ERICSSON REVIEW

2 1981

ERICSSON REVIEW

NUMBER 2 · 1981 · VOLUME 58

RESPONSIBLE PUBLISHER GÖSTA LINDBERG

EDITOR GÖSTA NEOVIUS

EDITORIAL STAFF FOLKE BERG

DISTRIBUTION GUSTAF O. DOUGLAS

ADDRESS S-126 25 STOCKHOLM, SWEDEN

SUBSCRIPTION ONE YEAR $12.00 ONE COPY $3.00

PUBLISHED IN SWEDISH, ENGLISH, FRENCH AND SPANISH WITH FOUR ISSUES PER YEAR

Contents

COVER
Inspection of silicon discs for monolithic circuits. An intense, yellow light is used which makes it easier to spot any defects

Manufacture of Monolithic Circuits

Ulf Jerndal and Eva Novak

This article describes the manufacture of monolithic integrated circuits at RIFA, the Swedish components manufacturer in the Ericsson Group. The most important procedures are described with the aid of a flow chart and the requirements regarding the work environment are discussed. The construction of the RIFA factory at Kista, near Stockholm, is described briefly, with regard to the stringent requirements concerning ventilation and the gas and water supplies. Finally the production yield is considered, and also the methods used to control and check the production.

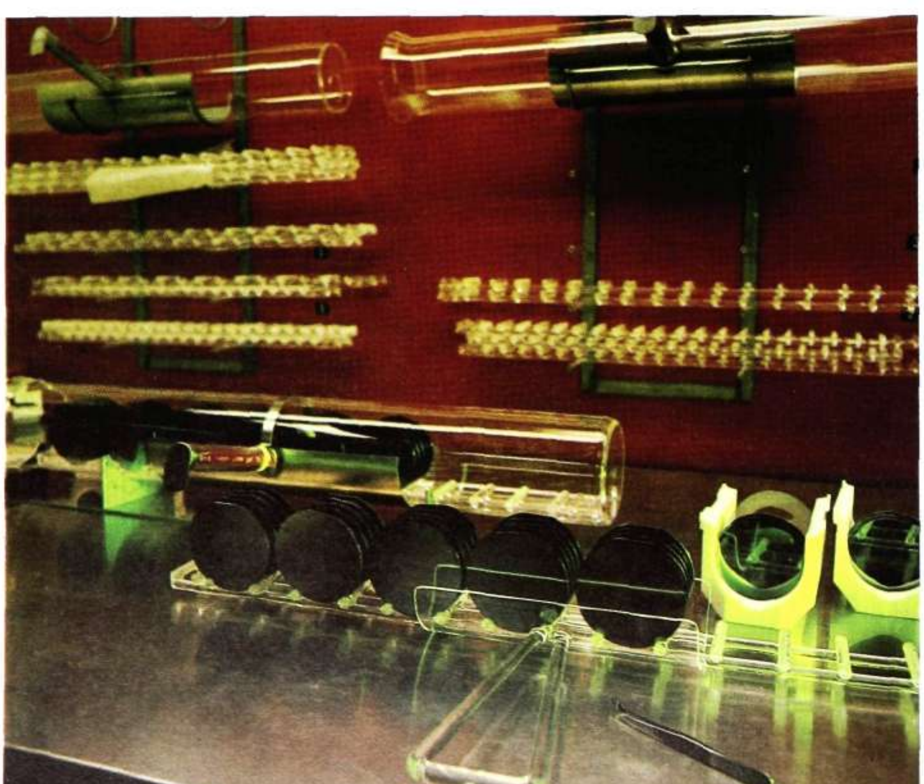
UDC 621.3.049.774:
658.51

The build-up of the major types of micro circuits has been described in a previous article in Ericsson Review[1]. This article describes the manufacture of bipolar micro circuits in the RIFA factory at Kista, near Stockholm. Several different basic types are manufactured, and the production processes and number of stages vary. The flow chart of fig. 2 describes one such process.

Production process

The production of monolithic circuits comprises a large number of process stages, all of which require extreme accuracy and cleanliness. Batches of about 20 wafers are processed in each stage. All micro circuits, both bipolar and MOS circuits, are manufactured in similar processes. Details in the production process, the number of stages and their internal order are varied so as to obtain the structure that characterizes the desired type of circuit.

Fig. 1
Loading wafers for oxidizing



Basic material, dopants and impurities
The basic material for the manufacture of circuits is discs of silicon, wafers or substrates, which are approximately 0.3 mm thick and have a diameter of 75 mm. The discs are sliced off a single crystal rod at exactly specified angles in relation to the crystal axes, and are highly polished. The silicon is very pure but small quantities of dopants are added.

The dopants are elements from group 3 or 5 in the periodic table, whose presence in silicon in very small proportions drastically changes its conductivity. Some common dopants that give n-conductivity (surplus of electrons) are antimony, arsenic and phosphorus. The most comon dopant for p-conductivity (deficiency of electrons, hole conductivity) is boron. Substrates for bipolar circuits are usually p-conductive, with a conductivity of 10 ohmcm, corresponding to 10^{14} boron atoms/cm^3 (0.001 ppm).

All process stages require extreme cleanliness and careful checking that no impurities are present. For example, heavy metals, even in very low concentrations, constitute traps for electrons and holes and have an undesirable effect on the electrical conductivity of the silicon. Similarly, sodium, a common impurity in most chemicals, is harmful to the silicon oxide. The manufacturing process therefore requires very pure chemicals. Almost all process stages are preceded by a cleaning stage. Such cleaning is adapted to the subsequent process stage and can consist of mechanical cleaning and etching in different acids. The cleaning usually finishes with a thorough rinsing in deionized water. All air and water supply is controlled, and the air and water is cleaned so that no impurities are introduced.

Oxidation
The cleaned silicon wafers are oxidized by heating to approximately 1000°C in an atomosphere of nitrogen, oxygen and water vapour. Careful control of time and the composition of the at-

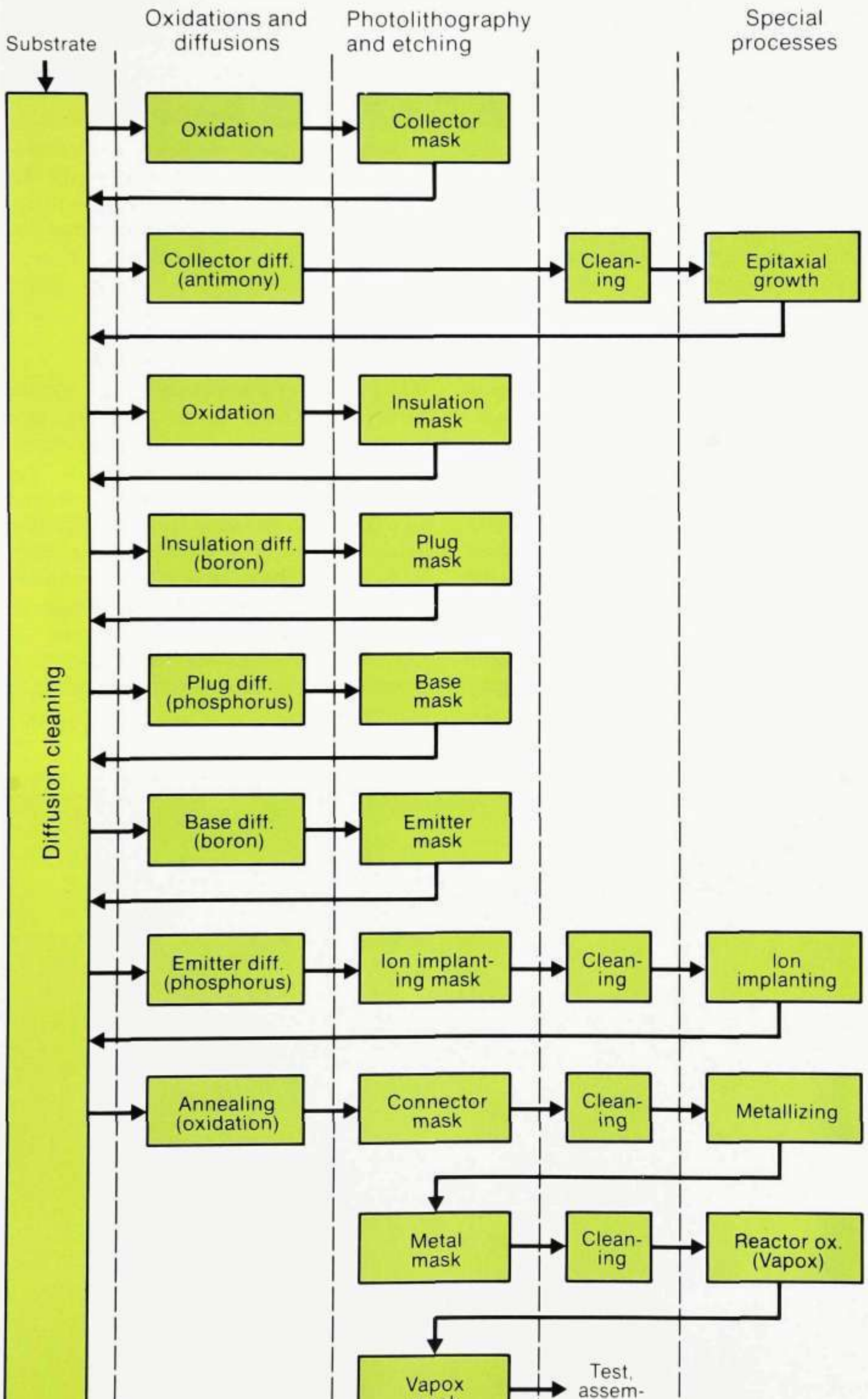
ULF JERNDAL
EVA NOVAK
AB RIFA

mosphere gives the desired oxide thickness, approximately 1±0.05 μm, fig. 1.

Photolithography

The various elements in monolithic circuits are very small, down to a few μm, and have dimension tolerances of the magnitude ±1 μm. The circuit pattern is defined and reproduced photographically. The circuit layouts for the different process stages are prepared with the aid of a computer and are transferred to masks, glass plates, which look like photographic negatives. The glass plates, which are first coated with a thin chrome layer, are then covered with a light-sensitive organic material called a photo-resist. A step camera, which can be programmed so that the glass plate is moved in exact steps, is then used to project a greatly reduced picture of the circuit layout on to the glass plate by means of ultraviolet light. When the plate is developed the photo-resist is removed from the exposed parts. The chrome layer is then etched away from these parts.

In a similar way the photomask pattern is transferred to the oxidized silicon wafer, which is first covered with a layer of photo-resist approximately 1 μm thick, fig. 3. The mask is copied on to the wafer in a contact or a projection pattern aligner using ultraviolet light. The wafer is then developed and etched. The manufacture of a bipolar circuit requires 8–11 photolithographic stages with the intermediate processes for treating the wafer. The accuracy in positioning any mask when copying it on the wafer is ±1μm in relation to the oxide openings from earlier mask stages. The pattern in the photo-resist is therefore checked in a microscope before it is etched out. Extreme cleanliness is also required. Above all there must be no dust particles. The photo-resist work is therefore carried out in a special room, called the yellow room, with very carefully filtered air, which is taken to the work position in a laminar flow.



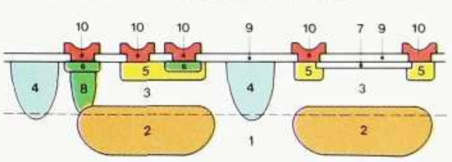
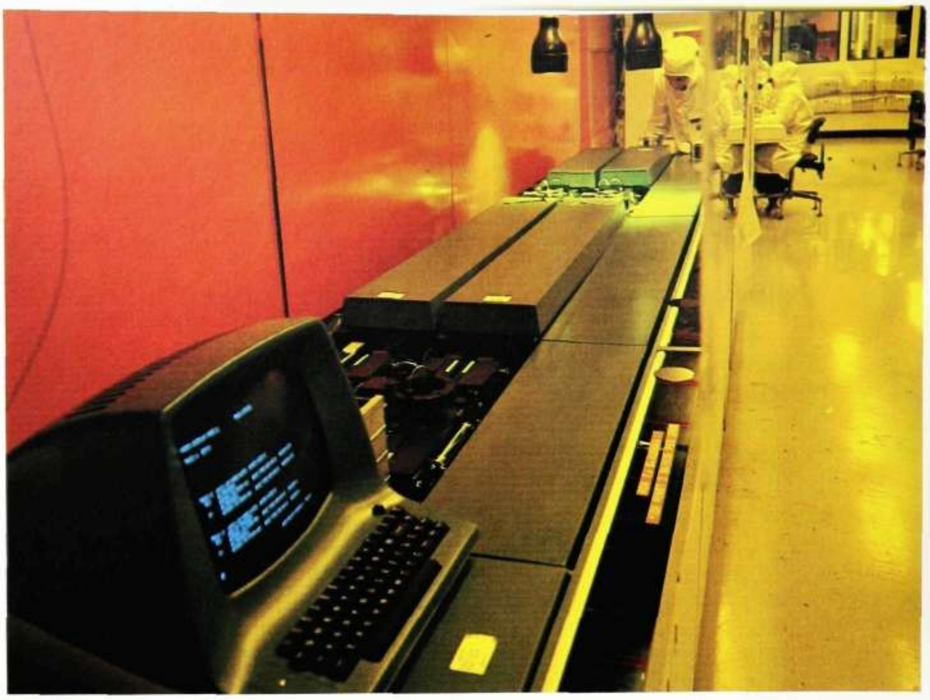


Fig. 2
A flow chart for the manufacture of a monolithic circuit

1. Substrate
2. Collector
3. Epitaxial layer
4. Insulation
5. Base
6. Emitter
7. Ion implanting
8. Plug
9. Oxide
10. Metal

Fig. 3
Equipment for applying photo-resist. At the rear a pattern aligner



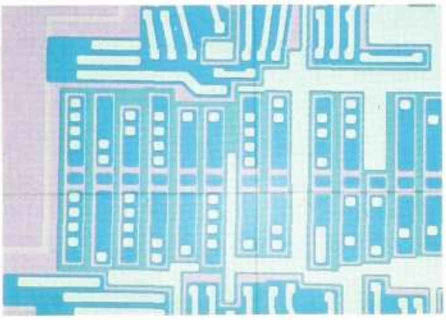


Fig. 4
Detail of a monolithic wafer after parts of the oxide layer have been etched off

Etching

Etched openings in the layer determine where the silicon surface will be conditioned in the different process stages, fig. 4. The oxide is fairly resistant to penetration (*diffusion*) by *dopants*. The openings in the oxide are etched out with hydrofluoric acid, whereas metals for conductor patterns are etched with other liquids. Dry etching methods have also been developed recently in which electric gas discharges at low pressure are used.

Diffusion

Dopants are usually introduced into the silicon by means of diffusion. The manufacture of bipolar circuits comprises 4–5 different diffusion stages, with different concentrations and types of dopants, and diffusions are made to different depths in the exposed areas. All diffusions are carried out in a similar way. First the dopant is deposited in the etched openings on the silicon. This is done by heating the wafers to about 1000°C *in a tube type furnace* with a gas mixture of nitrogen, oxygen and a gaseous dopant, fig. 5. The actual diffusion takes place at a temperature of 1000–1200°C, at which temperature the dopant penetrates the silicon to the desired depth, varying from 1 to 25 μm. The gas mixture in the oven is then changed so that a new oxide is formed over the oxide-free surfaces, ready for the next mask stage. The diffusion processes require careful control of time, temperature (± 2°C) and gas concentrations. Normally an accuracy for depth and conductivity of approximately 10% is achieved.

