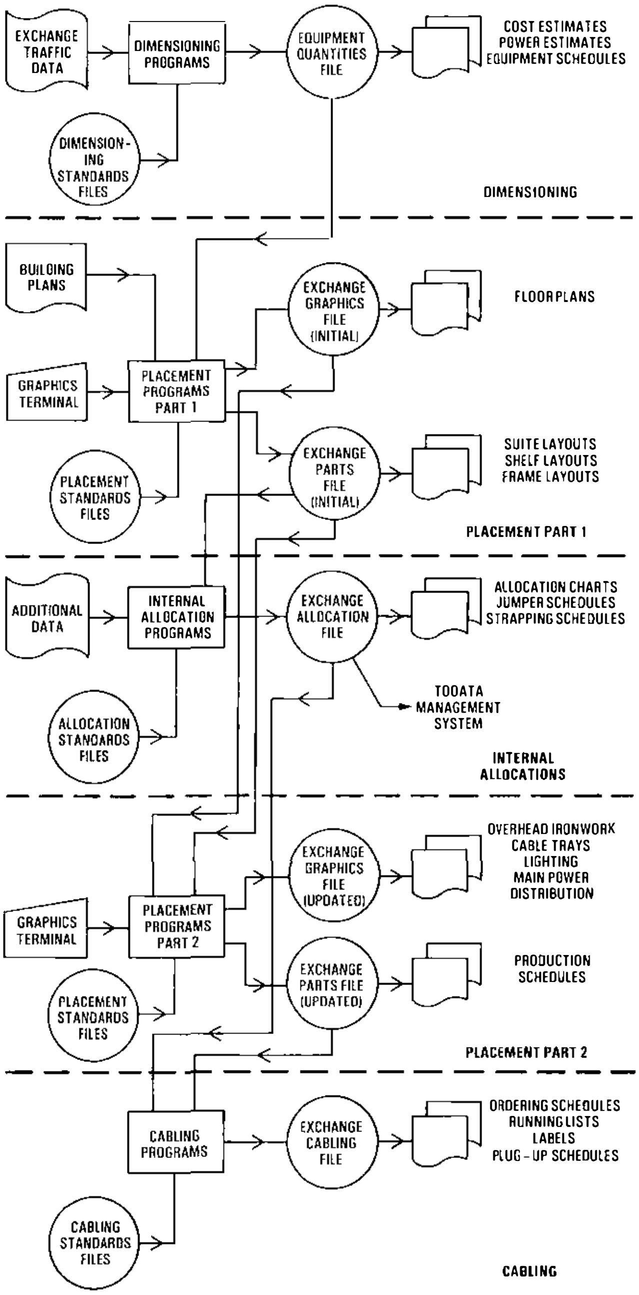


FIG. 2—EDCAD system inter-file processing

Placement Part 1

The equipment quantities file is then passed to the first part of the placement program suite, which positions each item of equipment within racks. Very often this simply involves deciding which standard rack layouts are appropriate for the equipment quantities. In other cases, each item is positioned individually according to a defined algorithm. If the equipment quantities do not fit any standard rack configuration, then shelf groups are positioned within the exchange taking into consideration the main cabling and other positional constraints.

The various distribution frame requirements are then determined and areas of those frames allocated to various equipments.

The program suite examines the building plans (which will previously have been entered into the system) and then positions the racks and frames on the available exchange floor area taking account of pillars and other obstructions. The resulting floor plan is displayed on a graphics display terminal which may then be used to change the location of the racks and frames to achieve an optimum layout and to take into account factors which the program has not considered. Checks are made that such changes do not violate any of the constraints; warning messages being given if appropriate.

When the user is satisfied with the layout, the various items of equipment are given a unique designation in a logical sequence which depends on their relative position within the exchange.

The outputs of placement part 1 are the *exchange graphics file* and the *exchange parts file*. The equipment quantities in this latter file are precise; the documentation production programs are used to produce production schedules, floorplans, and suite, rack, frame and shelf layouts as required.

Internal Allocations

The exchange parts file is passed to the internal allocations program suite; this identifies those items of equipment between which interconnexions have to be determined; for example, it selects the time switches to which a subscriber concentration module is to be connected. The program also determines the individual address to be given to each item of equipment on any particular highway. The output of the allocations program is the *exchange allocations file*, which is required by the cabling program and the data management system. The documentation production programs are used to produce allocation charts etc. from this file.

Placement Part 2

This program suite accesses the exchange parts file to obtain data on rack locations in order to decide upon the layout of the overhead ironwork, cable trays, and lighting arrangements etc. These results are displayed on a graphics display terminal, which provides the user with an interactive capability to modify the layout to accommodate exceptional circumstances.

The outputs of placement part 2 are an updated exchange parts file and exchange graphics file. Further production schedules are then produced together with various plans of the overhead ironwork, cable trays, etc.

Cabling

The cabling program suite accesses the exchange parts file and the exchange allocations file for data on the items to be cabled, together with information on the cable trays and other supporting structures. It determines the route of each cable and monitors the loading of the cable trays; if necessary cables whose lengths are not critical are re-routed to avoid congestion. The length of each cable route is then calculated, and the appropriate standard length of plug-ended cable is selected.

The output from the cabling program suite is the *exchange cabling file* and from this the ordering schedules, cabling running-out lists, labels and plug-up schedules are produced.

The system has thus produced a complete set of exchange data files recording the planned state of the exchange. There will be a *report back* procedure from the site during installation to ensure that any departures from this planned state found to be necessary will be recorded in the appropriate file. The files can be made available to other computer processes requiring the design information. They must be stored for reference when there is a further extension at the exchange.

CONCLUSION

An outline of the planned computer support facilities for the design and engineering of System X installations has been given in this article.

The modular nature of the system enables it to be introduced in stages and to be updated in step with the evolution of System X designs.

ACKNOWLEDGEMENT

The authors wish to thank their colleagues in the BPO and the UK Telecommunication Industry for their contributions to the project described in this article.

Post Office Press Notice

MONARCH 120: BRITISH TELECOM PLACES FURTHER LARGE ORDERS

British Telecom has placed orders worth £45M with GEC and Plessey for Monarch 120 private automatic branch exchanges (PABXs).

Monarch, the only entirely British digital switching stored-program control (SPC) PABX, was designed and developed by British Telecom and engineered by GEC and Plessey; this new order demonstrates British Telecom's continuing support for established British suppliers. The first production deliveries of these Monarch 120s, which are being supplied initially to customers in central London, were made in October 1980.

In addition, after extensive examination of small proprietary PABXs produced by manufacturers in the UK and elsewhere, British Telecom intends to negotiate a contract with Mitel Telecommunications Ltd. of Slough for small-to-medium PABXs. When field trials begun last autumn are successfully completed, it is anticipated that an initial order for £5M will be placed; the equipment will be produced at Mitel's Slough factory.

Announcing this further round of PABX orders, Mr. David Cartwright, British Telecom's Customer Switching Product Group Manager, emphasized British Telecom's determination to ensure continuity of deliveries of modern systems by giving its suppliers better advance notice of requirements. He stated that the order with Mitel demonstrated British Telecom's determination to widen its product portfolio in order to offer customers, as quickly as possible, a range of first-rate products in ready supply.

UXD5: A Small Digital-Switching Telephone Exchange for Rural Communities

Part 2—System Software and Operation

J. R. W. AMES, B.SC., M.SC., C.ENG., M.I.E.E., M. J. ELSDEN, B.SC., M. W. HILL, M.SC., C.ENG., M.I.E.E., and P. A. TRUDGETT, B.SC., M.SC., PH.D., C.ENG., M.I.E.E.†

UDC 621.395.2: 621.374

The UXD5 is a digital-switching telephone exchange designed for use in rural areas. The exchange is intended as a replacement for Strowger Unit Automatic Exchanges at present installed in the UK telephone network. Part 1 of this article gave a general description of the UXD5 design and its application; Part 2 describes the system software and operational aspects.*

INTRODUCTION

Part 1 of this article* gave a general description of the Unit Exchange Digital No. 5 (UXD5), which is a digital-switching telephone exchange for use in rural areas where telephone penetration is small. The UXD5 design is based on the Monarch 120 PABX[1], and the British Post Office (BPO) intend to use the UXD5 as a replacement for the Strowger Unit Automatic Exchanges (UAXs) now in service in the UK telephone network; in particular, for the replacement of UAX12.

Description of the system is completed in this article, which covers the system software, the interaction of software and hardware and the system operation. The system operation is described by examining the progress of a local-call connexion through the exchange.

SOFTWARE

The UXD5 software is based on, and uses, the same basic structure as that used for the Monarch 120 PABX[3]. Changes were made to the Monarch 120 PABX software to remove those facilities not required in a public exchange; the software was enhanced to provide the UXD5 with facilities that are almost identical to those of a UAX12.

The basic software structure is shown in Fig. 5; for ease of description, no reference is made in Fig. 5 to the use of two processors between which the software is split, since this feature is almost invisible to a programmer. Initially, the software is described as though it works on the main processor only.

Operating System

The operating system is a program that runs continuously, except when stimulated to call and execute other programs. The operating system exercises overall control of these other programs. The operating system is stimulated by either of the following signal states:

(*a*) Pulses, known as *interrupts*, are sent to the operating system at regular time-intervals. In the UXD5, these interrupts occur at 100 ms and 8 ms intervals. The interrupts force the microprocessor to stop its current task and execute a fixed routine in the operating system. This routine contains calls to programs known as *foreground processes*.

(*b*) Messages are passed to the operating system from programs that cause the operating system to run other programs. These messages comprise a common block of memory, 8 bytes long, shared by the operating system and the sending program (see Fig. 6). To send a message, the block is filled with the necessary data, and a call is made to the particular entry point in the operating system that deals with messages. All programs started in this way are known as *background processes*. A background process can be started by a message from

(*i*) another background process,
(*ii*) itself,
(*iii*) a foreground process, or
(*iv*) the operating system (only when the exchange is first activated).

The operating system performs several other functions to help in the control of the processes:

(*a*) Using the 100 ms interrupt signal, the operating system acts as a real-time clock and keeps a count of the date and time. Any process can obtain the time by sending a special message, which is returned by the operating system with the date and time appended.

(*b*) A time-delay function is incorporated so that any process which passes a message to the operating system can be restarted after a fixed-time delay. The delay period is set by the calling process.

(*c*) Messages to each process are queued so that no messages are lost during periods of high exchange activity.

(*d*) The operating system allocates priorities to each background process so that those processes that have a more urgent function in the exchange are always run when required, to the exclusion of the other processes.

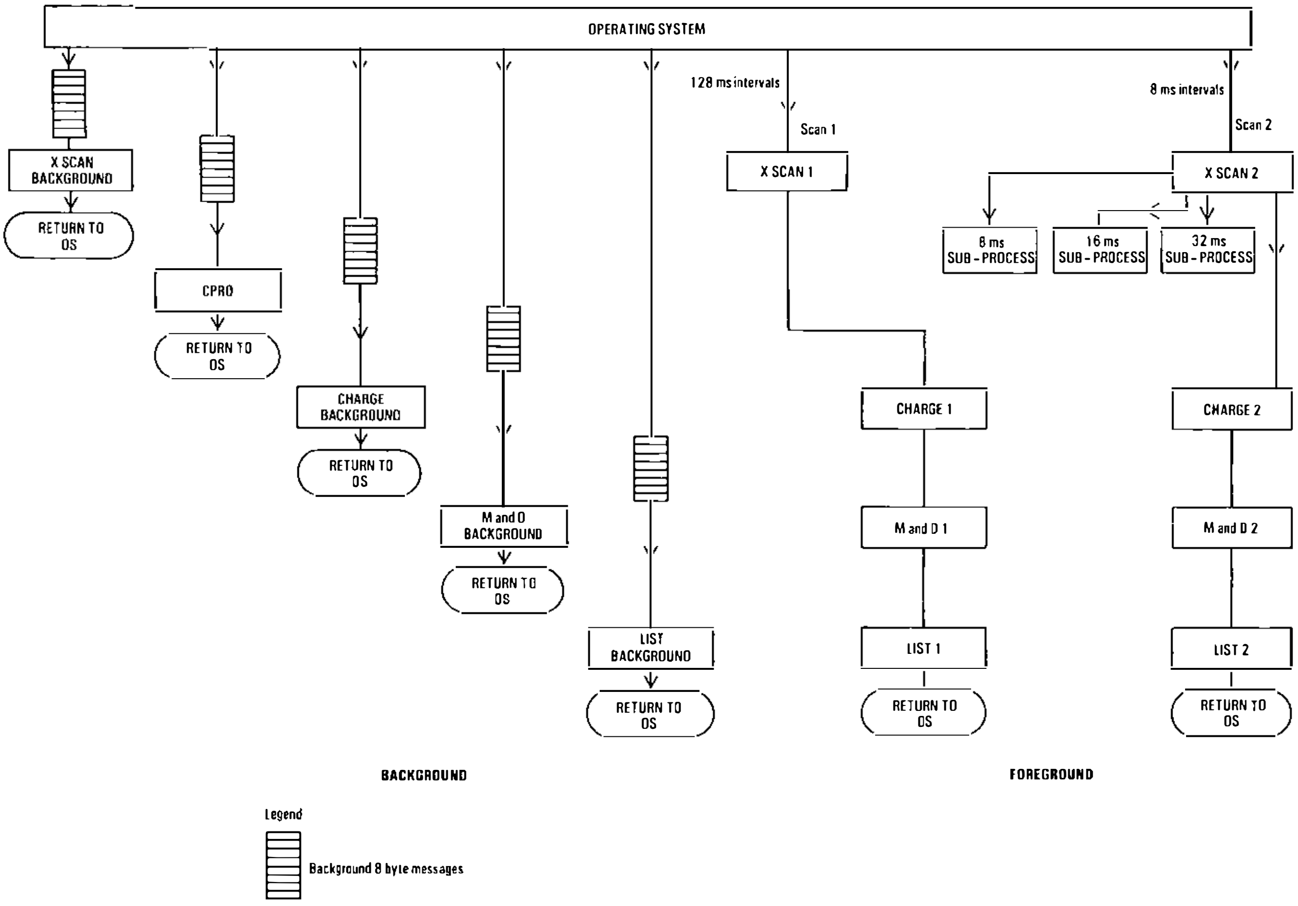
(*e*) The faster interrupts are controlled in such a manner that they can always interrupt the slower interrupts, but not vice-versa.

(*f*) The operating system examines all messages and checks that they have the correct format; if a format is incorrect, the message is stopped and stored in a fault record.

---

† Messrs Ames, Hill and Trudgett are with the Research Department, Telecommunications Headquarters. Mr Elsden is with the Exchange System Department, Telecommunications Headquarters

* Ames, J. R. W., *et al.* UXD5: A Small Digital-Switching Telephone Exchange for Rural Communities. Part 1—General Description. *POEEJ*, Vol. 73, p. 241, Jan. 1981



Note: Any process can send a message to the operating system to start a background program

CPRO: Call processing
OS: Operating system
M and D: Maintenance-and-diagnostics process
XSCAN: Exchange scan process

FIG. 5—Structure of basic software

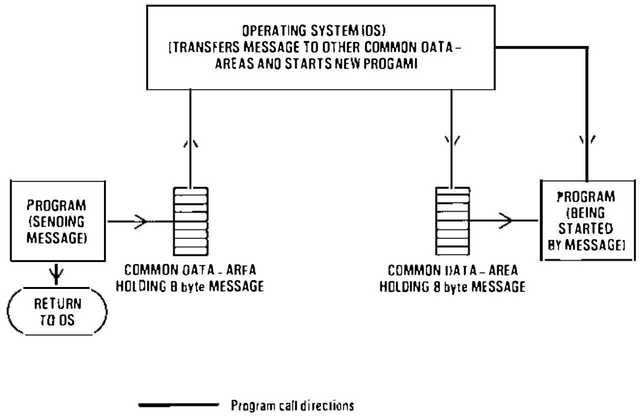


FIG. 6—Message flow

Control Processes

The control processes are divided into several groups according to function. Any one group can have a maximum of one background process, but may have several foreground processes running at different intervals. Processes in the same group share common data-areas, so that data can be saved and passed between processes without involving the operating system.

Exchange Scan

The exchange-scan (XSCAN) process group has elements in both foreground and background program areas. The function of the XSCAN process is to interface between

(*a*) inputs from the signalling-input card, outputs to signalling-output card and the time-switch, and

(*b*) those processes which perform the telephony functions.

The foreground XSCAN processes are concerned mainly with extracting relevant data from the signalling-input card and the sending of messages to the call-processing functions when a significant change has occurred.

The XSCAN process has two foreground processes:

(*a*) the slow process (scan 1), which runs every 128 ms (16 × 8 ms interrupts) and examines, via the signalling-input card, all ports on the exchange each time it runs, and

(*b*) the 8 ms process (scan 2), which is split into several parts.

The scan 2 sub-processes run at multiples of the 8 ms interrupt (1, 2 and 4) and scan selectively those ports which are liable to have fast condition changes; for example, a subscriber's line during dialling, a coin-collecting box line during the progress of a call when coin pulses can arrive at any time, and an incoming junction circuit when idle since, at any time, pulses must be detected without delay. The XSCAN background process does not scan; its main purpose is to handle the output functions from the time-switch or the signalling-output card.

The XSCAN processes are linked by a storage area in which

5 bytes of random-access memory (RAM) are reserved for each port on the system; these 5 bytes are known as the *handler record.* The first byte of each record contains the state of the relevant port, so that the foreground XSCAN processes know which changes from the signalling-input card are relevant. The state of the port can be changed by other process groups by sending a message to the XSCAN background process.

Call Processing

The call-processing group has only one background process, known as *call processing* (CPRO). The CPRO acts on messages from the XSCAN process and controls each individual exchange call.

Associated with the CPRO are data arrays called *call records.* A call record is associated with each call in the exchange and contains all the data relevant to that call. Thus, when call processing proceeds to a point where it is waiting for something to happen (for example, waiting for a called-subscriber answer (CSA) condition), it can return to the operating system with the re-entry point held in the call record. A message to the CPRO which is recognized as being from that particular call causes the CPRO to start from the point at which it stopped. Thus, call processing is run separately for each call and can continue from the correct place on re-entry.

Charge Process

The charge-process group has members in 3 sections: background, 128 ms scan (scan 1) and 8 ms scan (scan 2). The group controls all metering functions in the exchange when instructed via messages from the CPRO or the XSCAN process.

The 8 ms scan 2 process controls asynchronous serial communication channels which instruct the meter control to step a meter. The process also verifies that this has been done by receiving back the identical message. Also, by means of inputs from the exchange local-call timing equipment, it decodes local-call ordinary-subscriber charge timing and local-call coin-collecting box charge timing.

The scan 1 process maintains lists of the calls in progress and directs scan 2 to send the appropriate meter-control signals over the serial channel. The lists are updated and checked by the background process in response to messages from the CPRO.

The background charge process is instructed when a call has been established and when it is completed. Acting on this information, the background charge process uses local-call timing, unless a message comes from the XSCAN process indicating that metering-over-junction (MOJ) is valid in this case.

Maintenance and Diagnostics

The maintenance-and-diagnostics process has members in 3 sections: background, 128 ms scan 1 and 8 ms scan 2. The process works in two modes:

(*a*) it scans all cards in the exchange regularly to verify, as far as is possible, that they are functional, and

(*b*) it checks individual cards, under the control of the maintenance staff.

Under mode (*a*), the maintenance-and-diagnostics process runs at 14 s intervals, carrying out a different test each time. Thus, the whole exchange is tested every few hours, and the common-function cards are tested at regular intervals within this period. Under mode (*b*), messages are sent from the CPRO to start a particular test.

The maintenance-and-diagnostics background process is given a lower priority than either the CPRO or the charge background process; by this means, in a fully-loaded and busy exchange, the operating system can stop the scheduling of maintenance and diagnostic functions and can thus prevent unnecessary congestion in the system.

List

The list process group has processes in the background, 128 ms scan and 8 ms scan sections. It provides an interface to the maintenance teletype via a standard CCITT† V24 serial link. By means of inter-process messages, the list process is instructed to print-out relevant data; it can also pass input data from the maintenance teletype to the appropriate process. The list process has the lowest priority of any of the groups of processes.

Exchange Configuration Data Base

All fixed information about individual ports on the exchange is held in the exchange configuration data base, and the information can be accessed by any process. The data base is copied from a removable read-only memory (ROM) to a battery-backed RAM on initial activation of the system. The data in the RAM data base can be changed selectively from the maintenance teletype only after the relevant security procedures have been followed. At any time, on instruction from the maintenance teletype, the RAM data base can be copied to a new ROM.

The types of data held in the data base include: directory-number (DN) to equipment-number (EN) translations; EN to port-type tables; class-of-service (COS) tables; dialled number to call-type table (for example, an STD call if the first digit dialled from a subscriber is 0); lists of incoming and outgoing junctions, and PABX lines (for hunting for a free port). There are several more tables of data of a more detailed nature.

Interworking of the Central Processor Unit and the Pre-Processor Unit

The software is divided between two processors: the central processor unit (CPU) and the pre-processor unit (PPU). The PPU operates the exchange scan 2, 8 ms sub-process and the charge scan 2 process. The code for these processes is on the PPU board; accesses to the main backplane data and the address buses are necessary only from the PPU when input, output or common data areas need to be accessed.

The common data-area is contiguous, and the data types are split into two forms: those that are written to by either the CPU or the PPU, and those that are written to by both processors. Data that can be written to by both processors (for example, the handler records, as used by the XSCAN process) needs to be protected against errors caused by *read–modify–write* commands being attempted by both processors simultaneously. This protection is provided by using two flags held as bytes in the common data area, so that a processor can check the other processor's flag before writing to its own flag to signify that it is accessing the data. A final check is made on the other processor's flag before proceeding.

Apart from this protection sequence, program modules can be moved freely between the PPU and the CPU. Owing to the limited number of accesses made to the main bus by the PPU, the CPU is slowed down by less than 5%.

Software Overview

Two programming languages are used to write the software. For the more time-critical and input/output processes, assembler language is used. This is a set of statements that is related directly to the final machine code required; therefore, the programmer knows exactly how his program will affect

---

† CCITT—International Telegraph and Telephone Consultative Committee

the processor. The foreground processes and the operating system are written in assembler language.

Less time-critical processes are written in a high-level language called *CORAL*, which uses English-type statements and is therefore easier to understand and write. The programmer does not need to know the machine code that this language will produce. The background processes are written in CORAL.

The total software requires 68 kbytes of program code for the main processor and 6 kbytes of program code for the PPU. The CPU also has 16 kbytes of RAM, of which 1·5 kbytes are used as a common data area between the two processors. There are 2 kbytes of address space reserved for input and output functions.

SYSTEM OPERATION

To demonstrate the operation of the system, the progress of a local-call connexion through the exchange is described; the description indicates how the hardware and software components of the exchange interact during the progress of the call.

Own-Exchange Call

The progress of a call through the exchange, from subscriber 212 to subscriber 202, is now considered. Initially, the 212 line is in the idle state and is examined every 128 ms by the XSCAN process. When the subscriber lifts his receiver the change in loop status is detected by the line card, and the appropriate bits in the signalling input are changed by means of the signalling message stream, which flows from the line card via the shelf multiplexer. On the next 128 ms scan, the change in status is noted by the XSCAN process and an inter-process message is generated to inform the CPRO that line 212 is originating a new call. The messages refer to exchange ports by equipment number (EN) rather than by directory number (DN). The EN represents the physical location of the port, and can have any desired DN associated with it by means of a DN–EN translation table.

The progress of the call is indicated in Table 1, which lists all the inter-process messages generated during the call. On receipt of the message from the CPRO to set the state of line 212 (stored in the handler record) to *dialling enabled*, the XSCAN process begins to scan the appropriate signalling-in location every 8 ms in order to analyse the dialled digits. The final message in the initial sequence tells the XSCAN process (which controls the digital-switch hardware) to connect line 212 to the digitally-generated dial tone from the tones card. By this time, the CPRO has assigned a small area of RAM storage (the call record) exclusively to this call. Full details of the progress of the call (digits dialled, path set-up etc.) are stored in the call record. The CPRO is therefore able to handle a large number of different calls in turn, since the state of each call is remembered and can be recalled when action is required.

The first digit (2) is dialled and it is analysed by the 8 ms scan. When the inter-digit pause is detected, the CPRO is informed that a 2 has been dialled. On receipt of this message the CPRO fetches the call record, stores the 2, notes that it was the first digit dialled and sends a message to the XSCAN process instructing it to disconnect dial tone and connect silence before storing the modified call record for later use.

The second digit is analysed and sent to the CPRO, as is the third digit. On receipt of the third digit the CPRO is able, in this case, to determine the destination of the call. The DN–EN table is accessed to find the location of the appropriate line circuit in the exchange (in this case the EN is 69); the sequence of events is shown in Table 1. The CPRO instructs the XSCAN process to set the handler-record state of 212 to awaiting answer and to mark line 202. If line 202 is free, the mark will be successful and, on receipt of this message, the CPRO instructs the XSCAN process to connect digitally-generated ringing tone to line 212, while connecting ringing current to line 202. Because the ringing supply is not cadenced by the ringing generator, the ringing supply relay is operated and released under control of the XSCAN process via the signalling-output card to send ringing current immediately on line 202; this is followed by the standard public-exchange cadence.

On receipt of called-subscriber answered condition (CSA), lines 202 and 212 are connected together via the digital switch to allow conversation to take place, and local-call charging begins. When the calling subscriber clears, the on-hook condition is detected by the XSCAN process via the signalling-input card; the call path is then disconnected and charging is stopped.

A similar mechanism is used to control other types of call. For a call originating from a coin-collecting box, the coin-and-fee checking function is performed by the processor. In this case, the XSCAN process has to control the operation

TABLE 1

Messages Produced During a Call from Line 212 to Line 202

Subscriber Action	Message No.	Process		Message
		From	To	
Loop	1	XSCAN	CPRO	New call originating from EN 12
	2	CPRO	XSCAN	Set state of EN 12 to dialling enabled
	3	CPRO	XSCAN	Connect dial tone to EN 12
2	4	XSCAN	CPRO	Digit 2 received from EN 12
	5	CPRO	XSCAN	Connect silence to EN 12
0	6	XSCAN	CPRO	Digit 0 received from EN 12
2	7	XSCAN	CPRO	Digit 2 received from EN 12
	8	CPRO	XSCAN	Set state of EN 12 to awaiting answer
	9	CPRO	XSCAN	Mark EN 69
	10	XSCAN	CPRO	Mark on EN 69 successful
	11	CPRO	XSCAN	Connect immediate ring tone to EN 12
	12	CPRO	XSCAN	Connect cadenced ring tone to EN 12
	13	CPRO	XSCAN	Ring EN 69
CSA	14	XSCAN	CPRO	CSA from EN 69
	15	CPRO	XSCAN	Connect EN 12 to EN 69
	16	CPRO	XSCAN	Connect EN 69 to EN 12
	17	CPRO	XSCAN	Set state of EN 12 to busy talking
	18	CPRO	XSCAN	Set state of EN 69 to busy talking
	19	CPRO	CHARGE	Start charging
Clear	20	XSCAN	CPRO	Clear from EN 12
	21	CPRO	XSCAN	Set state of EN 12 to free
	22	CPRO	XSCAN	Connect silence to EN 12
	23	CPRO	XSCAN	Set state of EN 69 free
	24	CPRO	XSCAN	Connect silence to EN 69
	25	CPRO	CHARGE	Stop charging
	26	XSCAN	CPRO	Clear from EN 69

Note: Equipment number of line 202 is 69 and the equipment number of line 212 is 12

CPRO: Call processing

EN: Equipment number

XSCAN: Exchange scan

of the coin slots and to send a message to the CPRO when a coin is inserted. The CPRO controls the duration of the call and signals to the XSCAN process to terminate the call when the call time exceeds that allowed for the money that has been inserted. Compensatory time-allowances are made as necessary; for example, for the time taken for a coin to fall past the slot lock. Messages are sent to the charge process to record the value of the coins used.

Incoming and outgoing junction calls need a separate call control mechanism from that used for own-exchange calls. Metering-over-junction (MOJ), CSA and backward hold are recognized by the XSCAN process from an outgoing junction, and trunk-offer (TKO) and howler controls are recognized from an incoming junction. For outgoing junctions, the XSCAN process also needs to know from the CPRO whether the call is a manual-board call, a level-9 call or an STD call, as the return and forward signalling requirements can be different in each case. The CPRO detects whether the calling party releases the call, or if it is backward held.

Other types of call are catered for; for example, 999 calls, faultsman's ringback, test numbers and TKO. The differences for all these types of call are catered for by different routines within the CPRO.

CONCLUSION

The UXD5 has been developed in response to an urgent need for a modern system to replace ageing rural exchanges, mainly to be found in Scotland. Microprocessor technology has enabled the system to be developed as a small but sophisticated stand-alone exchange. Economies have been achieved by basing the design on the Monarch 120 PABX, which has provided both common hardware and a base from which to develop the system software.

The requirement for 2 versions of the UXD5 has been identified; the UXD5A, designed as a direct replacement for the UAX12, is a 150-line system and the UXD5B, being designed for both the BPO network and the export market, will have a maximum of 600 lines together with a range of enhanced facilities. Production versions of the UXD5A exchanges are scheduled to be available in late 1981; the UXD5B, which will supersede the UXD5A, is expected during 1982.

Book Reviews

Reliability and Maintainability of Electronic Systems. Edited by J. E. Arsenault and J. A. Roberts. Pitman Books Ltd. xiii + 584 pp. 215 ills. £18·00.

The requirement for new services and lower operating costs in the telecommunications field has resulted in a considerable increase in equipment complexity and has made great demands on those who design, produce, test and plan the maintenance of a wide range of systems. To carry out these functions efficiently, up-to-date information on the various subjects under the broad heading of reliability and maintainability (R & M) must be to hand. These subjects are covered in a number of separate publications, but this book has satisfied a long-standing need by drawing together mostly original contributions from selected authors who are currently engaged in using the techniques they describe. This approach can lead to obvious differences in the form and level of treatment from chapter to chapter, but here the effect is minimal and the result is a comprehensive and readable book suited to design engineers and managers as well as to reliability analysts.

The editors have organized the book into three parts: General, Reliability and Maintainability; these parts are further subdivided into 28 chapters. The division of material between, and the ordering within, the three parts appears somewhat arbitrary and, as the articles have been written in isolation, there is no cross-referencing.

Part 1 begins with a chapter on life-cycle costing, an important but neglected topic, and goes on to cover five other subjects, including R & M management, design automation and a welcome contribution on softwear reliability in which a strong case is made for top-down design and structured programming. In part 2 a brief introduction to the mathematics of reliability is followed surprisingly by chapters on thermal design and environmental factors before venturing into fault-free analysis, reliability testing and a useful introduction to sneak-circuit analysis. Part 3, which covers a large amount of ground, discusses system design, digital logic simulation and testing, sparing and maintainability testing.

It is in the selection and partition of material that the book is least successful. Many of the general, rather laboured, chapters on management and design could have been sacrificed to allow a fuller discussion of topics such as reliability growth and accelerated life testing. However, the overall impression is of a useful up-to-date addition to the present limited range of R & M books. Those requiring further reading can make use of the many references and the two appendices listing R & M documents and books.

C. L. Monk

Electronic Devices. F. R. Connor PH.D. Edward Arnold Ltd. ix + 121 pp. 76 ills. £3·95.

This book can be described as a very simple guide to electronic devices. This remark is in no way meant to undermine the usefulness of the book, since the text is well written and concise, and each device is explained in sufficient detail for the needs of the beginner. The book does not, however, treat either basic physics or device theory in sufficient depth to make it useful as a text for degree-level courses or their equivalent. Indeed, without some basic knowledge of solid-state physics the student could easily be bewildered by the way certain basic principles lacking adequate definition are used to explain device phenomena.

After very brief introductory chapters on atomic theory and semiconductor theory, the author devotes most of the remaining text to covering solid-state devices and vacuum devices. However, coverage of flat-panelled display devices is inadequate; and discussion of microwave devices and integrated circuits is contained in a few pages added as an afterthought at the end of the book.

The typical examination questions and answers which supplement the text are one of the good features of the book. Apart from helping to put the physics into context, this feature should appeal to those students who are not always sure of what is required of them in an examination. The book also contains unworked problems, a short set of references and an index.

R. W. Brander

System X: The Traffic Generator and Monitor

P. M. ANDREAE, B.SC., C.ENG., M.I.E.E., and P. J. BARRINGTON, B.SC., C.ENG., M.I.E.E.†

UDC 621.395.34: 621.395.31

The traffic generator and monitor (TGM) is a purpose-built item of equipment, which is installed at the switching systems test facility[1] *at the British Post Office Research Centre, Martlesham Heath. The TGM provides the exchange under test with a realistic traffic load through the telephony interface, and provides information enabling the quality of service given by the exchange to be assessed. The TGM is also used to find design deficiencies and to monitor the effects of modification and maintenance on an exchange carrying calls.*

INTRODUCTION

Design validation tests are being carried out on System X equipment at the switching systems test facility (SSTF)[1]. Any new versions of software and any significant hardware changes are tested prior to their introduction into in-service installations; the SSTF also provides maintenance support and back-up facilities for locating obscure faults and easing service difficulties. To fulfil this role effectively, specialized test equipment has been developed, a major item of which is the traffic generator and monitor (TGM).

Test-call senders are widely used for the acceptance testing of exchanges. However, they are limited in the number of simultaneous calls they can make, and each one has a low termination capacity and is relatively expensive. To enable large numbers of calls to be made, each call is held for a very short time and thus does not represent the type of telephone traffic that an exchange would normally handle.

For testing purposes at the SSTF, a relatively large traffic-generation capacity is required, with the ability to generate traffic whose characteristics are as near as possible to calls in the public switched telephone network (PSTN). The TGM uses computer control to generate a controllable and repeatable load on an exchange, and easy-to-use man–machine interfaces are provided to give a wide range of facilities to the user.

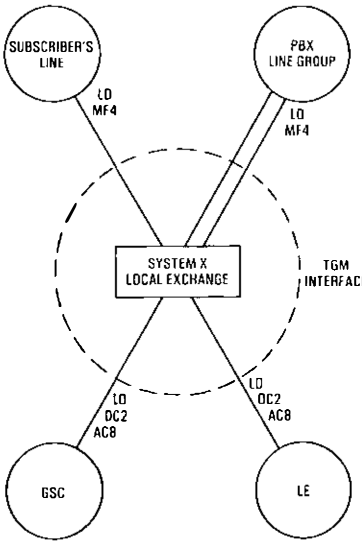
Two TGMs are used in the SSTF: the local exchange TGM, which has interfaces for subscribers' lines and junction circuits; and the trunk exchange TGM, which has interfaces for main network and junction circuits. Although the two systems are constructed separately, a modular design results in many parts, both software and hardware, being identical in both.

The TGM has been developed by the British Post Office (BPO) System X Development Department at Martlesham Heath, and both systems are now being used as part of the programme for testing the System X exchanges in the SSTF.

This article describes the facilities of the TGM, and the detail of the system design and its operation; it concludes with details of a future development.

BASIC CONCEPT OF OPERATION

An exchange being tested by the TGM is normally configured to model a typical exchange in the field, and the TGM simulates the traffic pattern of calls into that exchange. A typical arrangement for a local exchange is shown in Fig. 1; the arrangement for a trunk exchange is similar. Circuits from the TGM are grouped into routes and have the appropriate signalling systems. The TGM is sufficiently flexible to facilitate many different types of tests. The traffic characteristics of the TGM are defined in the data prepared for the TGM, and may be easily modified for particular tests. Also, the level of the traffic generated can be controlled dynamically throughout a test.



LE: Local exchange
GSC: Group switching centre
PBX: Private branch exchange
LD:, MF4:, DC2:, AC8: Line signalling systems

FIG. 1—Local-exchange network simulated by the TGM

The TGM operates by originating calls on incoming exchange circuits or subscribers' lines, simulating calls from other exchanges or subscribers, and answering calls on terminating circuits. The responses from the exchange are monitored throughout a call; the correct response depends on the type of call and the signalling system used.

The implementation of the TGM includes a computer, which is connected to a number of microprocessor systems controlling calls on individual exchange lines. The lines are either subscribers' lines with 10 pulses-per-second loop disconnect (LD) or multi-frequency MF4 signalling, or junction or trunk circuits on 30-channel pulse-code modulation (PCM) systems. Signalling on the PCM circuits can be either AC9 in-band, or time-slot 16 codes for LD, DC2 and AC8 signalling systems.

A test run is controlled from a computer terminal in the exchange area that prints out information on any unsuccessful calls as they occur. Comprehensive details of a run are printed on the computer line-printer.

---

† System X Development Department, Telecommunications Headquarters

FACILITIES

The facilities offered by the TGM are summarized below by outlining the characteristics of the traffic generated, the input data required to control the profile of the traffic, the interactive commands for controlling the TGM and the reports generated.

Traffic Characteristics

Circuits on the exchange under test are grouped into main and junction routes, PBX and subscriber lines. The characteristics of the traffic generated on each group may differ.

The TGM generates Poisson-distributed traffic, with both call-interval and call-hold times having negative exponential distributions. However, the call-hold times are limited to between approximately 20 s and 1 h, which is representative of the traffic encountered in the PSTN. The mean of the call-interval time distribution for each group is used to control the traffic level generated. The traffic can be routed to any number of groups, in any proportion, so that some outgoing routes are busier than others.

To simulate the variety of calls present in the PSTN, the TGM can generate the following types of call:

(*a*) an *effective* call, which is a call that is expected to be established, answered and metered, but which may meet a busy condition;
(*b*) a *no-answer* call, which is similar to an effective call except that an answer signal is not sent from the TGM terminating circuit;
(*c*) an *ineffective* call, which is a line seizure followed by an incomplete number of routeing digits; and
(*d*) a *false call*, which is a line seizure followed by no digits.

Both the call-type and the out-going group are chosen pseudo-randomly for each call generated on an incoming group, but in the proportions specified for that group. To simulate different exchange types in the existing network, the incoming circuit within the group can be selected either pseudo-randomly or sequentially with a fixed start.

The TGM has available a special facility, known as *flood*, which dramatically increases the calling rate; when it is invoked, the call interval and call-hold times are minimized.

Traffic Profile Data

The traffic profile data defines the traffic to be generated and the exchange configuration. The data includes the following information:

(*a*) timing information common to all groups (for example, pre-sending pause, inter-digit pause, time for called circuit to answer, holding times in the event of meeting specific supervisory tones and no-answer calls),
(*b*) signalling system used by each microprocessor (for example, Subscriber MF4),
(*c*) circuit numbers contained in each group,
(*d*) information related to originating traffic on each group (for example, circuit-selection algorithm to be used, percentage of each call type to be generated, offered traffic and mean call-hold time for effective calls),
(*e*) information related to terminating traffic on each group (for example, directory number of each subscriber's line, expected traffic level and mean call-hold time), and
(*f*) information related to traffic flow between groups (for example, percentage of a group's originated traffic to be offered to each group, routeing digits, charge bands, received digits and alternative groups used by the exchange).

