PRX

A general description of the PRX-system

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1 Introduction

The PRX computer-controlled telephone switching system is designed to operate in public telephone networks in widely varying applications ranging from simple local terminal exchanges to main transit centers, either in a large multi-exchange local or trunk network, or as a combined local and trunk exchange.
The system can be economically applied to initial traffic volumes as low as 100 erlangs, and extended to capacities of up to several thousand erlangs without major interference in the functioning of equipment already in service.
The PRX system employs high-speed glass-sealed minireed relays as crosspoints in a multi-stage linked switching network. The junctors and trunk terminating circuits consist largely of electronic components, completed by reed relays for signalling purposes. This switching network operates under the control of duplicated stored-program computers.
The computers are general purpose, process-control oriented data processors of the type TCP 18. TCP stands for Telecommunications Control Processor. They utilize fast electronic circuitry and ferrite-core memories to carry out the common-control functions associated with recognition, identification and routing of incoming calls, selection of suitable speech paths through the switching network, issuance of instructions to the network and monitoring to ensure that instructions have been properly executed, and maintenance of a continuous record of the network status.
The central control facility also performs the functions required for operation, administration and technical supervision of the exchange, including call accounting, development of traffic statistics, and automatic routine testing and display of equipment and line status information.
The system is fully compatible with existing electromechanical switching equipment, switchboards and other office apparatus, and can be installed in networks using any numbering plan and any signalling procedure. In local subscriber exchange applications, the PRX switching network is equipped for two-wire through-connections; four-wire switching networks may be installed in systems used as transit or trunk exchanges. Maintenance and administrative functions for a number of exchanges may be centralized and controlled from one location, acting as an operational and maintenance centre.

2 Block diagram

As shown in the general block diagram of Fig. 1, the system comprises four principal sections: Switching Network, Central Control Unit, Interface Equipment and Utility Equipment. Also shown are a Control Channel and a Data Channel, which permit the transfer of information between the central control equipment and the peripheral subsystems.

2.1 Switching Network

The heart of the switching network is a trunk-link network consisting of a six stage linked network composed of identical three-stage expanding and concentrating Trunk-link Blocks TB-A and TB-B.