Fig. 5
Diffusion ovens in the RIFA factory

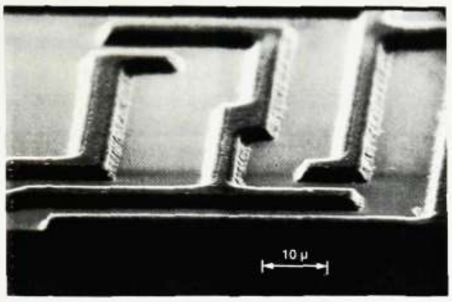
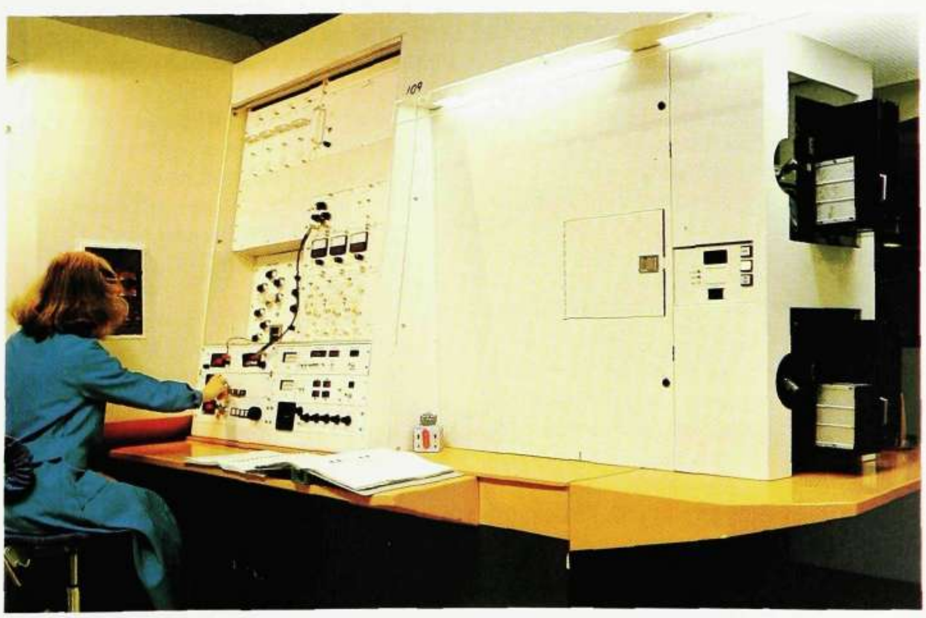


Fig. 7
Detail of an etched aluminium conductor pattern

Fig. 6
Equipment for ion implanting



Ion implanting

Alternatively the dopant can be introduced in the silicon by means of ion implanting instead of diffusion. The dopant is then gaseous in partial vacuum, and the atoms are ionized and accelerated in an electric and magnetic field and hit the silicon wafer, fig. 6. Since each ion has a certain electric charge it is possible to determine the exact dose of dopant by measuring the electric current of dopant ions. The field strength can also be adjusted accurately so that the ion energy can be regulated to a value within the range 10–200 keV. The depth of penetration into the silicon can be determined in this way. Normally an accuracy for conductivity of approximately 3% can be achieved with this method. RIFA uses ion implantation, for example, for manufacturing resistors and field effect transistors.

Epitaxial growth

By epitaxial growth is meant chemical deposition of molecular layers, for example of silicon on a silicon wafer, in the same crystal structure as the original substrate. Thus a new layer of silicon is built up, for example on npn transistors after the collectors have been made by means of diffusion. The unoxidized silicon wafers are heated to about 1200°C in the epitaxial reactor and are exposed to flowing gas composed of hydrogen and, for example, silicontetrachloride. The gaseous silicon compound decomposes on the silicon surface and new silicon molecules are deposited on the wafer. The growth rate is approximately 1 µm/minute. The type and degree of conductivity of the new silicon is controlled by the addition off gaseous dopants. The process is very sensitive to impurities both on the wafer surface and in the gases.

Reactor oxidizing

Whereas oxidation is used to coat open silicon surfaces after a process, reactor oxidizing is used, for example, to cover the completed circuit with a protective layer before it is encapsulated. The method, which is related to epitaxial growth, can also be used in other process stages. The gaseous silicon compound SiH_4 is dissolved at about 500°C in an oxidizing atomsphere. Silicon oxide is then formed and is deposited on the circuit. The oxide usually contains phosphor.

Metallizing

The monolithic circuit is coated with metallic layers, in which the connection pattern is etched out, partly in order to connect together the various circuit elements, fig. 7. The thickness of the metallic layers varies between 0.05 and 1.5 µm. The layers are applied by means of either cathodic evaporation or vacuum vaporization. The connection patterns are usually made of aluminium, but gold can also be used. Aluminium is vacuum vaporized to a thickness of about 1 µm. Other metals are used in thinner layers, platinum in the making of Schottky diodes and titanium as a separation layer to prevent the aluminium and silicon from forming an alloy.

Process testing

The microcircuit manufacturing processes are sensitive and the desired tolerances are close to the limits of what is technically possible. It is therefore necessary to carry out tests after almost every process stage. The process testing usually consists of measuring the physical or electrical characteristics of a special test wafer or an individual test circuit on a wafer. Some characteristics that are checked are the thickness of the oxide layers, the thickness and resistivity of the epitaxial layers, the resistivity of the diffused layers, the dimensions of the etched patterns, the quality of the metal layer and the param-

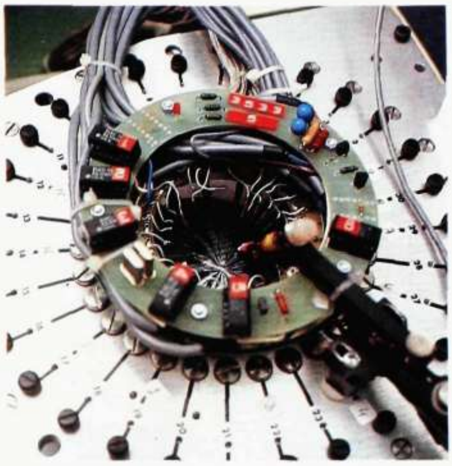


Fig. 8
Detail of a test station

Fig. 9
A supply floor in the factory

eters of the test transistors. The results of the process testing are necessary to obtain the optimum settings for the various process stages.

Wafer testing, assembly, final testing
A silicon wafer contains 200–2000 identical integrated circuits, future chips. A certain proportion of them are acceptable. Since the subsequent mounting and encapsulation is costly, all ICs must be tested before the wafer is cut up. Stored program controlled test equipment is used to carry out mesurements at the test points on the ICs, fig. 8. A few hundred measurements is a typical number, and the total test time per circuit is between 0.5 and 2 seconds.

After microscope inspection the wafers are packed and sent for encapsulation. The encapsulation is carried out in factories in the Far East using materials and work routines in accordance with RIFA specifications. The chip packages are tested for gas-tightness and the final testing is carried out using stored program controlled test equipment. Any remarks concerning faults that have occurred in connection with the encapsulation are brought to the notice of the encapsulation factory. The long-term performance of the circuits is checked by means of accelerated testing with increased voltage and temperature.

The RIFA monolithic circuit factory

When describing the various process stages it has been stressed that the production requires extreme cleanliness and also demands clean, filtered, cooled and dehydrated air, clean, deionized and filtered water and a large number of special gases, such as nitrogen, hydrogen and oxygen. These requirements are so stringent that they have greatly influenced the design and equipment of the RIFA factory for monolithic circuits. In addition the layout of the premises has been made as flexible as possible, in view of the rapid development of manufacturing techniques. The ground floor of the building contains plants for water purification and waste water treatment, cooling compressors and stores. Two floors are used for the manufacture of monolithic circuits and two for the supply of air, gases and liquids, fig. 9. Thanks to the separate supply floors it is possible to carry out most of the installation work for new machines without causing pollution of the manufacturing processes.

A separate part of the building contains fans, heat exchangers and filters for the air treatment. There is also supervision and control equipment that monitors the continuity and purity of the supply of gases and liquids.

Yield

The yield is a basic factor in all discussions concerning the manufacture of integrated circuits. It is defined as the proportion of accepted ICs out of the total number of circuits that it would be possible to manufacture from the material used. The yield for different stages can also be considered, for example from the handling, wafer testing, assembly and final testing stages.

It is desirable to be able to calculate the yield for a circuit in advance, so that the importance and effect of different construction parameters can be considered before production starts. Experiments, manufacture of prototypes and previous experience of similar designs are used to decide statistically the parameters that determine how the yield is affected by process techniques and design rules.

Wafer yield
A silicon wafer normally passes through 100–200 different substages during the manufacturing process. The wafers are often handled manually by different people and can be dropped, broken or scratched. Handling damage constitutes a not inconsiderable cost and one aim is therefore to automatize the processes to a greater degree.

Wafer probe yield
The production yield is determined by the size of the circuit and the fault rate, i.e. the number of imperfections per unit of area in the basic material and production masks, and by the number of faults that are introduced on the wafers during the manufacturing process. Faults occur in groups along the edges of the wafer and along surface scratches, as well as randomly. The larger the area of a circuit, the larger the probability that

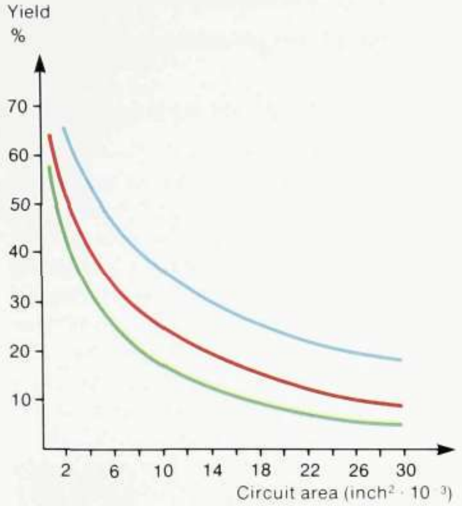


Fig. 10
The relationship between the wafer probe yield, circuit area and fault rate

the circuit contains at least one fault and must be rejected. The relation between yield, circuit area and fault rate is illustrated in fig. 10.

Faults on a wafer can occur in the substrate, epitaxial layer, photo-resist process, diffusion, oxidation and metallizing. Pinholes in the oxide and irregularities in the crystal structure are some spot faults. Scratches and grinding marks caused by impurities during mechanical grinding are line faults.

The most common causes of rejection are random faults in photo masks and photo-resist processes. Such faults can occur in any stage in the manufacturing process because of impurities in the environment, careless handling or bad process control. However, new methods for manufacturing masks, using electronic beam exposure, do not automatically reduce the fault rate.

The yield can be improved by increasing the degree of automatization, by keeping the number of process stages low, by consciously aiming at a low fault rate, by improving production masks and processes in each stage and by improving the design of the circuit.

Assembly yield
The assembly yield is defined as the proportion of faultless chips that have successfully been mounted and encapsulated. The yield is determined by such factors as the type of package and number of pins. The bonding, i.e. the connection of the pins to the outputs on the chip, is the most labour-demanding part of the mounting. An assembly yield of 95% is normal.

Final test yield
RIFA carries out a final testing of the circuits after the mounting and encapsulation and before delivery. The final testing yield is the proportion of encapsulated circuits that finally meet all demands. It is normally about 95%.

Process control and supervision

The various processes that are today used in the manufacture of integrated circuits will for a long time remain the basic production processes. These processes already include a number of automatic substages. It is also possible to work with large batches. A million transistors can be built op on one three-inch silicon wafer, and a few hundred such wafers can be processed simultaneously in a diffusion oven.

The production cost consists primarily of the cost of investing in machines and equipment, and not of material and personnel costs.

The main production problems today are how to assemble data, compile data in an acessible form and evaluate them, control and supervise the processes and minimize the need of operators. In view of the large number of process stages and batches in production and the relatively long manufacturing time, it is necessary to have a very well developed control and follow-up system. Information is required concerning every batch, each type of product, the number of wafers in the batch, the equipment used for each individual process, when each process was carried out, measurements and test values, yields and machine utilization.

RIFA therefore intends to use an on-line process control and data collection system for its manufacture of integrated circuits. The yield can be improved when the process and product engineers have better access to the relevant data. The dependence on operators can be reduced by using microcomputers for process control as far as possible and by providing detailed instructions, via data terminals, for each process in the production.

References

1. Bengtsson, P. et al.: *Choice of Monolithic Technique.* Ericsson Rev. *57* (1980):2, pp. 64–70.

Digital Transit Exchanges AXE 10

Torbjörn Andersson and Olle Ljungfeldt

Telephone exchange system AXE 10 comprises a number of subsystem which can be combined to form exchanges of different types and sizes, from very large transit exchanges to small rural exchanges.
This article describes the use of system AXE 10 for transit exchanges at all levels in the network. The functions of the various subsystems are also described, including the subsystem for operator handling of calls, which features operators' positions equipped with data display units and keyboards. All ticket writing has been replaced by direct input in data stores, which gives faster and more efficient call handling with less effort.

UDC 621.395.34:
681.327

In many countries the telephone networks are being converted to digital operation. Pulse code modulated transmission systems, digital switching stages and the integration of digital transmission and switching give technical and economic advantages. The four-wire transmission gives better transmission conditions and increased possibilities of combining exchanges. Local and transit exchanges can be combined and the number of network levels can thus be reduced. National transit exchanges can be equipped with facilities for traffic with mobile units[1].

The article first deals with some characteristics of the AXE 10 system which are of particular interest when the system is used for a transit exchange in a digital network.

System characteristics

High capacity

The size of the group selector stage can be increased in steps of 512 digital multiple positions to a maximum of 65 536. It is not sensitive to uneven loading and gives full accessibility between inputs and outputs. With an average traffic of 0.8 erlangs per multiple position the congestion is not more than 10^{-6} and thus negligible. This makes it possible to use free disposition of junction lines without regard to the amount of traffic they carry. A group selector stage of maximum size can handle a total traffic of about 25 000 erlangs.

The digital group selector operates rapidly, which, together with fast signalling systems, gives short through-connection times and reduces the post-dialling-delay.

The number of calls handled per busy hour can amount to between 600,000 and 800,000. The exact number depends on the proportions of simple and complex calls.

Fig. 1
A transit exchange in Kolding, Denmark, for 8000 junction lines

TORBJÖRN ANDERSSON
OLLE LJUNGFELDT
Telephone Exchange Division
Telefonaktiebolaget LM Ericsson

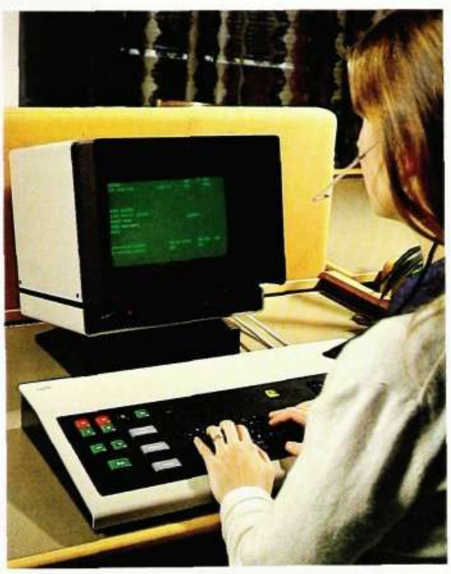


Fig. 3
The telephone operator uses her keyboard to enter order data on a form shown on the display unit

Flexible traffic routing

The central processor has a large capacity for number and route analysis. The number of area codes, routes and lines per route are unlimited, and so is the number of secondary routes in each direction. Any line can also be selected individually, for example for testing and measurements.