Interactive Command Data

Command data, which is entered by the user in an interactive conversational mode, controls the various options available in the TGM. Most commands can be entered at any time during a run. There are commands that

(*a*) start and stop the TGM,
(*b*) control the generation of originating and terminating traffic on individual circuits and groups,
(*c*) request print-out of circuits generating traffic,
(*d*) switch special monitoring facilities on or off,
(*e*) request and inhibit print-outs of various reports, and
(*f*) switch flood traffic on or off.

Reports

A number of reports are generated by the TGM to enable the performance of the exchange under test to be monitored. They are as follows:

(*a*) Print-outs in tabular form are provided to give an hourly summary of both required and achieved traffic for each route and the subscriber group in use. The tables are output to the line-printer by the TGM at hourly intervals throughout the run, or following a user's interactive request for an immediate print-out. An example of the print-out is given in Fig. 2.

(*b*) A number of timing measurements are made on each effective successful call; the measurements record the time between seizure of a subscriber's line and receipt of dial tone,

```
SUMMARY OF OVERALL ACHIEVEMENT - ORIGINATING SUBS                 EXAMPLE TGM RUN                    DATE 07 OCT 1980   TIME FROM 10:38:41 TO 11:48:41

                ----R E Q U I R E D----  ------------------------------ A C H I E V E D ----------------------------------

GRP   NO.  % OF CALLS  ERL   MEAN  CHT  -----S U C C E S S F U L   C A L L S---------  ------F A I L E D C A L L S------  SUM     ERL   MEAN
NO.   OF                                  EFF      INEFF       FALSE      NO    ANS     SUM  SUB BUSY      JUNC BUSY    GOS        OF ALL        CHT
      CCTS  E  I  F  N        EFF   ALL  NO.   %   NO.    %    NO.    %   NO.    %          NO.     %      NO    %      NO.   %    CALLS

31     8  100         0·350  180  180·0   5   83   0      0    0      0    0     0     5    1   16·667   0  0·000   0  0·000    6    0·324  175·1
32     7  100         0·300  180  180·0   6  100   0      0    0      0    0     0     6    0    0·000   0  0·000   0  0·000    6    0·354  182·1
33    10  100         0·500  180  180·0  11   92   0      0    0      0    0     0    11    0    0·000   1  8·333   1  8·333   12    0·486  152·0
34    12  100         0·550  180  180·0  11  100   0      0    0      0    0     0    11    0    0·000   0  0·000   0  0·000   11    0·589  192·8
35    15  100         0·700  180  180·0  13   81   0      0    0      0    0     0    13    2   12·500   0  0·000   1  6·250   16    0·635  160·0
36     9  100         0·600  180  180·0  10   91   0      0    0      0    0     0    10    1    9·091   0  0·000   0  0·000   11    0·581  185·3
TOTAL

 6    61  100                180  180·0       90          0           0           0              6·452         1·613       3·226          2·969  172·4
                      3·000               56        0           0           0          56    4              1             2          62
```

GRP NO.: Group number
EFF or E: Effective call
INEFF or I: Ineffective call
FALSE or F: False call
NO ANS or N: No-answer call

CHT: Call-hold time
ERL: Traffic level in exchanges per group
SUB BUSY: Calls meeting *engaged* tone
JUNC BUSY: Calls meeting junction busy condition
GOS: Calls failing due to exchange plus those meeting junction busy

Note: There are also similar achievement reports for terminating traffic on all subscriber groups, all incoming routes and all outgoing routes

FIG. 2—Example of an hourly achievement report for originating traffic on all subscriber groups

the time taken to switch the call, and the time for a *clear* signal to propagate through the exchange. The results of the timing measurements are output hourly to the line-printer and presented as pairs of tables for each measurement. A histogram table gives the number and percentage of calls with times that are within 11 specified ranges, plus mean, maximum and minimum times. A cumulative distribution table gives the percentage of calls with times less than 10 specified values.

(*c*) Details of call failures are printed-out on the user's teletype in the order in which the faults occur; the data is also stored in a permanent disc file for subsequent analysis. The fault report for each unsuccessful call contains the following information:

(*i*) the time that the fault was reported,
(*ii*) the expected incoming and outgoing circuit and group numbers,
(*iii*) the digits expected to be sent to the exchange,
(*iv*) the digits expected to be received from the exchange,
(*v*) the number of metering pulses expected,
(*vi*) the fault-category numbers, and
(*vii*) any call information that is not as expected.

(*d*) The user can nominate up to 40 subscriber circuits to be monitored for the duration of a test. When invoked by the user at the start of a run, the TGM stores circuit and directory numbers, a record of the time when the circuit was seized, call type, digits sent, the time when the called circuit answered and the calling circuit cleared, and the call-hold time for all calls originated by the nominated subscriber circuits. At the end of the run, call details are output in circuit number order to the line-printer.

(*e*) At any time during a run, the user can monitor an outgoing route from the trunk exchange for up to 300 calls, within the limit of 1 h. When invoked, for each call terminated on the nominated route, the TGM stores the circuit number chosen and the time the circuit is seized and cleared. This data is output to the line-printer at the end of the period.

(*f*) The number of calls offered per minute is output to the teletype at intervals defined by the user. This printing continues at a set interval throughout the test run, but it can be suppressed or restarted by the user at any time.

DESCRIPTION OF OPERATION

The operation of the TGM is functionally split between the computer and the microprocessors. The principal functions of the computer are:

(*a*) to provide the man-machine interface for controlling the TGM,
(*b*) to profile the traffic in accordance with the input data,
(*c*) to request the microprocessors to make calls and to specify the call parameters (that is, the type of calls, the call-hold time and the digits to be dialled),
(*d*) to analyse the data returned by the microprocessors about all calls, and
(*e*) to compile the various reports.

The microprocessors control individual calls on up to 30 circuits, monitor their progress, make timing measurements and report back to the computer at the end of each call.

The traffic profile data is validated and reformatted by a program on the computer which runs independently of the TGM. The output from the data validation program is entered on a disc file, and is used subsequently as input for the TGM run.

When a test run is initiated by the user, the TGM carries out the following main tasks before traffic generation can start:

(*a*) it reads in the reformatted traffic-profile data from the disc file specified by the user and loads it into core store in the form required by the TGM,

(*b*) it loads each microprocessor with the appropriate signalling system software (for example, Subscriber MF4 or PCM TS16 LD), and

(*c*) it loads each microprocessor with initial run parameters which are common to all groups, such as pre-sending pause and inter-digit pause times.

After completion of these tasks, the TGM informs the user that initialization has been completed. The user may then, and at any time thereafter, enable traffic generation to commence on selected groups or circuits. On enabling a group, or any circuits within a group, the computer generates call-interval times (CIT) for the number of circuits that have been enabled. The CIT is the time between the end of a call and the start of another call. The CIT always relates to a group of circuits, and its mean value is a function of the number of circuits, mean call-hold time and traffic level specified for each group. When a CIT expires, one of the circuits in the group is chosen for originating the call by using the circuit selection algorithm specified by the user. The traffic profile data is then used to generate the parameters of the call, which are held in a call record and also sent to the appropriate microprocessor to originate the call.

In the case of an effective subscriber's call, the microprocessor sets up the call by seizing the line and, on receipt of dial tone, dialling the required digits and waiting for a supervisory tone, such as *ringing* tone or *engaged* tone. On receipt of ringing current, the terminating microprocessor answers the call after a specified period and informs the computer that a call cannot be originated on the circuit. Both ends of the connexion then exchange their circuit identities, using 1000 Hz pulses, for the duration of the call.

The microprocessors at each end of the connexion monitor every stage and record the time of various events, such as seizure and receipt of dial tone. If either detects an error at any stage or if the originating microprocessor finds the call-hold time has expired, one informs the other over the speech path; both microprocessors then clear and report back to the computer giving the circuit identity of both ends, and the timing and error information. In the case of junction circuits, the received digits and the metering information are also returned.

The computer compares this information with its own records to check that the correct circuit answered the call and, for junctions, that the metering and received digits were correct. If any errors are detected or returned by the microprocessors, a fault report is output to the terminal and to a disc file for subsequent analysis. The computer also extracts information about the call for the hourly timing and achievement reports and then clears the call record. Finally, it generates another CIT for the same group of circuits.

The next CIT to expire for the same group causes another call to be set up on a different circuit within that group. This mechanism continues until a user disables traffic generation on the group of circuits.

When a user disables a group, or any circuits within a group, the computer ignores CITs for the number of circuits that have been disabled. This has the effect of reducing the traffic level on the group in proportion to the number of circuits disabled.

EQUIPMENT

The TGM consists of a mini-computer which is connected to up to 30 microprocessor systems; each microprocessor controls calls on up to 30 lines. The hardware interface between the microprocessor and the exchange is known as a *line unit*. At present, there are two types of line unit: one for subscriber lines with LD or MF4 signalling, and one for junction or trunk circuits that use 30-channel PCM transmission. Analogue junctions are derived from a 30-channel PCM system using a standard primary multiplex equipment with the appropriate signalling units. A block diagram of the TGM equipment arrangement is shown in Fig. 3.

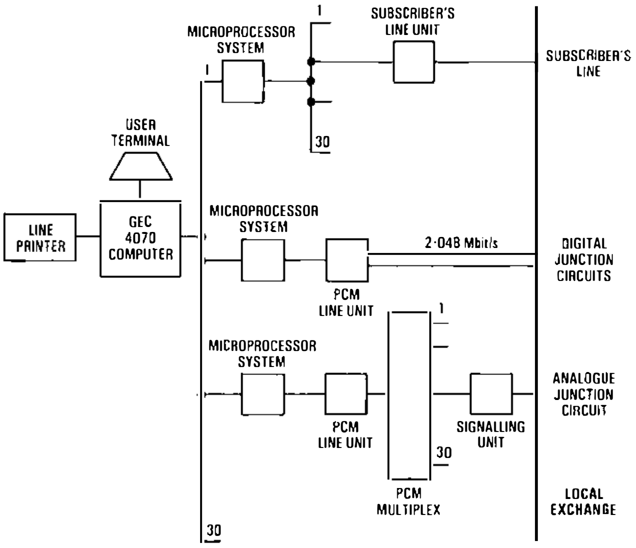
The local exchange TGM at the SSTF has the following circuits connected to it:

(*a*) 300 subscribers' lines, using LD or MF4 signalling,

(*b*) 25 incoming junctions and 34 outgoing junctions, which are routed on three 30-channel PCM systems, and

(*c*) 13 incoming 3-wire junctions and 16 outgoing 2-wire junctions, which are derived from one 30 channel PCM system.

The trunk exchange TGM connects 276 incoming and 407 outgoing circuits via 30 PCM line units. The TGM does not use Tep-1H equipment practice, as used in System X, because this was not available when the TGM development started. The individual parts of the TGM are now described in more detail.



PCM: Pulse-code modulation

FIG. 3—Block diagram of TGM

The Computer

The computer is a GEC 4070 having an internal core store of 416 kbytes. The mass storage is four 4·8 Mbyte disc stores on two exchangeable and two fixed disc packs. The peripherals consist of a paper-tape reader and punch, a 600 lines/min line printer and up to 4 visual-display units or terminals. One terminal is located in the exchange area and is used for the control of a test and the output of fault information as it occurs. The line-printer is used for the printing out of reports at intervals during a test run.

The microprocessor systems connect to a microprocessor bus controller in the computer. The controller board connects to the normal interface of the GEC 4070 computer and converts this to a simplified common bus for up to 30 microprocessor systems via a multiway ribbon cable. The data flow to and from individual microprocessors is controlled by star-connected leads known as *demand* and *grant*.

Timing measurements are carried out by a real-time clock distributed to all the microprocessors from a central source synchronized to the exchange clock. A digital input/output board in the computer is used to send a clock *reset* signal to all the microprocessors, which then count clock periods from the *reset* signal. Thus the time of occurrence of a particular event is the time the clock was reset by the computer, plus the time elapsed since the reset.

The Microprocessor System

The microprocessor system is based on the Motorola 6800, an 8 bit parallel microprocessor with an addressing capability of up to 64 kbytes. A system consists of 6 boards, which are 114 mm high by 203 mm deep, with gold-plated edge connectors. Two systems occupy a shelf in the line-unit rack. The separate boards of the microprocessor system are used to house the following:

(*a*) the microprocessor and programmable read-only memory (PROM),

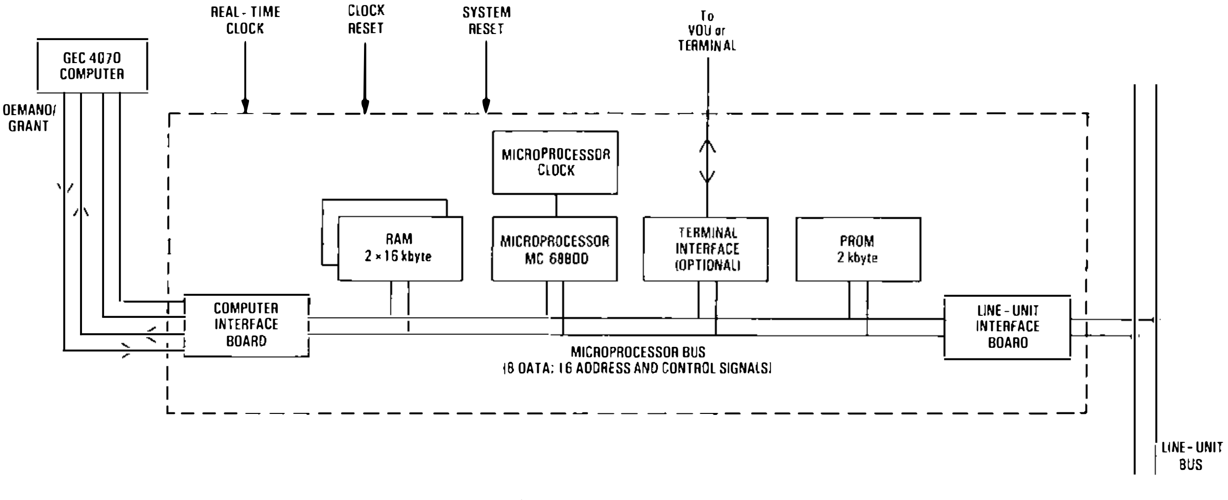
(*b*) random-access memory (RAM) (16 kbyte on each of 2 boards),

(*c*) the computer interface,

(*d*) the line-unit interface, and

(*e*) the terminal interface.

A description of each board follows; a block diagram of their interconnexion is shown in Fig. 4.



RAM: Random-access memory
PROM: Programmable read-only memory
VDU: Visual-display unit

FIG. 4—Block diagram of microprocessor system

Microprocessor and PROM Board

The microprocessor board contains the MC68B00 microprocessor with its clock and reset circuitry. The 2 MHz 'B' version is used because of the large amount of processing that has to be carried out in the 10 ms line scanning interval. Two 1 kbyte PROMs are mounted on this board; they contain the loader program which controls the transfer of software from the computer to the microprocessor system RAM during initialization.

RAM Board

Each RAM board holds sixteen 1 k × 8 bit RAMs, which hold the system program and data. Two boards, giving 32 kbytes of RAM per system, are normally installed.

Line-Unit Interface Board

The line-unit interface board buffers the address, data and control signals from the microprocessor bus to the line units. To simplify the design of the line-unit shelf, part of the address decoding is carried out on this board. The real-time clock and clock reset signals are input to this board, where they are detected by the microprocessor software.

Computer Interface Board

The computer interface board controls the transfer of data between the computers and the microprocessor. The data is transferred to or from the RAM using direct memory access (DMA) in bursts of 4 or 20 bytes. Transfers are initiated either by the computer or by an individual microprocessor using the demand and grant lines.

Terminal Interface Board

To enable the microprocessor software and line units to be monitored a terminal interface board is installed. The main component of the board is an asynchronous communications interface adapter (ACIA), which controls an RS-232C interface to a VDU or terminal. The access to the line-unit status, RAM or register contents is via a monitor program in RAM.

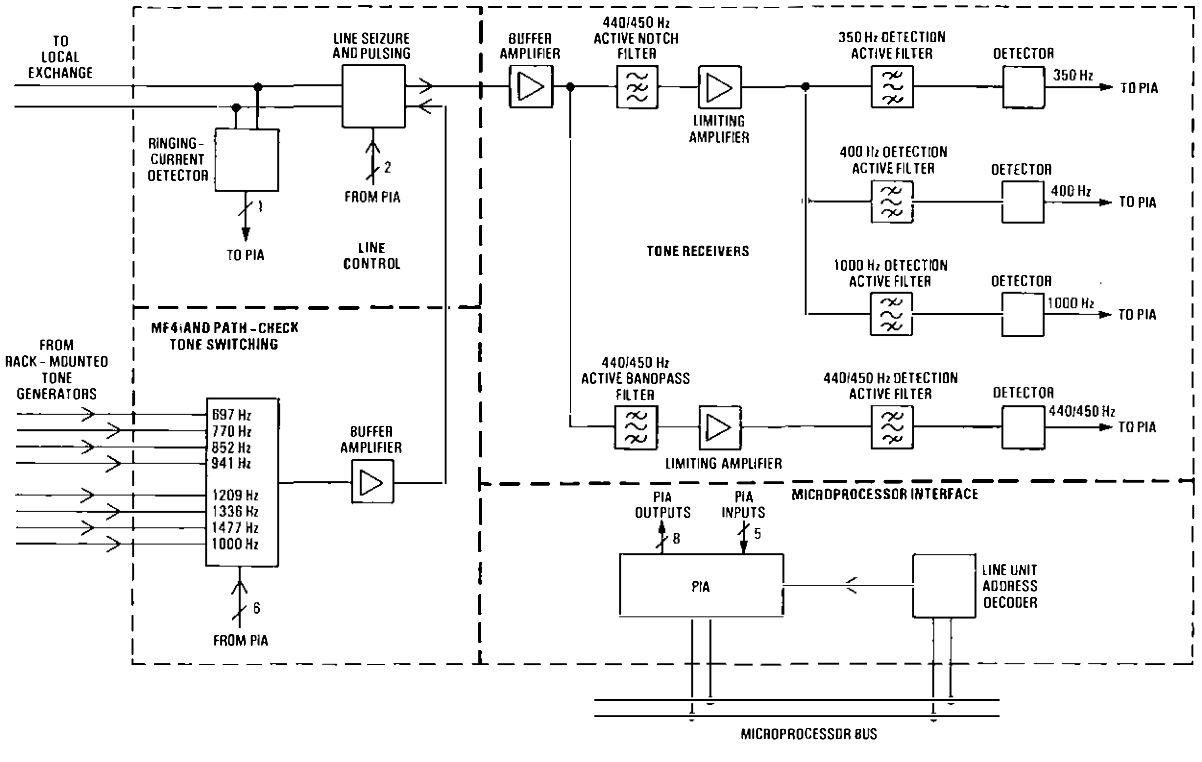
The Line Units

Two types of line-unit are in use at present: one for connexion to subscribers' lines on a local exchange, the other for connexion to a 30-channel PCM system for trunk or junction circuits.

The Subscribers Line-Unit

Up to 30 subscribers' line-units are controlled by one microprocessor. A line-unit carries out the functions of seizing the line, pulsing, tone sending and supervisory tone and ringing current detection. It also sends and receives the 1000 Hz tone used for checking the speech path during a call. Signalling to the exchange can be either LD or MF4, as specified in the traffic profile data.

A block diagram of the line unit is given in Fig. 5; a photo-



PIA: Peripheral interface adaptor

FIG. 5—Block diagram of subscribers line-unit

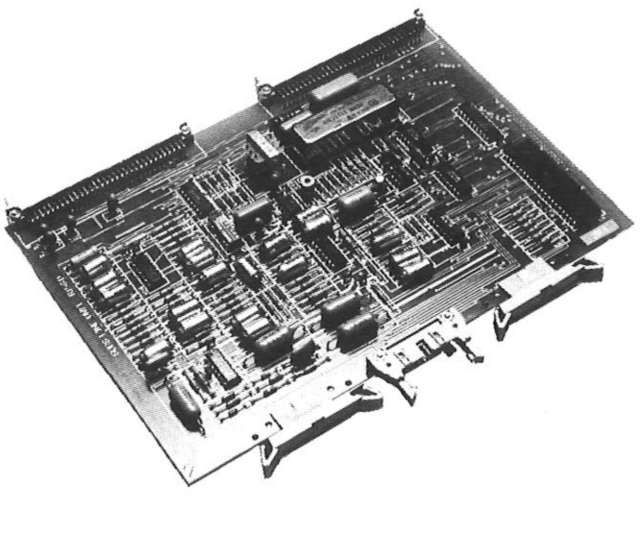


FIG. 6—The subscribers line-unit

graph of the line unit is given in Fig. 6. The board is a double-height eurocard, 160 mm deep by 233 mm high. The board has four main areas: tone receiver, tone sender, microprocessor interface and line control. The tone sending for the MF4 tones and 1000 Hz path check tone uses CMOS bilateral switches, controlled by the microprocessor, with the tones supplied from a central source on each rack. The tone receivers detect the following supervisory tones:

(*a*) 350 Hz + 440 Hz (dial tone),
(*b*) 400 Hz (number unobtainable, engaged and equipment-engaged tone) and
(*c*) 400 Hz + 450 Hz (ringing tone).

The line unit has 4 receivers: 350 Hz, 400 Hz, 440/450 Hz and 1000 Hz. Their design meets the requirement for the simultaneous detection of 350 Hz and 440 Hz, and for 400 Hz and 450 Hz. Tones from line are fed into a buffer amplifier and any tones other than 440 Hz or 450 Hz pass through a bandstop filter into a limiting amplifier, which produces a constant-amplitude output for all input signals above a certain level. The square-wave output passes into 3 active filters which produce a sine-wave output with an amplitude dependent on the signal frequency. Each output is fed into a detector which produces an output if a tone is present for more than 15 ms. Tones of 440 Hz or 450 Hz pass through a bandpass filter and then through similar stages as the other tones. The microprocessor software analyses the tone receiver outputs and determines from the cadence the actual tone being received. The line-unit is connected to the microprocessor by a peripheral interface adapter (PIA).

The PCM Line-Unit

The PCM line-unit, controlled by one microprocessor, handles calls on 30 circuits on a 2·048 Mbit/s PCM system. One line-unit occupies half a shelf and consists of 9 double-height eurocards. It conforms to the standard 30-channel PCM format in terms of data rate, signalling capability and alarm handling, as used in the BPO network. A previous article[2] in the *Journal* has described the 30-channel PCM system.

Signalling information is conveyed as codes in time-slot 16 (TS16), or as digitally-encoded pulses of 2280 Hz in the speech channel, for AC9 signalling. The path check can be either an analogue type, where the circuit identity is encoded in pulses of 1000 Hz, or a digital type, where the identity is sent as 8 bit codes in the speech channel. The former method is used on calls between subscribers' lines and junction circuits on the local exchange. The latter is used when a call originates and terminates on a PCM line-unit; it has the advantage of a fast transfer rate with less processing to be carried out by the microprocessor.

The line-unit is divided into two functional areas: the transmit section, which controls the data sent to line; and the receive section, which analyses the data received from the line. A block diagram of the PCM line-unit is given in Figs. 7 and 8.

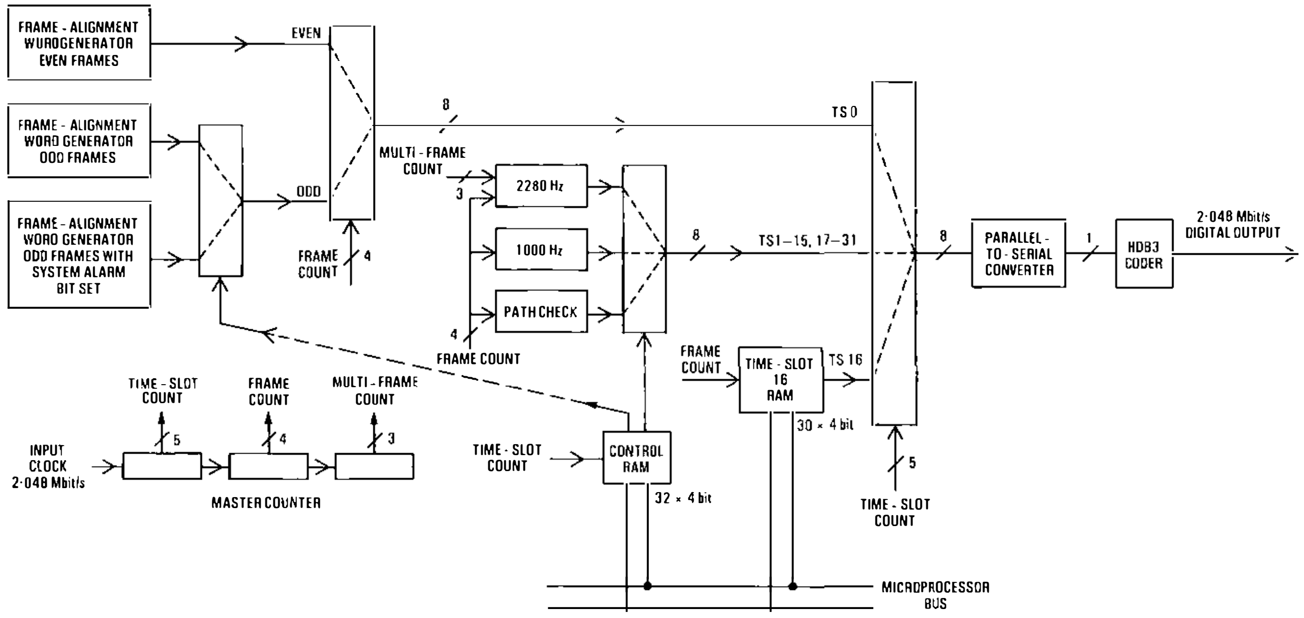
The digital signal sent to line from the transmit section is controlled by a master counter for multi-frames, frames and time slots. The frame counter controls the sending of the frame-alignment signal in TS0 and the TS16 signalling information set up by the microprocessor in the TS16 RAM. During time slots other than 0 and 16, the data sent to line in the speech channels is controlled by the time-slot counter and the data in the control RAM which, under the control of the microprocessor, determines whether tones or path-check data should be sent in a particular speech channel. The 1000 Hz for path check and the 2280 Hz for AC9 signalling are stored as samples in a PROM. Samples are selected in sequence by the frame counter, which runs at the 8 kHz sampling frequency. Additionally, the multi-frame counter controls the readout of the 2280 Hz samples from the PROM, which is stored as 2285·7 Hz to produce an integral number of cycles over 116 frames or 7 multi-frames. The digital path check is sent as four 8 bit codes in the appropriate speech channel in frames 0, 5, 10 and 15. These particular frames are chosen to ensure that the path check data is not recognized as a tone by the receive section. The resulting digital stream is converted from 8 bit parallel to serial and then to the HDB3 line code.

The receive section decodes the HDB3 line signal and extracts the clock signal. Frame and multi-frame alignment is detected and used to control the logic in this section. The occurrence of distant system alarms or distant multi-frame alignment loss is detected and signalled back to the computer. The loss of frame or multi-frame alignment or a high error-rate at the line-unit causes a similar action. The signalling in TS16 is written into the TS16 RAM and read by the microprocessor as part of the call processing. The tone receivers are designed for tones generated either digitally in the exchange or by the TGM subscriber line-unit tone source. The incoming data in each channel time slot is delayed by the period of one cycle of each tone to be detected and compared with the current data in that channel. A valid comparison of 5 of the 8 bits, to allow for noise and for tones originating from an analogue source, is persisted for 16 ms and is stored in the tone detector RAM to be read by the microprocessor. The path-check information is stored in the path-check RAM for each channel, and its validity is checked by using codes which prevent incoming encoded tones being written into the RAM and read as path-check data.

SOFTWARE

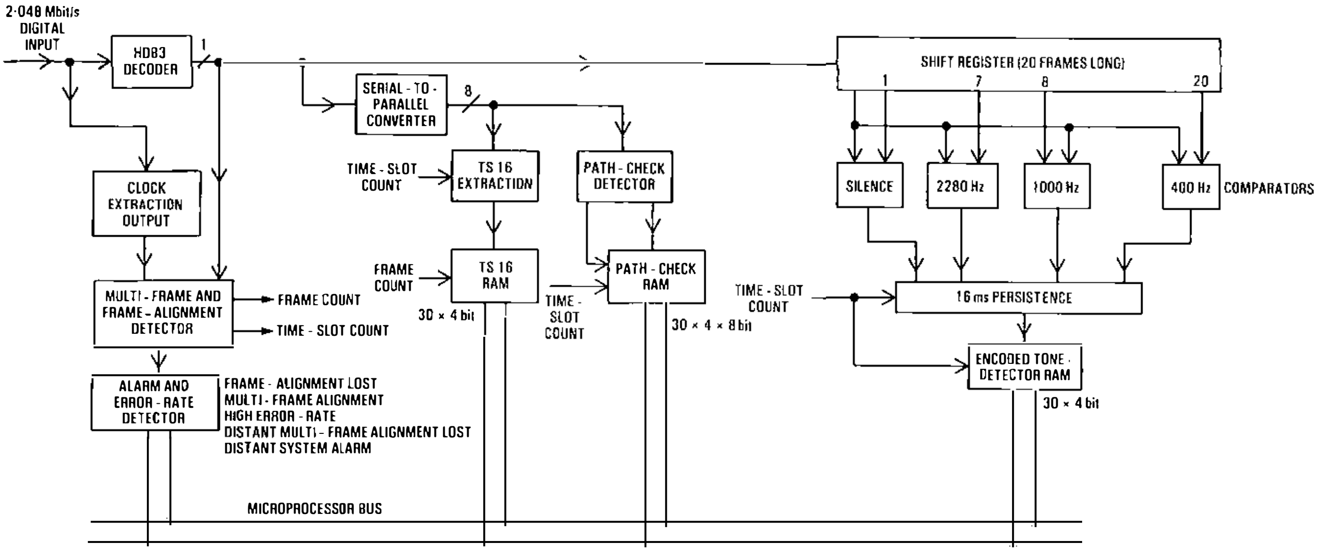
Most of the TGM software on the computer is written in CORAL, as implemented on the GEC 4070, but it has been necessary to include some Babbage (the GEC 4070 assembler language) to handle complex data formats and to maximize efficiency in the processing speed. The software resides in a specially constructed subsystem within the GEC OS4000 operating system. The subsystem is split into processes dealing with the following functions:

(*a*) management of the TGM subsystem,
(*b*) man–machine communication,
(*c*) data input and initialization,
(*d*) call-parameter generation,
(*e*) analysis of call data returned from the microprocessors,
(*f*) TGM and exchange error handling,
(*g*) microprocessor communication,
(*h*) production of timing and achievement of reports,



TS: Time-slot
RAM: Random-access memory

FIG. 7—Pulse-code modulation line-unit (transmit section)



RAM: Random-access memory
TS: Time-slot

FIG. 8—Pulse-code modulation line-unit (receive section)

(*i*) output of fault reports,
(*j*) call-duration and call-interval timing, and
(*k*) microprocessor program loading.

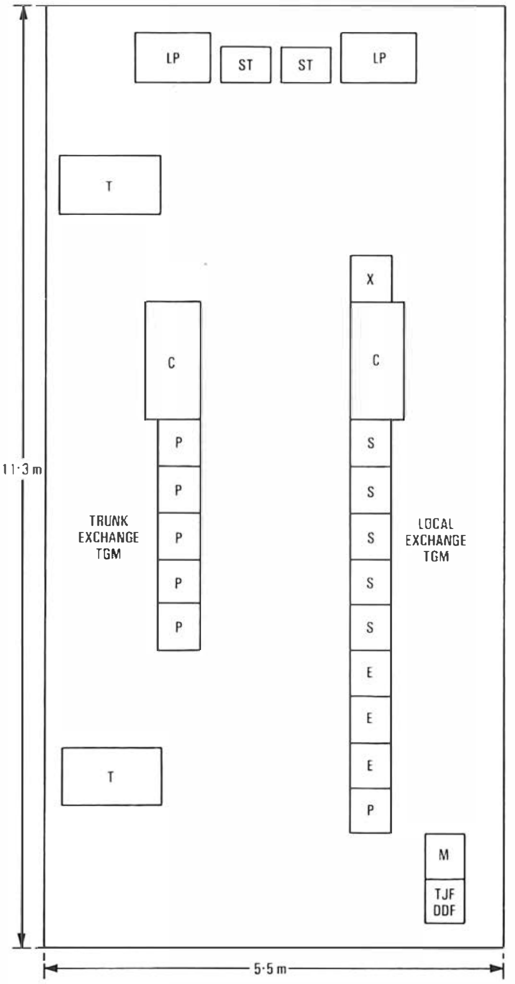
The TGM software, excluding the operating system, consists of 80 kbytes of code and 256 kbytes of data. Most of the code and data is core resident to ensure the speed of processing necessary for a large test run.

The microprocessor software is written in Motorola M6800 assembler language to ensure maximum efficiency in processing speed and size; it includes an operating system, call processing software and an on-line monitor. The operating system deals with communication with the computer and the scheduling of the call processing software to service each line every 10 ms. The call processing software is state driven and is split into line status modules for each stage of a call; this software is different for each signalling system. There is also an on-line monitor which serves as a diagnostic aid to access memory and registers. It is normally dormant until a terminal is connected to the microprocessor.

For the largest system, the microprocessor software consists of 13 kbytes of code and 12 kbytes of data.

EQUIPMENT LAYOUT

Two TGMs are in use at the SSTF: one is used with the local exchange and one with the trunk exchange. Both are installed in the same area, and the control terminals are located with the exchanges. A layout of the area is shown in Fig. 9.



LP: Line printer
ST: Computer system terminal
C: GEC 4070 computer
S: Subscribers' line-unit racks
P: PCM line-unit racks
M: PCM multiplex
E: Spare racks for extensions
X: Miscellaneous equipment rack
T: Table
TJF: Test jack frame
DDF: Digital distribution frame

FIG. 9—Floor plan of the TGM at the switching systems test facility

The GEC 4070 computer occupies two racks and is situated at the end of the suite of racks holding the microprocessor systems and line-units. There are two types of racks; one for subscriber line-units and the other for PCM line-units. Both types are similar and use 483 mm wide shelves in a commercially-available equipment practice. All the equipment is mains powered.

Each subscribers' line-unit shelf holds 15 cards. Two of these shelves combine with a microprocessor system to provide 30 lines. A set of tone-generator boards at the top of the rack supplies the MF4 and 1000 Hz path-check tones to each of the 60 line units on a rack. The computer and some of the line-unit racks are shown in Fig. 10. Six PCM line-units and microprocessor systems are mounted on one PCM line-unit rack to provide 180 trunk or junction circuits.

The microprocessor shelves are mounted with the backplane at the front of the rack and the cards are inserted from the rear. The ribbon cable linking the microprocessor systems to the computer is run along the rear of the racks; it is connected to each computer interface board via a connector on the end of the board.

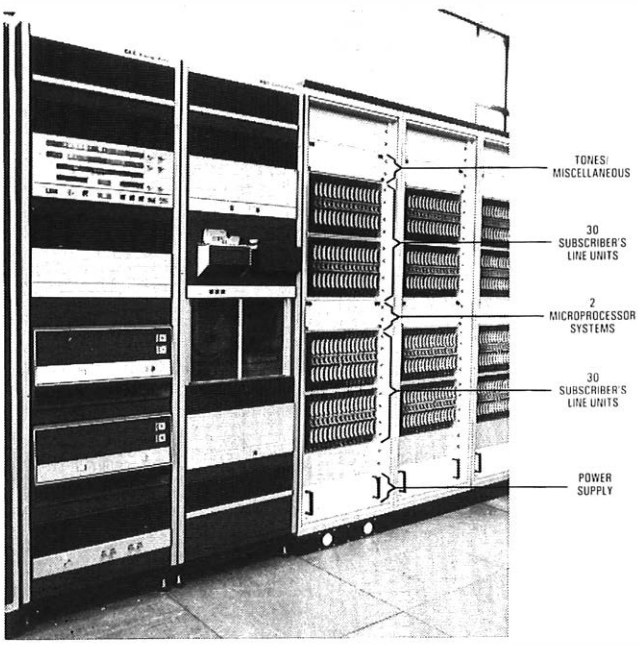


FIG. 10—The TGM computer and line-unit racks

Cables from the line-units to the exchanges are carried under the floor to a test jack frame (TJF) for subscribers' lines and for analogue junctions and to a digital distribution frame (DDF) for PCM circuits. These frames allow the testing and interception of circuits. The cables are then routed to the exchanges via the SSTF main distribution frame (MDF) and the DDF.

CONCLUSION

This article has described the facilities, operation and design of the TGM, which is now generating traffic to the System X exchanges at the SSTF.

Further development is now proceeding to provide the TGM with a common-channel signalling interface. It is based on CCITT No. 7[3] and will enable the TGM to simulate telephone traffic between System X exchanges, which use direct communication between processors for call control.

ACKNOWLEDGEMENTS

The authors wish to thank all their colleagues for their assistance in the development of the traffic generator and monitor.

References

[1] THOMAS, A. System X: The Role of the Switching Systems Test Facility. *POEEJ*, Vol. 73, p. 258, Jan. 1981.

[2] VOGEL, E. C., and MCLINTOCK, R. W. 30-channel Pulse-Code Modulation System, Part 1—Multiplex Equipment. *POEEJ*, Vol. 71, p. 5, Apr. 1978.

[3] PRICHARD, T. W. System X: Subsystems, Part 4—Common-Channel Signalling and the Message Transmission Subsystem. *POEEJ*, Vol. 73, p. 165, Oct. 1980.

A Computer-Based System for the Design, Measurement and Assessment of Telephone Sets

P. K. WEBB and J. G. ELLIS†

UDC 621.395.6: 681.3

This article describes a computer-based system in use at the British Post Office Research Centre for the measurement of the electrical and acoustic characteristics of telephone sets, and shows how the measurement data is used in a computer-aided network assessment program to determine the objective and subjective performance of telephone sets.

The article, which was first presented at the Institution of Electrical Engineers (IEE) Communications '80 Conference, Birmingham, is reproduced with the permission of the IEE.

INTRODUCTION

The transmission characteristics of a telephone set are designed with due regard to the very wide range of telephone connexions that can occur in practice. At one extreme, two telephone sets may be separated by only a few metres; at the other extreme, the two telephone sets may be at remote locations on different continents. The assessment of the transmission performance of a telephone set is based on the degree of user satisfaction when it is used on a representative sample of practical telephone connexions.