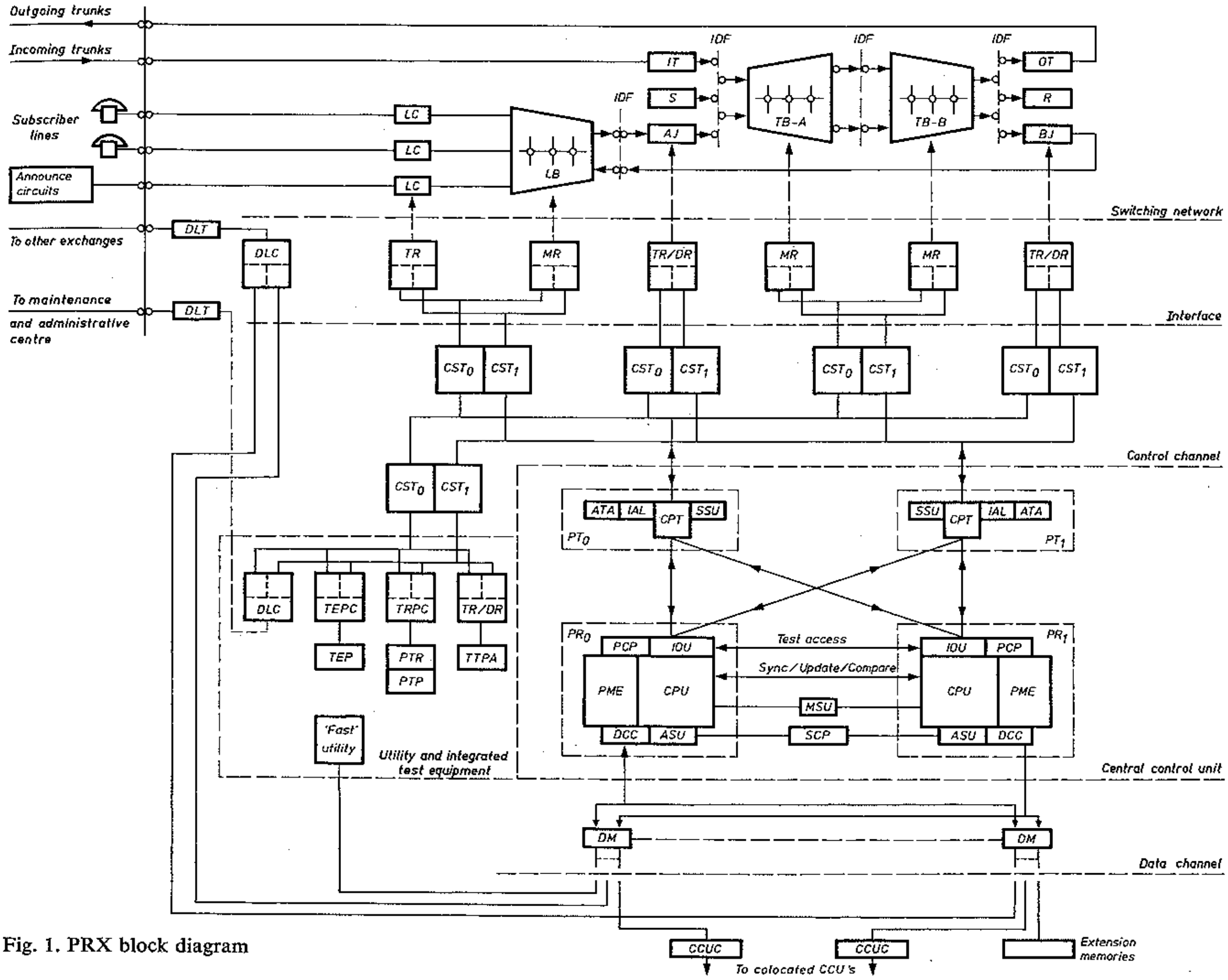


Fig. 1. PRX block diagram

The A-junctors AJ for originating subscriber line traffic and the Incoming Trunk-circuits IT are connected to TB-A, the B-junctors BJ for terminating subscriber line traffic and the Outgoing Trunk-circuits OT are connected to TB-B.

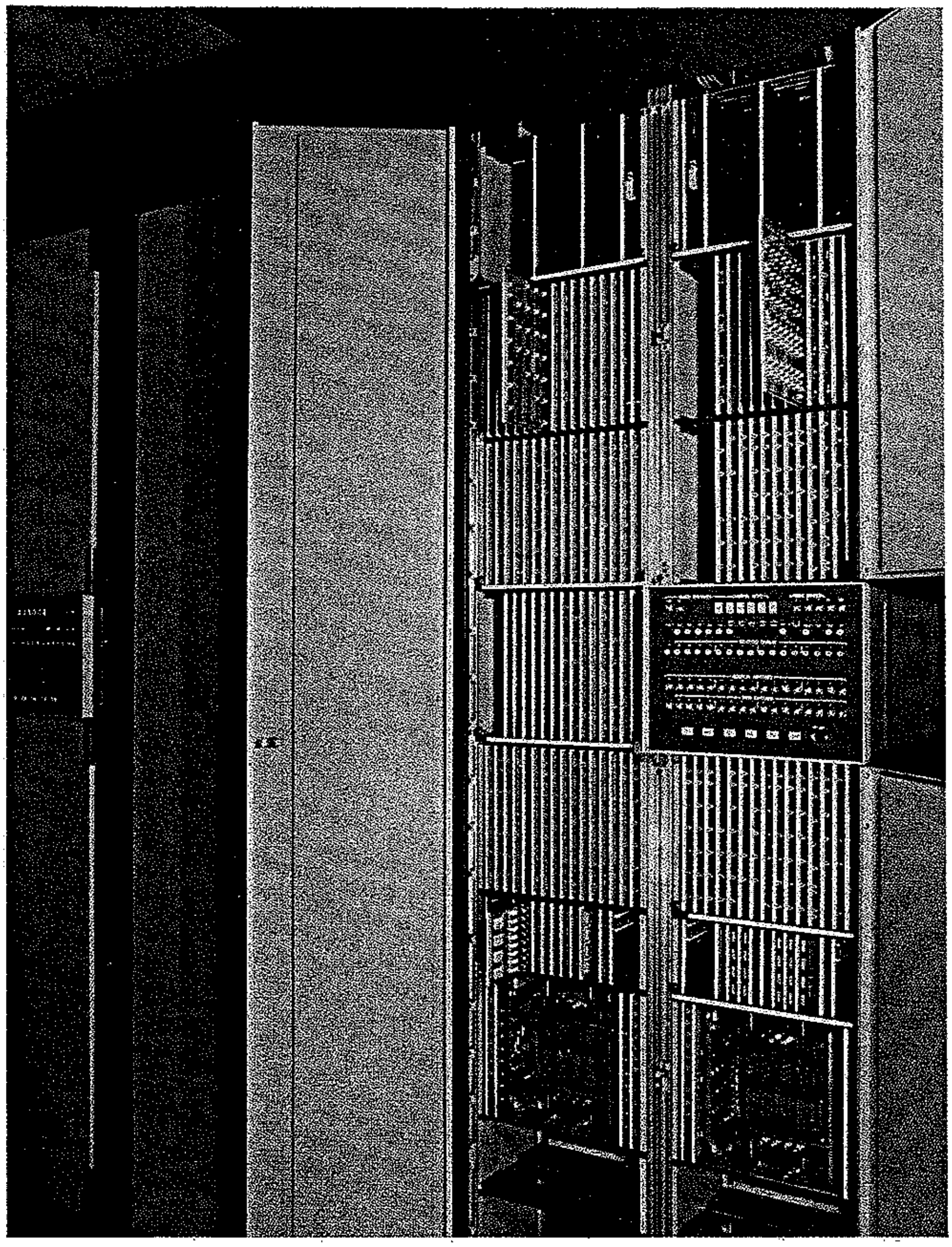
The subscribers lines are connected to the A and B junctors through three stage linked Line-Link Blocks LB. The reduction factors of these line-link blocks depend upon the traffic offered on the subscriber lines, so that a good traffic efficiency on the A and B junctors is obtained. The traffic flow through the line-link blocks is therefore bidirectional. Ordinary subscribers and PABX lines can be arbitrarily mixed on the subscriber line side. If required, heavily loaded PABX lines with unidirectional traffic can be connected directly to the trunk-link blocks. This switching network arrangement makes the configuration independent of the relative distribution between originating terminating, and transit traffic, and improves the traffic overload properties of the system.