An operator can easily alter the traffic routing by means of a command that changes the routing plan, fig. 2. Such tasks form part of the network management and simplify traffic control in the case of overload or other disturbances in the network.

Stored program controlled network synchronization

A prerequisite for digital networks is that the exchanges and PCM systems work in synchronism. The synchronization of AXE 10 can be carried out in different ways and is stored program controlled, so that the synchronization method best suited to the surrounding network can be chosen.

Standby equipment gives high reliability

High reliability is achieved by such means as duplicating the processors and the group selector and effectively limiting the spreading of any software faults. The quality of service is checked continuously by automatic monitoring of each connection.

Compact structure

Large exchanges require a floor area of only 15 m^2 per 1,000 circuits. This figure applies if approximately half the junction lines are digital. It does not include the space needed for the power supply equipment and control room.

Easy to adapt to future requirements

The memory capacity of the processors is sufficient to meet large future demands. The store of a central processor can be extended to 4 M words for programs and 8 M words for data.

New function blocks can be introduced and existing ones changed, normally without having to make changes in the other parts of the system. This is possible because the division into function blocks has been strictly observed, with standardized signal interfaces between the blocks, and because the addressing of the program and data areas in the blocks is done via a special reference store.

The data area allocations in an exchange can be altered by making changes in the reference store. Hence the operating staff can carry out extensions during operation by changing the data area allocations with the aid of commands.

High signalling capacity with CCITT no. 7

CCITT signalling system no. 7 is used for common channel signalling. Its high transmission speed, 64 kbit/s, enables very large quantities of information to be transmitted over the signalling channel per unit of time. This can be exploited in future for new facilities and for wider use of older facilities, for example call forwarding, outside the local exchange area. The large signalling capacity can also be valuable in integrated networks, in which the equipment is to be used jointly for telephony, data transmission, text transmission etc.

Operator handling with the aid of display units and keyboards

The writing of tickets for ordered calls

Fig. 2
An example of a network management action in an AXE 10 network, aimed at reducing the effect of an important route having been put out of operation

Ordinary route
Secondary route
Link from NMC (OMC) to AXE 10

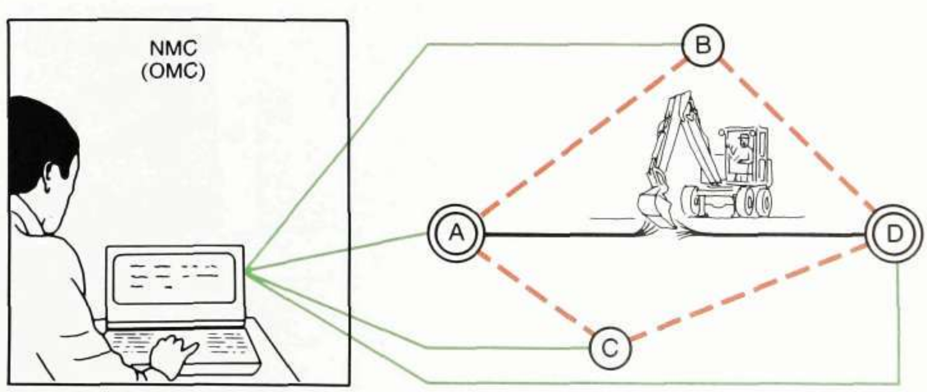
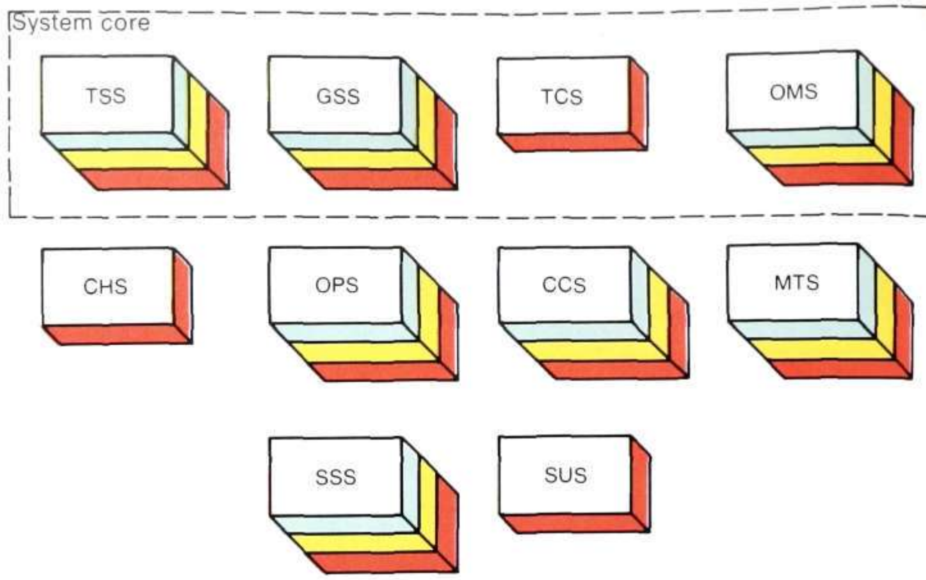


Fig. 4
The subsystems that are used in different types of telephone exchanges

Hardware
Regional software
Central software

SYSTEM CORE
- TSS Trunk and signalling subsystem, consisting of function blocks associated with the connected signalling systems
- GSS Digital group selector subsystem, consisting of a number of time and space switch modules and clock modules for synchronization
- TCS Traffic control subsystem, which contains programs and data for traffic routing, number analysis and supervision of connection and disconnection
- OMS Operation and maintenance subsystem, comprising aids for the administration and supervision of AXE 10 exchanges

ADDITIONAL SUBSYSTEMS FOR DIFFERENT APPLICATIONS
- CHS Charging subsystem, containing function blocks for pulse metering, toll-ticketing and accounting between adminsistrations
- OPS Operator position subsystem for manual handling of calls
- CCS Common channel signalling subsystem, for example for signalling in accordance with CCITT signalling system no. 7
- MTS Mobile telephone subsystem, interfacing with base radio stations for traffic with mobile subscribers[1]
- SSS Subscriber switching subsystem, which is divided into groups of 2048 suscribers, with an extension module of 128 subscribers
- SUS Subscriber services subsystem, comprising function blocks that vary depending on the requirements for facilities over and above the ordinary telephone traffic between subscribers



has been replaced by direct input of order data from a keyboard with a display unit at the operator's position, fig. 3. The operator fills in a form, which is displayed on the screen, with the information for each ordered call. The system processes these data in order to establish the desired connection. The handling procedure is simple and the handling time short. The method offers the possibility of new operator services. The operators' positions can also be remotely connected, which gives considerable flexibility as regards the location of the operators' room.

Efficient aids for operation and maintenance

Automatic supervision, built-in aids for testing and fault localization and the possibility of remote control of operation and maintenance functions help to make the work more efficient and reduce the work load.

Commands and printouts are formulated in the man-machine language, MML, recommended by CCITT. Its structure is simple, and it is easy to handle and simplifies the work.

Division into subsystems

An AXE 10 exchange consists of a number of subsystems. Certain subsystems are necessary for all applications, whereas the individual requirements decide which of the optional subsystems are to be included in an exchange. The interfaces between the subsystems are well defined, which means that the subsystems can be further developed independently of each other[2].

Each subsystem comprises a number of function blocks, which can consist of just software or software and the controlled hardware. In the latter case the software is divided between the central processor and a number of regional processors.

Fig. 4 shows all subsystems that are used in any type of telephone exchange.

The subsystems used in transit exchanges are described below.

Control system

The control system consists of a central processor and a number of regional processors which are placed together with the equipment that is to be controlled, fig. 5. A brief description of the control system is given below. A more detailed description will be given later in a separate article.

Central processor

The central processor, CP, hardware is duplicated for reasons of reliability. The duplication makes it possible to detect faults and locate the faulty printed

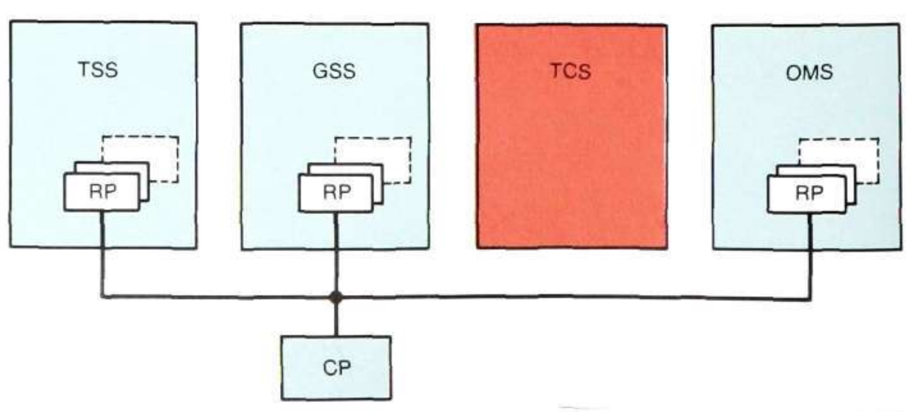


Fig 5.
Central and distributed control

- CP Central processor with duplicated central processing unit, data store, program store, reference store and the associated software
- RP Regional processors placed together with the controlled equipment

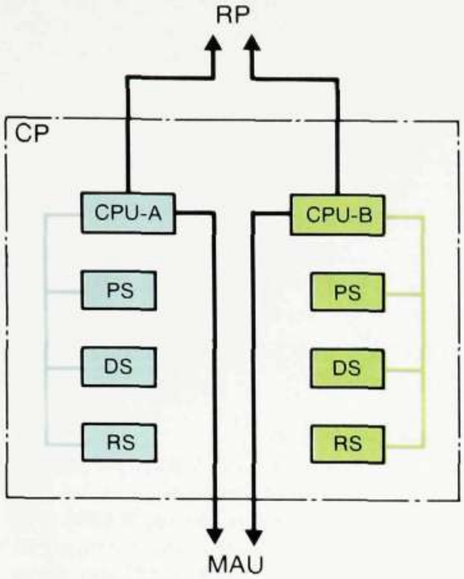


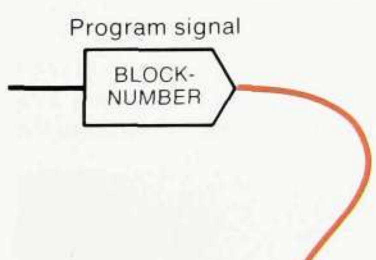
Fig. 6
The functional units in the central processor

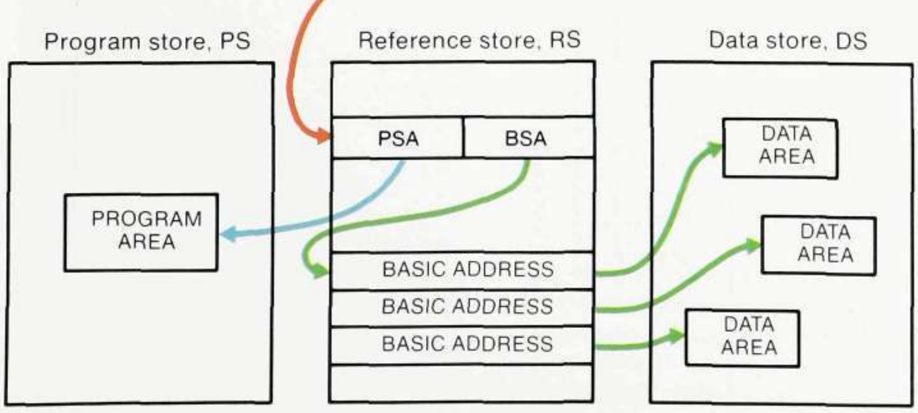
CPU	Central processing unit
PS	Program store
DS	Data store
RS	Reference store
MAU	Maintenance unit

Fig. 7
The method off addressing in AXE 10 using the reference store

PSA	Program start address
BSA	Basic start address

Each program signal from one function block to another contains the block number of the addressed block. This number gives the start address of the program area in PS allocated to this block and the required basic addresses in RS. Each basic address indicates the data area in DS that contains the relevant type of data. This addressing method permits automatic reallocationn of the programs and data areas for the different function blocks





board assembly very quickly. One processor part works in the executive mode, handling the traffic through the exchange, and the other works in parallel in the standby mode. A fault in the executive part never has time to interfere with the traffic since the other part is always ready to take control, and this is done without any break in the operation. The fault localization is carried out automatically.

The duplication also simplifies the introduction of new function blocks or the modification of existing ones, since changes can be carried out in one part at a time.

A processor consists of central units, CPU, data stores, DS, program stores, PS, and reference stores, RS, fig. 6. The reference stores contain addresses to the program areas in each function block and the data areas in each store. This addressing principle, which has been described in detail in a previous article[3], gives easy handling and great software reliability, fig. 7, since

- the programs in a function block can only address the data areas in that block. This protects the other store areas and prevents faulty addressing. All interworking with other function blocks is carried out by means of program signals. A function block can therefore only get access to information in the data area of another function block through questions and answers using such signals
- the address calculations are automatic and are included in the normal read and write instructions
- the areas in the data and program stores that belong to a certain function block are movable. Corrected or modified function blocks can therefore always be accommodated without special correction areas being needed. Extensions can be given the necessary data areas through reallocation of the data store by means of commands.

The central and regional processors are micro-programmed. This makes for very powerful machine instructions without complicating the hardware. The central processor stores are also self-administering and have a pre-planning function that calculates store addresses in good time before they are to be used. This increases the processor speed and gives it a high data processing capacity.

Complicated tasks that occur relatively infrequently, for example digit analysis, routing, tariff analysis and fault localization, are handled by the central processor.

Regional processors

Simple tasks of a repetitive nature that occur frequently, such as signal sensing, decoding of digit information, measuring time and operating relays, are allocated to the regional processors. They also handle the control of input and output devices. A regional processor consists of a central processing unit, CPU, a data store, DS, and a program store, PS.

Two regional processors normally control a number of equipment modules, EM, which form a magazine group. An EM contains a number of telephone devices of the same type.

Maintenance

The maintenance unit, MAU, supervises the control system and is programmed to carry out automatically the necessary actions when faults occur so that the traffic handling in the exchange can proceed uninterrupted. The following tasks must be handled:

- fault detection. The processors are monitored and faults in printed board assemblies and other disturbances are detected and recorded automatically
- fault localization. The effects of a fault are limited by the faulty unit immediately being blocked. Diagnosis programs are then used to locate the faulty printed board assembly

- checking that the fault-clearing actions carried out by the staff, e.g. change of printed board assembly, have had the desired effect.

The supervisory function utilizes the fact that all central equipment is duplicated, that stores and buses also include parity bits, that there are different types of store protection and time supervision, that special routine tests are carried out by both the central and the regional processors and that abnormal data processing gives rise to an alarm.

When a fault is detected the faulty processor part is blocked while the other continues with the traffic handling. The faulty unit in the blocked part is then located and diagnosed. Diagnosis programs then pinpoint the faulty printed board assembly.

Input and output

The following types of input and output devices can be connected:

- data display units with keyboards and printers or typewriters for the input of commands and output of operating messages
- cassette tape recorders and magnetic tape units for feeding in large amounts of programs and data, and for feeding out charging data and other information for further processing.

The input and output devices can be remotely connected via point-to-point or switched data links. Output can be made simultaneously to several devices in different places.