The first stage in the assessment is the measurement of the electrical and acoustic characteristics of a telephone set in isolation from other transmission items. The computer-based system described in this article is in use at the British Post Office (BPO) Research Centre, and it performs these measurements in accordance with CCITT* recommendations. The data is stored for subsequent analysis by a program which simulates telephone calls and estimates the degree of satisfaction of the users of each connexion. The program makes use of a substantial amount of information on the composition of the telephone network, and can simulate calls on a traffic basis. The performance of commercial or prototype designs of telephone set can be assessed, and the system can also assess hypothetical designs described by their electrical and acoustic characteristics; in this way, design targets may be derived.

MEASUREMENT SYSTEM

Measurements Required

Four characteristics of a telephone set are measured by the measurement system: they are

(*a*) the sending sensitivity,
(*b*) the receiving sensitivity,
(*c*) the impedance presented to line, and
(*d*) the impedance for zero sidetone.

In general, these characteristics are dependent on the line current and the frequency. The measurements are therefore performed at each of a set of line currents which cover the range occurring in the UK telephone network; that is, 25–100 mA. The line current is provided by a programmable DC source so that it can be controlled by the measurement program. The current source also provides a high impedance to audio-frequency signals. The DC voltage appearing across the line terminals of the telephone set is measured for each value of line current by means of an analogue-to-digital converter. The range of frequencies used extends from 200 Hz to 4 kHz. The four characteristics are sufficient to describe a telephone set so that its performance on any connexion can be evaluated by calculation.

Artificial Head

An artificial head has been constructed to enable a handset to be clamped in a defined position and orientation relative to an artificial mouth. An artificial ear may also be rested on the earcap (see Fig. 1). The position and orientation adopted is that defined in the CCITT Recommendation P76. This was changed at the 1980 Plenary Meeting of CCITT and is now known as *loudness rating guard ring position*. Use has since

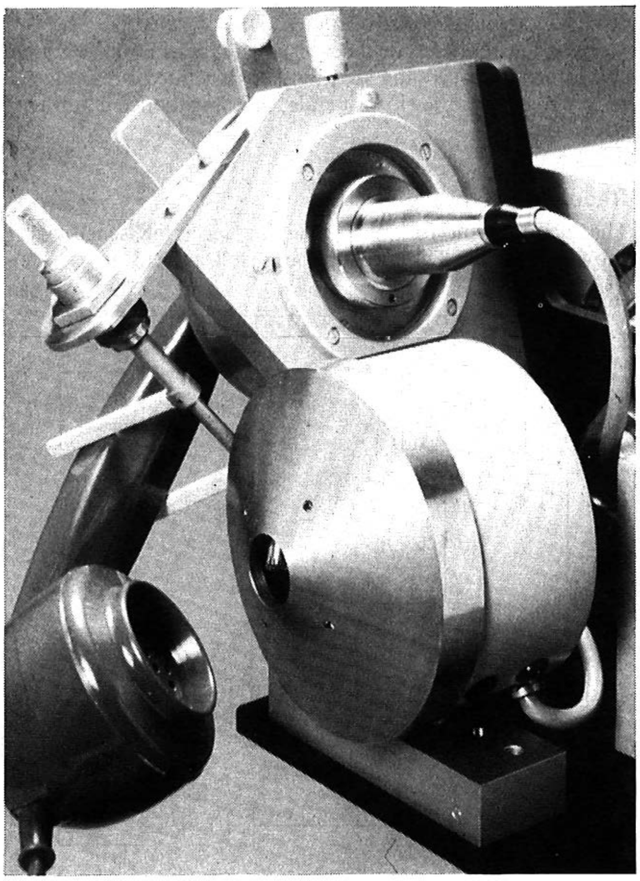


FIG. 1—Artificial head

---

† Mr. Webb is with the Research Department, Telecommunications Headquarters (THQ). Mr. Ellis, who was with the THQ Research Department, is now with Bell Northern Research Ltd. Canada

* CCITT—International Telegraph and Telephone Consultative Committee

been made of vector analysis techniques to simplify the interpretation of the basic definition. Vectors are also used to derive dimensions for the machining of the component parts of the head. Alignment gauges are used to check the final assembly.

The head assembly is mounted on a shaft so that it can be rotated to condition carbon microphones in accordance with the CCITT Recommendation P75. This facility was included so that modern designs of telephone sets with linear microphones could be compared with older designs having carbon microphones. A stepping motor provides the rotation via a complient coupling and notched belt drive. The drive electronics and associated logic circuits control the defined sequence of rotations. The logic could have been performed by the main processor, but it was decided to construct dedicated logic so that it could be used as an independent system.

Measurement Equipment

The measurement equipment comprises a commercial synthesizer and network analyser, used in conjunction with purpose-built equipment. The purpose-built equipment provides the necessary conditions for each measurement and consists, primarily, of a relay-switching arrangement. All equipment is controlled by a desk-top computer, and is therefore fully automatic. The test equipment configurations for the measurement of each characteristic are discussed below.

Sending Sensitivity

The basic arrangement for the measurement of sending sensitivity is shown in Fig. 2. The output amplitude from the synthesizer is programmed for each frequency to give the desired sound pressure at the mouth reference point of the artificial mouth. This is calibrated beforehand using a small microphone placed at the mouth reference point in the absence of a handset (in accordance with the recommendations of the CCITT). The microphone incorporated in the commercial design of artificial mouth is not used.

Although the telephone set is terminated in 600 Ω for the measurement of sending sensitivity, this value of resistance is purely arbitrary and, in principle, any impedance could have been used.

Receiving Sensitivity

The arrangement for measuring the receiving sensitivity is shown in Fig. 3. The measurement is straightforward except that a correction has to be made to the results because the sound pressure produced in the artificial ear does not accurately represent the pressure that would occur in a human ear. Determination of the correction is difficult as it involves measuring the pressure produced in a sample of human ears. Techniques have been developed to determine the correction factor and once the correction for a particular design of handset is known, it can be used for subsequent measurements, even if the circuit details change.

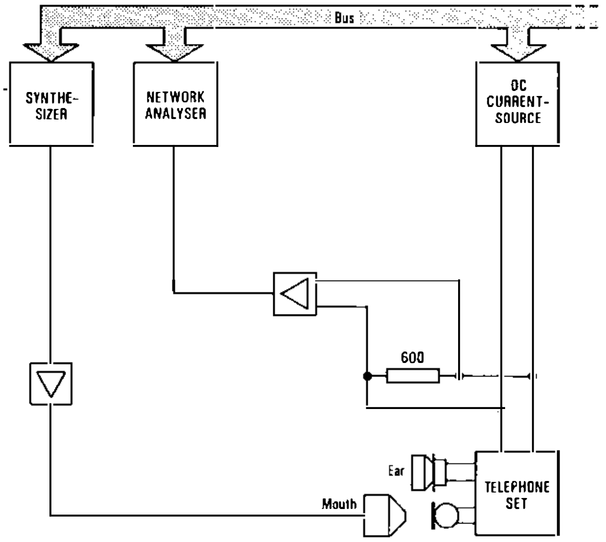


FIG. 2—Block diagram of the arrangement for the measurement of sending sensitivity

Impedance Presented to Line

The impedance presented to line is measured directly by taking the complex ratio of the alternating voltage to the alternating current at the line terminals, as shown in Fig. 4.

Impedance for Zero Sidetone

The impedance for zero sidetone is measured by terminating the telephone by a processor-controlled variable impedance, as shown in Fig. 5. An acoustic signal is generated from the artificial mouth and the impedance is adjusted until zero

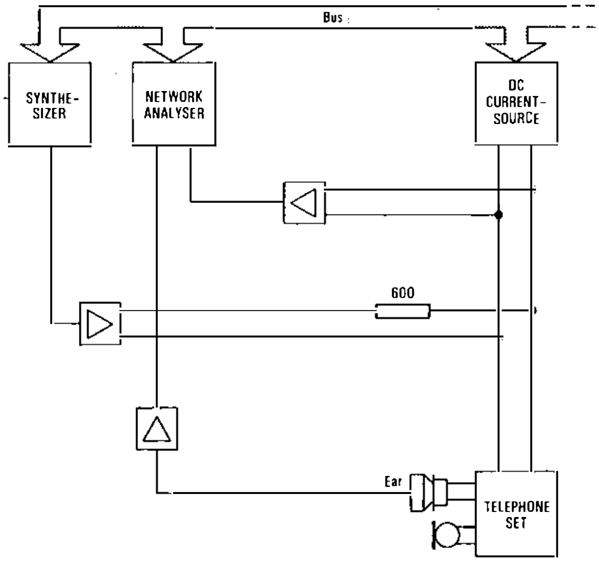


FIG. 3—Block diagram of the arrangement for the measurement of receiving sensitivity

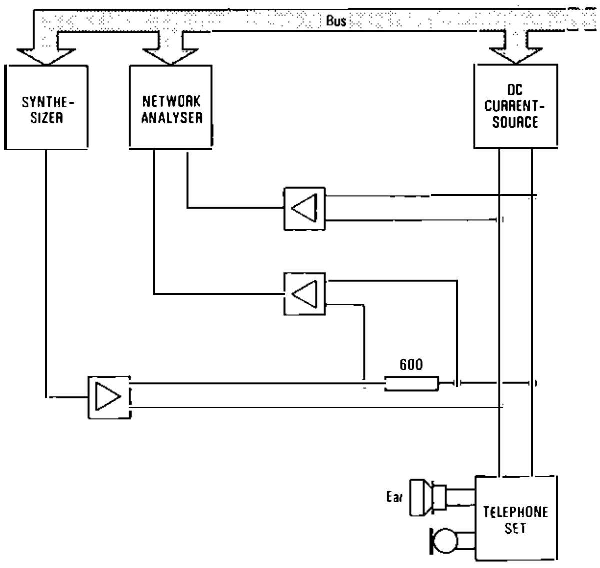


FIG. 4—Block diagram of the arrangement for the measurement of impedance presented to line

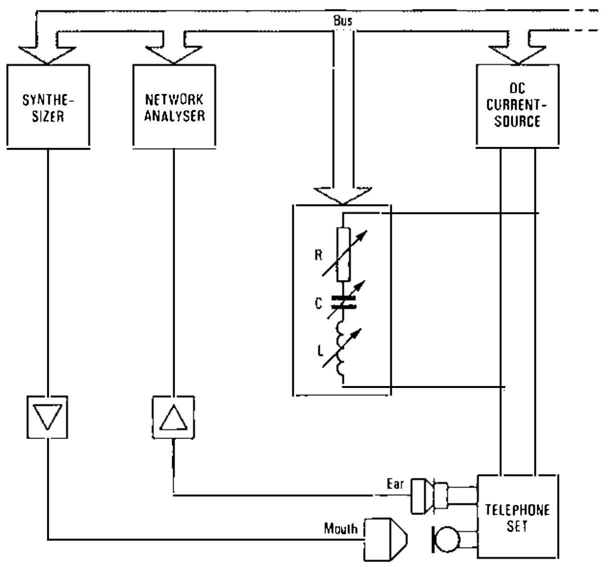


FIG. 5—Block diagram of the arrangement for the measurement of impedance for zero sidetone

sidetone is achieved. This measurement is a very tedious task if done manually, but the automated system performs each measurement very quickly; a feature only partly due to the inherent speed of automatic measurements. A very significant increase in speed has been achieved by the development and use of a fairly sophisticated convergence routine.

With each impedance tried by the processor, the sidetone path loss is measured; the degree of sidetone suppression is then computed by taking into account the sending and receiving sensitivities. It can be shown that each measurement of sidetone path loss is sufficient to define a circle in the complex impedance plane on which the impedance for zero sidetone must fall. The routine computes the centre and radius of each circle and evaluates the intersection points of two circles. Further measurements are then made to determine which intersection point corresponds with the impedance for zero sidetone, and to ensure good accuracy. A further increase in speed is obtained by making an intelligent guess for the first impedance tried at each frequency. This is based either on extrapolation from other frequency points or on values obtained for another line current.

The impedance for zero sidetone of some telephone sets falls in the negative impedance region at some frequencies. When this condition is detected by the program, measurements are made with a few purely reactive impedance terminations. The impedance for zero sidetone is then found from the intersection points of the circles resulting from each measurement.

Storage and Output of Results

The results of measurements on a telephone set are stored on a floppy disc for subsequent assessment. They may also be output to a printer or displayed graphically by an automatic plotter.

ASSESSMENT SYSTEM

Computer Program

The assessment system is based on a computer program known as *computer-aided telephone network assessment program* (CATNAP). It is a general-purpose program designed for examining transmission aspects of all parts of a telephone network. Although the program was written specifically to complement the telephone set measuring system, it has also been implemented on an international computer bureau system. CATNAP is being used throughout the world and is proving particularly useful in the transmission design of digital PABXs[1].

Calculation of Objective Characteristics

The user supplies the program with a description of a complete connexion. The information on the telephone sets at each end of the connexion is generally available directly from a file on a floppy disc. Information on certain other items in a connexion, such as transmission bridges, can also be obtained from data files. For some items, the program calculates the transmission parameters from information supplied directly by the user; for example, sections of cable are specified by their length and distributed parameters.

From the information supplied on each item in a connexion, the program computes the overall characteristics by a cascading process. The principal results are the overall loss in both directions and the sidetone-path loss at both ends. These are in terms of the acoustic reference points at mouth and ear. The user may also specify two interface points in the connexion, usually at the local exchange or international switching centre. The program computes the sensitivities between each acoustic reference point and the nearest interface.

Loudness Ratings

Up to this point in the assessment procedure, the calculation is performed at each of the set of frequency points; the next stage is to convert these figures into more meaningful frequency-independent quantities that relate to transmission planning. Loudness ratings are at present being studied by the CCITT; when they become standardized, they will replace reference equivalents[2].

Loudness ratings are measures of the relative loudness of certain parts of a connexion in terms of decibels. Like all decibel quantities, loudness ratings are relative to an arbitrary reference; in this case, they are relative to the loudness of a defined reference telephone connexion. The overall and sidetone loudness ratings are computed by the program from the frequency-dependent losses. Similarly, the sending and receiving loudness ratings are calculated from the sensitivities between each acoustic reference point and the specified interfaces. The sending and receiving loudness ratings are particularly useful in examining the regulation of telephone sets.

Subjective Performance

Although loudness ratings are very useful indicators of transmission performance, they do not relate directly to the degree of satisfaction experienced by the users of a connexion. Factors such as circuit noise, room noise, vocal level and the interaction between overall loss and sidetone are not taken into account. To provide the necessary information, many subjective tests have to be carried out in which pairs of subjects converse over a telephone connexion and then express their opinion on a scale such as 'excellent', 'good', 'fair', 'poor' or 'bad'. The results are scored from 4 to 0, and the mean score for a connexion gives a good measure of its subjective quality. By analysing the results of many such subjective tests, a mathematical model has been developed to predict the mean opinion score that would be obtained from a subjective test.

Simulation of Telephone Traffic

A subjective test in which 12 connexions are assessed would take about two weeks to perform. The mathematical subjective model, together with the transmission calculation part of the program, makes it possible to assess hundreds of connexions in a fraction of the time. Entering information on so many connexions into the program would be impracticable, so CATNAP incorporates a method of deriving a suitable set of realistic connexions by simulating telephone traffic on a Monte-Carlo basis. A telephone set may then be assessed in terms of a statistical distribution of performance parameters rather than by examining the performance of only a very limited number of hypothetical connexions.

ASSESSMENT OF A TELEPHONE SET

Sending and Receiving Characteristics

The regulation characteristics of a telephone set are usually examined by plotting the sending and receiving loudness ratings against the length of local line. A standard type of transmission bridge is included, and a single gauge of cable is assumed. This traditional method still proves most useful. An example of the regulation characteristics of a measured telephone set is shown in Fig. 6. The CATNAP program was used to compute the loudness ratings for a set of lengths of local line, and the results were automatically plotted.

Sidetone

The fact that only one cable gauge is used for examining the regulation characteristics of a telephone is of little significance. However, when sidetone is to be assessed, it is unrealistic to consider only lines composed of one gauge of cable. Information has been obtained on the composition of a large sample of local lines in the UK telephone network. The information has been stored on a floppy disc so that it may be assessed directly by the CATNAP program. Fig. 7 shows an example of the cumulative distribution of sidetone loudness ratings.

The results of subjective tests indicate clearly that sidetone becomes a very important factor when the overall loss of a connexion is high. The distribution shown in Fig. 7 was therefore calculated for calls via trunk junction circuits and trunk circuits. Information was supplied to the program on the statistical composition of trunk junction circuits in the UK. The characteristics of the trunk junction circuits have therefore had some influence on the distribution of sidetone loudness ratings; other classes of connexion could have been specified.

A graph of the distribution of sidetone loudness ratings is not very meaningful on its own; it is much more helpful when comparing two or more telephone sets having similar regulation characteristics. When trying to optimize the design of the impedance for zero sidetone, the sidetone performance of a number of hypothetical designs may be assessed and a realistic target can be set.

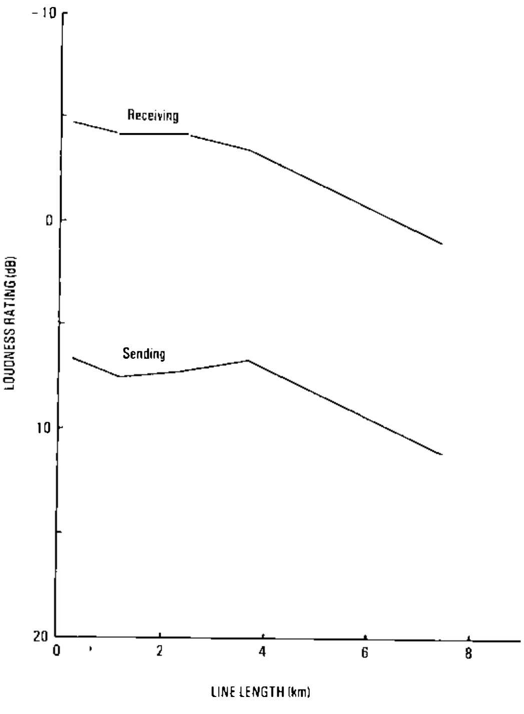


FIG. 6—Example of regulation characteristics

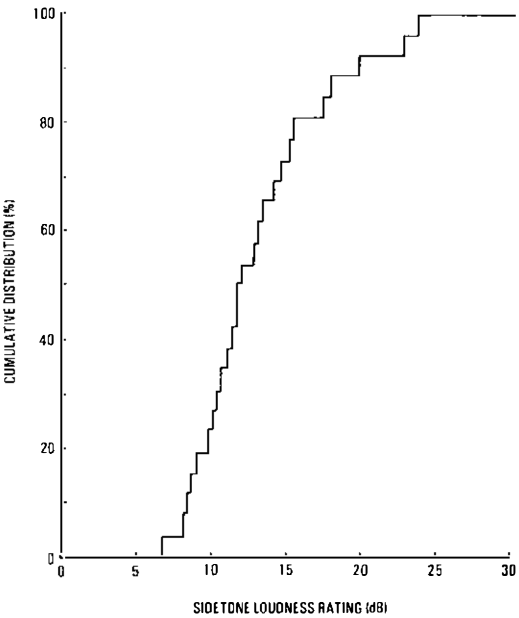


FIG. 7—Example of the distribution of sidetone loudness rating

Experience has shown that it is preferable to divide local lines into classes according to nominal loss or length. An improvement in sidetone performance for one class of line can give a degraded performance for another class. A compromise must therefore be reached, with the higher-loss lines having some priority.

Impedance Presented to Line

The impedance presented by a telephone set to line has relatively little effect on transmission performance. The effect of the impedance to line on the sidetone of another telephone set may be examined by specifying a number of short connexions. On the computer bureau version of CATNAP, the influence that the impedance has on the transhybrid loss of 4-wire transmission systems can be examined. Adequate stability margins and echo performance may then be ensured. (It is hoped to implement this facility shortly on the desk-top computer version of the program.)

CONCLUSION

The measurement-and-assessment system is proving very useful in the design and evaluation of telephone sets. It has been used to establish realistic design targets and to compare the performance of practical designs with the targets. It has also been possible to take into account the characteristics of future digital local exchanges. The system will ensure that future designs of BPO telephone sets will meet the requirements of the network and give good transmission quality to the customer.

References

[1] RILEY, G. I., and WEBB, P. K. Transmission Performance of 4-Wire Digital PABXs. IEE Conference: Private Electronic Switching Systems, Apr. 1978.

[2] Determination of Loudness Ratings: Fundamental Principles. CCITT, Recommendation P76, Orange Book, Vol. 5, 1977.

CJP3: A Computer Aid to Junction Network Planning

A. C. PUTT, M.I.T.E., T.ENG.(C.E.I.), and R. G. SMITHETT, B.SC.†

UDC 621.315: 681.31

The CJP3 system is the first of a new generation of computer systems used to aid the planning and use of the British Post Office junction network. This article describes how the basic files of line plant and circuit routeing information are used to assist in the network planning process, in identifying plant shortages and in the issue of circuit advices. An outline description is given of other computer systems that are planned for future use and which are based on the same files as the CJP3 system; these later systems will produce circuit advices and maintain plant utilization records automatically.

INTRODUCTION

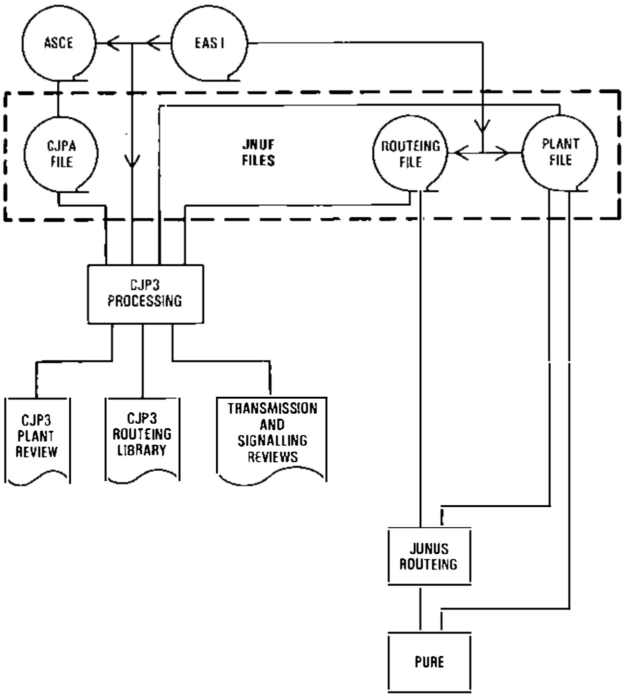
The need for computer assistance in the field of network planning in the British Post Office (BPO) junction network has been fully described in earlier articles[1,2] in this *Journal.* The Computer Aid to Junction Planning No. 2 (CJP2) system was oriented to the requirements of junction network planners, with an additional output for use by circuit provision control (CPC) duties. The operational procedures of the CJP2 system did not ensure that planners and users always proceeded in step; a factor which the complex network of the 1970s required and the projected network of the 1980s will demand.

The need to transfer the CJP2 system to a new series of computers, owing to machine obsolescence, combined with the results of a series of other feasibility studies into computer assistance in the CPC area, gave impetus to the setting up of a study team to look into the problems of bringing the CJP2 system up to date and of ultimately producing an integrated series of junction network systems.

The first priority was to replace CJP2. This article is principally concerned with its successor, known as the *CJP3* system, and the files, known as the *junction network update facility* (JNUF), from which the CJP3 system, and all future systems, will extract their data.

JUNCTION NETWORK UPDATE FACILITY

The basic principle of the new range of junction network systems is the use of common data files. These files are maintained by the JNUF, which is a computer system separate from the CJP3 system. The function of the JNUF is to deal with inputs, data vetting and the printing of file outputs. The files contained in the JNUF system are now described; the interconnexion of the files is shown in Fig. 1.



ASCE: Annual schedule of circuit estimates
CJPA: Computerized junction planning ASCE
EASI: Exchange and station information
JNUF: Junction network update facility
JUNUS: Junction network utilization system
PURE: Plant utilization record

FIG. 1—Interconnexion of data files

The Plant File

The plant file lists the engineering details of line plant for which the junction network planner is responsible; the file continues the nomenclature originated in the CJP2 system. The line plant is grouped into *links* (that is, all the plant used to interconnect two buildings); the links are subdivided into *arcs* (that is, plant having common electrical performance). Thus, within a *link*, 24-channel pulse-code modulation (PCM) groups, 0·9 mm and 0·63 mm audio cable each form separate *arcs*. Each *arc* is further sub-divided to show details of individual cables, PCM systems, or frequency-division multiplex (FDM) groups making up the *arc.*

The plant types that can be entered on to the JNUF plant file have been expanded from those of the CJP2 system. Thus, in addition to audio cables and 24-channel PCM groups shown on the CJP2 plant file, it has been possible to include junction and main network 30-channel PCM groups, multi-channel voice frequency (MCVF) telegraph systems, devolved FDM systems and many categories of audio cable that the planner may wish to separate. Examples of the latter can include unusable pairs, faulty pairs, external tie-cables, and pairs that are subject to electrical-induction interference. An example of plant file content is given in Table 1.

---

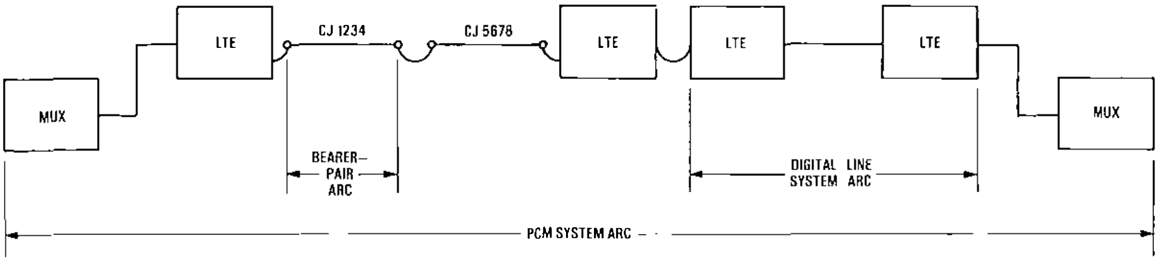
† Transmission Department, Telecommunications Headquarters

TABLE 1

Example of Plant File Content

Link	From	To	*Arc* Number	Plant Type	Length (km)	Capacity (Channels)			Spare Channels	Miscellaneous Channels	Miscellaneous Growth Factor (%)	Miscellaneous Maximum
						Existing	1990	1992				
6001	BDS	SVN	10	30-channel PCM	21·45	120	150	180	17	5	5	12

Note: The plant file also contains details of digital line systems used by the *arc*, and details of the groups making up the *arc*.



LTE: Line terminal equipment
MUX: Multiplex
PCM: Pulse-code modulation
ARC: An arc contains plant having common electrical performance

FIG. 2—Digital transmission hierarchy

A more extensive treatment of PCM groups is allowed within the JNUF and the CJP3 system. All 24- or 30-channel PCM groups and telegraph time-division multiplex (TDM) systems are given *link/arc* numbers. The PCM groups are routed over one or more digital line sections, and these are also identified by *arc* numbers. The digital line sections are carried over one or more bearer-pair *arcs*. Hence, there is a 3-tier hierarchy, as shown in Fig. 2. Thus, within the PCM channel *arc*, there are references to the digital line sections over which the former is routed; similarly the digital line sections include references to the bearer-pair *arcs*.

The plant file is output in three sections:

(*a*) The main part, detailing all audio cable, PCM, FDM, and MCVF *arcs*, together with references to digital line section and bearer-pair *arcs*;

(*b*) the PCM supplement, which includes details of PCM channel, digital line section and bearer-pair *arcs* only; and

(*c*) the CPC supplement, which is an abbreviated list of *link* and *arc* numbers, showing details of spare pairs totals, pair-numbering details, numbers and types of PCM signalling units and, finally, a list of spare-pair numbers.

The Routeing File

The routeing file shows how circuits are routed over a Telephone Area's line plant, as defined in the plant file. The CJP3 routes may include reference to a number of annual-schedule-of-circuit-estimates (ASCE) routes with the same transmission and signalling requirements grouped together, or to single ASCE components denoted by an ASCE entry number (AEN).

Each route consists of a number of physical paths over which the circuits may be routed; the routeing file contains details of the *arcs* forming each path and details of the transmission equipment and signalling type used.

There are two categories of path: *preferred* paths and *misroute* paths. The preferred paths are those over which the planner requires new circuits to grow. A maximum of 7 preferred paths, each comprising up to 5 *arcs* in tandem, are allowed. Misroute paths are merely a record of existing circuits that are routed in an unsuitable way, the result perhaps of expedient routeing in the past.

To determine how the circuits are to be allocated to the preferred paths, a matrix (known as the *pattern*) is held in the routeing file to show the percentage of circuits to be assigned to each preferred path for each year of the review period. Modifications may be made to the allocation of circuits to a preferred path by imposing a maximum circuit limitation on the path and by controlling the allocation of the excess circuits to other preferred paths. In addition, short-term limitations may be imposed on specific AEN components for particular preferred paths. This is known as the *component path maximum* and enables adjustments to be made for shortages of transmission and/or signalling equipment. From the circuit quantities of the AEN component(s) assigned to the route, a calculation is made of the year-end target for year 1 of the ASCE. This is based on the number of circuits that should exist for each AEN component on each preferred path at the end of the first ASCE year. The calculation is made by applying the pattern, which is first modified by any maximum circuit limitation and/or designated overflow, and then by any component path maximum that may exist. This target is used later in the CJP3 for the routeing library output.

The routeing file also includes details of PCM signalling units that are to be used for each AEN component associated with the route. An example of the content of a routeing file is given in Table 2.

Computerized Junction Planning ASCE

The computerized junction planning ASCE (CJPA) is an extract of the main ASCE file and holds details of each AEN; for example, terminations, levels and circuit quantities for the 8-year period. The CJPA defines the route to which each AEN is assigned, thus creating a linkage between the ASCE and the routeing file.

TABLE 2

Example of Routeing File Content

Routeing File Number	From	To	Transmission Limit (dB)	Resistance Limit (Ω)	Path Number	Percentage of Circuits on Path	*Link/Arc* References	Repeater Type	Sited at (Station code)	Signalling Type on Path
1234	BDS	SVN	4·5	1500	1	40	5001/10 2533/ 1	4-Wire	OUL SVN	AC9
					2	50	6001/10			PCM
					3	10	2531/ 3 2532/ 2 2533/ 1	Negative impedance	BDS SVN	LD

Note: The routeing file also contains details (for each AEN component using the route) of the total existing circuits, the existing circuits for each path, year-end targets and details of PCM signalling unit types.

The Regional Parameter File

The regional parameter file is an incidental file which holds information specific to a particular Region; it includes details of the order in which the various files and outputs are printed of regional extrapolation years and miscellaneous growth factors for each Area.

The Node File

The node file contains the details of spare transmission equipment in buildings at which line plant terminates. A number of exchange units and repeater stations may be grouped together within the same building complex, and the use of node numbers enables these to be identified.

The National Parameter File

The national parameter file has no application in the CJP3 system, but it holds the costings of line plant and transmission equipment. These enable the merits of expediently routeing a circuit to be assessed when the junction network utilization system (JUNUS), a future development, is unable to route circuits according to the routeing file.

In addition to the files within the JNUF, there are two national files required in the running of the junction network systems. These are the ASCE and the exchange and station information (EASI) files.

The ASCE file, which will be described in a future article in the *Journal*, is a document that forecasts circuit requirements for all traffic routes for the 8-year review period; it is an authority for the provision of circuits for the first year. The document is published on microfiche annually, and revised copies are produced every quarter.

The EASI file is a list of all exchanges and stations and includes all codes and names. It has facilities for assigning node numbers, which are used as a key by the JNUF/CJP3 systems to access the node file.

The JNUF system is a batch-processing system that uses documents from which data capture is by processor-controlled keying (PCK). An extensive set of vets and checks result in a high degree of monitoring of the data input with, for example, reports on incompatible plant types on the same path and divergence from the established transmission equipment planning rules. Facilities for running the system are provided by the BPO Data Processing Executive (DPE); at present, the JNUF system is being designed to run on the IBM 3300 at Harmondsworth, with a major run being in October/November of each year; monthly updates are provided throughout the year.

The JNUF is a large system; the files contain some 120 000 *arcs* and 77 000 routes, which together describe a network currently providing approximately 1 million public telephone circuits and some 300 000 private and miscellaneous circuits.

THE CJP3 SYSTEM

The CJP3 system makes use of the files processed by the JNUF system and provides a number of outputs, known as the *plant review*, designed specifically for the junction network planner, with other outputs to assist in the planning of transmission and signalling equipment. In addition, there is an output, known as the *routeing library*, designed for use by CPCs to enable junction circuits to be routed in accordance with the planner's design. With the extensive data held on file, outputs of statistics are also printed to allow Regions and Areas to monitor the state of their networks.

The Plant Review

The plant review is used by the junction network planner to identify line plant shortages and to provide assistance in determining the most economical means of overcoming them.

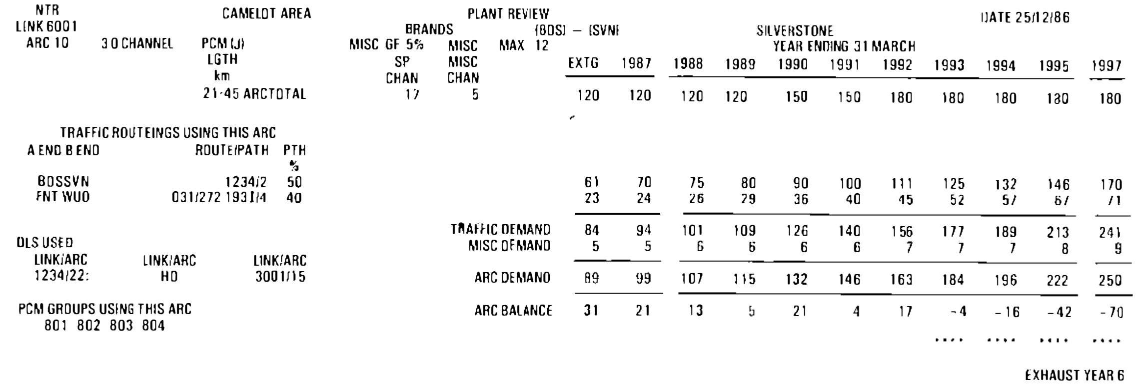
The wider range of line plant expected to be present in the junction network of the future has resulted in the output of the plant review being expanded. The output is printed in two sections:

(*a*) the main section, which consists of *arc* and *link* summaries of audio cable pairs, PCM channels, devolved FDM groups and MCVF groups; and

(*b*) the PCM supplement, which concentrates on PCM channels, digital line sections, bearer pairs and optical fibre transmission systems.

The planning process consists of applying ASCE circuit quantities for each year of the review period to the routes to which they are assigned, and dividing these among the preferred paths in accordance with the pattern and any maximum circuit limitation that may apply. The derived circuit quantities are then applied to each *arc* making up the preferred path and converted into a demand for audio cable pairs, PCM channels etc. according to the constituents of the *arc*. When, for example, the preferred path is used to provide 4-wire circuits, allowance is made so that the demand is adjusted accordingly.

The *arc* summary, which is the bulk of the output, compares the *arc's* capacity with the derived demand. The demand for miscellaneous circuits is derived by applying a percentage growth factor to the total pairs/channels at present used for miscellaneous circuits. The traffic and miscellaneous demand for each year are totalled and compared with the *arc* capacity. An *arc* balance for each year is derived and, when this becomes negative, the *arc* capacity is said to have been exhausted. In this manner, the capacity of each part of the network is monitored against the forecast demand for circuits; thus providing a firm basis for planning (see Fig. 3). The misroute



```
  NTR                     CAMELOT AREA              PLANT REVIEW                                                             DATE 25/12/86
LINK 6001                                     BRANDS          (BOS) - (SVN)                 SILVERSTONE
 ARC 10     3 0 CHANNEL     PCM (J)     MISC GF 5%    MISC    MAX 12                     YEAR ENDING 31 MARCH
                             LGTH         SP          MISC           EXTG   1987    1988   1989   1990   1991   1992   1993   1994   1995   1997
                              km         CHAN         CHAN
                            21·45 ARCTOTAL 17          5              120    120     120    120    150    150    180    180    180    130    180

        TRAFFIC ROUTEINGS USING THIS ARC
  A END B END              ROUTE/PATH  PTH
                                        %
   BOSSVN                      1234/2   50                             61     70      75     80     90    100    111    125    132    146    170
   FNT WUO            031/272 1931/4    40                             23     24      26     29     36     40     45     52     57     67     71

                                                      TRAFFIC DEMAND   84     94     101    109    126    140    156    177    189    213    241
DLS USED                                                 MISC DEMAND    5      5       6      6      6      6      7      7      7      8      9
  LINK/ARC        LINK/ARC          LINK/ARC
  1234/22:           HD              3001/15              ARC DEMAND   89     99     107    115    132    146    163    184    196    222    250

PCM GROUPS USING THIS ARC                                ARC BALANCE   31     21      13      5     21      4     17     -4    -16    -42    -70
   801  802  803  804                                                                                           ....   ....   ....   ....

                                                                                                                                  EXHAUST YEAR 6
```

FIG. 3—Planning output

circuits using the *arc* are also listed to allow the planner to consider these circuits when any assessment is made of the *arc*. When each *arc* has been output, a *link* summary, consisting of the totals of all the capacities and demands of the audio and PCM *arcs*, is printed. At the end of each Area's print-out, a comprehensive output of statistics is produced.

A supplement to the main plant review for PCM consists of *arc* summaries for the PCM channels; it is able to follow through to derive the demand for digital line sections by assuming one digital line section for every 24- or 30-channel PCM group or part of a group. Similarly, the demand for bearer pairs can be derived by assuming one or two bearer pairs per digital line section, according to whether double or single cable working is used.

The plant review is output in its entirety each year in October/November; facilities exist for individual *arc* summaries to be produced within the monthly updates to the JNUF system.

To supplement the statistics, facilities will be provided to allow information to be extracted by using the rapid-access management-information system (RAMIS). In this system, the files are restructured by a special suite of programs to allow information to be extracted by interrogation via a computer terminal. This allows information to be derived and tailored to meet the needs of local management.

The Transmission Equipment Review

The transmission equipment review provides information to assist in the planning of audio transmission equipment. The output, produced on a station basis, indicates the demand for transmission equipment for public circuit requirements; to this must be added the requirements arising from miscellaneous circuit demand.

The output is in two parts: an equipment summary and a station summary. From the details held for each path on the routeing file, it is possible to calculate the demand for transmission equipment from the ASCE circuits applied to the path. Additionally, by the application of the planning rules included within the program suites, the demand for passive equipment (for example, transformers and building-out networks) can be derived.

The equipment summary lists the equipment types, together with the route/path making use of the equipment type, the total circuits applied to the route and the derived equipment demand over the review period; the intermediate stations on the path being considered are also shown.