Senders and receivers are used for in-band signalling, such as MFC, keytone dialling, PABX direct inward dialling, etc. These devices are only required temporarily during the setting-up of a call. To obviate the need for inflexible and inefficiently used separate connecting stages, they are connected to the trunk-link blocks in the same way as trunks and junctors.

Switching matrices

The switching stages in the line-link and trunk-link blocks comprise switching matrices in a modular fashion.
For local exchanges three-contact reed-relays are used for the crosspoints. Two contacts are used for the switching of the two-wire speech paths, a third contact per crosspoint is used during the marking process and to convey the holding current for the relays, which are held in series within each three stage switching block. This third

Fig. 2. PRX cabinet



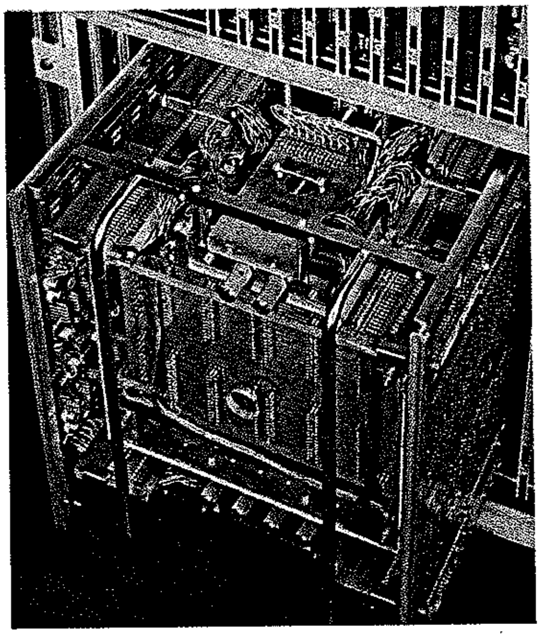


Fig. 3
Processor core memory module

wire, however, terminates at the first and third switching stages of each block. Outside the blocks all the interconnections from the switching blocks to the junctors, senders and receivers, and between the TB-A and TB-B are made with only two wires.
The setting up and release of connections in the switching blocks are effected exclusively by the markers; the junctors and trunk terminating circuits do not have a function in this matter.
The network layout, the free/busy /out-of-service states of all devices and links, and their current interrelationships, are contained in a system status map, which is stored in the core memory of the central control unit. This permits fully independent operation of the various parts of the switching network and, through this 'vertical' control procedure, a great flexibility in call processing.
The switching matrices are constructed on plug-in printed board crosspoint units of the size of 8×8 relays. One plug-in unit comprises either one 8×8, two 8×4 or four 4×4 matrices. By connecting units in parallel, other sizes e.g. 8×16 may be obtained.
Where four-wire trunk circuits terminate on the trunk link blocks and four-wire through-connection of these circuits is required, use can be made of five-contact reed-relays in the corresponding trunk link blocks. Hybrids can be interlaced between the four-wire and two-wire parts of the TB-A and TB-B blocks.

Data links

The Data Link Terminals (DLT) shown in Fig. 1 are used for common channel signalling to and from other exchanges, e.g. using the CCITT No. 6 system, and for the transfer of data to and from the remote maintenance or administrative centre. These data links are generally of the half- or full-duplex type, with transfer rates ranging from 200 to 2400 bands.