The operation staff have a total of about 500 commands at their disposal for various actions in the exchange. All input commands are checked both as regards the operator's authorization and the use of that type of command over the input device in question.

Digital group selector for 65,000 multiple positions

The digital group selector in system AXE 10 and its use have been described in previous articles[4,5]. A summary of the structure and main features of the selector is given here.

PCM systems as well as analog lines can be connected to the group selector. The latter are analog/digital converted in the signalling subsystem TSS.

The group selector has a time-space-time (TST) structure and is built up of time switch modules, TSM, and space switch modules, SPM, figs. 8 and 9. TSM contains stores for the PCM samples in the incoming speech direction, SSA, and the outgoing direction, SSB. The space switch module consists of cross point matrices for parallel transmission of 8-bit samples between SSA and SSB.

Two PCM channels that are to be connected together via the selector usually belong to different PCM systems in separate TSM and use different time slots in their respective systems. The incoming

Fig. 8
The digital group selector

Red line: Speech data for the incoming traffic direction
Green line: Speech data for the outgoing traffic direction
(1) Incoming and outgoing speech directions for a total of 16 first-order PCM systems
TSM Time switch module
SPM Space switch module
SSA Sample store for the incoming speech direction
SSB Sample store for the outgoing speech direction

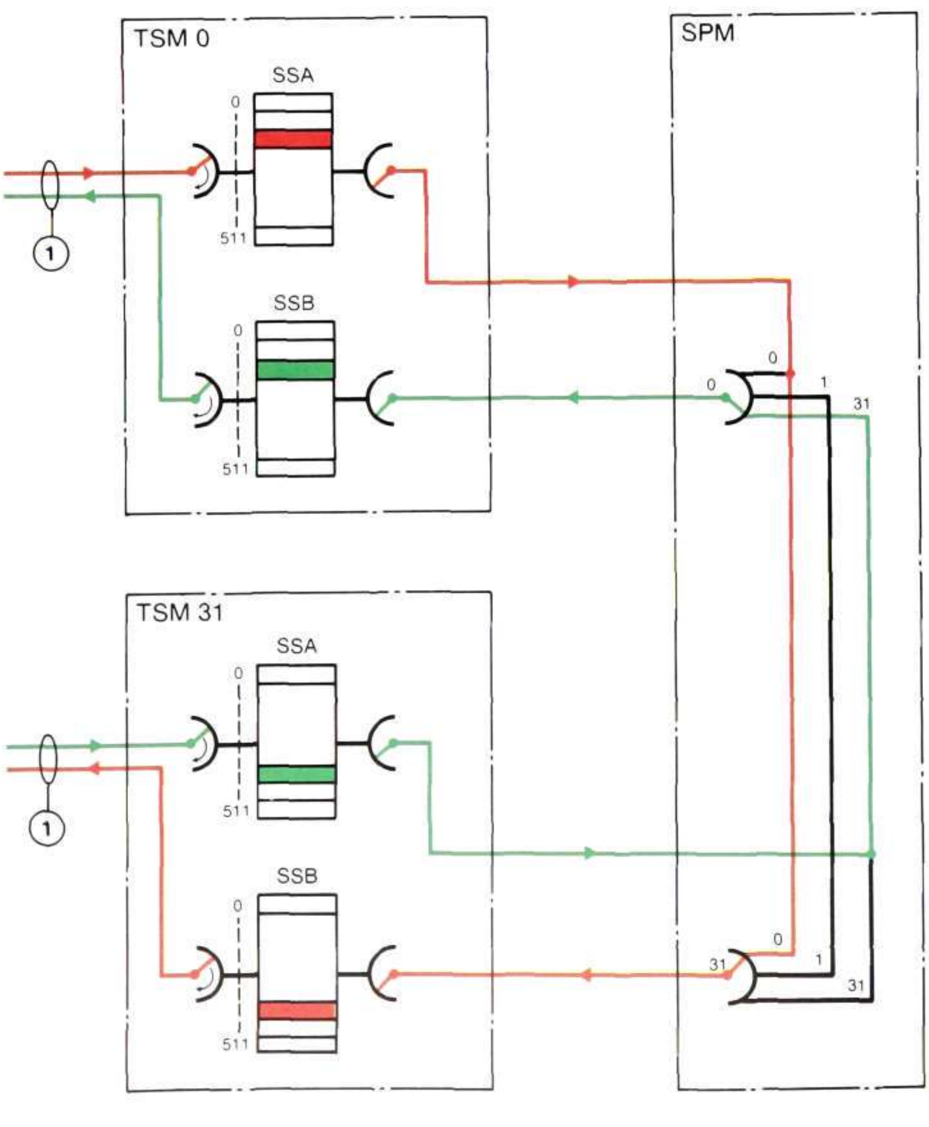
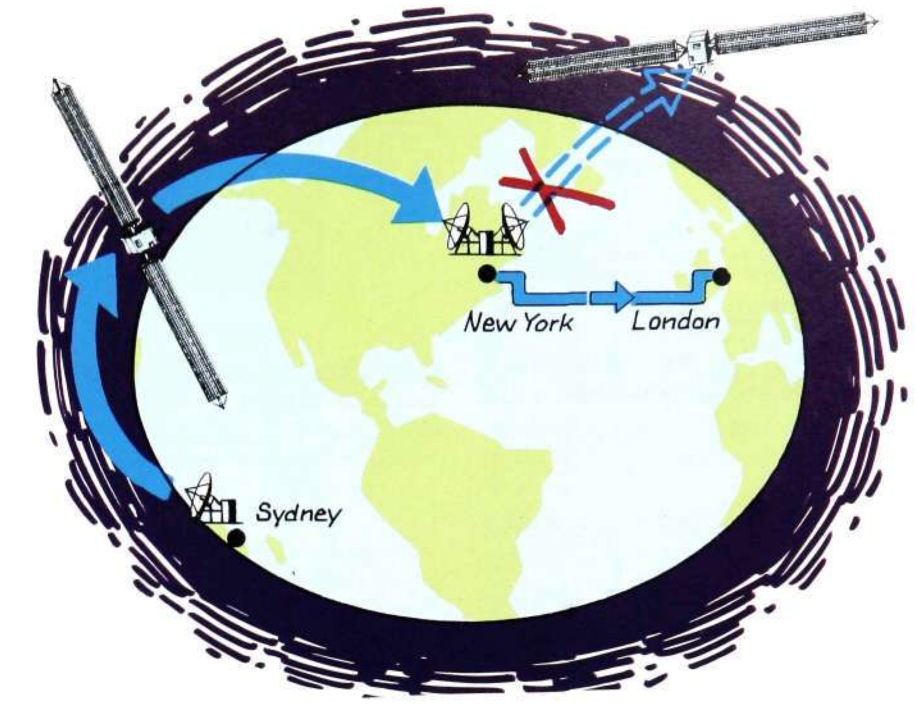


Fig. 10
AXE 10 prevents two satellite links from being connected in series in the same circuit



sample in each speech direction is stored in SSA, read from SSA to SSB, at a time that suits SPM, and is finally transferred from SSB to the time slot in the outgoing PCM channel.

Each time switch module has 16×32=512 multiple positions for the connection of 16 first-order PCM systems. 480 multiple positions are used for speech transmission and 32 for signalling and synchronization. When analog lines are connected, all 512 multiple positions can be used for speech transmission. One time switch module often gives suffficient capacity for the group selector in small primary centres.

Group selectors with more than 512 multiple positions are equipped with a space switch module, SPM. 32 TSM can be connected to an SPM, which can thus serve 512×32=384 multiple positions. A TSM can be connected to several SPM, with a maximum of four. Connecting each TSM to four SPM requiers a total of 16 SPM and gives a space switch matrix with 128 inputs and 128 outputs. The maximum size of the group selector will then be 512×128=65,536 multiple positions.

The selector equipement is duplicated. All calls are set up along identical paths in two selector planes, and the final choice of plane is made in the outgoing junction line equipment, after a check that both speech directions have been through-connected. This method enables any call to be automatically switched over from a faulty to a faultless plane.

The group selector synchronization can be arranged in different ways[2,4,5]. The synchronization is ensured by three identical clock modules, which in their turn are synchronized with highly stable external reference clocks or with clock signals from another exchange over PCM lines. The clock modules work in parallel, and the time control is regulated by regional and central software.

Traffic control

The traffic control subsystem, TCS, in AXE 10 is realized entirely in software. TCS controls and coordinates all activities in the exchange for the setting up, monitoring and disconnection of calls. The B-number is transmitted to TCS for analysis, routing and choice of secondary route. The setting up over a free line in the chosen route is initiated from TCS, as is the digit and signal transmission for establishing the remainder of the switching path. TCS also monitors the connection and controls the disconnection and exchange of signals associated with this.

The charging information for a call, the B-number and perhaps also the A-number, are assembled in TCS and transmitted to the charging subsystem.

When a call is set up, the combination of incoming and outgoing route is also analyzed. The analysis result and incoming signalling information is used, for example, for connecting or disabling echo suppressors and to prevent prohibited connection of satellite routes, fig. 10.

TCS also controls the various cases of operator handling and operator-controlled setting up of conference calls.

The assembling in TCS of number analysis, routing and traffic control facilitates flexible traffic management. The data for these functions can be changed by

Fig. 9
The digital group selector

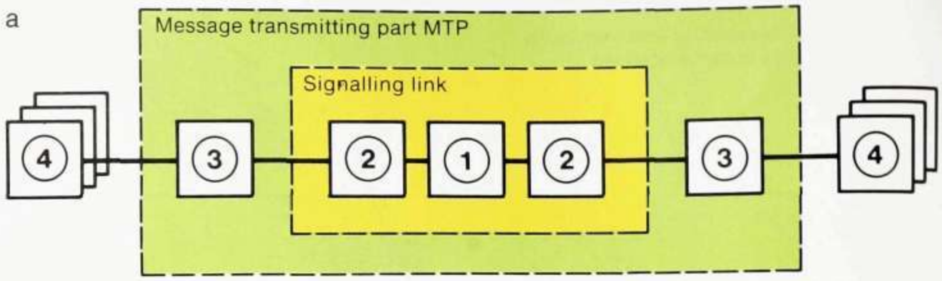
Fig. 12a
Functional diagram of comon channel signalling in accordance with CCITT system no. 7

(1) Data link, an optional time slot in a PCM system
(2) Signalling terminal, control and supervision of the signalling link
(3) Control of the signalling link network and routing of messages
(4) User parts, UP (CP functions in TSS)

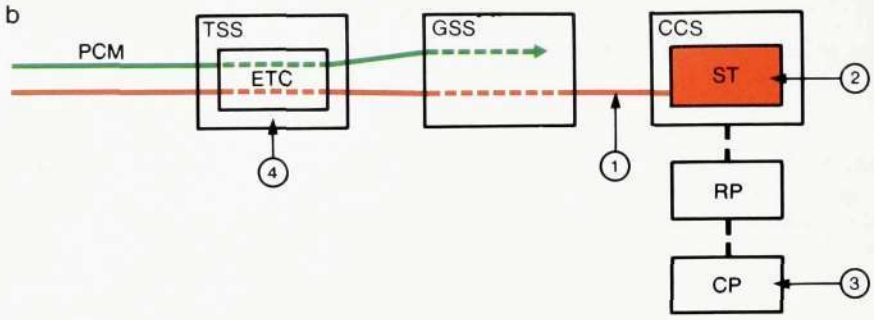
Fig. 12b
Hardware for common channel signalling in accordance with CCITT system no. 7 in AXE 10

(green line)	Speech channels
(red line)	Signalling channel
TSS	Trunk and signalling subsystem
ETC	Terminal circuit for first-order PCM systems
GSS	Digital group selector
CCS	Common channel signalling subsystem

a



b



means of commands. The administrative functions for this purpose and the functions for network manegement are described in the section Operation and maintenance.

Signalling

AXE 10 is designed so that it can easily be adapted to any existing international or national signalling system. Such adaption is made to the signalling systems recommended by CCITT, e.g. R2, no. 5, no. 6 and no. 7, and to a large number of national signalling systems.

The traditional channel-associated signalling over junction lines is handled by subsystem TSS. The interface conditions that are used between TSS and the other subsystems utilize the signal concepts in signalling systems R2 and no. 7, with additions for charging and maintenace. All translation between telephone signals and the standardized internal signals takes place in TSS, and the other subsystems are therefore entirely unaffected by any adaptation to a new signalling system.

Two signalling systems are described below, namely R2, which is an example of channel-associated signalling, and no. 7, which is an example of common channel signalling.

Channel-associated signalling

Signalling system R2 is intended for international and national traffic. In national networks R2 is often used in a modified form.

Line signalling over analog circuits is usually carried out using continuous out-band signalling. The two-way signalling channel provided by the common signalling time slot, T16, in the PCM system is used over digital circuits.

Register signalling is carried out using compelled MFC signalling. Six frequencies are used in each direction. The register signals are exchanged between code senders and code receivers.

Incoming, outgoing and two-way analog lines are connected via analog/digital converters to the 2.048 Mbit/s PCM interface of the group selector. Digital circuits are connected to the same interface via exchange terminal circuits, ETC.

Common channel signalling

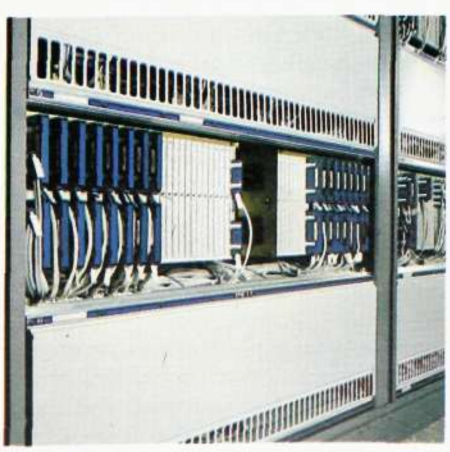
Signalling system no. 7 is intended primarily for telephone traffic between digital SPC exchanges in national and international telecommunication networks. It can also be used for operation and maintenance signalling. The exchange of signals between two exchanges takes place over a signalling link which is common to several speech channels. The signalling system is optimized for a transmission speed of 64 kbit/s on digital channels, but it can also be used at lower speeds on analog channels.

Signalling system no. 7 can be used with associated signalling when a route has a sufficient number of speech channels to carry the cost of its own signalling link. However, this signalling system is usually used with non-associated signalling, especially when the routes are small. This means that several routes use common signalling links via central signal transfer points, STP.

Fig. 12a shows a functional diagram of signalling system no. 7, and fig. 12b shows the associated hardware.

Signalling system no. 7 consists of a message transfer part, MTP, which is the same in most applications, and an individual user part, UP. MTP defines the interfaces and procedures for the signalling between exchanges. UP de-

Fig. 11
The trunk and signalling subsystem TSS



fines the signals and thus corresponds to the signalling diagram. The MTP functions are provided by a special subsystem, CCS, whereas the UP functions belong to TSS.

In the case of associated signalling at least two channels in the PCM route are used for the common channel signalling. The route can consist of one or more PCM systems. The signalling links are used in accordance with the load sharing principle. If a fault occurs on one link, all signalling is transferred to the remaining link(s).

The signalling links are switched through the switching network to a microprocessor-controlled signal terminal, ST, which is connected to a regional processor, RP. The latter handles, for example, the sending and receiving of signals, synchronization and detection and correction of transmission errors.

Since the signalling links and the signalling terminals are connected via the group selector, they are easily replaced by standby links or terminals if a fault occurs. It is also easy to reallocate the signalling terminals.