The station summary lists the total demand for equipment types at each station.

The Signalling Equipment Review

The signalling equipment review is produced to assist junction network planners and to provide information to the exchange planner giving details of signalling requirements for the junction network over the ASCE years 5–8. An output of similar format is given to the trunking and grading duty, informing them of signalling requirements for the period up to the fifth year of the ASCE.

The signalling requirements of each station, subdivided into sections of ASCE and direction of circuit, are also outputted for the first 5 years of the ASCE.

Details of test jack frame (TJF) and PCM signalling unit requirements for each station are also provided. The basis of the information for these is the routeing file, and the calculations are made by applying ASCE circuit quantities to the details of signalling systems and PCM signalling units held on the file.

The Routeing Library

The routeing library is the only output not directed at a planning function. Copies of the routeing library are supplied to the CPC duties and provide details of all routes authorized by the ASCE and controlled by Telephone Areas. The routeings are those laid down by the junction network planner on the routeing file and, with this information, a CPC can interpret precisely the planner's requirements. The routeing library is in two sections: each route shows ASCE-related data followed by the routeing data.

The ASCE related data shows each AEN component with details of exchange terminations and levels, as shown on the ASCE, and ASCE circuit forecasts for years 0, 1 and 2. Intermediate circuit conditions are also shown. The year-end target, taken from the routeing file, indicates the number of circuits that should be routed on a path for a particular AEN component by the end of that year. Following the introduction of the JUNUS, details of existing circuits for each AEN component/path will be output. When a route consists of a number of AEN components, total circuit quantities are calculated for the route.

The presence of existing circuits on file will also allow the existence of misroute circuits to be deduced by comparing the total existing circuits for the AEN component with the sum of existing circuits on the preferred paths. The routeing data shows each preferred path for each route in a format closely resembling that of the circuit advice (A886). Each *arc* is shown with the CJ cable, PCM group or FDM group numbers shown alongside to allow easy reference to cable/group appropriation records (A335) for pair/channel allocations. Resistance and transmission loss values, where appropriate, are also shown. Repeater types, together with signalling types, are shown at the exchange location.

Total year-end targets and ASCE forecast figures for the preferred paths are brought forward from the ASCE data.

The routeing library is printed in its entirety during October/November each year. Thereafter, whenever the ASCE circuit forecasts change during the first two full ASCE years, or when the planner makes a routeing file change, updated pages of the routeing library are produced automatically, so keeping the CPC fully informed of changes to the network. An example of a routeing library print-out is shown in Fig. 4.

```
   NTR                   CAMELOT AREA                        ROUTEING LIBRARY                                               DATE 25/12/86

   ROUTE                                                       BRANDS (BDS) - (SVN) SILVERSTONE

  ROUTEING FILE NUMBER 033/1234                                                                                              ASCE DATA SECTION 2

                      D     EXTG   FORECASTS-CCTS      PATH 1      PATH 2       PATH 3
         BOS SVN      I     CCTS    ASCE YR ENDING                                                                                                            MR
                      R      +ICP   31  MARCH         EXTG  TAR-  EXTG  TAR-  EXTG  TAR-                                                                      I T
 123456               N      1986  1987 1988  1969    CCTS  GET   CCTS  GET   CCTS  GET                                                                       S·E
 STGS        K1NOM
 L.7                  0        87   90  100   110       28    30    43     50    16    20                                                                     2
             L.3      1        38   40   50    55       10    15    18     25    10    10                                                                     0

   PCM SIGNALLING CARDS
                          30 CHANNEL (INTEGRATED SIG)
                          0  A1A      81A
                          I  81A      A1A

  ROUTEING FILE NUMBER 033/1234                   XMSN LIMIT     4·5 08   LO  LIMIT 1500 OHMS                             ROUTEING DATA SECTION 2

   P CIRCUITS-
   A YR ENDING                                        OTHER
   T 31 MARCH          SIG    XMSN                    AREA                  CJ/MU                                   CABLE      LNGTH     LOSS      RES      RES
   H 19881989          EQ;    EO:   %     @EXCHANGE   CNTL   LINK/ARC       NO  CAHLE/SYSTEM CODE                   TYPE        KMS       08     OHMS     AMP

    1      45    60    AC9                  BOS
                              AT          @OUL               5001/10    HF   BOS-OUL 901, 902,                  12CH        5.4                        100
                                                                                 903, 904, 905,
                                                                                 906.
          M/W=4               AT          @SVN               2533/1   CJ2345 OUL-SVN NO 2                       0.63 NL     5.3       1.21    583      100

    2      75    80                         BOS
                                            SVN              6001/10 PCM    BDS-SVN NO801, 802,                 30CH        21.45
                                                                               803, 904.

    3      30    35    LO     ANB   50    @BOS                                                                                                             220
                                            LYO              2531/3   CJ1235  BDS-LYO NO 2                      0.63NL      2 0       0.9     220
                                            OUL              2532/2   MU 301  LYO-OUL NO 1                      0.63NL      3.3       1.49    364
                              ANB   50    @SVN/A             2533/1   CJ2345  OUL-SVN NO 2                      0.63NL      5.3       238     583      220
                                            SVN                               2W INTERNAL TIE
```

FIG. 4—Routeing library output

THE FUTURE

The JNUF and CJP3 systems are the first of the new generation of junction network computer systems. There are other systems at present under development by the BPO which will be oriented towards the CPC functions. The first of these systems is the junction network utilization system (JUNUS).

The Junction Network Utilization System

The JUNUS system consists of two parts, the JUNUS plan and the JUNUS routeing stages. The JUNUS plan stage provides information to assist in determining a plan of circuit provision work for a year, taking into account priority (from a service standpoint) and plant availability. The priority will be determined by another computer system called the *junction network priority system* (JNPS). Summaries of ASCE requirements, line plant and transmission equipment demands will be produced to provide sufficient information to allow the CPC arbitration exercise to be completed without reference to any other documents.

The routeing stage of the JUNUS system produces circuit advice (A886) masters for new public and private circuits. When plant utilization record (PURE) becomes available it will be possible to provide circuit advices for cessations and rearrangements.

A circuit request will result in the output of a circuit advice and, for public circuits, the timing of submission of input will be based upon information provided from the JUNUS plan stage. Private speech circuits and data circuits will be requested by stating the terminal codes. A number of engineering performance specifications (EPS) are catered for and will enable out-of-area exchange lines, external extensions, inter-PBX lines and telegraph circuits to be provided via this system.

With the introduction of the JUNUS system will come on-line data input, where the files can be amended by inputting data via a computer terminal at the Region/Area level. This will allow day-to-day changes to the files to be made.

The On-Line Plant Allocation System

The on-line plant allocation No. 2 (OPAL 2) system will come into operation at the same time as the JUNUS routeing stage. It will be used in conjunction with the JNUF plant and node files to provide assistance with the manual routeing of urgent circuits, or those that cannot be routed and designed by the JUNUS system, identifying the shortest possible routeing between two stations.

The Plant Utilization Record System

The plant utilization record (PURE) system will hold cable pair, PCM and FDM channel appropriation records (A335) and circuit advices (A886) details. The appropriation records will be used by the JUNUS system to allocate pairs/channels to circuits, and will allow records to be updated automatically. Additionally, crosschecks between the detail of A335 records and A886 advices will be carried out automatically to show when pairs/channels shown as earmarked or working are really spare, and the historic A886 records will enable the JUNUS to produce circuit advices for rearrangements and cessations.

On-line facilities will enable the information on the A335, and A886 files to be viewed on a visual-display unit.

The Junction Network Priority System

The junction network priority system (JNPS) will not make use of the JNUF, but will predict probable exhaustion dates for each route and assign a provision priority indicator based on relevant factors; for example, opening-date circuit requirements (ODCR).

CONCLUSION

The introduction of the JNUF and the CJP3 systems during 1981 is only the first stage of a family of computer systems designed to aid the planning and efficient usage of the BPO's junction network, and to improve the co-ordination of these functions. In the next decade, the conversion of the UK transmission network to digital form will result in a more complex network, requiring considerable planning and utilization resources. The junction network planning systems will give assistance and will enable more effective overall control to be exercised.

References

[1] KYME, R. C. The Junction Network. *POEEJ*, Vol. 69, p. 175, Oct. 1976.

[2] DUFOUR, I. G. A Computer Aid to Junction Network Planning. *POEEJ*, Vol. 71, p. 45, Apr. 1978.

A Standard Range of DC Power Supplies for PBXs

J. T. BROOKFIELD, D.F.H., C.ENG., M.I.E.E., and M. K. TRIMBLE, B.SC., D.M.S.†

UDC 621.395.2: 621.314.6: 621.382.334

A standard range of thyristor-controlled rectifiers is now available for use with PMBXs and PABXs. This article outlines the requirements for the new development, and describes the design and operation of the rectifiers.

INTRODUCTION

Most private branch exchanges (PBXs) in the UK operate from −50 V DC, but a few older designs of private manual branch exchanges (PMBXs) operate from −24 V DC. Until recently, the standard British Post Office (BPO) rectifier plant available for use with this equipment was defined by performance specifications only. Although the performance of these rectifiers was satisfactory, widely varying electrical designs were used by different manufacturers. This has given rise to installation, maintenance and factory repair difficulties. Because of the trend towards increased power requirements, the disadvantage of being unable to use such rectifiers in parallel has become apparent. There is also a need for an automatic high-voltage shut-down and recycle facility for battery protection, and compatibility with the new generation of electronic PBXs has to be ensured.

These factors led the BPO to sponsor the development of a new and rationalized range of rectifiers, built to a standard design.

DESIGN PHILOSOPHY

The new range of rectifiers is used in customers' premises, and large numbers of the smaller versions are required. Cost and reliability are therefore the prime factors considered in their design. Since the mean time between failures (MTBF) of the units is directly related to the number of components, a simple design is essential. It is also important to restrict the floor space occupied and to keep any audible noise emitted to a minimum. To reduce variety, the new rectifiers have a limited number of output ratings, but are capable of working in parallel with other units, regardless of manufacturer; a standard design for both power and control circuits is therefore necessary. The control and alarm circuitry is designed for ease of maintenance replacement.

Most PBX power plants have, in the past, been based on the single-battery float arrangement shown in Fig. 1. The battery consists of modern high-performance Planté cells, which enables battery condition to be checked by visual inspection and provides confidence that the required capacity is available. To obtain long battery life and minimize maintenance attention required, the battery voltage is maintained between 2·25 V and 2·3 V per cell. The nominal output voltage of the rectifier (used as a battery charger) must therefore be 54 V for a 24-cell battery, and 27 V for a 12-cell battery. To prevent battery damage, over- and under-voltage output alarms are incorporated in the rectifier design. The new over-voltage shut-down facility provides an additional safeguard to prevent possible cell damage, and also enables the rectifiers to be used to power electronic equipment having a restricted input voltage range.

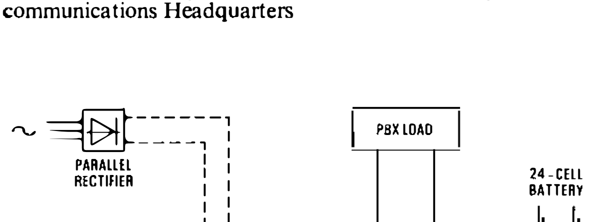


FIG. 1—Single-battery float arrangement

Customers are now given the option of foregoing the stand-by facility provided by the battery under mains failure conditions. Rectifiers that can deliver a sufficiently noise-free output, without the use of a battery to provide smoothing, have therefore been included in the range.

THE NEW RANGE

The Electricity Council recommend limits to the level of harmonic currents that may be drawn from the public AC mains supply*. Consequently, rectifiers with outputs of 100 A DC or more require a 3-phase mains supply. Therefore, the new range of rectifiers consists of two basic designs: Rectifiers 151 and 152 share the same design, are powered from single-phase mains supply, and deliver outputs of 5 A, 10 A and 25 A DC; Rectifiers 153 are powered from 3-phase mains and have output ratings of 100 A and 300 A DC. Details of rectifiers currently available are given in Table 1, from which it can be seen that standard control and alarm units have been designed for each range of rectifier.

The 27 V Rectifier 151 is designed mostly for use with PMBXs, but it can be used for transmission plant on customers' premises and as a charger for the batteries used to start main exchange stand-by engine-sets.

TABLE 1
New Range of Thyristor Rectifiers

Rectifier No.	Mains Input (A C)	Output (DC)		Control and Alarm Units
		Nominal Voltage	Maximum Current	
151C/10	240 V, single-phase	27 V	10 A	Control Unit 44A
151C/25			25 A	
152C/5		54 V	5 A	Control Unit 34A
152A/10			10 A	
152A/25			25 A	
152E/25			25 A	
153B/100	415 V, 3-phase		100 A	Control Unit 35A and Alarm Unit 43A
153B/300			300 A	
154A	240 V, single-phase	18–140 V	54–9 A	Control Unit 45A

---

† Energy, Transport and Accommodation Department, Telecommunications Headquarters

* Limits for Harmonics in the UK Electricity Supply System. The Electricity Council Chief Engineer's Conference, Engineering Recommendation G5/3

The Rectifier 152 is used as a 54 V battery charger for most PBXs, mainly mounted in floor-standing cases, but the Rectifiers 152/5 and 151/10 are light enough to be wall mounted. Fig. 2 shows the 2 case designs, while the floor-standing case, shown in Fig. 3, illustrates the strength and cheapness of the sheet-steel construction compared with the more conventional welded framework, clad with sheet steel. The wall-mounting case is a standard one, ensuring interchangeability with earlier models. The Rectifier 152E/25 has a case designed to match the equipment practice used with the PMBX 11. Like rectifiers with a B or D suffix (see Table 2), the 152E/25 has an output filter with improved smoothing and is therefore capable of working without a battery if necessary.

Rectifiers 153 are designed to be used with up to a maximum of four connected in parallel (as can Rectifiers 151 and 152), and are also capable of being mixed in sizes. Fig. 4 shows a suite of three Rectifiers 153 installed in parallel. In this installation, since two rectifiers are capable of supplying the full PBX load current, the third rectifier provides a stand-by for security.

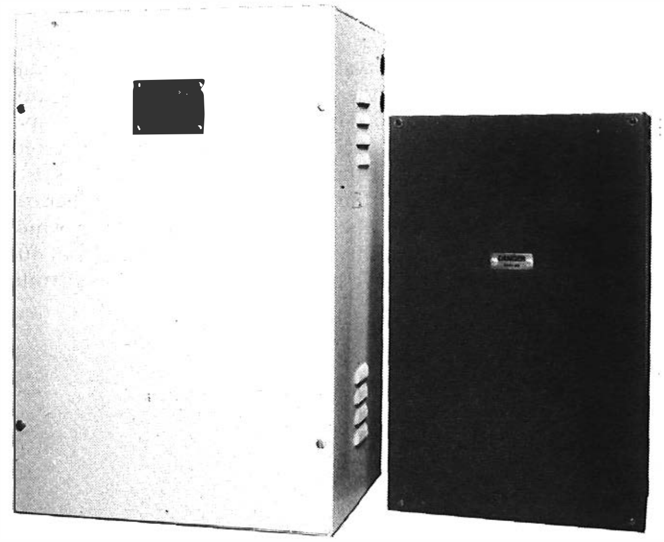


FIG. 2—Rectifiers 152A/10 (floor-standing) and 151C/10 (wall-mounting)

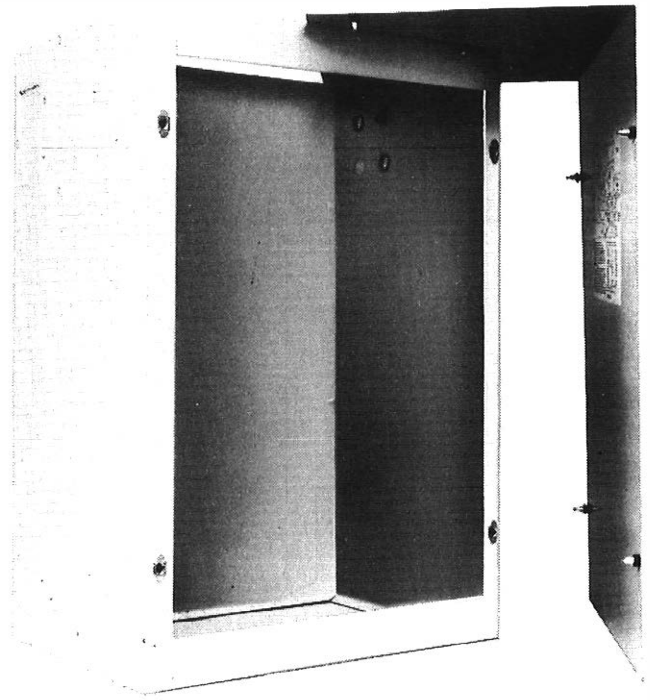


FIG. 3—Floor-standing case construction

TABLE 2
Rectifier Suffixes

Suffix	Capable of Use Without a Battery	Colour of Case
A	No	Light Straw
B	Yes	
C	No	Elephant Grey
D	Yes	
E	Yes	

The basic circuit design of Rectifiers 151 and 152 has been utilized to produce a transportable unit, known as the *Rectifier 154A*. This is intended for use as a variable-output-voltage rectifier to replace faulty plant in customers' premises or main exchanges. For simplicity, the description of this rectifier is omitted from this article.

The range has been developed in such a way that, where the need arises, rectifiers can be added by combining design features of existing versions. This can be done at minimum cost, and without increasing the variety of basic designs in service. In this way, prototype Rectifiers 152D/5 and 152B/10 have already been produced as 5 A and 10 A rectifiers respectively, for use without batteries.

PRINCIPLES OF OPERATION

Any voltage-controlled rectifier consists of:

(*a*) a power conversion circuit, capable of transforming AC to DC and delivering power to the output terminals at a voltage level greater than that desired, with the voltage ripple smoothed to an acceptable degree; and

(*b*) a control circuit, which continuously compares the


FIG. 4—Suite of three Rectifiers 153B/300 in parallel

sensed output voltage and current with a standard representing the desired output, and adjusts the power circuit so as to maintain the output voltage and overload current within specified limits.

The major components of Rectifiers 151, 152 and 153 are shown in block diagram form in Figs. 5 and 6, while Figs. 7 and 8 show the layout of the components. The control circuit for Rectifiers 151 and 152 consists of two parts: Part 1, a single printed-wiring board, fulfils the control and alarm function; Part 2 switches the power circuit, to provide the over-voltage shut-down and recycling facility under the command of the alarm function. The control and alarm functions are separated in the Rectifiers 153. The control circuit consists of four printed-wiring boards: the master control (Part 1) and one identical slave control for each phase (Part 2). The alarm function is performed by a separate printed-wiring board (Alarm Unit 43A), in conjunction with a mains contactor.

THE POWER CIRCUIT

Controlled rectifier designs differ mainly in the choice of technique used in the power circuit. These techniques include:

(*a*) *The Transductor* This consists of one or more ferromagnetic cores, upon which the main (AC) winding(s) and physically separate control (DC) winding(s) are magnetically coupled. The application of DC to the control winding varies the core flux, thereby changing the reactance of the main AC winding and controlling the flow of AC into an uncontrolled bridge rectifier. This technique, offering little opportunity for standardization, results in a proliferation of circuit designs.

(*b*) *The Series Transistor Regulator* In this technique, the energy is limited by a power transistor (or transistors in parallel) connected in series in the power circuit. High efficiencies are difficult to obtain, and transistor failure can result in high output voltage.

(*c*) *Pulse-Width Modulation* In this method, rectified AC is chopped by a transistor switched-mode circuit. The mark-to-space ratio of the resultant waveform can be varied according to the sensed output voltage. The waveform is transformed, rectified to DC, and smoothed to produce the desired output. As the power rating of semiconductors has improved, this technique has become increasingly attractive. Its advantages include reduced size, weight and cost of wound components. The speed at which the transistors switch results in an improved transient response over other designs; that is, rapid changes in load current have less effect on the value of output voltage. However, at the time when this development was begun, the technologies and power components for this form of conversion were not sufficiently well advanced.

(*d*) *The Thyristor Bridge* A thyristor functions as a diode that conducts in the forward direction only after a small trigger pulse has raised the potential of its gate connexion above that of its cathode. Thyristors can be used as components in a rectifying bridge fed with AC which, once triggered, continue to conduct until the anode potential equals that of the cathode (at the end of the AC half cycle). The rectifier can be controlled by varying the time in the half cycle at which the thyristors are fired. Efficiencies in excess of 90% at full load are possible. The thyristor technique compares favour-

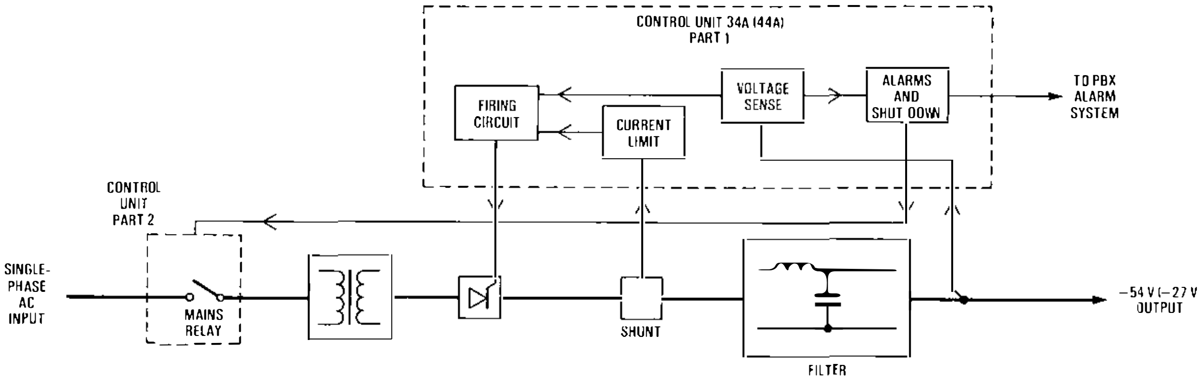


FIG. 5—Block diagram of Rectifiers 152 (and 151)

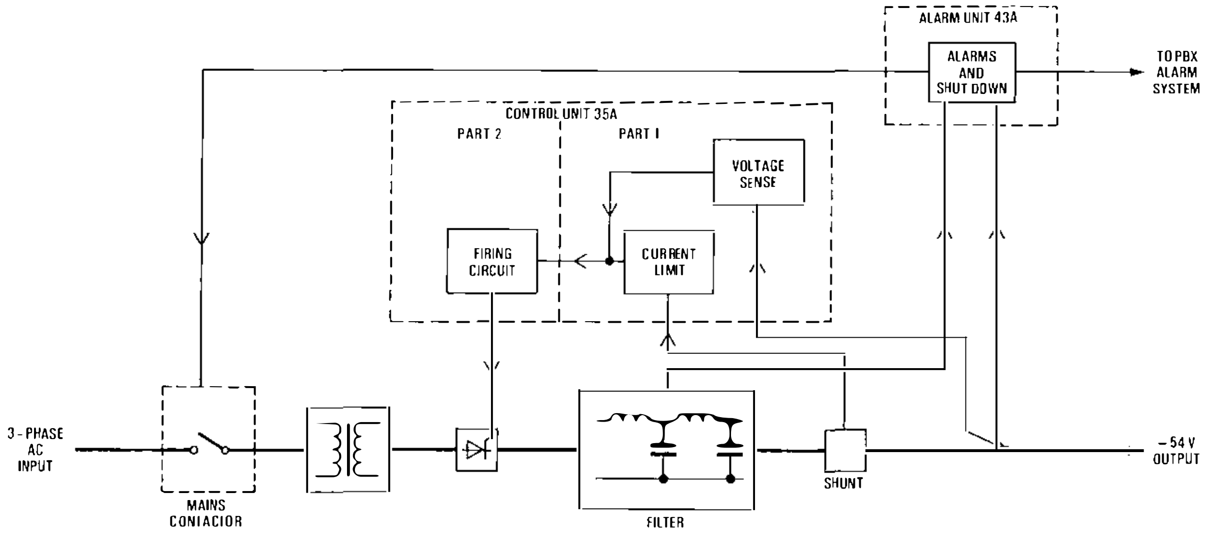


FIG. 6—Block diagram of Rectifiers 153

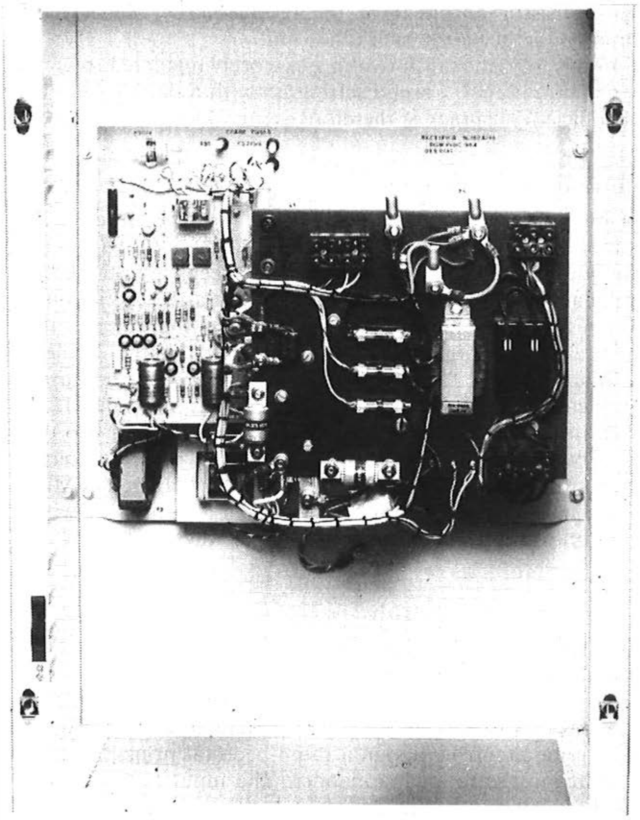


FIG. 7—Rectifier 152A/10

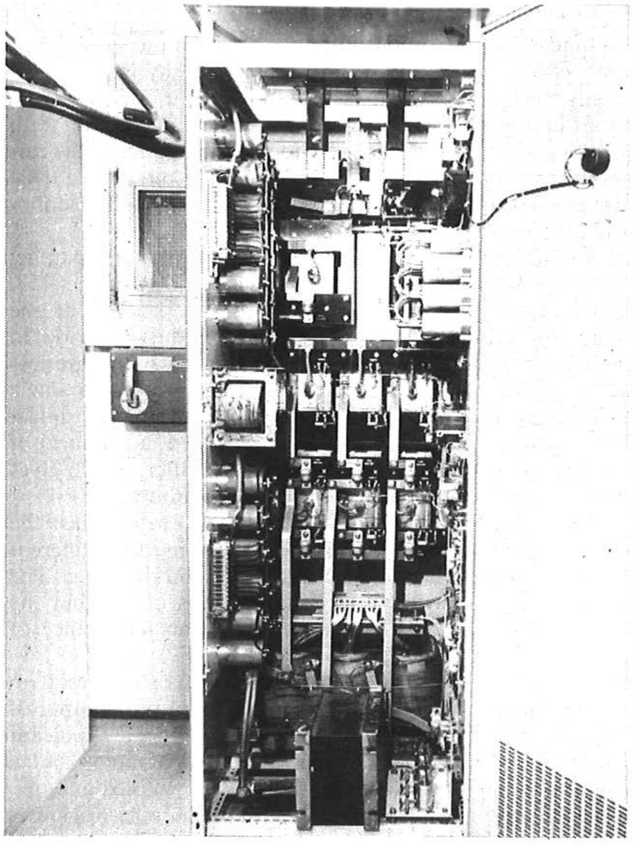


FIG. 8—Rectifier 153B/300

ably with the other methods in terms of cost, and presents greater opportunities for standardization of both power and control circuitry. As an additional advantage, a suitable single-phase thyristor design was among those of the old range purchased by the BPO and proved to be reliable. For these reasons, thyristor control was chosen for the new range.

Rectifiers 151 and 152

The rectifier circuit chosen for use in Rectifiers 151 and 152 is the single-phase half-controlled thyristor bridge shown in Fig. 9. Voltage control over the entire range is possible using half as many thyristors as are required in the equivalent fully-controlled bridge. The use of a freewheeling diode across the bridge output provides a path for current to continue to flow through the output filter inductors after the thyristors have ceased conducting. This prevents destructive reverse voltages from being produced.

Rectifiers 153

A half-controlled 3-phase thyristor bridge could have been selected for use in these larger rectifiers. However, a well proven control circuit for the fully-controlled bridge was commercially available. Consequently, the arrangement shown in Fig. 10 was chosen to shorten development time.

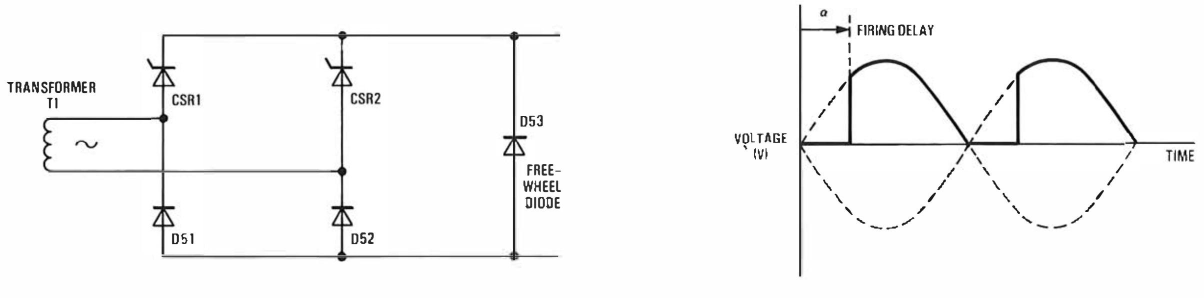


FIG. 9—Single-phase half-controlled thyristor bridge (Rectifiers 151 and 152)

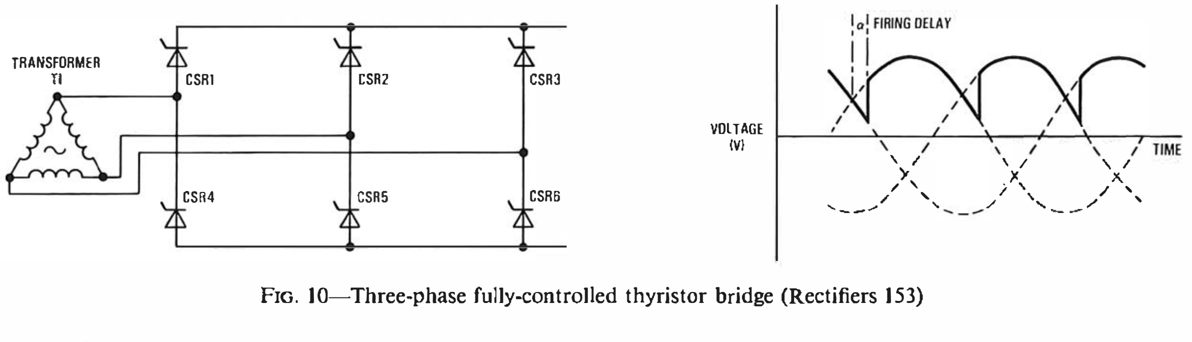


FIG. 10—Three-phase fully-controlled thyristor bridge (Rectifiers 153)

OUTPUT FILTERS

The function of the output filter is to smooth the steep-edged unidirectional pulses, resulting from the thyristor bridge (mostly at 100 Hz), to an acceptable level of ripple at the output terminals. This ripple is specified according to a weighting scale related to the audiometric response of the ear, to minimize the effect of hum on speech circuits. For PBXs, this limit has traditionally been set at 2 mV measured psophometrically weighted.

The filter consists of a series inductance and parallel capacitance. Use of a 2-stage filter, as in the Rectifiers 153, gives an overall attenuation equal to the product of the attenuation of each stage, thus representing a saving in components over a single-stage filter. These savings are less significant for output currents below 100 A, and so a single inductance/capacitance arrangement is used in the single-phase rectifier design. This has the added advantage of reducing the forward response time of the filter, which gives a better transient response than the 2-stage filter.

When batteries are used with rectifiers, they reduce the need for expensive filter components, resulting in a different filter design for the A and C coded rectifiers in the range. The resistance of the battery and its connexions is low, but the reactance can typically be represented by an inductance of 12 μH.

The steep switch-on characteristics of thyristors result in higher frequency harmonics than are present in the output of a transductor rectifier. This would usually require a significant increase in conventional inductance and capacitance, but a novel solution has been incorporated in Rectifiers 151 and 152. A small additional choke, in series with the output, attenuates the high-frequency ripple by a factor of 4 : 1. The reduced conventional filter size represents a saving of about 18% of the rectifier cost.

SHORT-CIRCUIT PROTECTION

All the single-phase rectifiers in the new range have the novel feature of protection against a full short-circuit across the output. The design of Rectifiers 151 was modified for use as an engine-set starting-battery charger by selecting bridge components and protection fuses capable of handling the energy stored in the filter components, together with that from a full half-cycle of output into the short-circuit. This is assumed to be delivered before the control circuit senses the condition and inhibits the output from the bridge. An output fuse and spare is no longer required; thus, reliability is increased and, for the small single-phase rectifiers, the savings more than cancel the additional cost of the facility.

THE CONTROL CIRCUIT

The Voltage Sense Circuit

Previous rectifiers have sensed the output voltage directly across the battery terminals and, in the past, many problems have resulted from the disconnexion of these sense leads. In the new range, the sense circuit is therefore connected at the rectifier output terminals, and the cable size for the rectifier-to-battery connexion selected to meet a maximum voltage drop of 0·5 V.

The sense circuit consists of a resistance chain, with a variable resistance that allows a proportion of the output voltage to be compared with a reference voltage derived from a Zener diode. The difference is amplified and presented to the control circuit as a variable voltage signal, the level of which is a function of the output voltage. Early versions of sense circuits were often very temperature sensitive, but now, to reduce the effects of temperature in the single-phase rectifiers, a 6·2 V Zener diode is included in the emitter circuit of the sense amplifier transistor. The temperature coefficient of the forward-biased junction of the sense amplifier transistor and that of the reverse-biased Zener diode almost exactly cancel each other out.

In this way, the output voltage is closely regulated to within ±1% of nominal. Careful setting up with a digital voltmeter of sufficient accuracy is therefore essential.

Current Sense Circuit

In both the single-phase and 3-phase rectifiers, the current is monitored by measuring the voltage drop across a shunt in the output circuit. When the current exceeds about 110% of full load, the voltage control is overridden and output voltage progressively decreased, thereby limiting the current to a maximum of about 115% of full load. This is achieved without the need for any adjustments, which was a cause of problems in the past.

In the case of the 3-phase rectifiers, the shunt is also used to drive an ammeter. On the single-phase unit, the output current can be checked with a standard BPO Meter, Multi-range No. 12 connected to two sockets that are fed with a fraction of the voltage developed across the shunt.

Thyristor Firing Circuit

The thyristors in the single-phase rectifiers are triggered into conduction by a direct voltage pulse. This is applied by the firing circuit to the gate connexion of each thyristor, via a bistable circuit changing state at the end of each half cycle. The firing circuit works on a ramp-pedestal principle, which operates in the following manner. The input to the bistable circuit is fed by a capacitor, which is discharged at the end of each half cycle by a transistor that conducts briefly. During the half cycle, the capacitor charges through a resistor. When this voltage, offset by the control current from the voltage and current sense circuits, reaches a critical voltage, the circuit is switched and a pulse is delivered to the appropriate thyristor. When the rectifier output voltage is too high, the critical voltage is reached later in the half cycle; the firing angle of the thyristors is therefore increased, and the rectifier output voltage reduced. The reverse occurs when the output voltage is too low. Hence, the output voltage is controlled.

The firing circuit of the 3-phase rectifier works on a different principle. Here, the thyristors are fired by pulses derived through six pulse transformers from a circuit consisting of the conventional transistor analogue of a programmable uni-junction transistor. The input to this circuit is again fed by a capacitor charging through a resistor to a critical voltage. In this case, however, the critical voltage at which the circuit delivers a pulse is varied directly by the voltage derived from the voltage and current sense circuits. When the rectifier output voltage is too high, the critical voltage is increased, the capacitor reaches this voltage later in the cycle, the firing angle of the thyristors is increased, and the rectifier output voltage reduced. Again, if the output voltage is too low, the reverse occurs.

A soft-start facility is incorporated in both firing circuits to prevent surges at switch on, and to allow the output current to build up slowly. This is achieved in both cases by a capacitor that inhibits thyristor firing until the capacitor is fully charged.

THE ALARM CIRCUIT

The alarm circuit for both single and 3-phase rectifiers provides high-voltage and low-voltage alarms when the nominal output voltage varies beyond permitted limits.

Additionally, the novel feature of high-voltage shut-down is incorporated. If the rectifier output voltage continues to rise above the high-voltage alarm value, the rectifier is shut down when the voltage reaches a preset limit. This is achieved by operation of the mains relay in the control unit of the single-phase rectifiers, and by operation of the mains contactor of the 3-phase rectifiers. The alarm circuit, which derives its power from a separate transformer from that in the power circuit, continues to monitor voltage. As the battery discharges and the terminal voltage decreases to a preset value below that for the low-voltage alarm, the rectifier restores the output. When no batteries are used, this recycling can be inhibited by the simple inclusion of a link on the alarm circuit.

The alarm circuits for both the single-phase and 3-phase rectifiers work on the same principle. A sample of the output voltage, derived from a potential divider circuit, is compared with the voltage developed across a Zener diode. For Rectifiers 151 and 152, a resultant change in voltage of points on the potential divider chain switches a series of transistors which, in turn, activates the alarm relay. For Rectifiers 153, the transistors are replaced by two integrated circuits: one a series of linear operational amplifiers, and the other a series of NAND gates, together forming a voltage-comparator circuit.

This use of logic gates in the Alarm Unit 43A has enabled a further novel feature to be included in the Rectifier 153 range. When rectifiers are operated in parallel, and the output voltage exceeds the shut-down limit, only the faulty rectifier is shut down. This is achieved simply by using one additional wire to signal to the alarm logic the presence of a ripple voltage in the output filter when the rectifier is delivering a load current. Under a high-voltage condition, the alarm circuit shuts down the rectifier it controls only if the volts are high *and* ripple voltage is present. Under these conditions, the remaining rectifiers would have shed load to the faulty one with the high output voltage and, consequently, would not shut down because no ripple voltage would be present.

CONCLUSIONS

Of the new range of rectifiers described in this article, over 10 000 Rectifiers 151 and 152, and over 50 Rectifiers 153 are now in service on customers' premises. They are used with most BPO rental range PBXs, and agreement has been reached with the Telecommunication Engineering and Manufacturing Association for their use with many proprietary PBXs. It is hoped that the introduction of the new range of rectifiers will contribute towards improved commissioning and maintenance performance by reducing the variety of designs.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of Electro Technical Assemblies (Sussex) Ltd., and Harmer and Simmons Ltd., who carried out the initial developments of the single-phase and 3-phase rectifiers respectively.