2.2 CCU Functions

All functions to be performed in the switching network for the establishment, supervision and release of connections are fully controlled by the Central Control Unit (CCU, see Fig. 1). Each CCU contains two parallel operating Central Processing Units (CPU) with their associated Processor core MEmories (PME, Fig. 3), which store the operational

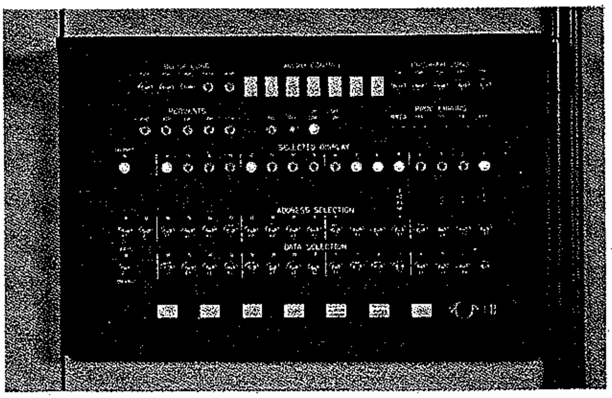


Fig. 4. Processor control panel

software programs as well as the data concerned. The functions of the CCU can be divided into four categories.

a The main task of the CCU is to control and schedule the switching functions. This involves, typically:

- investigating whether new signals arrive over the subscriber line, trunk and junctor circuits, etc. It does so by initiating an autonomous Input/Output Unit (IOU) at regular intervals to scan the test points in the switching network,
- processing the scan information and deciding upon actions to be taken, also considering information received from data links or other utility equipment connected to the CCU's,
- initiating the establishment of new connections in the line-link and trunk-link network, or releasing existing ones, by sending the required commands to the markers. Moreover, to send signals over the trunks or subscriber lines, by giving the required commands to the drivers in the trunk or junctor circuits; and finally, to send the required information to the data-link multiplexers, if common-channel signalling is applied,

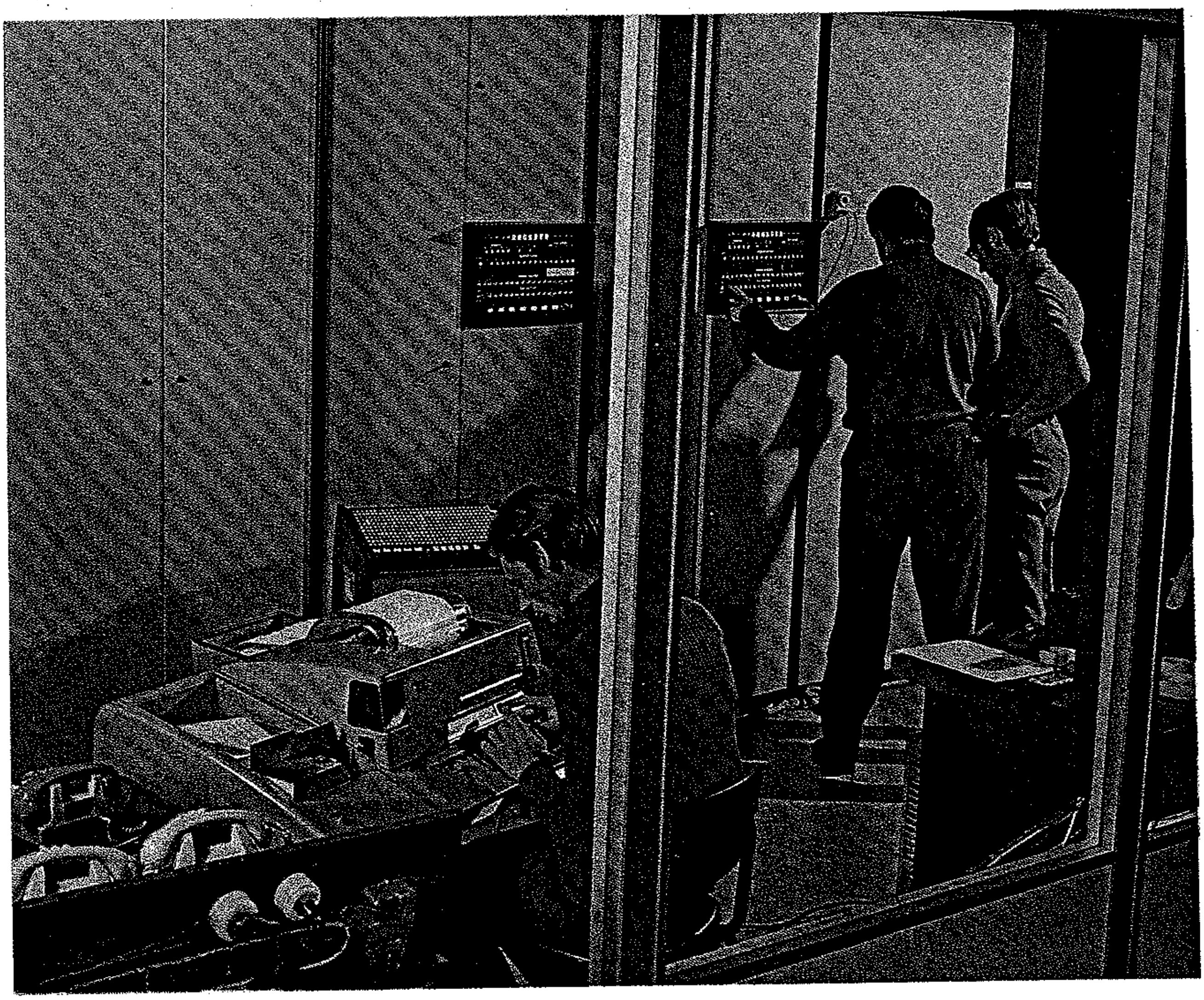
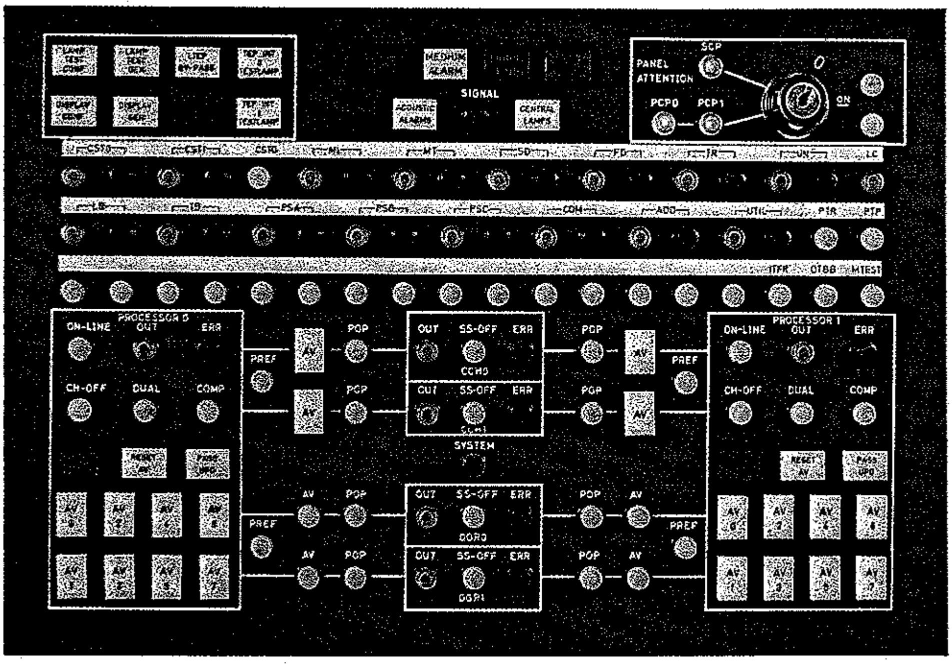