The signalling messages contain a label that gives the channel identification, and the message is thus associated with the correct speech channel.

When a transit exchange functions as a signal transfer point it sends out the incoming signalling message on the correct outgoing signalling link.

Charging and inter-administration accounting

The charging subsystem, CHS, provides complete facilities for tariff analysis and the settling of accounts between telecommunications administrations. CHS consists of central software.

The correct tariff for the charging of a telephone call is determined either in the local exchange where the call is initiated or in a higher-ranking transit exchange.

The system allows 255 different tarriffs. In the case of tariffs that are dependent on distance, the B-number is analyzed when deciding on the tariff. The day of the week, time of the day and type of service used may also affect the tariff decision. The relationship between the tariffs and these factors can be changed by means of commands.

There are two possible charging methods, pulse metering or toll ticketing, fig. 13. In the latter case the A-number, B-number, date, time and call duration are recorded. The call data are stored on magnetic tape. It is also possible to combine the two methods, for example so

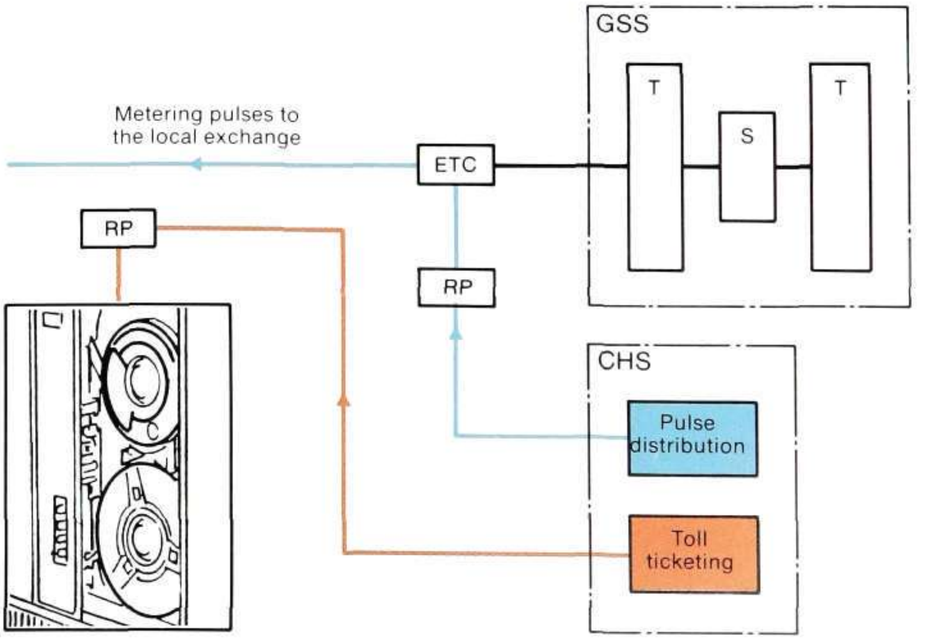


Fig. 13
The system provides pulse metering or toll ticketing

Box no. 1

OPERATOR FUNCTIONS

Call allocation. The calls are allocated to certain operators' positions with consideration given to the type of call, language group etc.

Call queue. If all operators' positions are engaged, the calls are put in queues for each type of origin, language, category or similar factor.

Direct completion. The call is set up while the subscriber waits.

Delayed completion. The call is set up as soon as possible or at a prearranged time.

Inquiry. This function is used, for example, when an operator must make an inquiry to another operator in order to be able to set up a call.

Transport. Used when a call has to be transferred from one operator to another during the setting-up process.

Conference call. A call with several participants, who are connected to centrally placed conference equipment.

Assistance operator funtions. An assistance operator can be connected in on international calls, for example if there are language problems.

Chief operator functions. The chief operator supervises the traffic intensity with the aid of queue indicators, ensures that a suitable number of positions are manned and redistributes the traffic to the positions if necessary.

Automatic toll-ticketing charging. The charging information is stored on magnetic tape or cassette tape.

Immediate pricing. The price information is given to the A-subscriber directly after the call.

that national calls are metered and toll-ticketing is used for international calls. If the metering method is used, a limited number of subscribers can have their calls specified on request.

The price information can be obtained as soon as a call is finished, which is of particular advantage to hotels.

The account-settling facility is always needed for international traffic and also for national traffic if the telecommunications of a country are operated by several administrations. The settling of accounts is based on the measurement of the total number of call minutes over each route concerned. Alternatively, in the case of national settling, and if the charging is handled by the transit exchanges, the number of charging pulses per route can be counted. The result is stored in the data store.

For safety's sake the charging and settling data in the data store are copied regularly in the form of output to a cassette tape recorder. The ordinary reading is carried out using a cassette tape recorder or another I/O device as desired.

Operator handling

Subscribers want rapid connection through the long distance network even when the calls are set up by operators. It is therefore essential that calls handled by operators can be set up quickly and efficiently. In order to achieve this it is necessary to abandon the earlier method of writing, sorting and distributing tickets, which is very time-consuming. There is also a need of new facilities, for example to be able to pay for calls by means of credit cards.

Subsystem OPS contains functions for operator handling, and the system has been designed to meet this and future demands. The operators are provided with data display units and keyboards, which can be connected to OPS either direct or remotely via data links.

Extensive ergonomic studies preceded the designing of the operators' positions. The environment has also been taken into consideration. Recommendations for layout, lighting and colour schemes have been prepared, fig. 14.

The operators' positions can be used for all types of traffic. The chief operator decides which type of traffic each operator is to handle. The right type of calls will automatically be routed to an operator's position when it is marked as attended.

When a call comes in, all available data on the call are shown on the operator's display, arranged on a form. The A-subscriber number is shown if it can be transmitted from the local exchange. The operator uses the keyboard to complete the form, mainly with the area code and B-subscriber number. OPS automatically processes these data and initiates the setting up of the call.

For calls that are ordered for a certain time, or which cannot be set up immediately because of a busy line or no answer, the information is stored in the system after entering the time for a new display. The data concerning completed calls are also stored. The operator can retrieve information concerning completed calls, for example in order to inform the A-subscriber about the price.

The handling process described here eliminates all ticket writing, and also a number of administrative routine tasks. The handling time for any type of traffic is short, because of the automatic processing in OPS. Tests have shown that the improvement is in the order of 20%. The advantages are even more pro-

Fig. 14
A recommended layout of operators' positions with data display units and keyboards

Box no. 2

OPERATION AND MAINTENANCE FUNCTIONS

Supervision

Blocking supervision, which gives an alarm if the number of blocked devices per route exceeds a present value.

Disturbance supervision, which indicates malfunctioning devices and routes, for example by monitoring signalling errors and time releases.

Seizure supervision, which checks that there has been at least one answered call on each junction line during a supervision period.

Seizure quality supervision, which indicates devices with faults that result in abnormally short seizure times, for example because of line faults.

Selector supervision, which checks that every call is correctly through-connected and disconnected. The clock distribution and the handling of addresses and speech samples in the selector are also supervised.

Load supervision, which monitors the load during busy periods and controls the number of calls being handled.

Route load supervision, which monitos the load on outgoing last-choice routes and a number of high-usage routes, and also the queue length on code receiver routes.

Testing and fault localization

Tracing of connection paths, to identify devices in the connection path. The device at which tracing starts can be selected.

Signalling and state recording, for analysis of signalling functions.

Device state indication, to indicate whether individual devices or groups are free, seized, blocked etc.

Test calls, for testing telephony devices and switching paths. The function permits operator monitoring and connection of measuring equipment for circuit testing. It is also possible to activate individual control points in the switching equipment, to decide in advance the switching path for test calls, to select devices and to inhibit the effect of time supervision.

Transmission measurements, to test the transmission quality of the junction circuits, can be carried out by connecting external equipment of type ATME 2 or ATME N2.

Code answer, which is needed for, among other things, transmission measurements and traffic route tests.

Statistics

Traffic recording on routes and number directions. The traffic in erlangs, number of calls, number of seized devices, number of blocked devices and call congestion can be recorded.

Charging recordings, for determining the distribution of calls on different tariffs.

Traffic observations, for assessing the quality of traffic handling as it is experienced by the subscribers.

nounced when many attempts at setting up a call have to be made.

The most important operator functions offered by the system are shown in box no. 1.

Operation and maintenance

In a transit exchange it is essential that the operation and maintenance functions are designed so that the work in question is simple and easy. National transit exchanges are often so situated in the network that they form a natural centre for the operation and maintenance activities for the transmission network and connected exchanges as well.

The software for operation and maintenance in an AXE 10 exchange is approximately of the same volume as the software for traffic handling. The operation and maintenance functions are assembled in subsystem OMS. The guidelines for the design of operation and maintenance facilities were as follows:

- the quality of service to be supervised by monitoring of all connections through the exchange
- the operating staff to be given only the information that is necesary for their work
- the day-to-day operation to be carried out by staff with experience of, for example, crossbar exchanges and who have had additional training in AXE 10
- the major part of the daily work to be carried out in the exchange control room. It is possible to centralize this work further, to operating centres. Even large exchanges can be left unstaffed.

The AXE 10 operation and maintenance subsystem contains functions in the following fields:

- supervision
- testing and fault localization
- statistics
- administration.

The following description of functions is limited to those of particular importance to transit exchanges. For further information regarding operation and maintenance functions reference should be made to a previous article in Ericsson Review[6] and box no. 2.

Supervision

Functions are included for supervising both hardware and software as well as the actual traffic. Data that are of interest to the supervision are continuously stored in the traffic handling subsystems. These data are checked regularly and an alarm is given in accordance with the service alarm principle when a predetermined quality level is no longer met.

Faulty units are automatically blocked for traffic. The traffic-carrying devices are also monitored to ensure that each

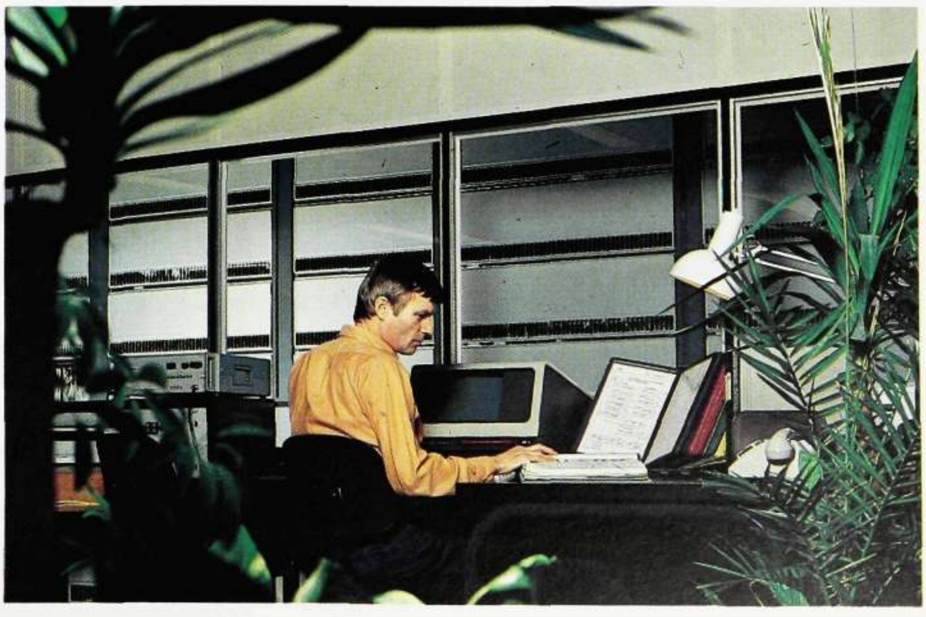
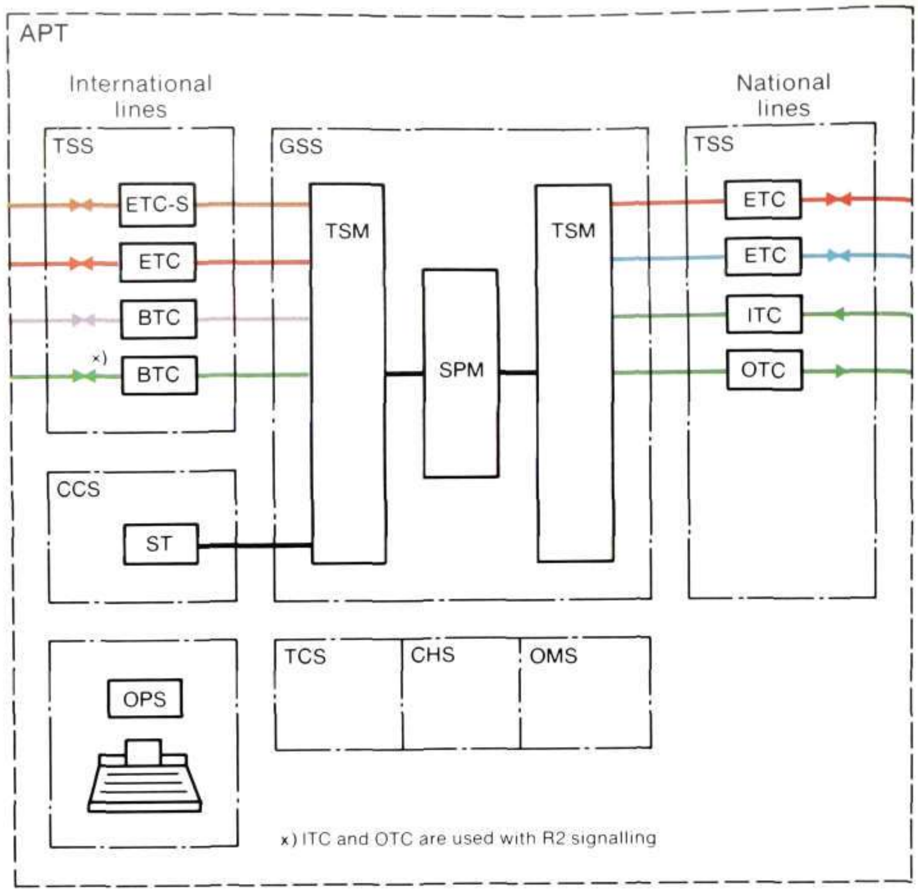


Fig. 15
The control room in the Kolding transit exchange, Denmark

Fig. 16a
AXE 10 as an international exchange



- Satellite circuits
- National and international PCM circuits with common channel signalling in accordance with signalling system no. 7
- National PCM circuits with channel-associated signalling, e.g. in accordance with signalling system R2
- International analog lines with common channel signalling in accordance with signalling system no. 6
- National and international analog circuits with channel-associated signalling in accordance with signalling systems R2 and 5 respectively
- Circuits to base radio stations for traffic to mobile units

TSS Trunk and signalling subsystem
ETC-S Exchange terminal circuit for satellite circuits
ETC Exchange terminal circuit for PCM system
ITC Incoming trunk circuit for analog traffic
OTC Outgoing trunk circuit for analog traffic
BTC Bothway trunk circuit for analog traffic
GSS Group switching subsystem (digital group selector)
TSM Time switch module
SPM Space switch module
TCS Traffic control subsystem
OMS Operation and maintenance subsystem
CHS Charging subsystem
OPS Operator position subsystem
CCS Common channel signalling subsystem
ST Signalling terminal

is seized in the course of the supervision period.

Digital transmission systems that are connected to AXE 10 are supervised in accordance with CCITT recommendations. The incoming bit stream is monitored for bit errors and loss of frame and multiframe alignment. Supervision of the signalling channel is particularly important for routes that use signalling system no. 7. The monitoring comprises, among other things, the bit error on the signalling channel, the load on the send buffer and the accessibility for the signalling traffic to different destinations when STP are used. If a fault occurs, the traffic is immediately switched over to the standby channel.