Book Reviews

Introduction to Digital Filters. Trevor J. Terrell. Macmillan Press. x + 222 pp. 103 ills. Hardback: £13; paperback: £5·95.

The field of digital signal processing is growing in importance because of recent developments in digital integrated circuits, microprocessors and digital telecommunications. The techniques used in this field are based on a set of mathematical methods which may be unfamiliar to many engineers. The purpose of this book is to introduce some of these techniques to readers who are new to this subject.

The first chapter of the book introduces the z-transform, the sampling theorem and the fast Fourier transform. The reader's understanding of these techniques is facilitated by a large number of numerical examples. Chapter 2 discusses the design of recursive digital filters; it deals adequately with the design of digital filters based on analogue prototypes using the bilinear transform and impulse invariant methods, but does not discuss the use of computer optimization techniques in recursive filter design. In chapter 3 non-recursive digital filter design is described, but with little discussion of the design of decimation and interpolation filters or of computer optimization techniques, in particular the program of Rabiner, Parks and McClellan, which is extensively used by designers in this field.

Quantization effects are explained well in chapter 4 with numerous worked examples illustrating the theoretical points under consideration. Chapter 5 is less satisfactory: it starts by describing the distributed arithmetic realization of Peled and Liu without reference to other techniques, for example, shift and add multipliers or logarithmic arithmetic; this is followed by a digression into microprocessor operation before the implementation of a simple non-recursive filter with microprocessor is considered. The special purpose microprocessors and peripherals now available are not discussed; moreover, the use of computationally efficient algorithms such as Booth's or Canonic Sign Digit Code, and the implementation of the fast Fourier transform are all omitted.

In summary, the strength of this book lies in its elucidation of fundamentals by means of the extensive use of numerical examples; its weakness is the somewhat idiosyncratic choice of material used in the chapters on design and implementation.

Dr. M. J. Carey

Computer Logic, Testing and Verification. J. Paul Roth, Ph.D. Pitman Publishing Ltd. xx + 176 pp. 54 ills. £15·50.

The development of any digital system involves three processes: the production of detailed circuit designs; verification of these designs to ensure that they are able to carry out their intended functions; and the specification of tests that can locate potential manufacturing and other faults in the production versions of these designs. Much work has been done over the years in developing methods of automating the above tasks, and the author of this book is a key worker in this field.

In fact, this book is a compendium of the contributions that the author and his colleagues have made to this development work. The author's treatment of the subjects is highly theoretical (in places excessively so) and the book is not, therefore, recommended as an introductory text. However, it may be of more interest to those readers who are already familiar with its subject matter. It is well organized and indexed, and each chapter has its own short bibliography. Unfortunately, as many of the references contained in these bibliographies are listed as personal communications to the author, they will be of restricted use to the reader. The chapters on the D-algorithm are particularly interesting. This is a method which the author devised for producing tests for logic networks and which is now used as the basis of several automatic test generation systems. The book describes not only the basic algorithm, but also its extension and use in the area of design verification.

C. M. Maunder

System X: Testing of Slide-In-Units

P. J. SHORT, M.SC.†

UDC 621.395.34

Automatic testing of Slide-In-Units (SIUs) is an essential feature of the manufacture and maintenance of System X. This article describes the principles of automatic testing of SIUs and the means by which the interchangeability of testing information between the System X manufacturers and the British Post Office is ensured.

INTRODUCTION

Comprehensive testing at all stages in the manufacture of System X exchange systems is necessary to minimize the cost of the manufacturing process, while maintaining high operational reliability. The cost of rectifying faults caused by component failures or assembly defects of the slide-in-unit (SIU) at the final system testing stage will be orders of magnitude greater than if these faults were detected at an early stage in manufacture. Testing must therefore be distributed throughout the manufacturing process to ensure that as few undetected faults as possible are carried through from one stage to the next. Fig. 1 illustrates the distributed testing strategy which is evolving with the development of System X.

The need for extensive testing at all stages of the manufacturing process dictates that the most efficient test techniques be used to minimize production costs. All stages of testing are therefore automated as far as possible. Furthermore, the scope of application of individual items of expensive automatic test equipment is maximized. General purpose automatic testers are therefore used to test most of the System X SIUs. Special-to-type test equipment is used only where it is economically beneficial to do so, or where the general purpose tester does not satisfy specific requirements.

Automatic testing of SIUs is not only economically desirable, but essential in many cases. The increased complexity of designs resulting from the use of microprocessors and other large-scale integration (LSI) devices demands that a very large number of test patterns be applied to an SIU to ensure reliable operation. The only viable method of generating this volume of patterns is by using programmable automatic test equipment. For this reason, such equipment is used extensively in repair testing of System X SIUs as well as in their manufacture.

AUTOMATIC SIU TESTERS

All automatic SIU testers used for testing System X are software programmable. All tests, whether specifying digital test patterns or analogue stimuli and measurements, are defined in a test program. This program is executed by the automatic tester in such a way that specified test patterns and other stimuli are applied to the SIU, and measurements are made sequentially in the order defined in the program. The test program is designed to exercise sufficiently the SIU so that an acceptable level of confidence that the SIU will function correctly in its working environment is achieved.

There are essentially 2 types of automatic SIU tester: the in-circuit tester and the functional tester. Both types have a role to play in the testing of System X SIUs (see Fig. 2).

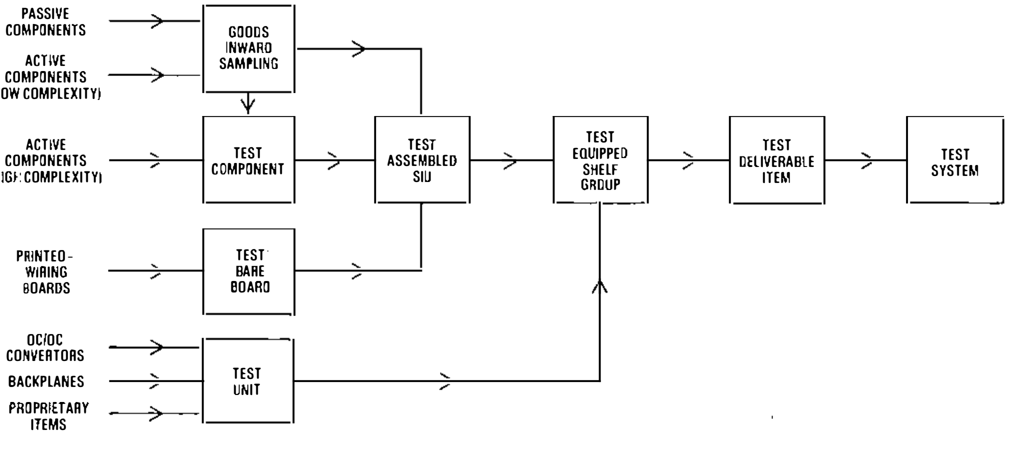


FIG. 1—Integrated testing strategy

---

† System X Development Department, Telecommunications Headquarters

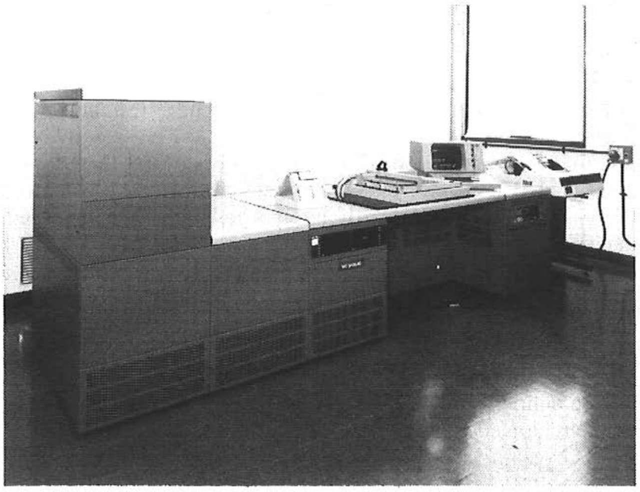


FIG. 2—An automatic tester

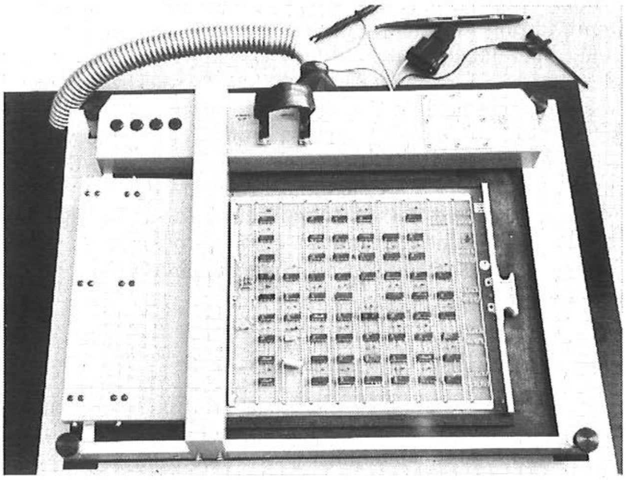


FIG. 3—A vacuum operated bed-of-nails jig showing a slide-in-unit in position

The In-Circuit Tester

The essential feature of in-circuit testing is that components are effectively tested individually on an assembled SIU. This is achieved by accessing every circuit node on the SIU via a bed-of-nails (BON) jig. The BON jig is a matrix of spring-loaded pins against which the SIU is held under pressure, applied either mechanically, pneumatically or by means of a vacuum (see Fig. 3). The pins make electrical contact with lands or track on the underside of the SIU.

In-circuit testing was initially developed as a means of testing for short circuits, continuity of tracking and for correctness of passive component values on assembled SIUs. All such tests are essentially simple impedance measurements, although guarding techniques are required to eliminate the effects of interaction between components. The technique has been extended to cover testing of discrete active devices; for example, the measurement of transistor gain. Most recent developments have enabled in-circuit techniques to be used in testing digital integrated circuits. This is achieved by the use of node forcing whereby the logical state of the output of a device is overriden by the tester to enable the alternative logic state to be applied to the input of a device under test. The duration of the forced condition is limited to ensure that the reliability of devices is not adversely affected by this condition. By using node forcing, it is possible to apply test input patterns to a device in isolation and to verify the output states against the expected conditions.

In-circuit testers are being used increasingly in the manufacturing environment for the following reasons:

(*a*) Typical assembly defects can be readily detected and diagnosed. In-circuit testing is ideal for detecting short circuits caused by solder bridges, incorrect component values or types, components incorrectly inserted and for detecting predominant types of device failure arising from thermal stress in the soldering process.

(*b*) The generation of in-circuit test programs is a less skilled and time-consuming operation than that required to produce a program for a functional tester. The process, which is largely automated, requires the programmer to specify only limited information about component types, values, location on the SIU and orientation. (The tester programming software generates the necessary test program from library data stored for each component type).

The scope of utilization of in-circuit testers for testing System X SIUs is at present limited because node forcing techniques are not approved by the British Post Office (BPO) for certain device technologies; in particular, for complementary metal-oxide semiconductor (CMOS) devices. These constraints derive largely from deficiencies in currently available testers regarding control of the parameters of the forcing signals. It is expected that improvements in tester design and increased knowledge of the effects of node forcing on device reliability will allow the benefits of in-circuit testing to be fully realized in the future.

The Functional Tester

The term *functional tester*, although in common use, does not accurately describe the purpose of this type of test equipment. The term implies that tests are carried out to ensure that the SIU performs its designed function. This may be interpreted as meaning that the tester simulates the working system environment of the SIU. However, in general, this is not the case. Rarely is it practicable for the tester to apply all the possible combinations of input stimuli to the SIU that may be applied in the working system. In many instances, it is also not possible to test the SIU at working system speed, even though this is a desirable objective. For these reasons, functional testing would be better described as *circuit stimulation*. The term functional testing is, however, used throughout this article.

The basic principle of functional testing is that stimuli are applied to SIU inputs and that the propagation of these stimuli through the circuit is monitored at outputs from the SIU and at any test points in the circuit. These measured responses from the SIU are compared with expected responses and a fail condition is registered if there is a discrepancy. Unlike in-circuit testing, the SIU circuit is tested as a complete entity and the interaction of devices is thereby validated as far as possible.

The object of functional testing of SIUs is to ensure that all parts of the circuit are adequately exercised to establish, at a high level of confidence, that an SIU will operate correctly in its working environment. Because the relationship between an input stimuli and its effects on a remote element of the circuit may be complex, the generation of a functional test program is a time-consuming task requiring specialist skills. This subject is discussed in greater detail later in this article.

Because the scope of in-circuit testing of System X SIUs is restricted at present, as described earlier in this article, functional testers are required to perform the role that the in-circuit tester is expected to assume in the future. In other words, the functional tester is required to detect and diagnose assembly defects, as well as component failures. When in-circuit testing is established as a viable technique, then, during manufacture, in-circuit testers and functional testers will assume complementary roles. Those roles will depend largely on the yield of the SIU assembly process, which is itself subject to change through automation. If the yield is high, it is possible that the first pass *go/no-go* test of the SIU will be performed by a functional tester and that only failed units will be passed to the in-circuit tester for fault diagnosis. Conversely, a relatively low assembly process yield could dictate that SIUs be pre-screened by an in-circuit tester before functional testing.

DESIGNING FOR TESTABILITY

It is essential at the SIU design stage that requirements imposed by the use of automatic test methods are accounted for. Certain requirements must be satisfied if an SIU is to be tested with an automatic tester. Other design features are desirable to reduce testing time, and hence costs, and to simplify the task of test program generation. All testability requirements are embodied in the hardware design rules for System X, which were the subject of a previous article in the *Journal*[1].

The majority of testability requirements are aimed at improving the accessability of circuit nodes to the tester. Accessability is necessary to ensure both visible and effective control of circuit operation in functional testing. Test points need to be provided so that the circuit can be effectively partitioned into small entities, ideally individual devices. By this means, the propagation of stimuli from the inputs through the circuit is more readily monitored, and the task of test program generation is simplified. Also, because isolation to a small group of devices is achieved directly, the fault diagnosis process is enhanced.

Effective control of circuit operation is also desirable to simplify program generation and to increase the speed of fault diagnosis. Specific measures are given below.

(*a*) A simple and direct means of initializing the circuit is provided; all circuit nodes being driven to a known state from unpredictable power-up conditions. For example, it is not necessary to clock counters or shift registers several times to ensure initialization; a direct clear input is made available to the tester where possible. These measures contribute to minimizing test times and test program generation costs.

(*b*) The facility is provided to replace a clock signal provided by an on-board oscillator with a signal from the tester. This allows the synchronization of circuit operation to other stimuli generated by the tester.

(*c*) Feedback paths in the circuit can be interrupted. Automatic diagnosis of faults in circuits that include one or more feedback path may not be possible if the path is not interrupted.

(*d*) Isolation of digital and analogue portions of a hybrid circuit can be achieved. If the interface between digital and analogue circuitry is not accessible to the tester, it may not be possible to simulate the digital element as described later in this article.

(*e*) Access can be obtained to microprocessor and memory device control, data and address lines to facilitate adequate testing of these complex devices. In particular, it should be possible for the tester to disconnect electrically (that is to force into a high impedance or tristate condition) any device driving a signal line also capable of being driven by one or more other devices; for example, a bus connexion. This action is independent of the state of other circuitry and thus allows individual devices to be effectively isolated for testing.

The testability of an SIU is further improved by avoiding the use of certain techniques and devices that would give rise to testing problems and/or excessive test times. The use of monostable devices and select or adjust-on-test components is therefore discouraged.

Test access to System X SIUs for functional testing is provided by means of a matrix of 80 test lands in addition to otherwise unused edge-connector pads. These test lands are accessed by the tester through a BON jig. Where possible, all essential access for control of circuit operation is made via unused edge-connector pads; this practice allows the expensive BON jig to be dispensed with in repair testing where increased diagnostic time is acceptable.

THE INTERCHANGE OF TEST PROGRAMS

At present, all the System X manufacturers are using different types of functional SIU testers. It has been necessary therefore to define standards which ensure that test programs may be interchanged effectively between the manufacturers so that an SIU design can be manufactured and tested by more than one supplier. Test programs are also supplied to the BPO for repair testing purposes.

Two basic standards are needed to interchange test programs: a definition of tester facilities (hardware), and a language in which to write the program (software).

Test Facilities

The definition of the facilities required of the tester so that it can test System X SIUs covers the following aspects:

(*a*) the numbers of digital drivers and sensors required to interface with SIU edge connectors and test lands,

(*b*) the number of logic families (differing drive and sense voltage levels) to be simultaneously accommodated,

(*c*) the number and scope of fixed and programmable power supplies required,

(*d*) the performance requirements for analogue instrumentation for voltage, resistance and waveform measurements,

(*e*) the performance requirements of analogue instrumentation for waveform generation,

(*f*) the capacity for simultaneous interconnexion of instrumentation to the SIU under test,

(*g*) operator interface facilities, and

(*h*) program timing control requirements.

The facility requirements have been formulated on the basis of a knowledge of the technology to be used in System X SIU designs. The object has been to ensure that a tester that satisfies these requirements will be capable of testing most System X SIUs.

Those SIUs not capable of being tested by the use of a general-purpose automatic tester satisfying the specified requirements will generally require a special test facility. This may comprise standard test instrumentation, such as oscilloscopes or signal generators, or take the form of a purpose-built tester.

As the technology of System X evolves, the tester facility requirements must be revised to keep in step. This process is a periodic rather than a continuous activity as it is not viable to replace regularly or modify test equipment. The facilities requirements must therefore remain stable for a period of several years.

Test Programming Language

The standard for ensuring interchangeability of testing information dictates the use of a high-level, tester-independent programming language. The majority of functional testers are conventionally programmed in a machine-dependent language analogous to the assembly code of a computer system. Test programs written in such a language are not generally interchangeable between testers of different manufacture. The use of a high-level, machine-independent, programming language overcomes this problem. Test programs written in such a language can be readily compiled to a specific machine-dependent form for use on a particular tester.

The programming language selected for use in writing System X SIU test programs is called *PROTEST*[2]. This language has been developed by the International Telephone and Telegraph Corporation (ITT) and its use is well established within that organization and its subsidiaries. It was chosen for System X work because the collaborating parties have experience of its use in testing TXE4 SIUs.

Unrestricted use of the PROTEST language is not in itself sufficient to ensure the interchangeability of test programs. Implementation of a particular test defined in PROTEST is dependent on the availability of the appropriate tester facility. The use of PROTEST must therefore be constrained so that it accords with the facilities requirements described above. For System X SIU test programs, therefore, a subset of the full PROTEST language has been defined which takes account of the limitation of the range of facilities required of a tester.

THE DIAGNOSIS OF FAULTS

While the primary object of automatic testing is to verify correct operation of an SIU, an effective means of diagnosing the cause of failure is also necessary. As will be shown later in this article, logic simulation can provide information to support this process.

At the simplest level, this information takes the form of a printed fault dictionary. The fault dictionary comprises a list of fault signatures, together with the device faults that could give rise to a particular signature. A fault signature is a list of the logic state variations that are observed at SIU access points for a particular test under fault conditions. If an SIU fails a specific test, with a knowledge of the access points showing incorrect logic states, it is possible to use the fault dictionary to predict the likely cause of the failure. Ideally, for each fault signature there will be only one possible cause of the fail conditions. Replacement of the indicated failing device should be sufficient to effect repair of the SIU. However, in practice, there will often be more than one possible failing device associated with a particular fault signature. One for one correspondence can be achieved only if the tester has access to all circuit nodes; this is not generally the case. The use of an oscilloscope or logic probe may therefore be required to isolate the cause of failure.

Most of the present generation functional testers now provide facilities for the automatic isolation of faults. Automatic fault diagnosis is generally achieved by the use of the guided probe technique (see Fig. 4). The probing of circuit nodes by an operator under tester control allows the tester to gain additional access to the circuit, over and above the direct connexions. Fault diagnosis using this technique is a multi-stage process.

FIG. 4—Automatic fault isolation using guided-probe technique

(*a*) The test program is run against the SIU and, if failing conditions are detected, the fault signature is recorded.

(*b*) The tester can scan an internally stored fault dictionary for a match with the recorded fault signature. If a match is found, then the possible failing devices are noted.

(*c*) On the basis of this prediction of possible failing devices, the tester selects an appropriate circuit node for probing. If no prediction is available because a fault dictionary does not exist, or no match with the recorded fault signature exists, then an access point to the SIU is selected as a start point.

(*d*) The operator is instructed to place the probe on the selected circuit node and to re-run the test program. The tester records the logical activity observed at the node during the course of the test program.

(*e*) This logical activity is compared with that for a good SIU, which is stored internally within the tester, and a pass or fail condition recorded for that node.

(*f*) On the basis of the pass or fail condition the tester decides the next circuit node to be probed, the process described in steps (*d*) and (*e*) then being repeated.

(*g*) The sequence of operations described in steps (*d*), (*e*) and (*f*) is repeated until the tester has isolated a device that has good input conditions applied to it but which produces incorrect outputs.

It should be noted that the minimum requirement to support automatic fault isolation is a database of information for the SIU comprising a circuit description and a record of good logical activity for all circuit nodes. The circuit description is required by the tester so that, using a suitable algorithm, the path by which a fault condition is propagated through the circuit can be tracked. The database may optionally include a fault dictionary. Although the tester can always work from an SIU access point to the failing device, the number of probing operations is reduced, along with diagnostic time, if a fault prediction can be made. This allows the tester to start probing at an internal circuit node which should be closer to the failing device.

The operator may override the automatic diagnostic process and control the sequence of probing operations directly. This can allow an experienced operator to achieve further reductions in diagnostic time and also help in the isolation of faults that the automatic diagnostic software is unable to pin-point.

Automatic fault diagnosis is included in the standard defining the facilities required for testing System X SIUs. In principle, this is of little significance during manufacture as the emphasis is on testing SIUs which are expected to be good. However, in the repair environment, where the emphasis is on testing faulty SIUs, automatic fault diagnosis is an important feature of the testers used. The inclusion of a capability for automatic fault diagnosis at the production testing stage thus allows the same testers and techniques to be used at the repair stage. This minimizes development costs and equipment variety as well as reducing production costs in the correction of faulty units.

TEST PROGRAM GENERATION

It was noted earlier in this article that the generation of functional test programs is a skilled and time-consuming task. The generation of programs for digital SIUs is, however, simplified by the use of logic simulation. The simulation of logic circuits under fault-free conditions, and with specific types of fault applied, provides the test programmer with the following information:

(*a*) output responses to a given set of input stimuli (this removes the need for the programmer to predict such responses),

(*b*) test program effectiveness in terms of ability to detect the simulated faults, and

(*c*) diagnostic data to support the manual or automatic diagnosis of faults as described earlier in this article.

The use of the test generation and simulation (TEGAS) logic simulator for design verification has been described in a previous article in this *Journal*[3]. TEGAS may also be used for fault simulation, as it is capable of simulating *stuck at* conditions on circuit nodes. The *stuck at* condition implies that a permanent logic ONE or ZERO state appears at a circuit node for the duration of the test program, regardless of what activity occurs under fault-free conditions. Such faults are considered to be detectable by a test program if, at some point in the program, there is a divergence of the simulated response of the circuit (as seen at access points to the SIU) when the condition is present, from that simulated without the condition applied.

The TEGAS simulator is being used effectively in the generation of test programs for System X SIUs. Although the programming interface to TEGAS does not use the PROTEST language, a software package has been developed to convert the TEGAS output file into the PROTEST format. This has further simplified the program generation process.

Other logic simulators are used for fault simulation of System X SIUs. These simulators form an integral part of particular test systems and have an advantage over TEGAS since a tester compatible database of diagnostic information to support automatic fault isolation is readily obtained. Although TEGAS does provide diagnostic information to aid fault isolation, the information is normally produced in the form of a printed fault dictionary used for manual diagnosis.

CONCLUSION

Automatic testing is an essential feature of the manufacture and repair of System X SIUs. This article has described the nature of automatic testers and the impact of their use on the design of SIUs. The measures required to ensure the interchangeability of test programs between manufacturers and the BPO have also been outlined. The benefits that derive from the use of logic simulation as an aid to test program generation have been identified.

References

[1] SWAFFIELD, J. L. Hardware Technology and Design Rules for System X. *POEEJ*, Vol. 73, p. 268, Jan. 1981.

[2] GILL, M. H. PROTEST: A Language for Testing. *Electrical Communication*, Vol. 47, No. 4 (1972).

[3] HORTH, P. J., and REYNOLDS, R. A. System X: Design and Support, Part 2—Computer Aided Design. *POEEJ*, Vol. 72, p. 234, Jan. 1980.

CANTAT 1 Reaches Design Life: A Pioneer of Long-Life Thermionic Valves

Twenty years ago, in the summer of 1961, the first telephone cable between UK and Canada was laid across the North Atlantic. It was then known simply as CANTAT† but, following the provision of a second UK–Canada cable in 1974, it has subsequently been referred to as CANTAT 1.

CANTAT 1 was the first transatlantic cable system to use a single cable for both directions of transmission, (the two earlier cables, TAT 1 and TAT 2, had used separate cables for E–W and W–E transmission). The main ocean crossing of some 3700 km, which was laid by HMTS *Monarch*, includes 90 submerged repeaters and has a bandwidth of 240 kHz in each direction of transmission; equivalent to eighty 3 kHz spaced telephone circuits. It was the first link in the Commonwealth round-the-world submarine telephone system.

CANTAT 1 will reach the end of its twenty-year design life this year but it is still functioning perfectly and there are no plans to take it out of service—certainly not until after TAT 7 comes into operation.

Much of the success of CANTAT 1 must be credited to the designers and manufacturers of the repeaters and, in particular, of the long-life thermionic valves they incorporated. The announcement of the death of Dr. Gilbert Metson in February reminds us of the immense personal contribution that he made to submarine cable engineering which has played such an important part in Britain's international communications.

Dr. Metson joined the British Post Office (BPO) Research Station at Dollis Hill after distinguished war service and set out to tackle the crucial problem of valve reliability. He assembled a small team, commissioned a valve making unit, and pursued an intensive programme combining personal research into the physics and chemistry of failure mechanisms with new approaches to materials, quality control and manufacturing processes. This was highly successful and led to the first submarine cables using valves of Dollis Hill manufacture being laid around the UK coast in 1953/4. Other systems followed in the late 1950s and the early 1960s, including the Newfoundland–Nova Scotia section of TAT 1, COMPAC, SEACOM—and, of course, CANTAT 1.

Gilbert Metson's many contributions are recorded in over 15 papers for the Institution of Electrical Engineers (IEE) which earned him both the Institution medal and a DSc. from Queen's University, Belfast.

Inevitably the valve has been supplanted by the transistor and Gilbert Metson in 1966, then Director of Research, was amongst those who strongly advocated solid-state technologies. The pioneering work of his valve group, with its highly disciplined approach to the chemistry and physics of impurities and the strict regulation of all fabrication processes, was the real foundation for subsequent work on highly reliable solid-state devices.

---

† CANTAT—A New Submarine Telephone Cable System to Canada. *POEEJ*, Vol. 54, p. 220, Jan. 1962.

System X: Subsystems

Part 8—Maintenance Control Subsystem

A. T. DANN, B.SC.†

UDC 621.395.345.004.5

This article provides a general introduction to the maintenance philosophy used on System X, outlines the requirements of System X exchanges to support the philosophy and defines the division of responsibilities within the exchange adopted to implement those requirements. It also describes the split of responsibilities between the maintenance control subsystem (MCS) and the subsystems whose equipment must be maintained, and gives a description of the MCS.

INTRODUCTION

Previous articles in this series have discussed various aspects of maintenance on System X. In particular, the articles on subsystems have discussed their internal maintenance and described the mechanisms designed into their hardware and/or software[1,2] for this purpose, often making reference to the maintenance control subsystem (MCS). This article gives an overall appreciation of the manner in which System X exchanges are maintained and how the MCS fits into the scheme.

MAINTENANCE PHILOSOPHY FOR SYSTEM X

In the UK network, the basic philosophy for maintenance of System X is centralization. While each exchange has a stand-alone capability, with local terminals supplying a man-machine interface (MMI), it can as an option also be connected to the local administration centre (LAC)[3] by a message transmission subsystem (MTS)[2] link. A central information handling capability can then be used at the LAC to ensure that maintenance is carried out in the most efficient manner[3]. At the LAC, information can be received from an exchange, and maintenance personnel can gain access to a system from the LAC via the MTS and the MMI.

LACs are expected to be provided on a basis of approximately three per telephone area, with at least one manned at any one time, and could cover some 150 000 local exchange connexions plus 20 000 erlangs of trunk traffic.

Fault Escalation and Fault History Records

The normal day-to-day maintenance procedures are intended to be backed up by a full escalation structure, whereby elusive or intermittent faults can be referred upwards to groups having specialized expertise. Similarly, off-line fault history records will be used to build up a library of historical knowledge on fault situations, enabling such techniques as fault pattern recognition to be used as a diagnostics aid.

MAINTENANCE REQUIREMENTS OF SYSTEM X EXCHANGES

To support the maintenance philosophy, System X exchanges must be able to meet certain functional requirements on maintenance, implying that each exchange must be able to perform maintenance-related activities. These fall into two main categories: handling of faults; and online updating of the service or maintenance state of the system resources, (a resource can be an item of hardware, or a software data structure).

Fault Handling

A System X exchange must function normally during a fault situation. To do this, the exchange must be able to detect and isolate the fault, perform such reconfiguration necessary to contain the effects of the fault, and then generate a report and any relevant alarm indications, both locally (if manned) and at the LAC. The system must also be capable of carrying out diagnostic and routining tests on manual command and, in some cases, automatically.

Resource State Updates

The system must preserve, and be able to make, on-line updates to the service or maintenance state of the resources constituting that system. This may need to happen both automatically (for example, as a result of a fault occurrence), or on manual command via the MMI, either at the local terminal or at the LAC.

Processor Control

System X uses a combination of overall central processor control and distributed microprocessors for localized control of certain functions. As explained in earlier articles in this series[4,5], processors offer a low-cost easily-managed form of centralized control. For maintenance purposes, it means that processing power is available for functions such as fault handling and resource state updating. In addition, fault information and resource data can be held in store and therefore be readily available on demand.

Division of Maintenance Responsibilities within a System

A System X exchange is made up of several subsystems. These are not only functionally separate, but have, in general, been developed separately. This had led to the policy that each subsystem with internal knowledge is responsible for providing the mechanisms for maintaining its own hardware equipment and resource data. This implies fault-detection and isolation methods, diagnostic routines, and the ability to generate and collate fault information. A subsystem must also be able to maintain and update secure (duplicated) copies of its resource data.

While it is practicable for each subsystem to supply the internal mechanisms for fault handling, centralized control allows more secure and efficient processing of maintenance/

---

† System X Development Department, Telecommunications Headquarters

administrative actions. The state of systems can be assessed, whereas subsystems can check only their own unit. There are also various explicit aspects of the maintenance function that make centalized control necessary and efficient, as follows.

(*a*) To output fault messages via the MMI, the sending subsystem must hold data relating to message formats. Because it is desirable that fault messages are generally of fixed format, it is efficient to retain the data in only one area.

(*b*) Under overload conditions, the system should shed low priority work. Within the maintenance sphere, certain actions are considered high priority (for example, fault reporting), while others, such as routining, are of low priority. It is reasonably simple for a centralized control to keep these functions separate, and stop processing on those activities banned by the overload level.

(*c*) Following a fault, or a demand from maintenance staff, resource-state changes (updates) must be made by the system. For a single update, more than one subsystem can be involved; for example, data relating to a single circuit is held by the call processing, digital switching, call accounting and, possibly, signalling interworking subsystems. To avoid the requester of the update having to be aware of all this, and the sequence of protocols involved, a centralized control is required.

In reality, the system consists of a hierarchy of interdependent resources; for example, a circuit depends for its existence upon a digital line termination (DLT) and a call processing subsystem band (Fig. 1). If the system is to be maintained in a consistent manner, a change of state should not be made to a resource within the system, without due regard to the state of resources that depend upon it (dependent resources), and those resources on which it depends (parent resources). These dependency hierarchies span more than one subsystem, so it is essential to maintain a central database of the structure.

In the strategy used on System X exchanges, the MCS forms the central control and communication link for maintenance activities between the subsystems and the MMI, and thence the staff (see Fig. 2).

MAINTENANCE CONTROL SUBSYSTEM

The MCS performs a series of maintenance related control functions which, in general, are provided in stored programs. The one exception is hardware malfunction and alarm detection equipment, which supplies inputs to the MCS software. Although a maintenance transaction may invoke more than one function, each function is self contained and, where one interacts or communicates with another (or with an external subsystem), it does so via a formal task interface. A task is an 8-word message[6].

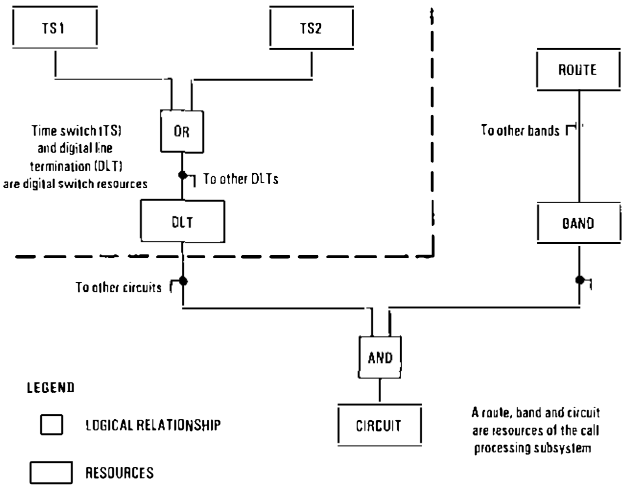
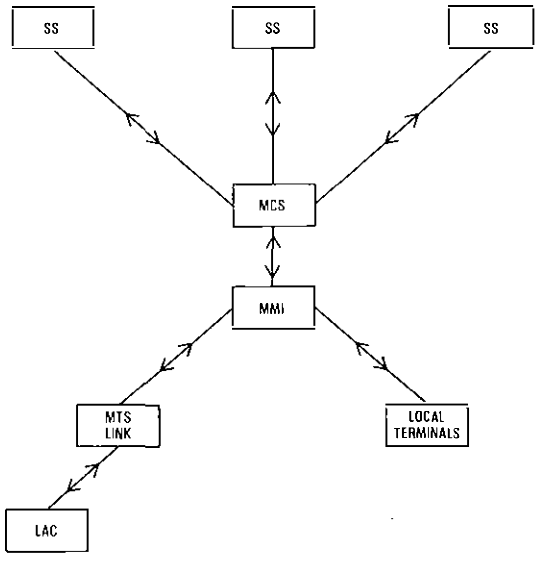


FIG. 1—Example of resource dependencies



SS: Subsystem
MMI: Man-machine interface
LAC: Local administration centre
MTS: Message transmission subsystem

FIG. 2—Communication flow for System X maintenance

Man-Machine Communications

Communication with the MMI processes of the operating system is achieved by the man-machine communications (MMC) function. The MMC handles input and output for all MCS functions and holds all required format data.

(*a*) *Input* The MMC conducts a dialogue with the MMI input process to validate a command and its associated parameters, compiles the input into a complete message and passes it to the function concerned.

(*b*) *Output* Messages passed across for output are queued in priority order and, subsequently, correctly formatted and output via the MMI output process.

Macro Handler

The macro handler facility is provided to enable frequently used, but complex, maintenance activities to be initiated by a single command via the MMI. The macro handler expands the single command into the component commands necessary to perform the overall task. An example is the insertion of a resource that has many constituent resources, perhaps in several subsystems.

A macro program is written and stored as a series of interpretive language statements for a unique action/resource combination. Language statements facilitate parameter checking, manipulation of parameter values, command calls to other MCS functions, and output of messages, both intermediate and final. The handler normally interprets and implements these statements sequentially, although iterative processing of any section of the macro program can be achieved. Commands to other functions are sent, and results returned, via the MMC function of MCS; the function being called treats the command exactly as if it had originated manually.

Processes

The MCS is implemented as several software processes[6], each containing one or more of the functions. Several factors influence the grouping, as follows:

(*a*) *Priority* High priority functions, which frequently communicate with each other, are generally held in the same processes for running efficiency. This helps to ensure that important maintenance actions are completed as swiftly as possible, even under overload conditions.

(*b*) *Periodic Functions* Some functions are invoked periodically, rather than on demand. It is more efficient to collect these functions together.

(*c*) *Code Size* It is important to have process sizes that are manageable and that comply with systems limits.

If extra facilities are required later, these can be included in additional process(es) without undue effect on the rest of the MCS.

Central to each process is the process manager, which controls scheduling and steering of tasks, as well as providing various utility facilities (for example, task passing and data securing) for the functions within the process.

Technology Independence

Because the MCS controls maintenance actions on systems resources in a purely functional sense, the technical details of carrying out that action are hidden from the MCS. Thus, the MCS is considered to be independent of technology. Changes to other subsystems, resulting from improved techniques or enhanced technology, will be reflected in the MCS only by possible changes to data tables.

For similar reasons, the MCS functional design is largely common for all system types. Differences in the resource structures of systems can be absorbed in the data tables compiled for a particular installation.

DESCRIPTION OF MCS FUNCTIONS

The MCS consists of several self-contained functions, and the following paragraphs describe each of these, any interactions being mentioned where appropriate.

Resource Management

The function of resource management is to control and co-ordinate the sequence of actions required of subsystems, or other MCS functions, in order to update the state of resources in a consistent manner. Resource management may receive requests for updates from maintenance staff via the MMI, or from another MCS function.

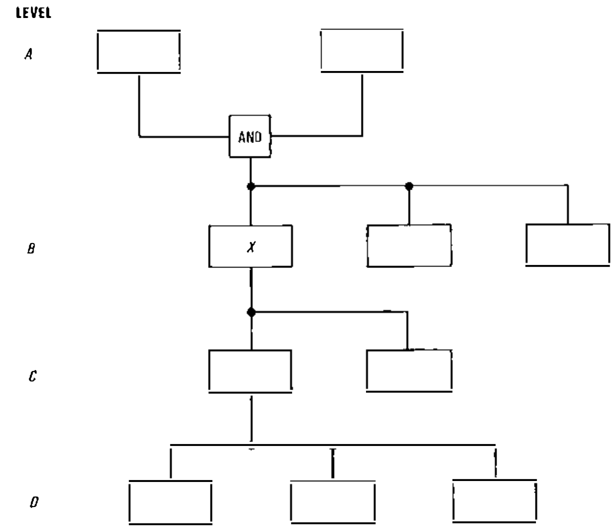
Each update is performed with reference to the resource hierarchy, held as a database within resource management. The database portrays not only the hierarchical structure, but holds the logical relationships that bind the dependencies; for example, a circuit is dependent upon a DLT *and* a band of the call processing subsystem, whereas a DLT depends upon the presence of only one or other of the duplicated time switch planes (see Fig. 1).