Fig. 5. Access devices to PRX: teleprinter and test panels

Fig. 6. System control panel



– registrating and updating the free/busy, in/out of service condition of all call-carrying and service elements in the exchange.

b A second task of the CCU is to control the system configuration. As for reliability reasons major system parts are duplicated and less important parts are sectionalized, various operational configurations are made possible within the system while in operation. Since there are alternative data highways between the processors and the periphery, a number of patterns can be formed between active and passive devices. The major task of configuration control is to monitor continuously by adequate software and hardware provisions the correct operation of the system hardware, and to take corrective isolation measures automatically if a fault is detected.

c A third function is to provide access to the system, in conjunction with the utility and test equipment. Access to the system is required for modifications in the exchange and service parameters in the memory, and, for maintenance purposes, to the hardware at different system levels. Access facilities include control panels, teletype and tape readers (Figs 4, 5 and 6) and test panel (TTPA, Fig. 7). These will be discussed in the following chapters.

d Finally, the CCU has to perform a number of monitor functions, such as traffic measurements, and a number of retrieval functions such as subscriber metering and other data read-outs. In general these functions are performed by overlay programs which are loaded on demand via the same utility equipment already described.

On-line control

To exercise this 'on-line' control of the switching network, a CCU is designed to execute any of the above mentioned functions in specified time-intervals, distinguishing different priority levels.
It is obvious that there is a limit to a CCU's capacity, not only determined by the number of subscribers and trunks, but also by the quantity of traffic offered. If the

limit is exceeded the load has to be divided over more CCU's in a multicontrol configuration which will be described below.
In cases of temporary overload, service reduction strategies take care of sensible degradation and fast recovery after the peak.