Alarms from carrier equipment are also acted upon. For example, if a pilot alarm is received, the corresponding traffic-carrying devices are automatically blocked.

Testing and fault localization

A number of test and diagnosis programs are provided for testing when alarms and faults occur. The programs are initiated either automatically or by means of a command.

The maintenance of the lines in the network becomes increasingly important the higher their level in the network hierarchy. The lines are then longer and the transmission equipment more expensive. Large transit exchanges should therefore be equipped with automatic transmission measuring equipment, ATME, for supervision of the transmission quality. The maintenance of junction lines is most suitably concentrated to special service positions, from which all lines and relay sets can be reached for measurements and tests. The positions must be equipped with input and output devices, since all actions require commands for their control, and all results are obtained as printouts.

For international exchanges it is of course particularly important that the maintenance of the exchange and lines can be carried out in accordance with international recommendations. The operation and maintenance functions of system AXE 10 enable service positions to be set up for the supervision and maintenance of international circuits and lines in accordance with the CCITT recommendations for international maintenance centres, IMC.

Statistics

The planning and follow-up of exchange and network extensions require traffic statistics for routes and number directions. AXE 10 contains traffic recording and statistical functions that are activated by means of commands. The results are either output locally in processed form on a printer, or processed or unprocessed on magnetic tape. The results can also be fed out to a remote device connected via a data link.

Administration

The administration of an exchange in-

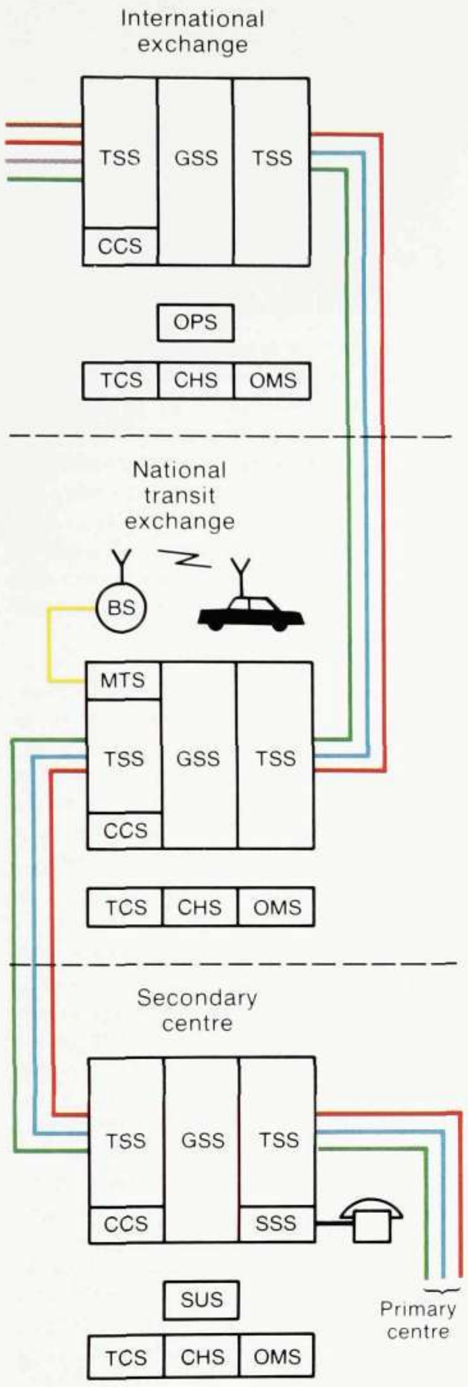


Fig. 16b
Routes between AXE 10 working as an international exchange and AXE 10 transit exchanges at various levels in the network. The colour codes are the same as in fig. 16a

cludes changing the semi-permanent data that describe:
- the build-up of the exchange
- routes and line allocation
- analysis conditions
- traffic routing plans
- charging conditions.

Some hundred commands are provided for these functions.

One aim when designing the administrative functions was to simplify the duties of the staff and minimize the effect of any mistakes.

Network management is a function of major importance in transit exchanges. It is used when there is an imbalance between the traffic load and the traffic capacity in the network. The operator is made aware of abnormal traffic situations, for example by means of an alarm from the route load supervision. He can then request information regarding the traffic load, congestion and blockings on the routes concerned. After analysis the operator carries out one or more remedial measures, such as
- activating on alternative routing plan
- cancelling an alternative routing
- blocking incoming junction line equipment
- blocking the traffic to certain destinations
- blocking the traffic from subscribers without priority
- routing to a route for announcing machine messages.

Transit exchanges at different levels in the network

The following tables show how AXE 10 is used as a transit exchange at different levels in the network and the functions that are associated with the various levels. Figs. 16a and b show which subsystems are required at the different levels.

International transit exchanges
- Operator handling
- Charging by means of toll ticketing
- International accounting based on the actual number of call minutes
- Analog international circuits with signalling systems R2, no. 5 and no. 6.
- Echo suppressors for satellite communication
- Analog carrier circuits and digital PCM circuits with R2 signalling to national transit exchanges
- Transmission measurements on international and national circuits
- Maintenance centres for international circuits

National transit exchanges
- Charging by means of toll ticketing for traffic from local exchanges with A-number identification
- Pulse metering of all other traffic, in which case the tariff can be determined at the transit exchange
- Mainly PCM circuits to subordinate exchanges, either with channel-associated R2 signalling or with common channel signalling in accordance with signalling system no. 7
- Traffic to mobile subscribers, who can be reached via base radio stations connected to subsystem MTS
- Transmission measurements on national circuits

Secndary and primary centres
- Charging by means of toll ticketing for traffic from local exchanges with A-number identification
- Pulse metering of all other traffic, in which case the tariff can be determined at the transit exchange
- Mainly PCM circuits to subordinate exchanges, either with channel-associated R2 signalling or with common channel signalling in accordance with signalling system no. 7
- Traffic to mobile subscribers, who can be reached via base radio stations connected to subsystem MTS
- Transmission measurements on national circuits
- Subscriber stages placed centrally as well as remotely in the network to replace small terminal exchanges.

References

1. Billström, O. and Troili, B.: *A Public Automatic Mobile Telephone System.* Ericsson Rev. *57* (1981):1, pp. 26–36.
2. Nilsson, B.Å. and Sörme, K.: *AXE 10–A Review.* Ericsson Rev. *57* (1980):4, pp. 138–148.
3. Hemdal, G.: *AXE 10–Software Structure and Features.* Ericsson Rev. *53* (1976):2, pp. 90–99.
4. Ericson, B. and Roos, S.: *Digital Group Selector in the AXE 10 System.* Ericsson Rev. *55* (1978):4, pp. 140–149.
5. Braugenhardt, S. and Nordin, J.-E.: *AXE 10 with Digital Group Selector in the Telephone Network.* Ericsson Rev. *55* (1978):4, pp. 150–163.
6. Söderberg, L.: *Operation and Maintenance of Telephone Networks with AXE 10.* Ericsson Rev. *56* (1979):3, pp. 104–115.

Time Division Multiplex for Telex and Data Transmission

Arturo Gatta and Giorgio Squartini

The Italian company FATME, a member of the Ericsson Group, have developed a time division multiplex system for telegraphy (telex) and asynchronous data transmission on telephone channels in accordance with CCITT Recommendation R.101, alternatives A and B.
The system, which is designated ZATF 46 CD, permits multiplexing of, for example, 46 channels for 50 bauds to a common bit stream having a bit rate of 2400 bit/s.
The system has been designed in collaboration with LM Ericsson, and the operation and maintenance functions are adapted to LM Ericsson's telex exchange system AXB 20. In this article the general features of the system and the electrical and mechanical construction of the equipement are described.

UDC 621.394
681.327.8

The continuous and rapid growth of telex and data traffic creates a demand for greater traffic capacity and new transmission facilities in the network. The capacity can be increased by means of time division multiplexing (TDM), a technique which, compared with voice-frequency telegraphy, permits more telegraph and data channels on the same telephone circuit.

To meet these demands FATME have developed a time division multiplex system, ZATF 46 CD. This system permits the transmission of 46 telex channels at 50 bauds over a single telephone channel in the form of a combined bit stream with a bit rate of 2400 bit/s. The equipment is programmable and allows mixing of different standard speeds up to 300 bauds, different character codes and signalling systems in the same transmission system.

One of the main features of the system is its low distortion; each transmitted character is regenerated in its ideal form, and thus also characteres which are received very distorted are retransmitted practically undistorted.

The multiplexing is based on the bit interleaving principle, which introduces minimum signal transfer delay through the system.

The equipment is built up of functional units. They consist of printed board assemblies with modern and reliable components. The printed board assemblies are plugged into narrow racks of the FATME N2 type, which are 2600 mm high, 120 mm wide and 225 mm deep.

Applications

The TDM system can be used for telex, telegraph and data networks and gives better utilization of the telephone channels than conventional VF telegraph systems. The system is suitable for both analog and digital networks, being connected to the line via a data modem and a data circuit terminating equipment (DCE) respectively. Fig. 1 shows some applications.

System ZATF 46 CD includes a data modem for 2400 bit/s which meets the requirements of CCITT Recommendation V.26, and thus no external equipment is necessary for connection to the analog telephone network. The system can therefore be connected direct to a

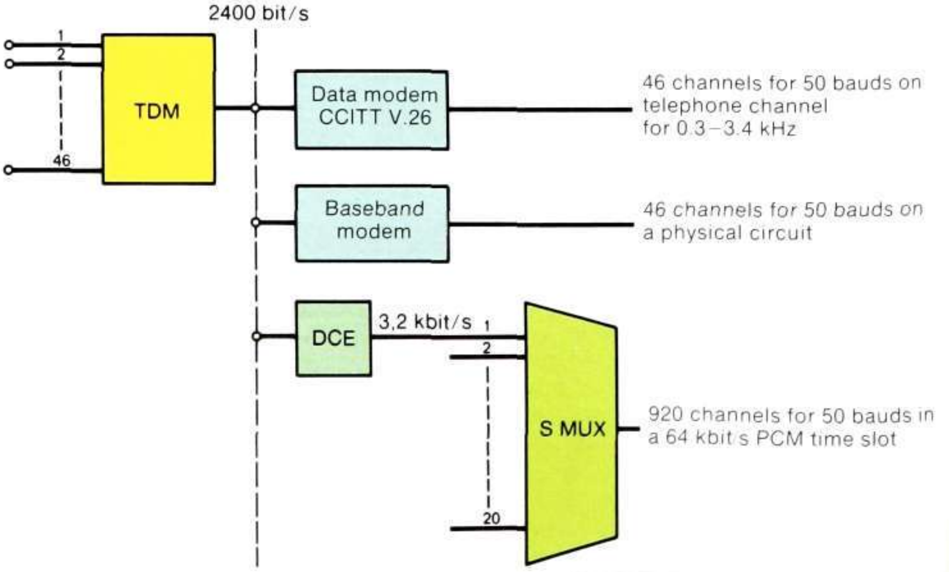


Fig.1
Connection of ZATF 46 CD to the telecommunication network

TDM Time division multiplex equipment
DCE Data circuit terminating equipment
S MUX Multiplexor towards the synchronous data network

ARTURO GATTA
GIORGIO SQUARTINI
FATME S.p.A.
Rome, Italy

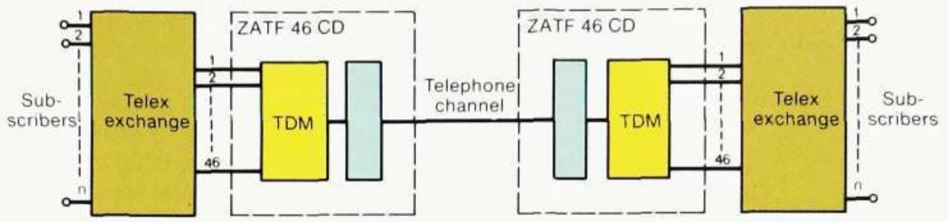


Fig. 2
ZATF 46 CD used for circuits between two telex exchanges other than AXB 20

TDM Time division multiplex equipment

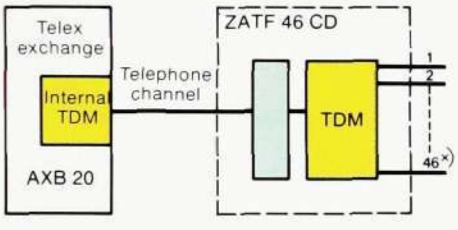


Fig. 4
ZATF 46 CD used to connect another telex exchange or remote subscribers to LM Ericsson's telex exchange AXB 20

TDM Time division multiplex equipment

*) One of the 46 channels is used for maintenance.

normal 4-wire telephone channel, which can be a carrier channel or a physical circuit for the frequency band 0.3–3.4 kHz.

If required, a 2400 bit/s baseband modem can be used instead of the internal data modem, fig. 1, for transmission over physical circuits.

Two or four ZATF 46 CD systems can also share a telephone channel equipped with a modem for 4,800 bit/s and 9,600 bit/s respectivley.

*The TDM equipment can also be con*nected to a higher order multiplex, for instance by using a multiplex, S MUX, in accordance with CCITT Recommendation X.50, fig. 1. A DCE must then also be used. The encoding format is 6+2 bits and the bit rate of the data signals is 3.2 kbit/s in the baseband. S MUX allows 20 data channels at 3.2 kbit/s to be multiplexed to a standard 64 kbit/s digital channel for PCM. The total capacity is then 920 channels for 50 bauds.

System operation

System ZATF 46 CD is primarily intended for use in telex networks, figs. 2 and 3. It is very suitable both for connections between telex exchanges and for remote connection of groups of subscribers to an exchange. Fig. 4 shows how the system is connected to the LM Ericsson telex exchange AXB 20.

AXB 20 is a stored program controlled exchange for telex and asynchronous data traffic. It has been designed for use *as a combined local and transit ex*change for both national and international traffic. It is particularly suitable for the connection of remote subscribers via concentrators or multiplexors such as ZATF 46 CD, since it contains a built-in multiplexor and modem. This means that no channel interface units are needed on the exchange side[2,3].

ZATF 46 CD contains functions for the operation and maintenance of unattended system terminals. One of the 46 channels in the system is then used as a maintenance channel for the necessary *signalling.*

Lines to teleprinters can be connected in three ways:
- double current in full duplex, 4-wire circuits on two wires with an earth return circuit
- single current in half duplex on 2-wire circuits
- V.21 subscriber modems in full duplex on 2-wire circuits.

The telegraph signals coming from each subscriber or from the telex exchanges have a standardized speed and character structure, since 7.5 unit elements (20 ms) and the international telegraph alphabet no. 2 are used.

A central logic device in the TDM scans the channel inputs in turn, and after signal generation combines the signals for all the 46 channels into a single bit stream. The resultant signal, with a bit rate of 2.4 kbit/s, is then taken to the internal modem, which converts it to a VF signal for transmission over the line.