Other logical dependencies have been identified; for example, mutual dependency. Because of these relationships, when the state of a nominated resource is to be changed, the state of the parents must be consistent with the change, and the states of its dependents may have to change to maintain consistency of the system.

The possible states that a resource may hold are conceptually graded in levels. The lowest level is *not equipped* and the highest level is *in service to normal traffic*. In general, the MCS applies the rule that a resource may not hold a state that is higher than that of its parents; for example, a circuit may not be *in service* if its parent DLT or central processing band is *not equipped*.

To complete an update request, resource management must perform two functions: validating against the resource hierarchy; and co-ordinating the execution of changes to maintenance states. To carry out the validation, resource management must obtain the identities and state of the parents and/or dependants of the target resource, which it does by parent/dependant identity requests to the subsystem that owns the resource.

The validation algorithm is iterative such that resource management propagates down the hierarchy until it reaches either the lowest level resources in the branch, or a logical function that indicates that no further propagation is necessary. It then returns back up the tree, performing the necessary updates to the dependants to put them in a state consistent with the original request. Finally, the nominated resource is updated and the transaction is completed. Fig. 3 illustrates the procedure.



If X is to be updated from out-of-service state to in-service state:

(*i*) resource management checks that resources at level *A* are both in service by making parent requests to ascertain their identities and states;

(*ii*) resource management propagates down the hierarchy by making dependent requests to level *D*: and

(*iii*) any resources dependent on X, marked dependent-out-of-service, are placed in service.

FIG. 3—Example of procedure for updating state of resource

Fault Management

Fault management provides the central control for dealing with faults that occur within the system. The function basically can be considered as two major areas:

(*a*) fault handling and reporting, and
(*b*) fault clearance.

FAULT HANDLING AND REPORTING

All detected faults occurring throughout the system are reported to fault management, where the report is analysed and appropriate actions taken. The actions vary according to the category of report, which might be any one of the following:

(*a*) hardware fault report,
(*b*) software inconsistency,
(*c*) transient fault report,
(*d*) circuit fault report, or
(*e*) rollback/restart report (from the operating system rollback process).

Reports type (*b*), (*c*) and (*e*) require no specific action by fault management, other than to generate an output report via the MMI.

For hardware fault reports, depending on the information contained in the fault report, which is of a fixed format, fault management may instigate any of the following actions:

(*a*) By request to resource management, it can cause the faulty resource and those resources dependent on it to be placed out-of-service. This is necessary to preserve the security of the system.

(*b*) It can generate any necessary audio and visual alarm signals, both locally and at the LAC.

(*c*) It can record the fault and all relevant information in a fault archive that is maintained as a database within fault management. The information remains there and is accessible to maintenance staff until it is overwritten by new faults, in a basically sequential manner, but with regard to the status of the fault; that is, cleared faults are over-written before active faults that have been reported but are awaiting clearance.

(*d*) It can output a report to the maintenance staff, via MMI.

Output by the MCS is directed, according to the various categories, to one or more output ports, which may be cartridge, visual display terminal, etc., both at the LAC and locally in the exchange.

Fault Correlation

Owing to the nature of the system hierarchy, when a fault occurs on a resource high in the tree, several of the resources dependent on it down the structures can appear to be faulty and reports generated on them by their owning subsystem. To avoid the maintenance staff being overwhelmed, fault management performs a correlation on the incoming reports.

This is done by comparing all reports arriving within a given period against a resource structure. The incoming report most likely to be associated with the prime cause of the fault is determined, the item is put out-of-service, and reported. If the rest of the batch appears to be faulty because of their dependency, they should then be made dependent-out-of-service by the hierarchy-based update procedure. Those not dependent-out-of-service are assumed to be unrelated and an attempt is made to return them to service. If this fails, the report is included in the next batch and the procedure is repeated.

FAULT CLEARANCE

Once a fault has been physically cleared, the system has to be returned to the original working status. This is instigated by maintenance staff typing in a clearance command, using the same serial identity furnished by fault management in the fault report. On receiving the command, fault management reverses the actions taken when processing the fault report; that is, it requests the return to service of the resource and its dependents, cancels the audio and visual signals and marks the record as cleared. A cleared report is also output.

Automatic Return-to-Service Option

For certain resource types, a facility exists whereby the owning subsystems can report a fault and, on subsequently detecting the removal of the fault symptoms, automatically instigate the clearance by sending an automatic return-to-service request. Fault management is informed that this option is being used in the original fault report.

Circuit Faults

These are treated similarly to those resources having automatic return-to-service option. Because the call processing subsystem is able to detect symptoms on circuits that may be interpreted as an occurrence or removal of a fault condition, a special category has been used to cover them. A circuit reported on the first class of symptoms is taken to be faulty and processed as such by fault management. If a message is received which reports symptoms indicating the removal of a fault and a fault record exists on the same circuit, the clearance is automatically invoked.

Multi-Threading

Processing of a fault report by fault management is driven by the fault record it sets up. By keeping an indication of the current status of processing on the fault in the record, fault management is able to process faults in parallel. When a response to one of the actions instigated arrives, the relevant record is accessed and processing of that fault continues to the point of another request/report being sent out.

Malfunction Reporting and Alarm Control

This function has two distinct responsibilities:

(*a*) to convey System X and non-System X alarm conditions to maintenance staff using audio and visual indicators locally and at the LAC (non-System X equipment will be situated alongside System X equipment and must be catered for), and

(*b*) to provide a link between subsystems and certain sections of their hardware between which there is no direct communication.

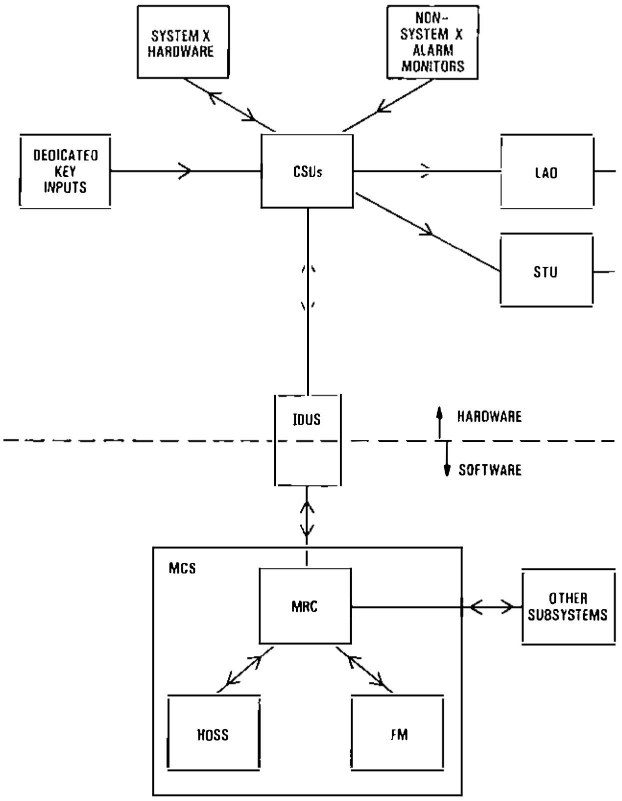
Malfunction reporting and alarm control is realized by software control, which has access to hardware units known as *common services units* via the input/output utility subsystem. These units provide input terminals for monitor purposes, and output terminals to enable ON-OFF conditions to be applied to System X equipment and output audio and visual indicators (see Figs. 4 and 5).

Connected to input terminals are:

(*a*) System X monitor points,

(*b*) non-System X alarm monitors, for example, intruder alarm, and

(*c*) certain input keys used by maintenance staff to convey a message to the system; for example, *staff-present*.



CSU: Common services unit
LAD: Local alarm driver
STU: Signal transmission unit
IOUS: Input/output utility subsystem
MRC: Malfunction reporting control
FM: Fault management
HOSS: Hardware-only subsystems software

FIG. 4—Hardware/software structure for malfunction reporting and alarm control

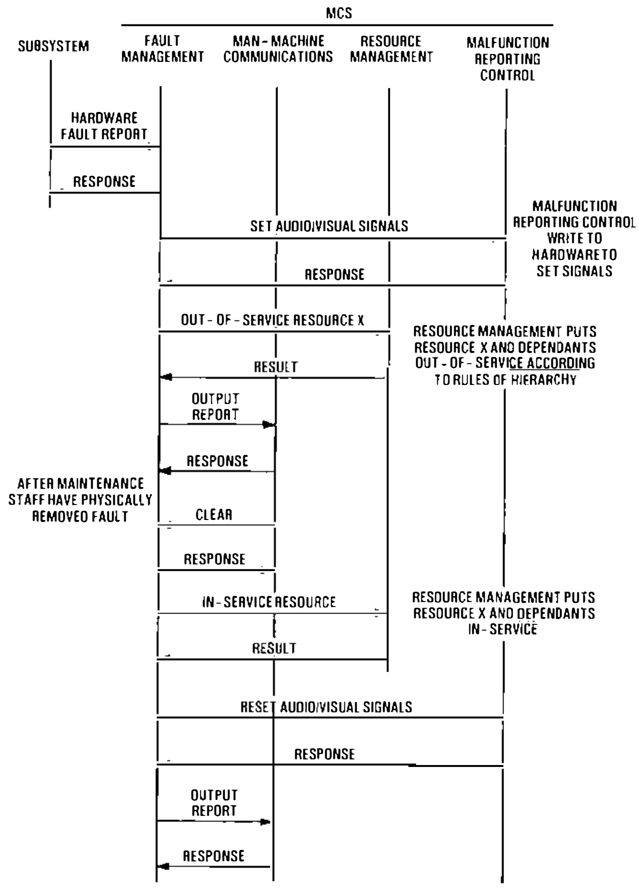


FIG. 5—Example of message sequence resulting from hardware fault report

MALFUNCTION REPORTING

System X hardware resources, monitored and driven by inputs and outputs from the common services unit, are recorded in an updatable malfunction reporting control database. Subsystems owning the equipment may request the malfunction reporting control either to obtain the monitored condition of a resource or to change the state of an output. The malfunction reporting control translates to the relevant terminal address from the database before obeying the request. If an autonomous change occurs on a monitor input the malfunction reporting control either reports it to the subsystem or generates a fault report direct to fault management, according to the data held against the resource.

ALARM CONTROL

The responsibilities of the alarm control function are:

(*a*) to respond to non-System X alarm monitor input changes by sending a fault report to fault management;

(*b*) to activate and reset the outputs controlling the audio/visual signals, thereby presenting maintenance staff with the overall fault situation on both System X and non-System X equipment (fault management will provide the driving information in terms of required indicator conditions although, for security, there is additionally a hardware link between non-System X monitor inputs and alarm drivers);

(*c*) to respond to changes occurring on the terminals monitoring input keys, by taking the appropriate action. Such action might comprise

(*i*) resetting the alarm bell,

(*ii*) altering the staff-present record and outputing a report, and

(*iii*) initiating an automatic *return-to-service* to fault management in response to manual operation of a non-System X alarm-clear key.

Diagnostic Control

To locate a fault with finer resolution than would perhaps normally be possible, subsystems may provide diagnostic facilities. Initially, the diagnostic facility will be run only by manual command, but a later possibility is for automatic operation as a result of a fault report. Diagnostic control provides overall system control and supports the subsystem protocol necessary for the facility. This role is performed in three stages described below.

(*a*) *Processing the Request*

Diagnostic control holds data tables on diagnostic functions in the system and records of those in use, enabling it to confirm that those requested are available and that the relevant subsystem is able to run them (the particular diagnostic function may already be in use, or the subsystem may be busy with others). A manually updatable record of inhibited diagnostic functions aids further validation of a request. Diagnostic functions are run only on out-of-service resources; diagnostic control, therefore, must determine the state of the nominated resource by making a request to resource management. If all conditions are favourable, diagnostic control sets up a record for the diagnostic function and sends a request to the appropriate subsystem.

(*b*) *Monitoring Subsystem Progress*

While diagnostic functions are in progress, diagnostic control polls the subsystem periodically to ensure satisfactory progress. If an unexpected status reply, or no reply at all, is returned, diagnostic control curtails the transaction and reports accordingly.

(*c*) *Processing Results*

Any intermediate or final reports on results returned by the subsystem are formatted by diagnostic control and output to the requester.

Two levels of diagnostic functions have been defined:

(*a*) *First Line* These are predetermined logical sequences of tests and analysis programs which, when run for a given resource type, either locate the fault to a replaceable unit or report no fault found.

(*b*) *Second Line* A comprehensive set of commands, supported by diagnostic control, enables maintenance staff to manipulate the test parameters and programs, thus providing a flexible and powerful diagnostics aid when attempting to isolate a difficult fault. Once diagnostic control has validated and initiated a request for second line diagnostics, it responds to maintenance staff with a tag number, which is also sent to the subsystem. Subsequently, any input bearing that tag is passed directly to the subsystem and resulting responses passed to maintenance staff. The second line mode is curtailed by a command from the originator, or by some abnormal message from the subsystem, causing diagnostic control to abort the diagnostic functions.

Routine Control

Routines are used throughout the system to exercise equipment systematically so as to expose dormant faults. Some routining is entirely under the control of the owning subsystems; for example, routines may be run following the occurrence of a rollback/restart of the subsystem. Other routines are run periodically, or on command from the maintenance staff. It is these that are under the control of the MCS routine control, which maintains an updatable record of all routines under its control; the record is updatable because the facility exists for manual insertion or removal of routines on-line. Information will be held relating to the use of each routine. If it is run periodically, details of the times or period must be held. A list will be kept of routines with inhibitions set on them. Inhibitions may be set and reset manually via the MMI.

Routine control must process manual requests for routining as well as schedule periodic routines. This is achieved by comparing the current clock time with the time the next scheduled routine is to be initiated. Before initiating any routine by sending a command to the relevant subsystem, routine control ascertains that conditions are correct and, in the case of a request, the routine/resource combination is valid. Checks would be made to determine that

(*a*) no inhibition is set against the routine,

(*b*) the routine is not already running,

(*c*) the system load level (as indicated by the overload control subsystem) allows routining, and

(*d*) the resource to be routined is in service (determined from status requests to resource management).

If the checks are favourable, a control record is generated and the routine command sent. Routine control polls subsystems running routines for a status report, either periodically or on command from the maintenance staff. On completion of the routines, if the result is a failure, or the routine was requested manually, routine control outputs a report and terminates the control record.

Trunk and Junction Routining Control

Routining of outgoing trunk and junction circuits is controlled by trunk and junction routining control, under the overall drive of routine control, which is responsible for periodic scheduling and processing of manual requests. Trunk and junction routines are recorded in the data in routine control in terms of either a single circuit, a network band of outgoing circuits (16 circuits), or a route of outgoing circuits. It is the responsibility of trunk and junction routining control to initiate routining of each individual circuit within the group specified; thus, data must be held to identify all circuits on each route. Through resource management, the state of the circuit is checked to ensure that it is in service, before a request is sent to the signalling interworking subsystem to perform the test. For this, a call is set up from a signalling interworking subsystem trunk and junction routiner (the actual one may be specified by routine control), to a similar equipment in a neighbouring exchange.

Test failures are reported back to routine control as they occur and, when the routine is completed, a final message is also sent. When a busy circuit is encountered, trunk and junction routine control can either step on to the next one or apply camp-on-busy; the call processing subsystem marks the circuit and, when it is cleared down, it is busied out for testing. Routine control specifies which option is to apply.

Hold and Trace

System X must be able to hold a call and trace its path across the network, and both the MCS and the call processing subsystem are involved in providing these facilities.

The call processing subsystem is responsible for applying the hold conditions and providing terminal information for call-trace purposes. Communication between exchanges during the hold or trace operations is between their call processing subsystems, responses being passed back along the chain to the exchange originating the request.

The MCS is responsible for processing requests for hold or call/path trace, which may arrive from maintenance staff, or from a traffic-handling subsystem, when a malicious call indication is detected.

Hold or cancel hold requests are queued by hold and trace, and released to the call processing subsystem at the rate at which they can be handled; that is, hold and trace controls scheduling of hold operations. For each trace initiated by hold and trace, a record is set up. All intermediate responses are stored in the record and, on completion of the trace, the information is used to provide an output report. If a path trace is requested, all node terminals are output. Where only a call trace is specified, the end terminals are supplied in the report.

Private-Circuit Control

Private circuits that are connected through the exchange, as opposed to those provided manually via the distribution frame, are handled by the private circuit control function of MCS. Private-circuit control is deemed the resource owner and is responsible for the circuit during its life as a private circuit. Any resource updates are therefore performed by private circuit control on secured data held against each private circuit currently connected across the exchange.

Before a circuit can be used as a private circuit, it must first exist in the system data. An existing public circuit may be used, or one can be specially inserted using the normal update command, resulting in the relevant data being inserted in the appropriate subsystems. The specified circuit is then withdrawn from public use and inserted as a private circuit. Private-circuit control initiates the connexion through the switch and sets up the resource data.

Because it has no physical connexion to the circuits and has no call-handling functions, the MCS cannot provide fault detection on the private circuits it owns. Normal mechanisms, existing in traffic carrying subsystems, are therefore relied upon to generate fault reports.

Hardware-Only Subsystem Software

There are certain areas in the system (for example, the analogue line termination subsystem, and the network synchronization subsystem) where the functional role is realised in hardware and does not have associated software in the processor. However, for maintenance of these areas, some software is necessary; this maintenance software resides in the MCS. It is known as the *hardware-only subsystem* software function and treated as the owner of the resources constituting those areas served. Other functions of the MCS communicate with hardware-only subsystem software via the same interface formats used when communicating with other subsystems.

For fault detection, most of the hardware-only subsystem software equipment is connected to common services unit inputs, and thus monitored by the malfunction reporting control hardware scheme. The network synchronization subsystem, however, is monitored by a dedicated microprocessor, directly linked to a port of the serial input/output. Hardware-only subsystem software has the responsibility for interpreting the changes of condition reported to it by either the malfunction reporting control or the input/output utility subsystem, and generating any fault reports necessary.

Other functions of hardware-only subsystem software are

(*a*) to preserve and update secured data on the maintenance states of its resources by supporting the resource management updating interfaces, which includes supplying dependency information, and

(*b*) to handle any routining and diagnostics functions that may be defined for those areas under hardware-only subsystem software, supporting the relevant interfaces used for these functions.

CONCLUSIONS

This article has described the maintenance facilities provided for System X and the methods by which they are controlled; practical experience of live exchanges will undoubtedly indicate the need for others. Greater understanding of the maintenance needs of the system should also enable the facilities to be tuned to provide the most efficient and effective maintenance of the system.

ACKNOWLEDGEMENTS

The author wishes to thank his colleagues in the System X Development Department of the British Post Office and the development teams at the Plessey Company responsible for the detailed design of MCS for their assistance in the preparation of this article.

References

[1] Risbridger, J. N. A. System X: Subsystems, Part 1—The Digital Switching Subsystem. *POEEJ*, Vol. 73, p. 19, Apr. 80.

[2] Prichard, T. W. System X: Subsystems, Part 4—Common Channel Signalling and the Message Transmission Subsystem. *POEEJ*, Vol. 73, p. 165, Oct. 80.

[3] Walji, A. A. Architecture of System X, Part 4—The Local Administration Centre. *POEEJ*, Vol. 73, p. 36, Apr. 80.

[4] Jones, W. G. T., Kirtland, J. P., and Moore, B. W. Principles of System X. *POEEJ*, Vol. 72, p. 75, July 79.

[5] Belton, R. C. System X: Subsystems, Part 3—The Processor Utility Subsystem. *POEEJ*, Vol. 73, p. 158, Oct. 80.

[6] Elmore, J. A. System X: Subsystems, Part 6—Software Subsystems. *POEEJ*, Vol. 73, p. 223, Jan. 81.

Post Office Press Notice

BRITAIN SIGNS SATELLITE DEAL WITH SCANDINAVIA

As part of its continuing drive to improve communications, British Telecom has signed an agreement with four Nordic countries to provide mutual access to the International Maritime Satellite Organization's (INMARSAT's) ship-to-shore communication satellites. INMARSAT was set up to procure and operate a global system of satellites that will bring dramatic improvements in communications with shipping and the oil exploration industry. It has 30 member countries, and Britain has a 10% share.

The deal will enable British telephone and Telex users to link up with the INMARSAT Indian Ocean satellite through a new ground aerial at Eik, Norway. At the same time, Scandinavians will have access to the Atlantic Ocean maritime satellite through British Telecom's earth station on Goonhilly Downs, Cornwall. In this way, British Telecom and its counterparts in Denmark, Finland, Norway and Sweden can, by constructing only one aerial each, provide service covering the two ocean regions at a substantial saving in capital and operating costs.

INMARSAT plans to lease capacity in satellites in geostationary orbit over the three main ocean areas—Atlantic, Pacific and Indian oceans; this capacity will become available in 1982.

Ships will be fitted with small dish aerials pointed at their nearest satellite. This will enable them to send and receive telephone and Telex calls faster and more reliably than by the existing maritime radio services. The calls will be routed through the satellites to and from specially equipped earth stations.

As announced in October 1980, British Telecom has placed a £2¾M contract with Marconi Communication Systems for the supply and installation of aerial and radio equipment at the Goonhilly earth station. Its 13·7 m diameter steerable dish aerial—the fifth for this busy site—will be locked onto INMARSAT's Atlantic Ocean satellite. The access-control and signalling equipment associated with the aerial will be supplied by the Digital Communications Corporation under a further contract worth some £2¼M.

The Nordic agreement, which will run for ten years from the start of service, also provides for the British Telecom and Nordic aerials to be used by other countries for maritime communications via INMARSAT's satellites. The four Nordic administrations and British Telecom have started joint marketing activities to persuade other European administrations to use these services and to share the resulting revenues. At the same time, joint negotiations are being held with administrations in the Far East likely to build aerials to work to INMARSAT's Pacific Ocean satellite. If these talks are successful, British and European customers will be able to communicate with ships in all three major ocean areas by using a rapid and high-quality communications system in which costs to users will be kept to the minimum practicable level.

As also announced recently, INMARSAT will lease capacity in three different satellite systems. It is shortly to place contracts worth £75M with the European Space Agency (ESA), International Telecommunication Satellite Organization (INTELSAT) and the US Marisat Consortium of the USA for leases of satellite capacity from 1982 to 1989.

The ESA will provide two dedicated satellites, MARECS A and B, which are being built by a European consortium headed by British Aerospace and which include communications packages from Marconi Space and Defence Systems. Later flights of INTELSAT V, the first of which was launched in December 1980, will also be provided to complete the first phase of the INMARSAT system.

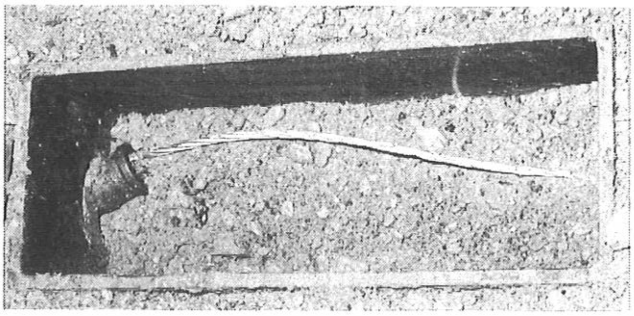
At present only about 400 ships of the worlds' merchant fleet are equipped for satellite communications. By the mid-1980s, when ship-to-shore services by this means should be well established, it is expected that more than 2000 vessels will use the INMARSAT system.

Victorian Telecommunications: An Historical Discovery

J. C. DUNCAN†

INTRODUCTION

A telephone cable that once formed part of a telephone line used by Queen Victoria almost a century ago was recently discovered at Windsor in Berkshire by British Post Office (BPO) engineers. A specimen length of this rare cable, unused since 1900, was donated to British Telecom Museum; another piece was sent to the laboratory of Thomas Bolton and Sons Ltd. for spectrographic examination. This article describes the finding of the cable, outlines the results of the spectrographic examination and relates how the chance discovery of some important historical documents revealed hitherto forgotten facts not only about this unusual cable, but also about Windsor's telecommunications heritage.



The cable and jointing chamber

THE CABLE

While carrying out underground cable survey work in the grounds of Windsor Castle, BPO engineers unexpectedly came across a cable marker partially obscured by bushes in the border of a lawn near the Royal apartments which Queen Victoria had once occupied. As the presence of a conduit or a cable was not indicated on the underground plant diagram for this particular area, an excavation was made to clarify the situation. At a depth of 600 mm, the engineers uncovered a flat diamond-patterned iron plate with raised lettering which, when cleaned, became legible as *Post Office Telegraphs*.

Further digging around the edges of the plate revealed that it formed an integral part of a buried iron-box. When the cover was removed, a cable insulated with gutta-percha was found laying at the bottom of the chamber. The cable, devoid of any external protective sheathing, consisted of 4 wires, each separately covered with a coating of gutta-percha. The conductors had been twisted into a gentle helix along the cable's length to keep them tightly together and in close formation. Surprisingly, the gutta-percha gave the appearance of being a material that would still function satisfactorily as an insulator; with continual bending, the leather-like substance exhibited a high degree of elasticity which displayed a firm grip on the metal conductors.

Routed in a 50 mm diameter iron pipe, the cable passed through the jointing chamber in a continuous length. To locate the cable's destination, an electrical device was used to induce an electric field into the 4-wire cable; the induced current was then intercepted by a receiving instrument. One end of the cable was traced to a brick-built chamber in a drive some 70 m away, and the other end to Frogmore House, a former residence of Queen Victoria's married children.

The carriageway-type box was opened and 4 wires, the remnants of the gutta-percha cable, were found protruding from a hole in the wall adjacent to a buried polyethylene cable. In the dank atmosphere of the brick jointing-box the gutta-percha insulation had crazed, and much of it had parted from the wires. But, although a thick film of green copper carbonate had formed on the bare conductors, the gutta-percha in the cavity of the brick wall was still in a remarkably good state of preservation.

An attempt was made to withdraw the cable from the iron pipe, but it could not be moved because silt had filled the bore. However, a small portion of the cable was snipped off and despatched to the metallurgical department of Thomas Bolton and Sons Ltd. for spectrographic analysis to determine the percentage composition of the metals, and to ascertain whether the wire had been produced by this company, which had been manufacturers of electrical wire for telecommunications purposes since Victorian times.

Gutta-Percha

The properties of gutta-percha, realized in 1843, created great interest among scientists. The gum from which gutta-percha is made derives from the bark of certain trees belonging to the sapotaceae species found in Malaysia and the Pacific Islands. The gum is extracted by tapping the bark or by boiling the leaves. Although gutta-percha is an isomer of rubber, its properties are unlike rubber. When the material is placed in boiling water, it becomes pliable, but on cooling, it reverts to its former tough leather-like state.

Enterprising firms soon produced an amazing variety of articles from this resin. Some of these, such as tubing, machinery belts and lifebuoys, were strictly functional articles, but others, such as elaborate picture frames and inkstands, were ornamental. Gutta-percha shoe soles successfully kept out the wet and were popular with the public. Today, gutta-percha has little commercial value but, interestingly, it is still used for the outer covering of golf balls.

The idea of adopting gutta-percha for cable insulation is said to have stemmed from a conversation between Michael Faraday and William Siemens, a German-born inventor who had made England his home. Apparently, Siemens, on Faraday's recommendation, obtained a sample of the resin and sent it to his brother, Werner von Siemens, the founder of the Siemens and Halske engineering firm in Prussia, who was later to be credited with making the first practical use of the material for wire covering. Meanwhile, in England a 2-mile trial length of wire covered in gutta-percha was laid in the Channel, in a large bight, with both ends at Folkestone harbour. One end was connected to the railway telegraph system, and the other end taken on board the *Princess Clementine* moored alongside the quay. Messages were passed from London to the ship via the cable, a distance of about 85 miles.

Although gutta-percha solved the need for effective insulation, the problem of providing outer protective sheathing on cables still remained. With the early cables, the gutta-percha coated conductors would be passed to a wire-rope maker to be lapped with hemp strings, coated with tar, and

---

† Reading Telephone Area

wound helically with zinc-dipped iron wires. Despite the vulnerability of the gutta-percha to sharp nodules of spelter protruding from the roughly galvanized armouring wires, the cables proved reasonably successful.

Several methods of sheathing the insulation with a metallic covering were tried. On single-conductor telegraph cables, the problem was easily surmounted by the use of hydraulically pressed lead sheathing, but on multi-core cables the task proved more difficult to resolve. Attempts were made to produce a lead-sheathed multi-wire cable, but were not successful. However, in December 1869, William Alfred Marshall, a telecommunications engineer of Middlesex, filed a patent that introduced a fresh approach to the problem.

The basis of Marshall's method was to wrap the wires in cotton, or some other material, and to steep them in a vat of molten paraffin wax. Next, the wax-saturated conductors were drawn through long lengths of pre-formed lead tubing while air was simultaneously drawn out of the tubing by a vacuum process.

In 1870, a length of this cable was laid in Windsor Great Park for the Postal Telegraph Authorities to provide a telegraph link between Windsor Castle and Cumberland Lodge, a distance of nearly 3 miles. Unhappily for Marshall, the cable failed after a few months of service.

Electrolytic Refining of Copper

Initially, wire-drawing for telegraph lines was not considered an exact science, and little regard was given to fine limits: it was felt that, as long as the wire was made of copper, wire-drawing would not impair its electrical characteristics. It was not until the 1880s that William Preece, then Engineer-in-Chief of the BPO, approached the wire manufacturers, Thomas Bolton and Sons, on the subject of electrolytically refining the copper to improve its mechanical and electrical characteristics. In 1881, Thomas Bolton, following Elkingtons patent of 1865, installed an electrolytic pilot-plant at his Widnes works; the following year he expanded his equipment to cater for the electrical industry's growing demand for a grade of metal of reliable consistency.

SPECTROGRAPHIC EXAMINATION OF THE CABLE

Thomas Bolton and Sons Ltd., to whom the piece of cable was passed for analysis, were able to confirm that, although the fact could not be verified, the company had probably been the original manufacturers of the cable. Boltons subjected 35 mg of each of the 4 conductors to total volatillization on a photographic spectrometer to ascertain by atomic absorption the chemical concentrates of the individual metal contents. Three of the conductors contained 0·13% lead but, surprisingly, the fourth conductor contained 0·2%. The oxygen content was 0·08% in each conductor, and was distributed throughout the wires in the form of cuprous oxide.

The high oxygen content, as compared with modern-day electrolytic tough-pitch copper having an oxygen level of between 0·02% and 0·05%, is explained by Bolton's past method of casting. Previously, hand ladles were used in the casting of wire bars. The act of pouring molten metal into a mould caused oxygen to be absorbed in the process. In addition, lead was deliberately added to prevent cracking during casting and, subsequently, in the process of hot and cold rolling. However, this practice was discontinued in the early 1920s, because lead precipitated a crystalline structure in the copper that adversely affected its conductivity.

Impurities

Table 1 lists the main trace elements found in the copper wires; each of these played a significant role in determining the attenuation characteristics of the wires. The high content of iron that was found could well be attributed to the wire-rolling operations.

TABLE 1

List of Impurities found in the Copper Wires

Element	Symbol	Less than (Parts per Million)
Aluminium	Al	10
Antimony	Sb	10
Arsenic	As	10
Bismuth	Bi	3
Chromium	Cr	5
Iron	Fe	30
Manganese	Mn	10
Phosphorous	P	Not detected
Silicon	Si	10
Silver	Ag	2
Sulphur	S	20
Tellurium	Te	10
Tin	Sn	3

Physical Characteristics

Microscopic examination of the conductors revealed some distortion in the face-centred cubic-lattice grain structure: the grains were elongated in the direction of rolling. But the grain-size diameter of the copper cables, 0·025 mm, was the same as that used in modern telecommunications systems. It is worth mentioning that, compared to conventional copper-wire cable, the cuprous oxide was distributed in a random fashion instead of being aligned in a compact orderly state and that the particles were of a much larger size than expected. Generally, the wires were in a relatively soft condition with an ultimate tensile strength of 222 N/mm; on a 5 mm specimen, the elongation was 29%. Some slight variation in the wire diameters was apparent: it fluctuated between 1·27 and 1·28 mm. The gutta-percha insulation enveloping each wire had been extruded over the conductors in two layers of 2·5 mm diameter to give a total thickness of 5 mm. (This process had been carried out by the Gutta Percha Company of Silvertown, London.)

A CHANCE DISCOVERY

In November 1980, some minor roofing repairs were being carried out in the premises of a shop near Windsor Castle. Until 1912, the shop had belonged to the National Telephone Company Limited (NTC). The present owners, aware of the building's former importance, had taken a keen interest in its history, and this proved fortunate, for when the builders removed a section of the roof that had been sealed off, they found scattered among the rafters remnants of NTC documents covering the period 1894–1907.

Why these NTC documents were left in this attic will probably never be known. However, one possible explanation is that the garret was used as a clerical storeroom. Certainly, a roof derrick to radiate wires across the town did exist; it is therefore possible that, although the attic was used regularly up to the time of its vacation in 1922, the papers were overlooked when the derrick was removed and the loft restructured.

The NTC documents comprised, among other things, letters, telephone accounts, workmen's time-sheets and stores requisition books. Their condition varied: some were perfectly preserved, but others had completely disintegrated. The reports of the former managers of the Windsor telephone district and the antiquated letter-books containing correspondence that had taken place between the NTC's Windsor office and its administration centre at Reading proved to be a particularly rich source of information. By supplementing these documents with information drawn from Windsor Castle's archive, it became possible to trace the telecommunications history of both Windsor and the Crown, and the reason for the installation of the gutta-percha cable.

THE ELECTRIC TELEGRAPH

Cooke and Wheatstone invented their electric telegraph in 1837. By 1842, 17 miles of telegraph route had been constructed along the railway line between Paddington and Slough; yet 7 more years passed before the wires were extended to Windsor. Vehement opposition to the railways by the Crown and by Eton College was the reason for the delay. Eventually, in 1849, the railway, and with it the electric telegraph line, was extended to Windsor.

But, for the Electric Telegraph Company, who had nurtured the idea of a Royal appointment to supply a telegraph line to the Castle, it was a bitter disappointment, because the Crown continued to use the public telegraph office for the next 5 years. However, with the coming of the Crimean war in 1854 the Crown changed its mind. Telegraph messages, lengthy military despatches and news of the war flooded the public telegraph rooms at Windsor and hindered other state business. Faced with long delays in the office, the Queen ordered her own telegraph instrument, which was duly installed in November 1854.

THE TELEPHONE

No record of telecommunications activity in Windsor Castle is to be found in the archives for the period after 1855 until the telephone made its appearance in 1878.

The telephone was introduced in Britain in July 1877, when W. H. Preece brought over the first pair of telephones from America. At Osborne House, Isle of Wight, on the evening of 14 January 1878, less than two years after he had patented the telephone, Bell demonstrated the use of the telephone to Queen Victoria. The Queen, writing in her journal, noted that "it is rather faint, and one must hold the tube close to one's ear". After the demonstration, the Keeper of the Privy Purse, Sir Thomas Biddulph, wrote to Bell to tell him that the Queen would like to purchase the two instruments used in the demonstration at Osborne House. In reply, Bell offered to "make a set of telephones expressly for Her Majesty's use". Presumably this was done, for there was no further correspondence with Bell, and certainly no indication that he was responsible for the installation of telephones at Windsor. However, the Lord Chamberlain's report of expenditure for 1878 does list "a telephone for Windsor Castle", and, in the following year, further spending for the installation of telephones is recorded.

In 1882, three telephones were hired from the United Telephone Company (UTC), but subsequently removed because the rental charged for them was considered to be too exorbitant. However, before this was done, 6 telephones were purchased in December 1883 from Taskers, a firm based in Sheffield.

The Queen had expressed a desire to have a telephone link between the Castle and Frogmore House, the occasional residence of her married children. This meant that, when the Court was not in residence at the Castle, telephone communication could be made with the Queen while she was visiting her children. In December 1883, the superintending engineer of the General Post Office issued instructions for the laying of a 50 mm diameter iron pipe and a 4-wire gutta-percha cable from Frogmore House to the Castle, a distance of 1138 m. In March 1900, the line was abandoned when the NTC laid a 7-pair 0·9 mm cable in a 76 mm diameter iron pipe to Frogmore House.

ACKNOWLEDGEMENTS

The author wishes to extend his grateful thanks to the following: to Her Most Gracious Majesty, The Queen, for permission to quote from the Royal Archives at Windsor; to Thomas Bolton and Sons Ltd., and in particular to their chemist, Mr. G. Sale; to colleagues in the Reading Telephone Area External Planning Division, Works Group and Drawing Office; and to D. & M. Dennis of Windsor for supplying NTC documents for use in the preparation of this article.

Problems with a River Crossing

K. G. TALLYN and T. D. GRINDROD[†]

While a 4-way junction duct route was being laid along the A3054 road between Newport and Ryde on the Isle of Wight, two interesting problems were encountered. At Wootton, which is halfway between Newport and Ryde, the main road crosses a waterway at Wootton Bridge. On the north side of the waterway there is a tidal creek that is subject to tides of up to 3·6 m high; on the south side of it there is a freshwater boating lake that is fed by streams and retained by sluice gates built onto the side of the bridge. The width of the creek and bridge is 28 m; westwards, the lake extends a further 100 m. The bridge is in effect a dam, for the lake was originally created to serve a watermill, long since demolished (see Fig. 1).

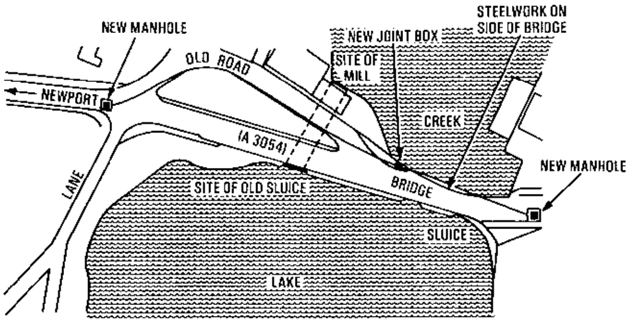


Fig. 1—Plan of the area

[†] Portsmouth Telephone Area

The first problem, already foreseen, was how to lay the duct over the waterway. The bridge could not accommodate the four duct ways within its structure, as too much plant belonging to other services was already buried under the highway surface of the bridge. The Highway Authorities had long-term plans to rebuild the bridge, but the realization of these plans was too distant to enable the British Post Office (BPO) to meet the rapid growth in circuits that was required. Since the north side of the bridge was free of fixtures, it was decided to attach standard BPO 100 mm diameter steel ducts supported by unistrut brackets to that side and to use 100 mm stainless steel expansion bolts for fixing the bearers to the bridge face. The ducts would then be kept in place by saddle clamps, and all fittings would be nylon coated to prevent sea-water corrosion.