2.3 CCU layout

The central control unit, as mentioned, includes two-real time PRocessors (PR, see Fig. 1), each comprising a Central Processing Unit (CPU), an Input/Output Unit (IOU) and a Processor core MEmory (PME).
Moreover, each CCU includes two Processor Terminals (PT) for the transfer and distribution of information to and from the switching network via control channel and interface. Each PT comprises a Control channel Processor Terminal (CPT), an Interrupt ALlotter (IAL), an Autonomous Transfer Allotter (ATA) and a Subsystem Switching Unit (SSU).
In multi-control offices, or in case of common channel signalling, two Data Channel Controls (DCC) are included for access to the other CCU's and to the data links involved.
The two processors operate instruction-synchronously in a dual mode, and are continuously compared for proper performance. The configuration is governed automatically by a program-controlled Alarm and Switchover Unit (ASU), and manually by the System Control Panel (SCP, Fig. 6).
Interrupt allotters determine the relative priorities of simultaneous interrupt requests. Groups of interrupts are each masked by a register which is set by the program in accordance with its software priority. The ATA allots requests for the autonomous transfer of data to the memory.

Central processor unit

The central processor TCP 18 unit is a binary single-address machine with a word and instruction length of 16 bits; it has six program-accessible registers. The general-purpose instruction package comprises 26 memory-reference and 54 control, transfer and logic instructions. Address modification and indirect-addressing is specified per instruction, and full addressability of the memory is obtained by relocating the 8-bit address field of the instruction using the contents of an 18-bit relocation register, which is loaded per program module. Interrupts, autonomous transports and scan results received via the input/output unit have hardware priority over instructions. A program hesitation technique is used, in which the processor control decides after each completed instruction which operation will be executed next. The data channels have memory access priority over the central processor, and operate using the cycle-stealing principle. A crystal-controlled processor clock provides

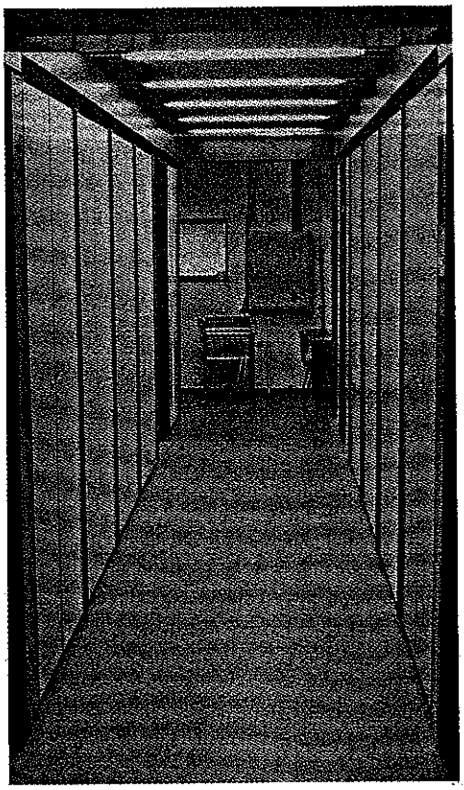


Fig. 7. Cabinet aisle of PRX
In the background the transportable test panel (TTPA) is shown

16 time slots with an interval of 110 nanoseconds. Moreover, each central processor unit is equipped with a real-time clock which is used to schedule the autonomous scan procedure in accordance with the real-time requirements of the telephone equipment, to measure the recognition time of signalling systems, to guard the operation time of slow subsystems such as markers and drivers, etc. The basic clock period is 12.5 milliseconds, which can be halved or doubled by means of strapping.

Processor core memory

Each central processor has its own core memory (Fig. 3) which is used unstratified for program and data; a write-protect bit in each word is used to prevent mutilation of program or fixed data. In addition, hardware-protected memory areas are reserved for data channel transports and special programs such as bootstrap, etc.
The core memory capacity is extensible to a maximum of 16 modules of 16 384 words each. A module contains a stack of ferrite-core matrices driven in a coincident-current mode with a common current source, which allows a dissipation as low as 60 watts. The access time to any word in memory is 600 nanoseconds, and a full read/write cycle requires 2 microseconds. Interaction of the memory with the central processor unit is asynchronous, and is controlled by the processor stop clock facility.

Input/output unit

The input/output unit permits asynchronous co-operation between the central processor unit and the interface equipment, and is to some extent independent of its associated central processor unit. It contains six registers, three of which are used to store data required for the autonomous scan procedure which determines the current status of the exchange. The test points in subscriber line circuits and junctors are arranged in groups of 16 which are scanned in a parallel mode. The scanning is not performed by program to prevent the processor loading from becoming very high to yield only a small amount of status changes. The procedure is a program-initiated hardware subroutine which autonomously increments the current memory address and seizes the appropriate registers of the central processor to perform compare, load and store functions at the moment the new status of the test points in the switching network is received. At the end of each autonomous scan cycle the collected logical differences ('events') are processed by program.
Approximately the same procedure is used in the case of autonomous data transports via the control channel.
A test-access connection between the dual processors is provided, through which a faulty processor can be investigated by means of diagnostic programs in the on-line machine.

Control channel

The Control CHannel (CCH) connects the CCU to the interface equipment. This channel is designed for general use and bridges long distances within the exchange at a basic speed of about 200 000 words per second, despite the relatively high-noise environment of a typical existing electromechanical telephone exchange. The transformer-coupled twisted-pair bus system comprises 8 address lines and 16 data lines outgoing from the CCU, and 16 data lines incoming, in addition to parity and control lines.