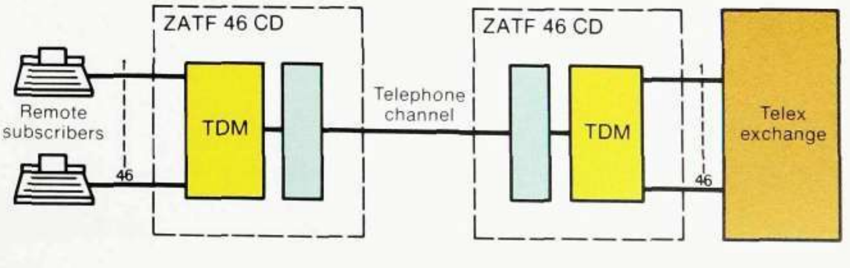


Fig. 3
ZATF 46 CD used to connect remote suscribers to a telex exchange other than AXB 20

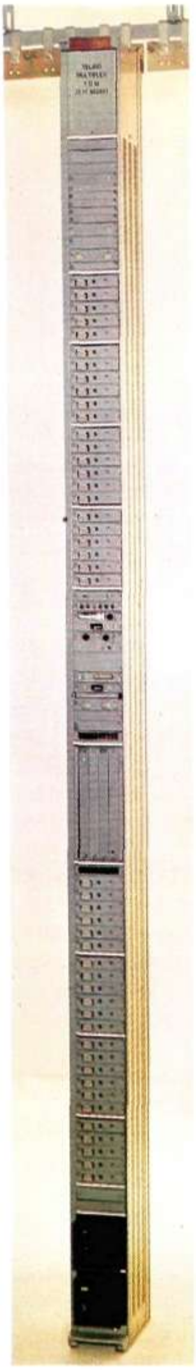


Fig. 5
ZATF 46 CD for double current working

In a similar way the VF signal coming from the line is converted in the receiver to a digital signal. This signal is demultiplexed by the TDM equipment, which separates the data for each channel, restores the telegraph signals and transmits them to the telex subscribers or the telex exchange.

System flexibility

System ZATF 46 CD meets CCITT Recommendation R.101, alternatives A and B, for different combinations of asynchronous channels having different data transmission rates, different code structures and different alternatives for signalling and fault supervision. See the technical data at the end of the article. The choice of alternatives in the wide range available is made by means of strappings for each individual channel in a common strapping field.

Since alternatives A and B have different synchronizing procedures and work with different formats, adaption to one of these two alternatives must be made by changing programs in the central control unit. No units have to be changed, only a few programmable memories (PROM) and a few straps.

Data transmission rates and character structures

When the FATME TDM system is operating according to alternative A it allows the multiplexing of two telegraph speeds, 50 and 75 bauds, both with 7.5 elements. When it is operating according to alternative B it can handle simultaneously the complete range of standard speeds from 50 up to 300 bauds and all codes with 7.5, 9, 10 or 11 elements per character.

Telex signalling alternatives

The system is so flexible that it can handle all types of signalling used for telex. Each low speed channel can thus be strapped for any of the CCITT signalling types: A, B with keyboard selection, B with dial selection, C or D.

Alarms

The equipment continuously monitors the local functions and the quality of the received signal, and it also receives alarms from the far end terminal. Alarms are given for the following faults:
- loss of synchronism
- loss of carrier, which is detected by CCITT circuit 109 in the modem
- deterioration of the signal quality, which is detected by CCITT circuit 110 in the modem
- faults in the central logic equipment, which are detected by an internal test loop and parity checking in connection with memory operations
- programming errors, which can lead to two channels using the same time slots
- faults in the far end terminal
- power failures.

Alarms are given for the individual connected circuits in the case of
- too high distortion of the incoming signal
- line breaks.

Mechanical construction

The ZATF 46 CD equipment is mounted in the FATME N2 rack, which is 2600 mm high, 120 mm wide and 225 mm deep. Five such slim racks can be installed side by side and then form a 600 mm wide rack group.

The steel rack side plates are joined to a bottom plate and some further plates, which are mounted at different heights depending on the functional division of the rack. The bottom plate has adjusting screws for levelling the rack.

The two steel rack sides are provided with slots in modular steps of 5.08 mm for plastic guides that ensure correct insertion of the plug-in units. The units consist of printed boards of fibreglass reinforced epoxy laminate equipped with components and gold-plated contacts for the external connections. The boards can have double-sided printed wiring with through-plated holes and two different widths are used: single and double N2 boards. The single-width boards are inserted horizontally, taking up the whole width of the rack. The double-width ones, whose larger surface is particularly useful for complex digital functions, are inserted vertically. A mechanical locking device prevents the printed board assemblies from being removed accidentally.

Fig. 8
ZATF 46 CD for single current working

The front of each unit is fitted with a plastic protective cover with access points for U-links, test plugs etc.

The space at the left-hand side of the rack, behind the unit connectors, is used for the rack cabling.

At the top of the rack the external cabling is connected to the connection panel, which is accessible from the front. This allows the rack to be taken out of operation for fault clearing and also makes it easy to replace.

Fig. 5 shows the rack layout for system ZATF 46 CD with double current working. The TDM central logic, fig. 6, and the service unit, fig. 7, divide the channel interface units into two groups. The data modem is placed at the top of the rack and the power supply packs at the bottom.

Fig. 8 shows the rack layout for single current operation. Due to the higher power dissipation in the equipment when this operating mode is used, particularly for short subscriber lines, two racks are used, each contaning the interface units for 23 channels.

Circuit description

A brief description of the various circuits in the transmission equipment is given below.

Channel interface units

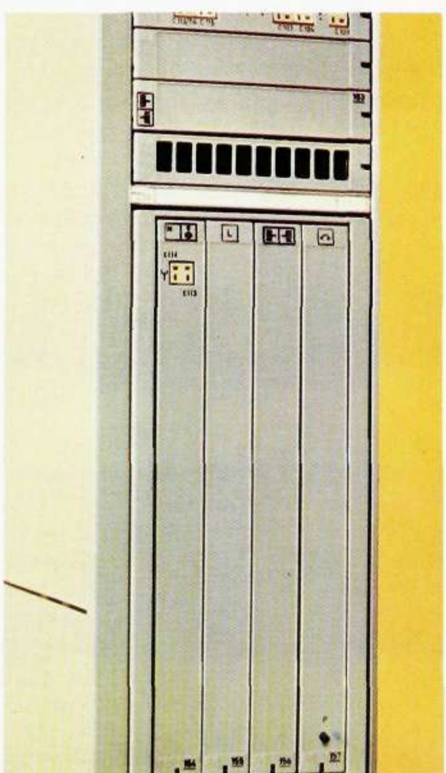
Five main types of channel interface units have been developed to meet the requirements of different types of line signalling:

Double current and high voltage

This unite, fig. 9, is designed mainly for matching towards conventional telex exchanges, for which a ±20 mA telegraph signal current is normally required. The voltage of the regenerated signals can be adjusted up to ±60 V.

Double current and high voltage with fault localization facilities

This unit has the same electrical characteristics as the first one but is designed mainly for interworking with subscriber apparatus and conventional electromechanical exchanges. It has built-in fault localization facilities, for example open line alarm. The unit also contains digital loop connection facilities, which are particularly useful for testing remote



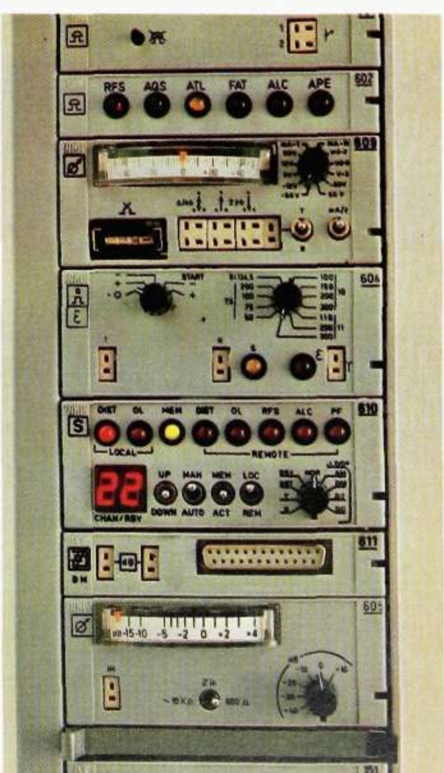
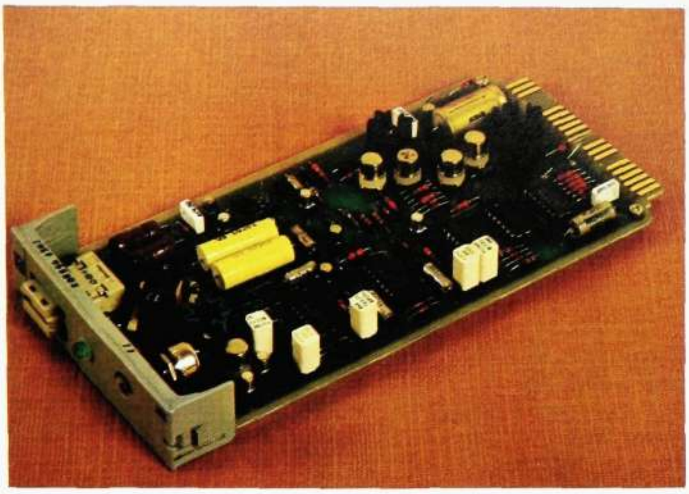


Fig. 6, left
Central logic unit

Fig. 7, right
Service unit



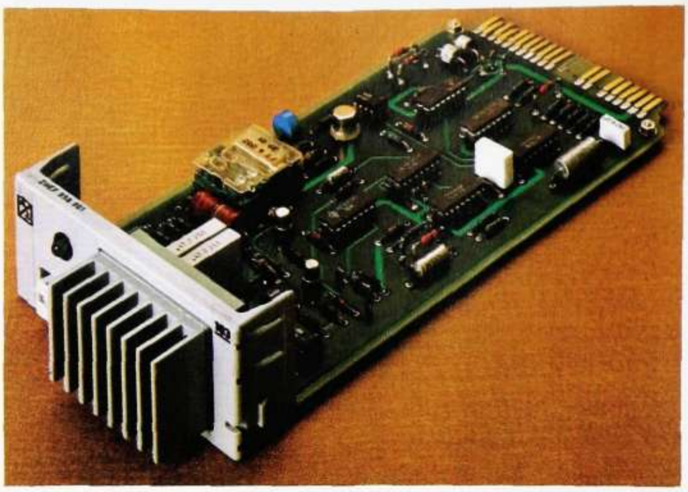


Fig. 9, left
Channel interface unit for double current and high voltage

Fig. 10, right
Channel interface unit for single current

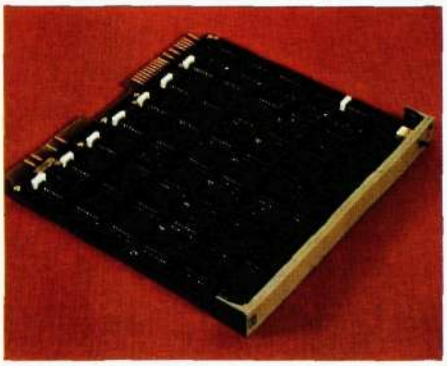


Fig. 12
Strapping field

subscriber equipment. The unit is equipped with efficient lightning protection.

Double current and low voltage
This unit is designed for matching to new electronic telex exchanges having an interface in accordance with CCITT Rec. V.28. In this case the voltage is ±12 V and the line current not more than 12 mA.

Single current
This unit, fig. 10, is designed for a nominal current of 40 mA and ±60 V voltage and has efficient lightning protection.

VF signalling in accordance with Recommendation V.21
This unit is designed for V.F. signalling using frequency shift modulation.

Central logic equipment
The central logic unit consists of a central processing unit, a store, a multiplexing unit, a demultiplexing unit and a strapping field.

The channel interface units are connected to the central unit via buses. Fig. 13 shows a simplified block diagram of the system. In this diagram three buses are shown: the address bus and the send and receive data buses. Exchange of data with a channel interface unit takes place when this particular unit is addressed.

The strapping field, fig. 12, permits individual strapping of each channel as regards speed and code structure.

The information in the strapping field can be transferred to the central unit store by pressing a reprogramming button. It is then possible to remove the strapping board for changes without disturbing the operation of the equipment. This gives the system complete flexibility and the possibility of reprogramming on site.

The action to be taken in the case of a multiplexor fault can also be arranged by means of straps. The following three alternatives are available:
- switching over to steady start polarity
- switching over to steady stop polarity
- switching over to steady start polarity after loop connection of the channel towards the local end for 5 seconds.

All timing information is derived from a central crystal-controlled clock. This timing gives scanning of every channel input at the centre of each unit element, counted from the beginning of the start element, and forming of a common single bit stream.

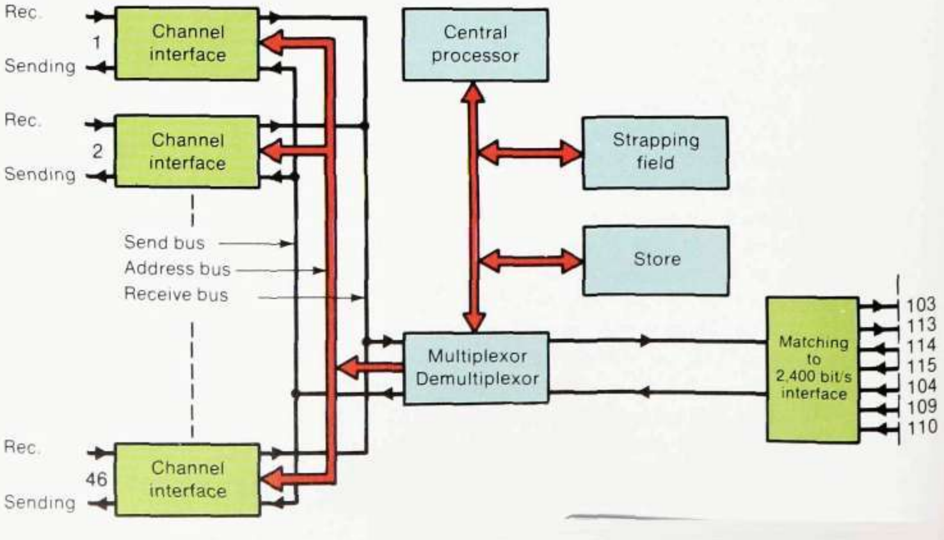
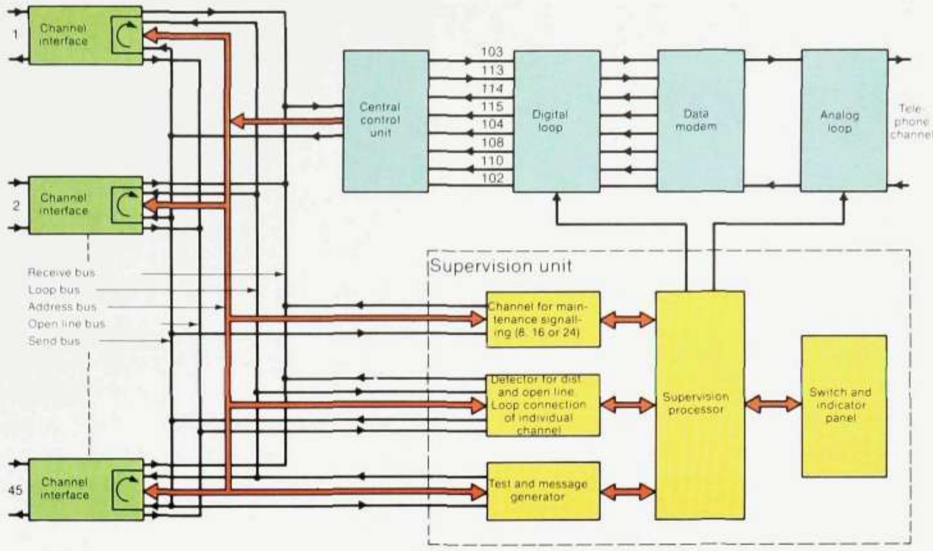


Fig. 11
Simplified block diagram of ZATF 46 CD

Fig. 13
Simplified block diagram of ZATF 46 CD with a supervision unit



Technical data

Type of system	Code and speed dependent time division multiplex in accordance with CCITT Recommendation R.101	
System capacity		
–Alternative A	Modulation rate, bauds	Number of channels
	50	46
	75	22
–Alternative B	Modulation rate, bauds	Number of channels
	50	46
	75	30
	150 or 134.5	22
	100 or 110	15
	200	10
	300	7
Speed tolerance	Max. +2% for 50 and 75-baud signals. Max. +1.8% for all other permitted speeds	
Highest acceptable distortion of the unit pulse to the receiver	46.6%	
Maximum start-stop distortion at the channel output	3%	
Types of channel interface units	–Double current, high voltage –Double current, low voltage –Single current –V.21 signalling	
Channel interleaving	On a bit basis	
Bit rate after multiplexing	2,400 bit/s	
Internal data modem		
Modulation method	Differential 4-phase, code A or code B	
Line connection	4-wire	
Nominal impedance, line side	600 ohms	
Send level limits	−0.5 and −46 dBm	
Receive level limits	−3 and −43 dBm	
Power supply		
Mains voltage	220 V	
Limits	+10 and −15%	
Frequency	45 and 65 Hz	
Battery voltage	48 or 60 V	
Limits	+20 and −15%	
Rack		
Height	2,600 mm	
Width	120 mm	
Depth	225 mm	

A bit interleaving multiplexing technique is used in order to achieve minimum transfer delay. Two different code structures can be used as recommended in CCITT Recommendation R.101.