The actual work proceeded very quickly, as the contractor was fortunate in being able to work during a spring-tide period when low water lasted for longer than average. In order to maintain the formation and to protect the shores from erosion the ducts were boxed in concrete at the points where they left the shore; all bearers and brackets were fitted in one day.

Work on the agreed duct route under the old road west of the bridge progressed steadily until a workman nearly lost his road drill in a hole which appeared some 50–75 mm below the road surface near the old mill site. An investigation revealed that the workman had uncovered the old mill-race culvert which the Highway authorities believed had been completely filled in. The lake-end of the culvert had been sealed off, but at the point where the hole was situated the culvert was 3·5 m deep and 12 m wide, with a domed roof built of bricks. Although the seaward end had also been sealed off, sea water leaked in at high tide and rose very nearly to the roof of the culvert.

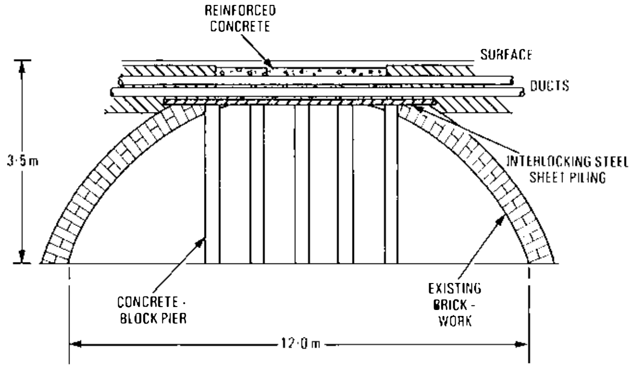


Fig. 2 –Crossing the culvert

Quite a large section of the culvert roof would have had to be removed to provide reasonable depth of cover over the new ducts; but the real problem was how to support the duct nest and the road surface. To fill the culvert with rubble and/or concrete would have been too expensive, as the concrete would have required a considerable amount of shuttering which would eventually be abandoned.

The BPO Works Supervisor, therefore, decided to build piers made from concrete building blocks to support the interlocking sheet-steel piling. The relatively small gaps to the north and to the south were filled with timber shuttering, and the steel ducts then laid in reinforced mass concrete (see Fig. 2). The road surface was reinstated in the normal way; conventional duct laying was then resumed.

The International Telecommunications Energy Conference

The third International Telecommunications Energy Conference (INTELEC 1981) is to be held at the Royal Lancaster Hotel, London, W.2 from 19–21 May 1981. The conference is being organized by the Electronics and Power Division of the Institution of Electrical Engineers in association with the Institution of Post Office Electrical Engineers (IPOEE) and other professional institutions.

The conference, which will be opened by Mr. P. Benton, Managing Director (Telecommunications) of the British Post Office (BPO), will discuss 65 papers, presented by authors from 15 different countries, covering a wide range of topics including:

AC and DC telecommunications power plant;
DC–DC converters and inverters;
uninterruptable power supplies;
energy conservation and building environment;
solar and wind power;
power distribution and economics;
power system reliability.

Synopses of some papers were published in the February 1981 issue of *Communications International.*

An exhibition of manufacturers' equipment and components will be associated with the conference with 30 companies, including the BPO, being represented.

Social functions for delegates will take place on 2 evenings during the conference and a social programme for ladies accompanying delegates has been arranged for the first 2 days of the conference.

Copies of the conference programme and registration and hotel booking forms can be obtained from the INTELEC 1981 Secretariat, Institution of Electrical Engineers, Savoy Place, London WC2R 0BL.

On the evening before the conference (Monday, 18 May) Mr. N. Osifchin, Director of Bell Building and Energy Systems Laboratory in the USA, will give a lecture to the London Centre of the IPOEE entitled *Management and Design for Energy Conservation in the Bell System.* This lecture, which will be given in the Lecture Theatre at the Institution of Electrical Engineers, Savoy Place, will be preceded by the Annual General Meeting of the IPOEE commencing at 17.00 hours. Delegates to INTELEC 1981 are invited to attend this lecture, which should provide an interesting appetizer to the conference.

D. A. SPURGIN

The British Post Office External Students' Scheme for Technical Education

D. C. YOUNG†

UDC 373.63

This article describes the philosophy behind the design of learning packages for use by British Post Office (BPO) students undertaking technical education who are unable to attend college-based courses. These learning packages continue BPO tradition of providing correspondence courses for home study, and their introduction coincides with the change from courses organized by the City and Guilds of London Institute to those organized by the Technician Education Council and the Scottish Technical Education Council.

INTRODUCTION

For many years the British Post Office (BPO) has published and distributed correspondence courses covering technical subjects; in fact, such courses were in existence with the National Telephone Company when it was taken over by the BPO in 1912. From 1931 onwards (apart from a break during the second world war), the BPO has provided correspondence courses to assist students who are unable to attend college-based classes to receive technical education.

These correspondence courses cover the courses of the City and Guilds of London Institute and provide valuable assistance to the distance learner and, within the resources available, have allowed many students to pass the appropriate examinations (see Fig. 1). Since 1945, a staff of full-time authors and editors and part-time tutors has catered annually for some 2500 students averaging 1·6 courses per student and has also provided relevant technical education on selected topics.

In September 1980, 5123 learning packages were distributed covering Technician Education Council (TEC) and Scottish Technical Education Council (SCOTEC) courses. These learning packages are a new type of self-contained correspondence course which has been designed to meet the requirements of the TEC courses. A whole range of course material has been written, together with the operational requirements of the new scheme; the scheme has been entitled the *British Post Office External Students' Scheme*. The philosophy behind the TEC courses has been previously described in the *Journal**.

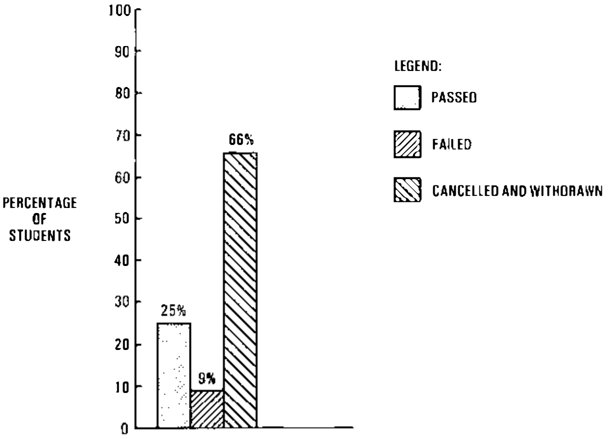


FIG. 1—Academic performances on BPO correspondence courses 1974–75

The subjects available are TEC units in Mathematics I, Physical Science I, Line and Customer Apparatus I, Telecommunications Systems I, Electrical Drawing I, Telephone Switching Systems II, Lines II, Transmission Systems II, and General and Communication Studies A and SCOTEC units in Telecommunications Systems I, Mathematics I/II and Electrical Engineering Principles I.

HISTORY OF THE SCHEME

The setting-up of the Technician Education Council in 1973 and the Council's policy statement on the proposed coverage of an external students' scheme, triggered off a new appraisal by the BPO of its existing scheme of correspondence courses. When it was subsequently discovered that the TEC did not have the immediate resources to take over the BPO's heavy existing commitments, it was decided to remodel the existing course design and to make use of the latest educational and communication technology to cover level 1 units of the new TEC certificate programme.

At this stage, a 20-man working party under the chairmanship of Professor G. Holister of the Open University was formed as a joint venture between the TEC and the BPO to develop a packaged learning course for the subject of Telecommunications Systems I. The working party consisted of 7 technical-college lecturers, 6 BPO authors and representatives, and one member of the Council for Educational Technology. This team has now been disbanded.

The first independently-produced packaged learning course (for Line and Customer Apparatus I) was designed, written and published by the Vocational Training Division of the BPO. Many new ideas in presentation were incorporated in meeting the need to cover the new TEC learning objective syllabus. The courses in Telecommunications Systems I and Line and Customer Apparatus I were followed by a course in Electrical Drawing I, and all 3 courses were introduced for the 1978–79 academic year.

OBJECTIVES OF THE SCHEME

Primarily, the External Students' Scheme is aimed at students who cannot, for valid reasons, attend a technical college in the normal way. It may be that the student is ill or has domestic circumstances which prevent him from attending college or that the nearest suitable college is too far away for him to travel there. Whatever the reason, the BPO is anxious

---

† Telecommunications Personnel Department, Telecommunications Headquarters

* BLAKEY, H. and STAGG, B. The Technician Education Council. *POEEJ*, Vol. 70, p. 219, Jan. 1978.

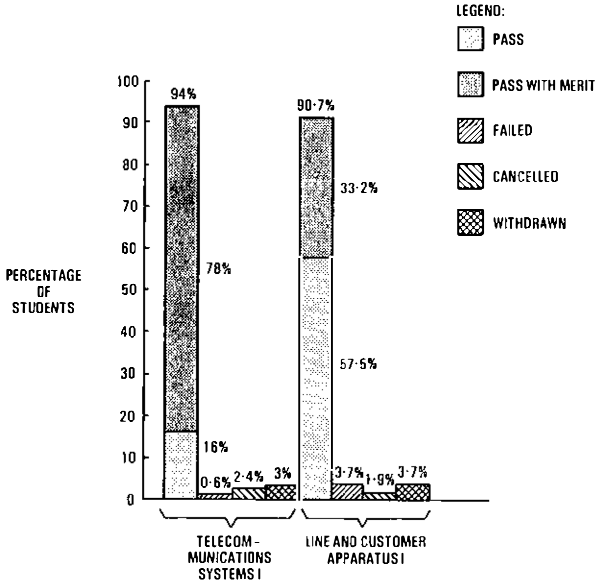


FIG. 2—Academic performances on BPO-tutored external student scheme 1978–79

to ensure that such students are not placed at a disadvantage compared with students who are able to attend college-based courses. The validation exercises which were carried out on the Telecommunications Systems I and the Line and Customer Apparatus I packaged learning courses suggest that this objective has been attained (see Fig. 2).

Comparison of the Schemes

An appraisement analysis of the performance of college-based (so-called *internal*) students has identified the following parameters:

(*a*) the average annual success rate, in terms of the number of students obtaining pass and pass-with-merit certificates at various levels,

(*b*) the average drop-out rate, in terms of the number of students who fail to complete a course,

(*c*) the availability of tuition on relevant course syllabuses,

(*d*) the magnitude of course fees,

(*e*) the uniformity of course levels, and

(*f*) the availability of performance monitoring.

Objectives of the External Students' Scheme

The objectives of the External Students' Scheme can be identified as follows:

(*a*) to achieve the same annual success rate as the Internal Students' Scheme,

(*b*) to keep the drop-out rate to a minimum and, if possible, to ensure that it is not higher than that of the internal students' scheme,

(*c*) to ensure that tuition is available, on relevant course syllabuses, to all students who are unable to study as internal students,

(*d*) to ensure that the fees charged to external students are not more than those charged at colleges to internal students,

(*e*) to ensure that the correct level of student attainment is achieved, and

(*f*) to ensure that facilities are provided for monitoring performances.

OBJECTIVES AGREED WITH THE TECHNICIAN EDUCATION COUNCIL

Agreement was reached between the BPO and the TEC that the BPO would

(*a*) provide packaged learning material for use on level 1 courses,

(*b*) establish a network of participating colleges and tutors, and

(*c*) provide administrative support.

PROCEDURES

In TEC terminology, the BPO external students' scheme is called a *collaborative scheme*, in which the BPO acts as the *exporting* college and the participating colleges act as *importing* colleges. In practice, this results in the BPO writing, publishing and distributing the learning packages and in the participating colleges tutoring the students. In addition to the college tutors, there is a substantial back-up facility provided by the BPO in that it provides its own industrial tutors to cover the specialist units and to provide a truly national coverage.

The role of the educational technologist is an important consideration in the initial setting-up of distance-learning schemes. In retrospection, the role of the educational technologist can best be described as an adviser to the management team. The technologist has a catalytic effect on the development of the scheme: his presence allows many dormant but fruitful ideas to be introduced. The manager of a new scheme, however, has a different role; he has to co-ordinate the management team and achieve the scheme's objectives by taking a practical and balanced view of all the considerations involved (for example, employers' educational policy, finance, printing and publishing resources, and staff motivation).

ASSESSMENT

The External Students' Scheme has an important assessment feature. Students are assessed internally by means of in-course tests and an end-of-course test. In the overall assessment, these are weighted 60% and 40% respectively. Successful students who obtain a pass or a pass-with-merit are awarded records of success (subject to internal and external moderation). The record of success is valid for entry into the next level of the appropriate TEC subject and the student may transfer to a college-based course if one is available.

External students do not have to travel to a college to sit examinations of either type, in-course or end-of-course. Facilities are available for the tests to be taken at BPO centres near to the student's place of work, under the control of a BPO invigilator.

DESIGN OF PACKAGED LEARNING COURSES

What comprises a packaged learning course? It is learning material that includes everything the student needs to help him to pass the course, packed into an attractive binder. Along with a well-presented text, the learning material includes instructions on its use and self-assessment questions to allow the student to monitor his own progress. Some of the packages include audio cassettes, and it is planned to introduce them into all the packaged learning courses.

The design of the Line and Customer Apparatus I course is related to:

(*a*) *The audience* The package material must communicate effectively with the particular audience (the student) and has to motivate him properly.

(*b*) *The mode of study* The design must take into account the students' environmental features produced by the mode of study. The package and the scheme have to overcome the factors that prevent the student from attending a college.

(*c*) *The expected learning behaviour of the student* The package material has to cover fully the requirements of the syllabus learning objectives. The correct level must be achieved.

Existing students studying the BPO correspondence courses for the City and Guilds of London Institute examinations receive 14 or 15 lessons throughout the year which amount to a large quantity of paper that has to be read. Students receiving the new learning packages receive 3 packages providing a total of approximately 50 segments or lessons. Each segment contains about 500 words and represents approximately 1 h of reading for the student. Segments usually cover teaching points and only the specific telecommunications principles as outlined by the specific learning objectives. Five or six segments constitute a section.

The BPO external students' scheme is, however, much more than a collection of learning packages. It consists of an experienced, well-trained team of authors, editors, tutors, invigilators, training officers and publishers (illustrators, printers and distributors). The scheme, using procedures acceptable to the TEC, was set up after additional consultation with the technical colleges at a conference in 1978. It was obvious from the start that the existing organization would provide the ideal administrative basis for the new scheme.

An important part of the scheme is the way in which learning material is presented to the student. In designing the Line and Customer Apparatus I course, the learning packages are personalized so that the student feels that he is in touch with real people and not just a machine. For example, the editor signs his name, the student is addressed as "Dear Student" and the authors write in the first person. There is plenty of student participation built into the course and the planned use of situation audio cassette tapes provide an additional human touch, which is all important to the isolated student. As an experiment, cartoons have been used in the early part of the course so that the student is introduced to the technical subject matter in easy stages.

One of the many new features of the scheme is the face-to-face tutorials. BPO students may, if required, be allowed up to 20 h of absence from their official duties to attend tutorials for remedial action.

The learning packages have been given a distinctive logo so that students soon readily identify the learning packages and associated material.

Distance learning schemes such as the External Students' Scheme are classified under the heading of *open learning systems*. J. Coffey of the Council of Educational Technology defines the term *open learning system* as "one in which the restrictions placed on students are under constant review and removed wherever possible". The External Students' Scheme is designed to provide the student with more opportunities to learn and to remove some of the conventional administrative and educational constraints.

FACTORS CONTRIBUTING TO A SUCCESSFUL SCHEME

As already stated, the BPO External Students' Scheme has introduced many new design features into the new packaged learning courses and procedures. Which factors make the greatest contribution to the overall success of the scheme? Some work has been done on this aspect, but obviously the opportunity to use control groups and to obtain the necessary statistics is limited at this stage.

Many of the factors involved may be treated as hygiene ones (for example, presentation of written learning material, provision of audio cassettes, film strips and overlays) in that failure to maintain them results in a fall in overall system performance.

The main contribution to the positive motivation of the external student is the provision of a degree of validated in-course assessment in addition to terminal examinations leading to a recognized award. Thus, if a scheme incorporates 2 or 3 in-course assessments in addition to the terminal examination, the student drop-out rate will be lower and the overall system performance increased.

This view is supported by M. Guggenheim and P. Lazenby of the Faculty of Education at Huddersfield Polytechnic in an article on *Microcomputer Management Learning* in the *Vocational Aspects of Education*.

ADMINISTRATIVE SUPPORT

In order to launch the scheme and provide the necessary administrative support, handbooks have been produced for training officers and for the authorized participating colleges. These handbooks contain the scheme objectives, schedules of procedures, programmes and the TEC submission document. A series of seminars has been conducted with those officers, such as Area Training Officers, who are immediately involved with the scheme. Special stationery has been designed and published and the opportunity has been taken to provide a much-needed rationalization of the forms used to administer technical education.

FUTURE DEVELOPMENTS

Short-term plans cover the provision of packaged learning courses at level 2 and 3 of the TEC certificate programme. Table 1 shows the current TEC certificate programme matrix and Table 2 shows the proposed revision of the matrix. Development work is continuing on external student schemes and long-term plans envisage computer applications and also the use of viewdata services, such as the BPO Prestel service.

TABLE 1

TEC Certificate Programme Matrix

Mathematics I	Physical Science I	Line and Customer Apparatus I	Telecommunications Systems I	Electrical Drawing I
Mathematics II	Electrical Principles II	Electronics II	Transmission Systems II† Radio Systems II† or Telenhone Switching Systems II† or Lines II†	General and Communications Studies A
Digital Techniques III† Transmission Systems III†	Electrical Principles III	Electronics III	Telephone Switching Systems III or Radio Systems III or Lines III	General and Communications Studies B

† half-unit

TABLE 2

Proposed Revision of TEC Certificate Programme

Mathematics I	Physical Science I	Line and Customer Apparatus I or Industrial Skills and Practice	Telecommunications Systems I	Micro-Electronics I† General and Communication Studies†
Mathematics II	Electrical and Electronic Principles II	General and Communication Studies	Transmission Systems II† Lines II† or Radio II† or Telephone Switching Systems II†	Micro-electronics II
Electronics III	Electrical Principles III Transmission Systems III	Digital Techniques II† Digital Techniques III†	Lines III or Radio III or Telephone Switching Systems III	General and Communication Studies

† half-unit

CONCLUSIONS

Harrogate, the long-established printing and publishing centre for the existing correspondence courses, plays a large part in the new scheme. In addition to printing, publishing and distributing packaged learning courses, the centre also provides the Training and Education Policy Division with an on-demand statistical service. (See Table 3.)

There may be cases where colleges insist on a minimum number of students before they will establish a tutorial group; in cases where it is not possible to meet this minimum figure, students will be enrolled with Harrogate and will be tutored by BPO tutors.

Students under the care of college or BPO (industrial) tutors receive the same care, attention and expert advice. Internal moderation of the BPO tutoring scheme is carried out by the Training and Education Policy Division and external moderation by the TEC and SCOTEC. Training and Education Policy Division also deal with special cases and appeals and monitor overall progress of the scheme.

Does the BPO get value for money? The economics of the new scheme show that it will prove favourable to the BPO. A much improved pass rate is envisaged, coupled with the fact that the scheme is operated on a marginal cost basis and the expected college fees should be no more than normal evening class fees.

Guildford Education Services, in a report on a preliminary survey on the educational effectiveness of the Post Office Telecommunications scheme concludes that, allowing for certain survey constraints, the scheme is educationally effective.

TABLE 3

Example of Training Statistics

	Phase Test 1	Phase Test 2	Phase Test 3	End-of Unit Test	Overall Assessment
Sample Number	200	200	100	200	175
Range	46%–100% (54%)	31%–97% (66%)	15%–90% (75%)	20%–92% (72%)	27%–92% (65%)
Mean	89·4%	70·3%	55·6%	62·5%	68·4%
Median	92·0%	71·0%	–	63·0%	70·0%
Mode	97·8%	74·0%	60%– 65·0%	69·0%	79·0%
Standard Deviation (Sample)	10·4	13·1	15·5	12·9	11·9
Standard Deviation (Population)	10·4	13·1	15·6	12·9	12·0
Skew	−0·75	−0·2	–	−0·04	−0·4
Standard Error of the Mean	0·7	0·9	1·6	0·9	0·9
Population Mean (95% Level of Confidence)	88·0%– 90·8%	68·5%– 72·1%	52·4%– 58·8%	60·7%– 64·3%	66·6%– 70·2%
Population Mean (Weighted)	17·6– 18·2	13·8– 14·4	10·4– 11·8	24·4– 25·6	66·6– 70·3

The Institution of Post Office Electrical Engineers: London Centre—Past and Present

K. W. STOATE, B.SC., C.ENG., M.I.E.E.†

INTRODUCTION

In May 1905 there was a meeting of senior officers of the British Post Office (BPO) Engineering Department to consider the formation of an Institution of Engineers in the Post Office. The proposal put before the meeting was:

> *For some considerable time past there has been a strong feeling on the part of Electrical Engineers in the Post Office service that the great developments in every branch of Telegraph and Telephone Engineering, and the increasing responsibilities of their position, justifies the formation of a new organization which would enable them by the exchange of opinion to keep abreast of the rapid progress in the various disciplines developments.*

After due consideration it was decided to establish an organization to be known as *The Institution of Post Office Electrical Engineers* (*IPOEE*).

On 7 December 1905, the Government Treasury Department gave an initial sum of £500 toward the setting up of the IPOEE, and they gave an undertaking to provide £250 annually towards the operating costs.

On 6th July 1906, the IPOEE was formally inaugurated; its first President was Sir John Gavey, who was the Engineer-in-Chief of the Post Office Engineering Department from 1902–1907.

At its inception, the IPOEE consisted of the London Centre, known as the *Metropolitan Centre*, and 13 provincial centres. The Metropolitan Centre included the Engineer-in-Chief's Office and the metropolitan districts; among the provincial centres was one for Southern Ireland. The headquarters of the IPOEE was at No. 8 King Edward Street. Membership was restricted to all ranks above and including Inspector; Senior Clerks were also included.

The first Chairman of the London Centre was Mr. J. W. Woods. The lectures presented during the first year included: *Telephone Transmission*, by J. G. Hill; *Electric Wave Propa-*

---

† Mr. Stoate was Vice-Chairman of the London Centre of the IPOEE from 1978 to 1980.

FIG. 1—Sir John Gavey (First President of the IPOEE)

gation, by J. E. Taylor; *Post Office Telegraph*, by J. S. Brown; and *Trunk System Signalling Telegraph*, by M. McIlroys. All lectures were held at King Edward Street.

The London Centre also provided a library service, which was available to IPOEE members in the rest of the country. Also, visits were organized to places of interest.

ASSOCIATION WITH THE IEE

No description of any part of the IPOEE activities would be complete without mention of the Institution of Electrical Engineers (IEE). The founding of this great professional Institution was started by telegraph engineers in May 1871; at that time, it was known as the *Society of Telegraph Engineers*. It was one of a large number of learned societies formed in the 18th and 19th centuries. The sister Institutions that had been formed earlier in the century were the *Institution of Civil Engineers* in 1818, and the *Institution of Mechanical Engineers* in 1847. The name Society of Telegraph Engineers continued until 1888 when, in view of the ever widening scope of the Society to include power generation and allied subjects, the name was changed to the *Institution of Electrical Engineers*.

From the very start of the IEE there has been the closest ties between BPO Engineers and the IEE; many BPO Engineers are of course members of this professional body.

In June 1910, the headquarters of the IEE moved into the well-known site at Savoy Place, London, and has remained there ever since, although the building has been considerably altered both externally and internally.

In 1922, the London Centre of the IPOEE started to hold some of its lecture meetings at the IEE building at Savoy Place, and this arrangement with the IEE has continued until the present day.

The IEE building at Savoy Place is shown in Fig. 2, and Fig. 3 shows the IEE main lecture theatre, which is considered one of the best appointed in London.

FIG. 2—The IEE building, Savoy Place, London

Photograph: Institution of Electrical Engineers

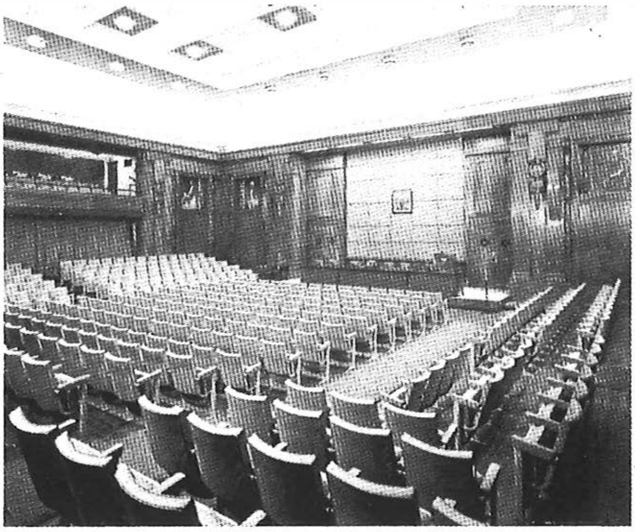


FIG. 3—The IEE main lecture theatre

Photograph: Institution of Electrical Engineers

GROWTH OF THE LONDON CENTRE

1906–1919

It is very interesting to note that a scan through the considerable number of documents and minutes of the period has revealed that our predecessors considered they were in a fast advancing technology and that telephone systems were in a constant state of development.

The period before the outbreak of the first world-war (1914–1918) saw the London Centre gain in status and popularity. Seven or eight papers a year were read, and the membership increased from approximately 450 in 1906, to 800 by 1914.

Another noteworthy event which reflected on all sections of the IPOEE was the first publication, in 1908, of the *Post Office Electrical Engineers' Journal*, which was published, as now, on a quarterly basis. In the first year of publication, the *Journal* contained a total of some 40 major articles. The publishing of the *Journal* gave a decided impetus to the prestige of the IPOEE, and this was most noticeable at Headquarters (that is, in the Metropolitan Section).

The development of the London Centre was impeded during the period of the first world-war; papers were still read, but they were fewer in number. The number of members dropped, and in 1919 was approximately 700.

1920-1939

In the period between the two world-wars the London Centre continued to grow. One important change was the splitting of lectures into two classes: formal and informal. The formal lectures were held at the IEE Savoy Place, and the informal lectures were held in Post Office buildings; for example, at Waterloo Bridge House. The purpose of the informal meetings was to encourage discussion in a friendly and familiar atmosphere, as distinct from the rather awe-inspiring atmosphere of the IEE lecture hall.

By 1935, the membership of the London Centre had grown to 2040; the library contained 1000 books; and 11 technical periodicals were on circulation to members. As examples of the activities of the London Centre during this period, the programmes of formal and informal lectures for 1935–36 are given in Tables 1 and 2 respectively.

During 1935–36, visits were made to The Royal Arsenal, Woolwich; The National Physical Laboratory; and The Pyrene Company Ltd.

TABLE 1

Formal Meetings 1935-1936

Subject	Lecturer
External plant layout for automatic exchange conversions in the City of London	L. Meek
Ultra-short-wave radio telephone circuits	D. A. Thorn, BSC. (ENG)., and H. T. Mitchell, A.M.I.E.E.
Broadcast interference	J. Neale
Some practical aspects of telephone conduit and manhole construction	C. F. Thomas and A. T. Soons
Maintenance, use and development of motor transport	R. T. Robinson, A.M.I.E.E.
Recent developments in unit automatic exchanges	B. Winch, A.M.I.E.E. and C. G. Grant
Laying submarine cables	Messrs. Siemens, Bros. & Co. Ltd.

TABLE 2

Informal Meetings 1935-36

Subject	Lecturer
Power work in the London Engineering District	H. W. Fulcher, M.I.E.E.
Basic principles underlying carrier telephone practice	C. E. Palmer-Jones
Private teleprinter-circuits	T. G. London, A.M. INS. BE.
The case for aerial cable	R. MacWhirter, B.SC., A.M.I.E.E.
The development of picture transmission from mobile transmitting-apparatus	J. Stratton, A.C.G.F.C., A.M.I.E.E.
Some notes on the provision and layout of automatic exchanges	A. W. Webb

1939-45

During the second world-war there was a considerable reduction in the activities and facilities provided by the London Centre. No meetings were held in the 1939–40 and 1940–41 sessions. However, from 1941–42 until the end of the war an increasing number of meetings occurred each year, and in 1944-45 6 formal and 6 informal meetings were held, which were up to peacetime standards.

ASSOCIATE SECTION

No history of the London Centre or of the national IPOEE can be complete without mention of the Associate Section, or *Junior Section* as it was called when first established on 23rd May 1932; the first President of the Junior Section was Mr. C. W. Brown.

The formation of the Junior Section was almost entirely due to the imagination and energy of Mr. E. Gomersall, who was Chairman of the London Centre in 1931–1932. The initial membership was 500, which included all grades of workmen and youths-in-training. The Junior Section ran its own meetings and visits, and members also enjoyed the facilities of the main IPOEE library. There was an annual subscription of 2/6d.

The Junior Section pursued the same objects as its senior partner in fostering interest, promoting communication and disseminating knowledge relating to developments in technology; it fostered discussion and debate on Technical Instructions Workmens' Pamphlets; it gave prizes for the best written papers, as well as encouraging members to take part in the main IPOEE essay competition. Other centres quickly set up Junior Sections following the example of the London Section.

The name of the Junior Section was changed in the late 30's to the *Associate Section*, and its senior partner was termed the *Senior Section*.

A considerable reduction in the activities of the Associate Section occurred during the period of the second world-war. After the war, personal interest by Senior Section members stimulated interest in the affairs of the Associate Section and the membership increased to 2480 in the 1949–50 session and, by 1956, had increased to over 4000.

At the present time, the Associate Section is structured in two parts: the London Postal section, which has a membership of 350; and the London Telecommunications section, which has a membership of 7500. The Associate Section is managed by a committee consisting of a Chairman from each of the 14 area groups, which include the International Telephone Area, London Test Section and Regional Headquarters. The Associate Section produces its own Journal, called *New Quarterly Journal*. Officers are appointed to liaise with the Senior Section; at present, the Associate Section Liaison Officers are Mr. N. Bell from the LTR and Mr. E. Clark from the LPR. Each May, the activities of the Associate Section are reviewed at Conference, at which reports are given from such people as the Senior Quiz-Organizer, the Visits Secretary, the Librarian and the Treasurer.

The conference activities are concluded with a dinner in honour of Mr. C. W. Brown, the first President of the Junior Section; at the dinner, awards are presented by the President. Without doubt, the development of the Associate Section of the London Centre has achieved a status that lives up to the dreams of its instigator, Mr. E. Gomersall.

THE PRESENT LONDON CENTRE ORGANIZATION

Since 1945, the London Centre has slowly developed, and facts about its present working are given below.

The London Centre is managed by a committee headed by a Chairman and Vice-Chairman. These two officers are appointed by the President of the IPOEE and serve for two years; to maintain continuity of management, the appointments overlap by one year. A list of past Chairmen and Vice-Chairmen of the London Centre from 1926 is given in the appendix.

The other officers of the committee, who are selected by ballot and serve for two years, include:

(*a*) a Secretary,
(*b*) an Assistant Secretary,
(*c*) one member from salary bands 1–8 in THQ and the LTR,
(*d*) one member from salary bands 9 and 10 in THQ,
(*e*) one member from salary bands 9 and 10 in the LTR or the LPR,
(*f*) one member from the Executive Engineer (EE) grade in THQ,
(*g*) one member from EEs in the LTR or the LPR,
(*h*) two members from the Assistant Executive Engineer (AEE) and the Inspector grades in THQ,
(*i*) one member from AEEs, in the LTR or the LPR,
(*j*) one member from Inspectors in the LTR or the LPR, and
(*k*) one member from the Draughtsman and Illustrators grades.

From time-to-time, as a need arises, members are co-opted to serve on the committee.

The membership for the year ending April 1980 was 4984 and consisted of 3462 from THQ and 1522 from the London Telecommunication and Postal Regions.

Facilities Provided by the London Centre

The main function of the London Centre is to provide a series of lectures at a suitable lecture theatre (usually at the IEE, Savoy Place) on subjects of interest in communication technology. Other facilities available to members are

(*a*) visits to places of interest (for example, Air-Traffic Control, West Drayton, and the Ford Motor Works at Dagenham),
(*b*) the use of library facilities, and
(*c*) the opportunity to receive periodical publications which are on circulation to members.

In 1979–80 the London Centre arranged 10 lectures; 340 people took part in 20 visits; the library contained 2500 books; and 15 periodicals were in circulation.

In 1978 it was decided to cease the distinction between formal and informal lectures; all lectures now have the same status and are held at the IEE, Savoy Place.

In recent years, there has been a central theme running through each year's lectures. In the year 1979–1980, the theme was *Human Relations*.

Under the guidance of the present London Centre Chairman, Mr. K. E. Ward, the theme for the 1980–1981 session was *Modernization*, and the lectures have emphasized not only the changing technical scene but also the changes that may result from the relaxation of the Post Office monopoly. This 'liberalization' was clearly demonstrated in the first lecture titled *British Telecom in the Changing Environment*, given by the Deputy Managing Director: Telecommunications, Mr. J. Harper. This lecture was followed by a description, given jointly by Mr. Bryan of STC and Mr. Leggett of British Telecom, of the most modern processor-controlled exchange in current production, TXE4A.

The lectures presented or planned for the 1980–81 session are given below.

FIG. 4—Mr. K. E. Ward: Chairman, London Centre

18 November 1980	*Modernization of the UK Telecommunications Network*, by C. R. J. Shurrock, THQ/DNS.
27 November 1980	*Monarch and Herald—Engineering for Installation in Customer's Premises*, by F. E. Wright, THQ/BS4.2.3.
11 December 1980	*Telconsult—A Worldwide Consultancy Service*, by J. F. Boag, General Manager British Telconsult.
20 January 1981	*Network Management*, by R. Madden, Network Manager, American Telephone and Telegraph Company Long Lines.
16 February 1981	*Evolution Towards an Integrated Services Digital Network (SDN)*, by A. G. Orbell, THQ/NS2.
26 February 1981	*The Impact of Digital Telephony on Transmission Standards*, by K. R. Harrison, THQ/NS2.1.4.
9 March 1981	*Users View of British Telecom*, by G. Waggett, Head of Telecommunications Section, Post Office Users National Council.
23 March 1981	*Local Network Evolution*, by A. G. Hare, THQ/SES6.
6 April 1981	*Worldwide Marketing of System* X, by J. H. A. Sharpley, Managing Director, British Telecommunications Systems Limited.
18 May 1981	*Management and Design for Energy Conservation in the Bell System*, by N. Osifchin, Director, Bell Building and Energy Systems Laboratory.

Two of the above lecturers are visiting speakers from overseas organizations, and one is from the Post Office Users National Council. Such speakers inject a fresh interest into a session and provide a new slant to the thoughts of British-Telecom oriented members. All these lectures have the same theme that characterized the first talks in 1906, namely an involvement in the ever-developing technology and its ramifications; they also provide an essentially independent forum for any member to debate technical and policy matters with experts in that particular field.

CONCLUSIONS

It speaks much for the energy and enthusiasm of the committees of the London Centre that the centre has continued to grow and provide worthwhile lectures, visits and library facilities for its members. However, interest has to be constantly stimulated.

A few years ago, there was a noticeable falling off of attendance at the main meetings. This was counteracted by prompt circulation of the programme card, by Newsletters, and by the introduction of attractive posters, one of which won a recent award in the publicity field. These measures produced good results and attendance is now good, although it can always improve. The London Centre committee extends its thanks to all members for their support, which is given in their own time and outside the normal course of their duty.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the help he has received from Mr. R. Cross of the IPOEE Central Library, Mr. D. Lane, Librarian of the Institution of Electrical Engineers, and Mr. R. Gray, Librarian and Archivist of the Associate Section of the London Centre.

Chairmen and Vice-Chairmen of the IPOEE London Centre

YEAR	CHAIRMAN	VICE-CHAIRMAN
1926–27	Col. A. G. Lee (E)	Mr. J. W. Atkinson (L)
1927–28	Capt. B. S. Cohen (E)	Capt. J. Hines (L)
1928–29	Mr. W. J. Bailey (L)	Mr. P. J. Ridd (L)
1929–30	Mr. A. B. Hart (E)	Mr. F. H. Wise (L)
1930–31	Mr. E. Gomersall (L)	Mr. P. T. Wood (L)
1931–32	Mr. F. G. Greenham (L)	Mr. N. J. Wilby (L)
1932–33	Mr. J. Hedley (E)	Mr. S. C. Bartholomew
1933–34	Mr. B. O. Anson (E)	Mr. A. Wright (L)
1934–35	Mr. J. W. Atkinson (L)	Mr. A. O. Gibbon (E)
1935–36	Capt. J. G. Bines (E)	Mr. H. W. Fulcher (L)
1936–37	Mr. P. J. Ridd (L)	Mr. P. B. Frost (E)
1937–38	Mr. R. G. deWardt (L)	Capt. A. C. Timmis (E)
1938–39	Mr. G. F. O'dell (E)	Mr. C. W. Brown (L)
1939–40	Col. F. Reid (E)	Mr. C. H. Phillips (L)
1940–41	Mr. A. Morris (L)	Mr. B. W. Harding (E)
1941–42	Mr. A. Morris (L)	Mr. B. W. Harding (E)
1942–43	Mr. F. O. Barralet (E)	Mr. W. F. Boryer (L)
1943–44	Mr. F. E. Nanoarrow (E)	Mr. F. B. Chapman (L)
1944–45	Mr. A. Morris (L)	Mr. E. H. Jolley (E)
1945–46	Mr. R. M. Chamney (E)	Mr. A. E. Stone (L)
1946–47	Mr. P. B. Frost (E)	Mr. C. F. Moffat (L)
1947–48	Mr. A. H. Mumford (E)	Mr. H. F. Epps (L)
1948–49	Mr. W. S. Procter (L)	Mr. R. W. Palmer (E)
1949–50	Col. J. Reading (E)	Mr. A. E. Penney (L)
1950–51	Mr. W. T. Gommell (E)	Mr. J. J. Edwards (L)
1951–52	Mr. H. R. Harbottle (E)	Mr. J. Stratton (L)
1952–53	Mr. R. S. Phillips (L)	Mr. F. Hollinghurst (E)
1953–54	Mr. F. C. Carter (E)	Mr. G. S. Berkeley (L)
1954–55	Mr. W. F. Smith (E)	Mr. E. C. C. Greening (L)
1955–56	Mr. E. H. Jotley (E)	Mr. J. G. Straw (L)
1956–57	Mr. G. S. Berkeley (L)	Mr. A. J. Jackson (E)
1957–58	Mr. H. G. Beer (E)	Mr. L. F. Salter (L)
1958–59	Mr. H. Williams (E)	Mr. S. M. E. Roussell (L)
1959–60	Mr. L. F. Scantlebury (E)	Mr. S. I. Brett (L)
1960–61	Mr. T. H. Flowers (E)	Mr. H. M. W. Ackerman (L)
1961–62	Mr. R. H. Franklin (E)	Mr. C. G. Grant (L)
1962–63	Mr. R. O. Carter (E)	Mr. R. W. Hopwood (L)
1963–64	Mr. S. J. Edwards (E)	Mr. A. W. Pearson (L)
1964–65	Mr. W. J. E. Tobin (E)	Mr. T. J. Rees (L)
1965–66	Mr. E. W. Anderson (E)	Mr. T. J. Morgan (L)
1966–67	Mr. A. J. Thompson (L)	Mr. H. C. S. Hayer (E)
1967–68	Mr. W. H. Maddison (E)	Mr. W. G. Roberts (L)
1968–69	Mr. D. E. Watt-Carter (E)	Mr. D. W. R. Cobbe (L)
1969–70	Mr. T. J. Morgan (L)	Mr. D. G. Jones (T)
1970–71	Mr. T. F. A. Urban (T)	Mr. R. J. Griffiths (L)
1971–72	Mr. R. W. White (T)	Mr. F. C. Gould-Bacon (L)
1972 73	Mr. G. E. Brett (L)	Mr. J. F. Bampton (T)
1973–74	Mr. C. F. Davidson (T)	Mr. A. J. Chappel (L)
1974–75	Mr. E. V. Partington (T)	Mr. J. I. Collings (L)
1975–76	Mr. B. R. Horsfield (T)	Mr. B. F. Yeo (L)
1976–77	Mr. R. J. Bluelt (L)	Mr. H. J. C. Spencer (T)
1977–78	Mr. C. K. Price (L)	Mr. R. C. Bolton (T)
1978–79	Mr. C. K. Price (L)	Mr. K. W. Stoate (T)
1979–80	Mr. K. E. Ward (T)	Mr. K. W. Stoate (T)
1980–81	Mr. K. E. Ward (T)	Mr. R. Wilkinson (L)

(E) : Engineer-in-Chief's Office (T) : THQ (L) : LTR

The First Installation of the Electronic Exchange System UXE8

W. M. OLIVER†

Following an examination of proprietary exchange systems in 1978, the Scottish Telecommunications Board and Telecommunications Headquarters of the British Post Office (BPO) concluded that the Pentex ERS (Electronic, Reed, Small) system manufactured by Plessey Telecommunications Ltd. (PTL) should be evaluated as a modern replacement system for some of the BPO's very small local exchanges, most of which are UAX12s and UAX13s. The Pentex ERS, designed to serve 50–500 customers' lines, is one of a series of complementary systems that have evolved from the TXE2 system; Pentex systems are marketed for export by PTL.