2.4 Interface equipment

The interface between the central control unit and the switching network consists of a group of standard control devices: testers, markers and drivers, described below, and the Control channel Subsystem Terminals (CST). The CSTs are connected by a duplicated bus-system to the Control channel Processor Terminal CPT in the cen-

tral control units (Fig. 1).
The control devices consist of a common sectionalized matrix and duplicated controls. A number of these controls are connected in a duplicated manner to a pair of CSTs, which act as a two-way connection to the control channels.
The matrices of all the interface subsystems are housed in the same cabinets as the equipment to be controlled, which reduces installation wiring substantially. The controls, including the common bus terminals, are common to up to four cabinets, and are connected via connector-terminated cables.
The switching network controls include Testers (TR), Drivers (DR) and Markers (MR). These are briefly described below, with reference to Fig. 1.

Tester

The tester function is used to detect changes of state on subscriber circuits and on units such as incoming and outgoing trunk circuits, originating and terminating junctors, and signalling units. The signals received in those circuits are first integrated and then offered as valid signals to the tester.
The individual test points are resistor-capacitor gates, and are arranged in a matrix of up to 64 words of 16 points, which can be fully addressed by interrogation instructions from the central processor unit.
The test result is transferred to the processor, and is either used as a 'last look' condition during call processing or, if it is associated with a scan procedure, is compared with the previous state stored in the processor core memory. The test rate and sequence are determined by the central control unit; the response time of the tester is of the order of microseconds.

Driver

The drivers are signal distributors which deliver line signals to the junctors, trunk circuits and signalling units in response to commands from the central control unit. Under stringent real-time conditions, a fast driver is used to operate and release reed relays or flip-flops in peripheral units. The fast driver consists of a matrix of up to 64 half-words, each comprising 8 flip-flops. These flip-flops can be controlled individually or in groups by set and reset instructions, which have an operating time equal to that of the tester.
For reasons of economy, non-time-critical points in the switching network are served by a slow driver controlling reed relay matrices to access the peripheral relay sets. Since the reaction time is generally incompatible with the speed of the central processor, the drivers contain buffer circuits which store commands and permit the processor to proceed to other functions. The overall operating time required to set or reset a relay is less than 8 ms, including the time needed for checks. A maximum of 8192 points may be served by a slow driver.

Marker

The markers establish paths through the switching network by actuating the appropriate reed relays on the basis of commands from the central control unit. The markers are basically slow drivers, operating three relays in series; they have no decision-making capability, since the free-path selection is done by the central control unit. Reed-relay matrices provide access to the outlets and multipled vertical control wires of the speech-path network, via which the crosspoint relays are operated and checked stage-for-stage in a coincidence configuration. The operating time for establishment of a connection, or release of a standing connection, is less than 12 ms. A marker can handle up to 4096 subscriber lines or 1024 trunks.

2.5
Utility equipment

To operate the PRX system a group of special equipment is provided which permits man/machine communication for operational and maintenance purposes. Utility equipment can be situated locally at the exchange site; part of it may be located at a distance and connected to the exchange by data links.

The local part comprises the 'slow' utility equipment: teleprinter TEP, low-speed paper tape punch and reader, an optional high-speed Paper Tape Punch (PTP) and reader (PTR) or compact magnetic tape unit, used to load non-resident overlaid programs, and to retrieve bulk data, and finally a Transportable Test PAnel TTPA (Fig. 7) which permits manual testing of the switching network and the interface equipment. Moreover, the local part contains a System Control and display Panel SCP (Fig. 6), for supervisory purposes and manual overriding of the system configuration. This panel, as well as the usual Processor Control and display Panel (PCP, Fig. 4) are

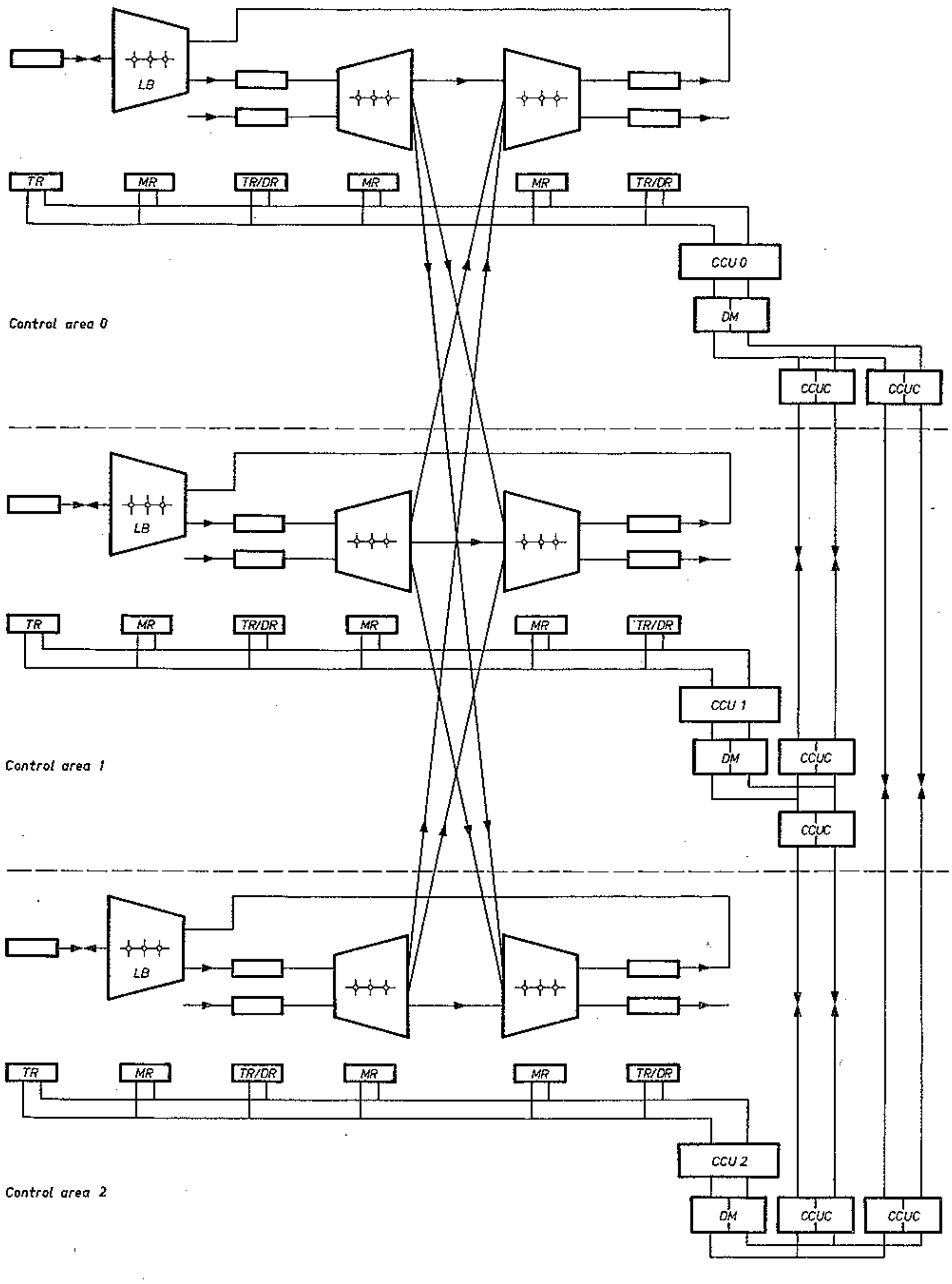


Fig. 8. Connection of co-located central control units

located conveniently on cabinet fronts.
This group of equipment is connected to the system through the bussystem and separate CST's as described above.
Fast utility equipment can be connected via the data channel terminals of the CCU's. In an off-line configuration it is used for program development (assembly, debugging, etc.) or system test or simulation purposes, and may include magnetic tape units, line printers and other high-speed peripheral equipment. Optional extension memory capacity, for instance a magnetic disc subsystem may be used in an on-line configuration in a large exchange when such subscriber data for optional subscriber services as abbreviated dialling, directory lists, etc., exceeds the storage capacity of the CCU core memory and the frequency of its use is low.

3 The multi-central control concept

During its lifetime a public telephone exchange will grow to many times its initial capacity. The PRX system permits virtually unlimited expansion of the switching network. If the capacity of a single central control unit is exceeded, more CCU's can be incorporated in a multi-central control configuration.
From the switching point of view, the overall system will then be subdivided into a number of control areas (Fig. 8). In this configuration each CCU with its own memories, will control its allocated part of the switching network as a self-contained exchange, in the way a smaller exchange is controlled by its single CCU. Hence a CCU has no access to, or responsibility for, those parts of the switching network controlled by other CCU's. Information related to the build-up, supervision and release phases of a call to be handled by two CCU's is transferred over a high-speed internal parallel data link between their data channels. The links are arranged on a point-to-point basis between CCU's, being connected in each case via a Central Control Unit Coupler CCUC and a Data Multiplexer DM. The control messages between CCU's contain basically the same types of telephone events and directives as used in the data traffic between distant PRX exchanges (CCITT No. 6 or other common-channel signalling systems).
The use of a standard format for the messages transmitted between the CCU's, the absence of special error correction procedures which would be required on external data links, and the speed with which the parallel internal data links can operate, reduce the increase in processor loading in this multicentral control arrangement to less than 10%, independent of the number of CCU's involved.