It was decided that twelve ERS exchanges, modified by PTL to include the BPO's coin and-fee-check, local-call timing and combined 1/9/0 junction facilities, should be purchased for installation at appropriate locations in Scotland West Telephone Area. The new type of exchange has been designated UXE8 by the BPO. Sites for the exchanges within the areas served by the comparatively new TXK1 group switching centres at Newton Stewart and Girvan were subsequently selected and plans made for the exchange replacement work. The contract placed with PTL stipulated that the first installation, to replace a UAX14, would be installed and commissioned by PTL's staff, and that the UXE8 would be subject to an in-service trial for a period of twelve months from the date the exchange entered public service; certain service performance criteria were specified so that the new exchange could be assessed by the BPO. Agreement was also reached with PTL on the cost of the project; the training of BPO staff; the specifications to be adopted for acceptance testing and commissioning; specialist technical assistance and feedback on system performance; and the provision of test equipment. It was proposed that equipment for the remaining eleven of the twelve proposed UXE8s should be supplied to the BPO for installation by direct labour. A description of the UXE8 was published in a previous issue of this *Journal**.

When the first UXE8 was brought into public service at 08·00 hours on 22 May 1980, 315 customers' lines at Wigtown, a small community in South West Scotland, were transferred from the UAX14. The installation of five traffic racks and three miscellaneous racks was completed in two weeks during December 1979. Commissioning commenced in January 1980 and the multi-call sample tests were successfully concluded during April 1980. Although Signalling System (SS) AC No. 8 and SSDC No. 2 junctors for the UXE8 were not specifically required for the Wigtown installation, PTL supplied them at the request of the BPO; these items were also successfully tested.

The UAX14 has been retained on standby; in the event of a serious failure occurring in the UXE8 equipment, a changeover will be effected. However, to date, the UXE8 has met most BPO and PTL requirements and orders have been placed for equipment for the remaining eleven exchanges.

---

† Scotland West Telephone Area

* POULTNEY, A. E., and LASHMAR, J. C. Small Exchange Modernization: New Electronic Exchange Systems UXE7 and UXE8. *POEEJ*, Vol. 73, p. 82, July 1980.

New Digital PABX for Exeter Telephone Area Office

R. G. HAYNES† and R. M. DUDDY*

The provision of a new Telephone Area Office (TAO) at Commercial Road, Exeter, brought 430 office-based staff together under one roof for the first time and the opportunity was taken to rationalize in-house communications and to provide direct access to several outstations. After studies by the Traffic Planning Group and the Sales Division, a set of criteria was submitted to South Western Board Headquarters and to Telecommunications Headquarters for consideration. As a result, a Plessey PDX 800 PABX was selected as meeting the varied requirements of customers and staff; the first stored-programme controlled (SPC) PABX for use by British Post Office staff. The staff concerned with the new PABX visited the manufacturers to receive instruction on the system, its service features and the various facilities available to extension users.

Two operator's consoles were provided at the TAO and these are staffed on a rota basis by staff from Exeter auto-manual centre, where the service position has been reduced to an out-of-working-hours service only. Most of the 470 extensions can be called by direct dialling-in, which reduces the operator load, and this will be further contained by extended use of the various facilities available to extension users and operators. A System Manager has been appointed to arrange user training, to oversee the operators' work and to co-ordinate the maintenance of in-house records. He also makes the necessary changes to the processor store via a teletype access and monitors the system performance. Installation commenced in November 1979 and the exchange was accepted for service in March 1980.

The Plessey PDX 800 is a SPC, time-division multiplexed, 4-wire switched system, in which a number of bidirectional interface circuits are interconnected by switching circuits onto a common 384 slot (340 speech slots, 9 control slots and 35 spare), 83.3 μs digital bus under the control of the operational program. The 2-wire speech path from an extension is split into a TRANSMIT and RECEIVE signal by the hybrid at the interface. The TRANSMIT signal is routed to the coder, which converts the analogue signals to digital signals for transmission to the digital bus; a decoder carries out the reverse process in the RECEIVE direction. The system is compatible with 7 different signalling systems for inter-PBX working and has a maximum capacity of 120 exchange lines and 800 extensions. The equipment is housed in enclosed double-bay 1730 mm cabinets and powered by a mains-driven 100 A, 50 V DC power unit.

---

† Exeter Telephone Area

* South Western Telecommunications Board Headquarters

Institution of Post Office Electrical Engineers

General Secretary: Mr. R. E. Farr, TE/SES5.3, Room 1420, 207 Old Street, London EC1V 9PS; Telephone: 01-739 3464, Extn. 7223.
(Membership and other local enquiries should be directed to the appropriate Local-Centre Secretary as listed in the October 1980 issue and as amended below.)

CHANGES TO THE RULES OF THE INSTITUTION

Council has agreed the following rule amendments.

Rule 24 Amend to read.

"The first Chairman of a new Provincial Centre shall be appointed by the Chairman of Council. Thereafter, and for all existing centres, outgoing Chairmen shall seek the agreement of the Chairman of Council to the nomination of a successor. Vice-Chairmen shall be nominated by the Local-Centre Chairman concerned. Six members . . .".

Rule 26 *Issue of nomination and voting papers.* All dates to be advanced by 2 weeks to read respectively:

"18 January, 24 January, 18 February, 8 March, 3 April."

Ties. Amend to read.

"In the event of tie, the Chairman of Council or Local Centre, as the case may be, shall have the casting vote between the candidates who tied for the representation concerned."

Rule 35 Replace by the following.

"Council shall arrange for the publication of the Institution's Journal and any papers, either read at meetings of the Institution or which may be calculated to advance the objects of the Institution, as selected by Council. Every Corporate and Non-Corporate Member shall be supplied with a copy of each issue of the Journal. Every Corporate Member shall be supplied with a copy of each Printed Paper published by the Institution but Non-Corporate Members shall receive only the unrestricted issues of such Printed Papers."

Rule 36 Replace by the following.

"Council will consider those papers submitted to it by Local-Centre Committees under Rule 43, in respect of the following courses of action:

(i) to print in full
(ii) to print in abstract
(iii) not to print
(iv) to present whole or part to the Board of Editors of the Journal
(v) to place the manuscript in the Central Library.

The selection of papers to be printed for circulation shall be vested solely in the hands of Council. No paper shall be printed unless at least nine votes in favour of that action are given by members of Council."

Rule 43 Replace by the following,

"It shall be the duty of each Local-Centre Committee to consider all papers presented at meetings of the Institution held at its Centre, as soon as possible after the papers are read, with a view to deciding by vote whether Council shall be requested to take action under one or both of Rules 36 and 46."

Rule 44(i) Amend to read.

"To arrange that any paper recommended by the Local-Centre Committee for printing and/or the award of an Institution Medal shall be promptly submitted to the Secretary for consideration by Council."

Rule 45 Replace by the following.

"(*a*) *Institution Senior and Junior Medals* One silver and one Bronze Medal to be called 'Institution Senior Medals', and one Silver and one Bronze Medal to be called 'Institution Junior Medals' may be awarded yearly to authors for the best papers read at meetings of the Institution during the twelve months ended on 30 June of the previous year.

(*b*) *Institution Field Medals* Three Bronze Medals to be called 'Institution Field Medals' may be awarded yearly for the best papers on field subjects primarily of Regional interest. The papers to be considered for these medals shall be those read by members at meetings of the Institution during the twelve months ended on 30 June of the previous year."

New Rule 45X (This is a temporary number pending future Rules revision.) This rule is to be inserted between Rules 45 and 46 and is to read as follows.

"All members of the Institution shall be eligible to receive Senior and Field Medals, but the award of Junior Medals shall be restricted to members who, when the paper was first read, were of the ranks included in Groups 6 to 16 (Rule 18). No member shall be eligible to receive more than one medal in the same year. For papers by joint authors a similar medal shall be awarded to each author, but a paper by joint authors shall not be eligible for Junior Medals unless all the authors were of the ranks included in Groups 6 to 16 (Rule 18) when the paper was first read."

Rule 46 Replace by the following.

"The selection of papers for the award of Institution Medals from those papers recommended for consideration by Local-Centre Committees under Rule 43 shall be the responsibility of Council. Unless the final decision as to the award of each of the seven medals be unanimous, application shall be made to the President of the Institution for expert assistance."

New Rule 46X (Temporary number) To be inserted immediately after Rule 46.

"The medals for papers read in any session shall be presented at the Annual General Meeting of the Institution of the succeeding session."

CHANGES OF LOCAL-CENTRE SECRETARIES

Mr. L. J. Hobson has taken over as Secretary of the London Centre from Mr. Armitage (details of his address were given in the October 1980 issue). The Assistant Secretary is Mr. G. P. Jones, THQ/NE/NS2.1.1; telephone 01-261 1055.

Mr. N. Braid, STB/HQ.S114, telephone 031-222 2348, has taken over from Mr. Walker as Secretary of the Scotland East Centre.

RETIRED MEMBERS

The following members, who retired during 1980, have retained their membership of the Institution under Rule 11(a):

Mr. S. B. Watkins, "Windcroft", Wren Park Close, Ridgeway, Sheffield S12 3XT.
Mr. J. E. Roberts, 12 Tenby Drive, Cheadle Hulme, Cheadle, Cheshire SK8 7BR.
Mr. L. W. Hill, "Inglenook", 39 Stratford Road, Watford, Herts WD1 3NY.
Mr. W. Smith, 33 Northview Road, Westgate Hill, Bradford BD4 6NS.
Mr. F. H. Bradley, 31 Wheatley Grove, Ben Rhydding, Ilkley, W. Yorks LS29 8SA.
Mr. W. I. L. Rae, 53 Church Lane, Oulton, Stone, Staffs ST15 8UB.
Mr. H. Thorpe, 29 Hillswood Drive, Endon, Stoke-on-Trent ST9 9BL.
Mr. R. G. Simmons, 29 Pinewood Drive, Bletchley, Milton Keynes MK2 2HT.
Mr. J. C. Dignan, 13 Meadowfield Drive, Edinburgh EH8 7NY
Mr. A. A. Philie, 11A McKenzie Road, Broxbourne, Herts EN10 7JQ.
Mr. L. A. Salmon, 26 Perne Avenue, Cambridge CB1 3SA.
Mr. A. A. Buckeridge, 5 Upper Berkeley Place, Clifton, Bristol BS8 1JS.
Mr. K. G. T. Bishop, 28 Towncourt Crescent, Petts Wood, Orpington, Kent BR5 1PQ.
Mr. K. O. L. Hobbs, 29 St. Leonard's Road, Headington, Oxford OX3 8AD.
Mr. R. V. Little, 33 Mancroft Road, Caddington, Luton LU1 4EJ.
Mr. T. W. Jenkins, 9 Hendremawr Close, Tycoch, Sketty, Swansea SA2 9ND.

Mr. T. Lynas, 85 Kings Drive, Bristol 7.
Mr. A. E. Pullen, 23 Llanaway Close, Godalming, Surrey GU7 3ED.
Mr. E. A. Askew, 65 Longmead Drive, Sidcup, Kent DA14 4NY
Mr. G. A. Bryan, 29 Daleside, Gerrards Cross, Bucks SL9 7JE
Mr. W. B. Green, 30 Chelwood Crescent, Leeds LS8 2AQ.
Mr. A. Ferguson, 8 Deeside Park, Aberdeen AB1 7PQ.
Mr. K. Gray, 24 Eden Road, Oadby, Leicester LE5 4JP.
Mr. G. Haley, 8 Sullivan Place, Waldringfield, Woodbridge, Suffolk IP12 4QT.
Mr. G. King, 40 Heath Gardens, Walton, Stone, Staffs ST15 OAW.
Mr. H. Turner, 44 Yoxall Avenue, Hartshill, Stoke ST4 7JH.
Mr. F. H. Saxby, 30 Highbury Road, Keyworth, Nottingham NG12 5JB.
Mr. E. L. Bubb, 51 Kingsale Road, Salcombe, Devon TQ8 8AW.
Mr. C. C. Harrison, 55 Stanley Road, Benfleet, Essex SS7 3EN.
Mr. C. Wilkins, 2 Limetree Avenue, South Benfleet, Essex SS7 5AB.
Mr. F. K. Marshall, 11 Wells Park Road, London SE26 6JQ
Mr. F. Newton, 134 Westwick Crescent, Sheffield S8 7DJ.
Mr. A. F. Simpson, 27 The Layne, Elmer Sands, Middleton-on-Sea, Bognor Regis, West Sussex PO22 6JL.
Mr. A. F. Bareham, 47 Elthorne Park Road, Hanwell, London W7 2JB.
Mr. S. E. Freere, 70 School Lane, Solihull, West Midlands B91 2NL.
Mr. R. E. King, 90 Manor House Lane, South Yardley, Birmingham B26 1PR.
Mr. F. C. Salter, 20 Ercall Lane, Telford, Shropshire TF1 2DY.
Mr. S. Bates, 55 Blossomfield Road, Solihull, West Midlands B91 1ND.
Mr. W. E. G. Harris, 3 Carmen Avenue, Shrewsbury SY2 5NP.
Mr. A. L. Goodrick, 7 Crossfield Drive, Swinton, Manchester M27 3TN.
Mr. J. D. Armitage, 4 Fairwood Road, Llandaff, Cardiff CF5 3QT.
Mr. A. W. Jones, 14 Elm Close, Newquay, Cornwall TR7 2LN.
Mr. A. H. Elkins, 30 Eastleigh Road, Barnehurst, Bexleyheath, Kent DA7 6LV.
Mr. G. R. Brown, 12 Lynthorpe Grove, Fulwell, Sunderland SR6 9HH.
Mr. H. P. Greenwood, 17 Imber Drive, Christchurch, Dorset BH23 5BE.
Mr. J. T. Ingle, Gore Lane Farm, Alderley Edge, Cheshire SK9 7SP.
Mr. G. H. Franklin, "Stone House", West Felton, Shropshire.
Mr. J. E. Ramm, 34 Buckstone Avenue, Alwoodley, Leeds LS17 5HP.
Mr. T. Mirfin, 5 Hall Close, Dronfield Woodhouse, Sheffield S18 5ZA.
Mr. R. J. Martin, 17 Woodlands Drive, Ruishton, Taunton TA3 5JU.
Mr. N. J. S. Rutter, 23 Gerrard Crescent, Brentwood, Essex CM14 4JU.
Mr. J. Taylor, 73 Buckstone Avenue, Alwoodley, Leeds LS17 5EZ.
Mr. C. J. Macpherson, 6 House O'Hill Crescent, Edinburgh EH4 5DH.
Mr. D. C. Smith, 25 Homefield Road, Radlett, Herts.
Mr. L. F. Miller, "Silverhaze", 16 Sherwood Road, Seaford, East Sussex.
Mr. R. G. Upton, 2 Gaywood Avenue, Cheshunt, Waltham Cross, Herts.
Mr. D. W. E. Wheele, 13 Rollswood Road, Welwyn, Herts AL6 9TX.
Mr. E. R. Oakley, 27 Dickens Close, Hartley, Dartford DA3 8DP.
Mr. K. Megginson, 16 Ryndale Walk, Scarborough, N. Yorks YU12 6JU.
Mr. J. L. Middleton, 25 Amhurst Road, Manchester M14 6UR
Mr. S. J. Rawlinson, 1 Easdale Close, Bolton-le-Sand, Nr Carnforth, Lancs LA5 8LX.
Mr. M. C. Eames, 27 Woodsland Road, Hassocks, West Sussex BN6 8HG.
Mr. J. Stott, 8 Links Road, Kennington, Oxford OX1 5RX
Mr. S. Lassey, "Tresscotte", Village Street, Norwood Green, Halifax, W. Yorks HX3 8QE.
Mr. C. A. Rolfe, 25 Anglessey Close, Ashford, Middlesex TW15 2JH.
Mr. G. A. Axe, "Fairchildes", Salston Ride, Ottery St. Mary, Devon EX11 1RH.
Mr. H. E. P. Burwell, 12 Magdalen Drive, Woodbridge, Suffolk IP12 4EF.
Mr. J. D. Collingwood, "The Old House", 23 Folly Lane, Stroud, Glos.
Mr. S. Roberts, 131 Heygarth Road, Eastham, Wirral, Merseyside L62 8AL.
Mr. R. P. Sims, 22 Dobbs Lane, Kesgrave, Ipswich IP5 7PX
Mr. F. Armitage, 25 Yewdale Avenue, Barrow-in-Furness, Cumbria LA14 3PQ.
Mr. D. Goodship, "The Crest", Tockholes Road, Darwen BB3 1JY.
Mr. J. D. Renaud, 12 Church Walk, Penn Fields, Wolverhampton WV3 7BY.
Mr. R. A. Bayes, 85 Bradford Road, Menston, Ilkley W. Yorks, LS29 6BU.
Mr. H. B. Cooper, 11 St. John's Road, Stanstead, Essex CM24 8JP.
Mr. A. R. Fleming, 137 Deeside Gardens, Aberdeen AB1 7QA.
Mr. D. C. Masters, 17 Ruffetts Way, Tadworth, Surrey KT20 6AF.
Mr. R. Corbishley, 98 Wordsworth Avenue, Penarth, South Glamorgan.
Mr. G. Turner, 2 Bollans Court, Goodramgate, York YO1 2QB.
Mr. J. E. Howarth, 38 Saltdean Drive, Saltdean, Brighton BN2 8SB.
Mr. L. Atherton, 40 Armadale Road, Deane, Bolton, Lancs.
Mr. E. H. Francis, 5 Catalpa Close, Malpas Park, Newport, Gwent NP7 6JW.
Mr. R. W. Barton, 49 Cranston Park Avenue, Upminster, Essex RM14 3XD.

Members about to retire are reminded that they, too, may secure life membership of the Institution at a cost of only £3·50 (which is likely to be increased in 1982). Enquiries should be directed to their Local-Centre Secretary. Members living in or moving to an area served by a different Centre from that to which they currently belong may find it more convenient to arrange a transfer to the new Centre's membership list before retirement; this will ensure advice of local activities.

THE FEDERATION OF TELECOMMUNICATIONS ENGINEERS OF THE EUROPEAN COMMUNITY (FITCE)

Written confirmation of the latest FITCE proposals concerning IPOEE membership is still awaited.

R. E. Farr
Secretary

Notes and Comments

CONTRIBUTIONS TO THE JOURNAL

Contributions to the *POEEJ* are always welcome. In particular, the Board of Editors would like to reaffirm its desire to continue to receive contributions from Regions and Areas, and from those Headquarters departments that are traditionally modest about their work.

Anyone who feels that he or she could contribute an article (short or long) of technical, managerial or general interest to engineers in the Post Office 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*, NEP 12, Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY.

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*, NEP 12, Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY.

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 £1·30 each (including postage and packaging), for all issues from April 1974 to date, with the exception of April and October 1975 and April 1976. Copies of the April 1973 issue are also still available.

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.

ISSN

Each issue of the *Journal* carries on its spine a code known as the international standard serial number (ISSN).

ISSNs are allocated by the UK National Serials Data Centre at the British Library, and each ISSN is unique to the publication to which it is assigned. This means that ISSN 0032-5287 identifies the *POEEJ* in any language in any part of the world. The value of the ISSN is that it is particularly useful to libraries having computerized acquisition, loan, and catalogue reporting and listing systems.

A separate number, ISSN 0309-2720, is assigned to the *Supplement*, and is shown on the title page.

Associate Section Note

LUTON

The Luton centre continued its activities through the winter months, and most meetings were well attended.

The Lotus car plant at Norwich was visited by 10 members, and a family day-out to the Severn Valley railway was attended by 45 people. The visit to the Building Research Centre at Watford in October proved interesting, as various experiments were in progress; these included field trials on building materials and wind-tunnel testing of structures.

Dave Robinson gave members an interesting talk and slide presentation on the subject of Swiss railways. In November Dave Jones, in conjunction with Peter Harries, gave a talk on the theme of amateur radio. Afterwards, a presentation was made to Tom Little, who was retiring from the Post Office. (Tom was the first chairman of the Luton Centre.)

The centre's programme is already filling up for 1981, and it is hoped that this year will be as successful as the last.

PETER R. OSBORNE

Post Office Press Notices

ADVICE ON 'ILLICIT TELEPHONES'

With Government support, British Telecom is giving its customers new advice on the purchase and use of privately supplied telephone attachments. The message is 'get the best use and value out of the telephone service. Avoid the risk of buying unauthorized instruments to connect to the public network'.

The Government's British Telecommunications Bill, now before Parliament, proposes certain changes, but Mr. Peter Benton, Managing Director of British Telecom, stated in London recently 'We have a duty to tell customers that it is not the Government's intention to allow a free-for-all.'

He said 'The only equipment at present permitted is that certified by British Telecom as suitable for use as an attachment. Changes are proposed in this system, but the Government is as anxious as we are to ensure an orderly transition to the new arrangements. Regulations will still be necessary to ensure that the interests of customers are protected. Only equipment which conforms to safety and technical standards established by a Government-approved body will be permissible.'

At present, British Telecom operates a certification scheme for privately-supplied attachments. This ensures that the equipment is technically compatible with the British network; that it presents minimum risk of injuring staff or damaging the system; that it does not interfere with other customers' use of the network; and that it is correctly connected, to help in diagnosing faults. Several thousand types of attachments, available from approved suppliers, are authorized for use on the public telephone network. Since April 1980, a certification number scheme has been in operation for telephone answering machines. Certified machines carry labels bearing British Telecom's certification number; these indicate that they have passed safety and technical tests and that they are suitable for use on the British telephone system.

This year, British Telecom intends to extend the certification number scheme to other types of attachments, such as facsimile machines and intruder alarms, and, in the next three years, to all new types of attachment such as privately-supplied telephones.

In addition, British Telecom currently offers an extensive range of standard telephones, including those having push-buttons instead of dials. And there are some 30 or so decorative designs—the special range marketed by british industry but supplied and maintained by British Telecom. All have been specially designed, or modified, for use on the British telephone network.

This cannot be said of most telephone equipment now on sale in shops and department stores, despite various claims that it meets British Post Office standards. Some sales promotion does not give anything like the full story. The plain fact is that these privately supplied telephones are not certified for connexion to the nation's public telephone system.

Nearly all unauthorized telephone equipment offered for sale in the UK is made and designed for use abroad. If connected to the British network, it may not work properly. Telephones designed for overseas use are frequently insufficiently sensitive for satisfactory operation on all lines in the UK. Mains-powered equipment could be electrically unsafe.

British Telecom points out that it is not only the people who have bought and connected this equipment who suffer. The victims are more often the callers. They make calls that are ineffective because the apparatus does not respond correctly, or because it gives poor-quality reception. British Telecom has a duty to protect its customers. With the full approval of the Secretary of State, it will discharge its legal responsibilities. Where customers persist in the use of uncertified apparatus, British Telecom, regretfully, will have no alternative but to disconnect the telephone line.

CARD-IN-THE-SLOT TELEPHONES TO GO ON TRIAL

Public telephones that use plastic cards instead of coins are to be tried out this year by British Telecom. About 200 of these card-in-the-slot telephones are to go on trial in busy places like airports and mainline railway stations in London, Birmingham and Manchester. They will be sited near ordinary coin-collecting telephones in order to give users a choice of either kind. In addition to making inland calls on these card-in-the-slot telephones, users will be able to dial directly to 101 countries.

Customers will have to buy special cards, similar in shape and size to credit cards, to use the new telephones. These cards contain telephone credit units which are erased by a thermal process when the card is inserted into the card-in-the-slot telephone to pay for calls. The price of the units will be 5p, and two different value cards will be available: one of 40 units costing £2, and a double-sided card of 200 units costing £10.

Compared with coin-operated telephones, card-in-the-slot telephones have a number of advantages. The cards are a convenient light-weight alternative to coins (for example, the 200 unit card is equivalent to two hundred 5p or one hundred 10p coins), and they avoid the need for repeated insertion of coins on long-distance calls. The absence of cash makes them less attractive to criminals and vandals; by removing the need for regular visits to collect cash or clear jammed coin boxes, they enable British Telecom to make savings.

Making a call from a card-in-the-slot telephone will be easier than from the ordinary coin-operated telephone. The caller merely lifts the receiver, puts the telephone debit card in the slot provided and dials the number to connect the call in the usual way. Of course, no pay tone interrupts the initial connection; it will still be possible for a user to make 999 emergency calls free of charge from a card-in-the-slot telephone without having to insert a card.

When the card is inserted, a visual display on the telephone lights up to show the number of credit units available; this figure decreases as the call proceeds and successive units are erased from the card. With card-in-the-slot telephones (as with other telephones) the rate at which credit is used up will depend on the distance of the call (that is, whether it a local, trunk or international call) and the time of day it is made. When the credit on the card has nearly run out, the visual display starts flashing and the caller hears a warning tone in the receiver. The customer can then use up the remaining credit; the call is automatically cut off a few seconds after it has all run out, and the spent card is returned to the caller.

Alternatively, the caller can continue talking by pressing a special button on the front of the telephone; this automatically removes the remaining credit from the card, stores it in an electronic memory, returns the used card and allows the caller to insert another card (or the second side of the double-sided 200 unit card). When the handset is replaced, charging for the call stops immediately and the card, complete with any credit remaining, is returned to the caller after a few seconds.

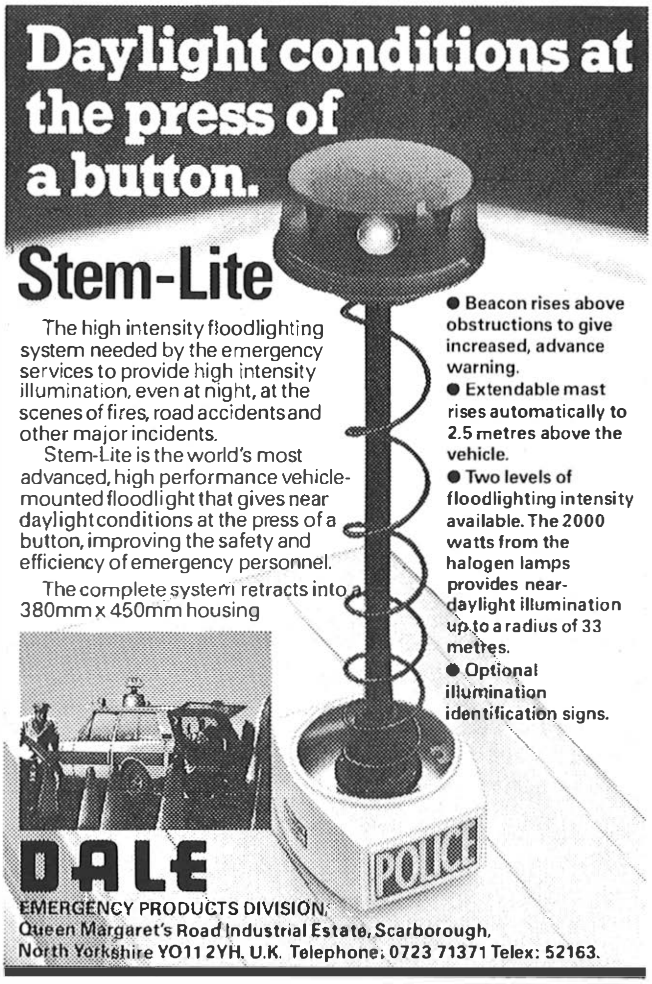
For the trial, British Telecom is planning to make cards available from various sites in the areas where card-in-the-slot telephones are installed. British Telecom hopes that these sites will include newsagents and tobacconists as well as telephone shops and post offices. Trial card-in-the-slot telephones will be supplied by the Landis and Gyr Group; they will use the Sodeco debit card incorporating holographic technology, which is based on special patterns of light, to provide a high level of security against fraud or forgery. If the trial shows that customers like card-in-the-slot telephones, British Telecom will consider the possibility of installing more of them in town locations where there are also coin-operated telephones nearby.

INDEX TO ADVERTISERS

Advertisements

Communications, advertisement copy, etc., should be addressed to Mr. N. G. Crump, The Advertisement Manager, POEEJ, Room 506D, 2–12 Gresham Street, London, EC2V 7AG (Tel: 01–357 2089).

No responsibility is accepted by the Journal for any of the private or trade advertisements included in this publication.



The Post Office Electrical Engineers' Journal

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 80p per copy (£1·30 per copy including postage and packaging); annual subscription: £5·20; Canada and the USA: $12·00.

The price to British Post Office staff is 48p per copy.

Back numbers will be supplied if available, price 80p (£1.30 including postage and packaging). At present, copies are available of all issues from April 1974 to date with the exception of the April and October 1975 and April 1976 issues.

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 £7·50, 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 enquiries relating to advertisement space reservations, copy, proofs, etc. should be addressed to Mr. N. G. Crump, The Advertisement Manager, *Post Office Electrical Engineers' Journal*, Room 506D, 2–12 Gresham Street, London EC2V 7AG (Telephone: 01-357 2089).

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

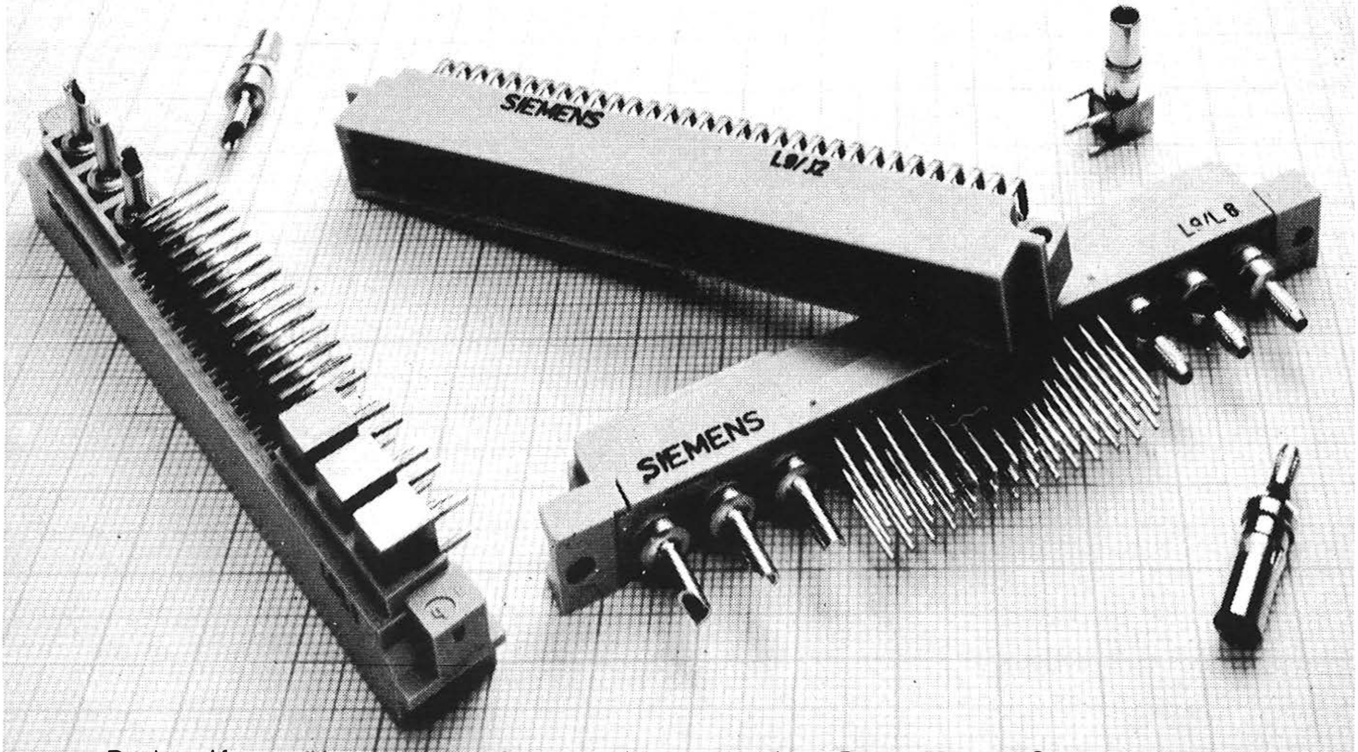
With the exceptions indicated above, all communications should be addressed to the Managing Editor, *The Post Office Electrical Engineers' Journal*, NEP12, Room 704, Lutyens House, Finsbury Circus, London EC2M 7LY (Telephone: 01-357 4313).

Model-Answer Books

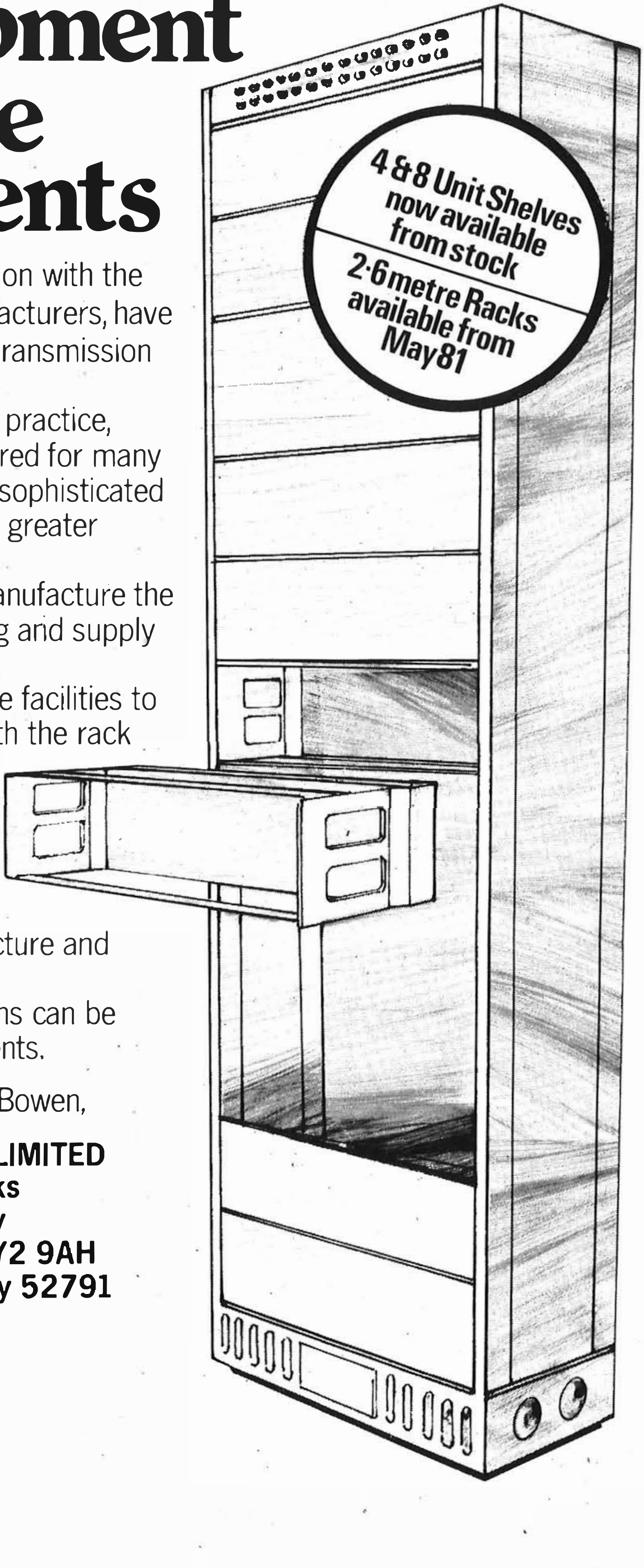
Books of model answers to certain of the City and Guilds of London Institute examinations in telecommunications are published by the Board of Editors. Copies of the syllabi and question papers are not sold by *The Post Office Electrical Engineers' Journal*, but may be purchased from the Sales Department, City and Guilds of London Institute, 76 Portland Place, London W1N 4AA.

Published by *The Post Office Electrical Engineers' Journal*, 2–12 Gresham Street, London EC2V 7AG,
and printed in Great Britain by Unwin Brothers Limited, The Gresham Press, Old Woking, Surrey


SYSTEM PAPST
MADE IN W-GERMANY
PAPST-MOTOREN KG
7742 St. Georgen



SIEMENS
L9/J2
L9/L8
SIEMENS


4 & 8 Unit Shelves now available from stock
2·6 metre Racks available from May 81