The 2400 bit/s bit stream is converted from TTL levels to the electrical characteristics specified in CCITT Recommendation V.28. This is the standard interface between the multiplex equipment and the external or internal data modem.

Supervision equipment

The supervision unit, which contains a microprocessor, is a powerful device for monitoring and fault tracing. It is particularly useful when one ZAFT 46 CD terminal is unattended.

One of the 46 channels in the circuit is used as a maintenance channel, fig. 12. This allows the supervision unit to check the operation of the system. The quality of the incoming telegraph signals can be monitored and open line conditions detected. If there is an alarm at the far end terminal, for example if the distortion exceeds a preset value or there is an open line, the supervision unit sends a message to the attended multiplex. The message includes the number of the affected channel.

The near-end supervision unit receives the alarm message and displays it on an indicator. It also records the number of resynchronizations and on request transmits this information to the remote terminal.

Subscriber equipment can be tested from the supervision unit, which then transmits a special distorted test message. Similarly it can also check a distorted message received from the subscriber.

The same type of exchange of messages is used when a remote multiplex is operating in conjunction with AXB 20[3,4].

Data modem

The modem equipment operates at a data rate of 2,400 bit/s, synchronously over 4-wire telephone lines. The modem interfaces are in accordance with CCITT Recommendations V.24, V.26 and V.28.

References

1. CCITT: *Recommendation R.101.* Orange Book, Vol. VII, Geneva 1977.
2. Strindlund, E. et al.: *AXB 20–All Electronic, Stored-Program-Controlled System for Telex and Asynchronous Data Traffic.* Ericsson Rev. *54* (1977):1, pp. 32–40.
3. Strindlund, E. et al.: *AXB 20–Description of System.* Ericsson Rev. *54* (1977):1, pp. 41–51.
4. Lögdberg, L.E. et al.: *AXB 20–Operation and Maintenance Characteristics.* Ericsson Rev. *55* (1978):3, pp. 106–112.
5. Gatta, A. et al.: *Sistema TDM per la transmissione di segnali telegrafici e dati tipo ZATF 46 CD.* Not. Tecn. FATME No. 23, June 1978.
6. Squartini, G.: *Sistema TDM per la transmissione di segnali telegrafici e dati.* XXV International Scientific Meeting on Electronics, March 1978, Rome.

Computer Controlled Interlocking System

Hans S. Andersson and Gunnar Hagelin

LM Ericsson, in collaboration with the Swedish State Railways, have developed a computer controlled interlocking system for railway yards. The computer control means a considerable modernization of equipment compared with electromechanical technology. This modern interlocking system is already in operation in Sweden in the Gothenburg and Malmö areas.
The authors describe the system and how its fail-safe function has been achieved. This is followed by a description of a planning system for installations, and the article concludes with a brief account of the installations already in operation.

UDC 656.25:681.3

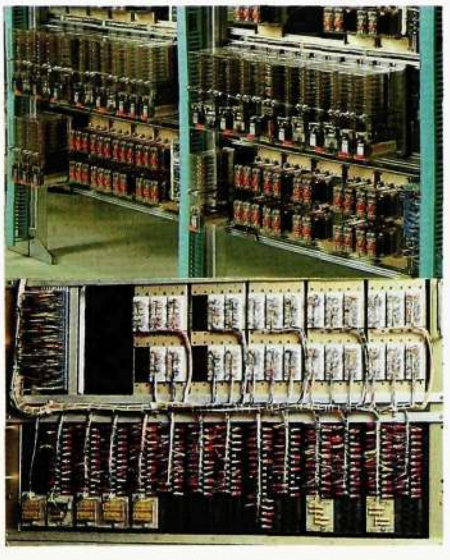


Fig. 1
The degree of safety obtained with robust relays, large insulation distances between the circuit elements, guided contacts and simple circuit structure corresponds to what is obtained with large information and system redundancy in a computer controlled system

Interlocking systems are used in railway signalling systems in order to ensure the safety of train movements. Before any train is moved a train route is prepared, which is then protected by the interlocking system against

- other trains in the train route, by checking that the track is clear
- other frontal train movements, by checking that there is an overlap area also beyond the end of the train route and that signals in the opposite direction show stop
- other flanking train movements, by checking that conflicting train movements are prevented by trap points and signals at stop
- changes in the point positions, by checking that all points in the actual train route, the overlap area and the flank protection area are locked in the correct position.

The protection is supplemented by a regulation that instructs the driver to keep within the applicable speed limit and to stop the train at the end of the train route. Equipment is also available which supervises the speed of the train and brakes it automatically if the driver does not comply with the regulations, as has been described in previous articles in Ericsson Review[1,2].

The checking that all conditions for authorizing a train movement have been met is carried out wholly automatically in modern signal safety systems. Conventional systems use safety relays, the contacts of which are connected together to form current paths that correspond to the different conditions. In LM Ericsson's new system, the interlocking conditions are checked by a computer, figs. 1 and 2.

System principle

Stored program control has been chosen for the interlocking function because the increasing demands for more complex interlocking conditions have made it very difficult to design systems using relay technology that can easily be modified and extended. The use of

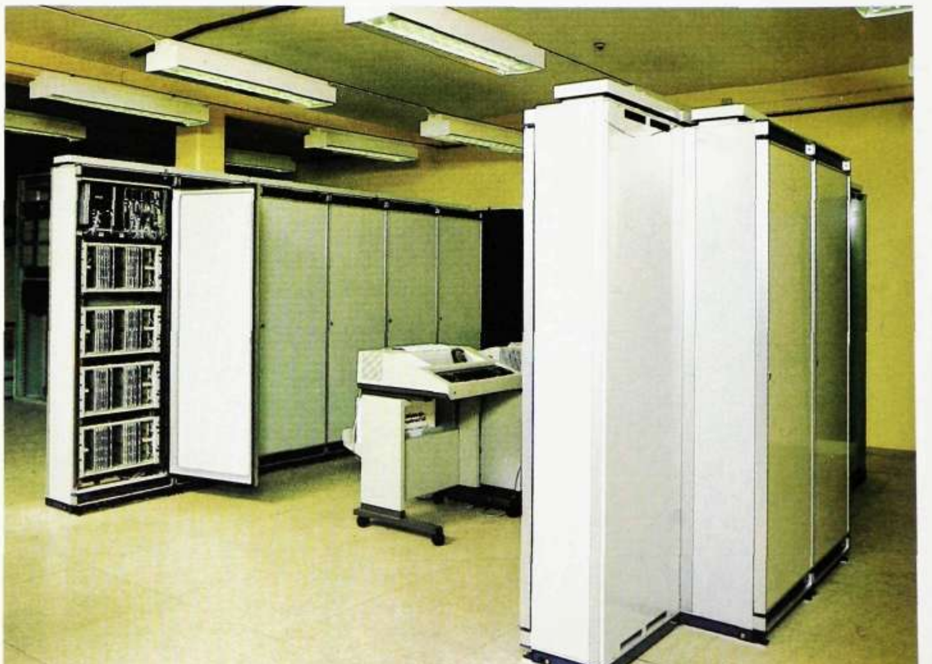


Fig. 2
The LM Ericsson computer UAC 1610 P for stored program control of the signal box for the Malmö railway yard area, in south Sweden

HANS S. ANDERSSON
GUNNAR HAGELIN
Signalling Systems Department
Telefonaktiebolaget LM Ericsson

computer control for the interlocking function makes the matching to the remainder of the signalling equipment easier. The overall cost is lower, not only for the equipment itself but also for the planning and installation.

The trackside devices, such as track circuits, points, signals etc., are connected in groups to concentrators, which are then connected, via transmission links, to the interlocking computers. Messages are transmitted in both directions in serial form, and each message is supplemented with redundant information in order to ensure fail-safe function.

The system comprises (see fig. 3):
- control and supervisory subsystem
- interlocking subsystem
- transmission network between the interlocking subsystem and the trackside concentrators
- subsystem for interfacing between the concentrators transmission terminals and the trackside devices.

The first two subsystems are computer controlled and the computers are duplicated to ensure availability. The transmission network is supplemented with alternative routes.

A documentation system, which uses a separate computer has also been developed for the planning of installations.

Control and supervision subsystem

In the new interlocking system colour displays replace the old type of indication panels, where lamps were used to indicate train positions, signal conditions, point positions etc. Each operator now has a work position with two display units and a keyboard which is used to give all commands, figs. 4 and 5. One display gives an overall picture of the supervised track area, and the other gives detailed information for a selected part of the track.

Different types of alarms are also shown on the display units, and the operator can enter commands via the keyboard to display alphanumerical information concerning a particular alarm.

The system also permits automatic commands. Such commands are programmed in advance and are released when certain conditions are met. The operator can also compile automatic functions himself, for example for frequently recurring shunting movements.

Commands to the interlocking system, for example the setting up of a train route, are always reviewed before the interlocking system starts to arrange safeguards, block devices, change points etc. This is done to prevent the system

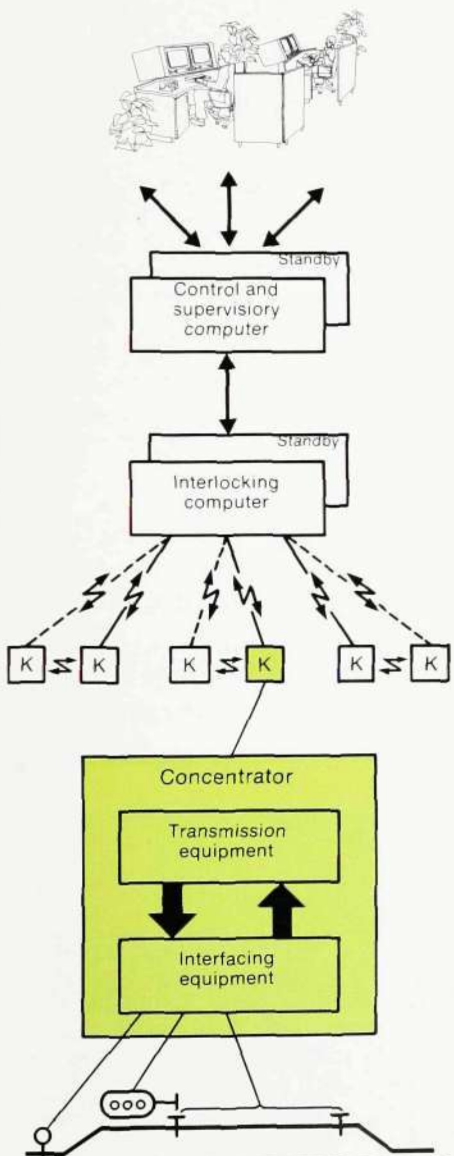


Fig. 3
The main parts of the interlocking system

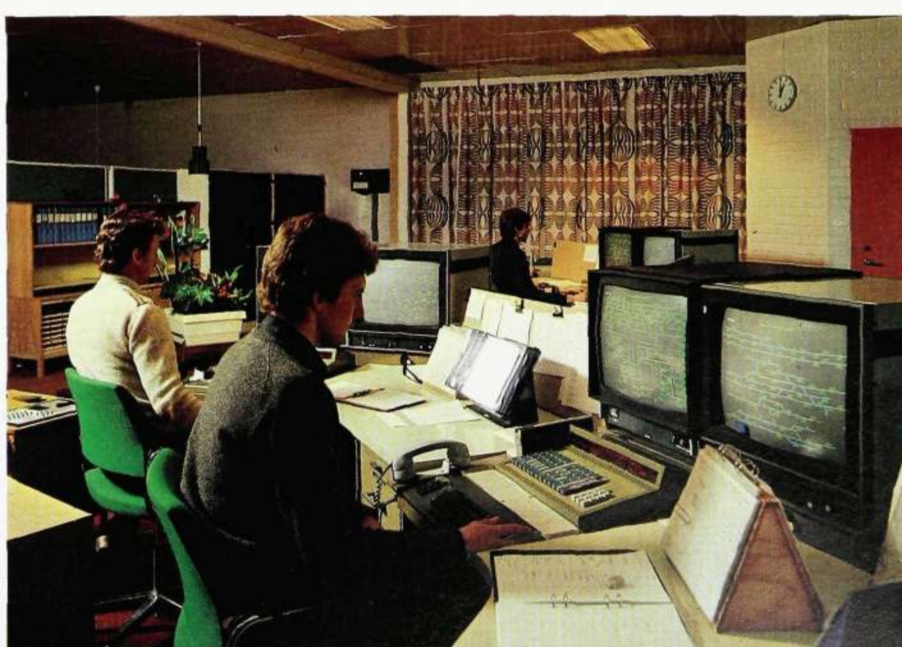


Fig. 4
The control office for the Gothenburg railway yard area, western Sweden

Fig. 6
The processing stages during an operating cycle

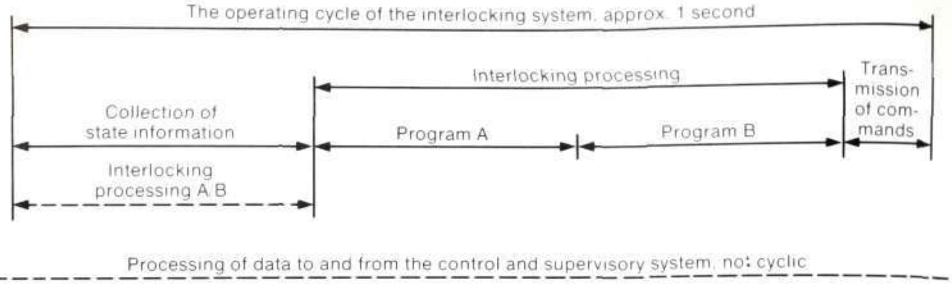


Fig. 5
Keyboard for the input of commands

from being loaded with unnecessary blockings. A command that is not accepted in the review is put in a command queue, and is then reviewed repeatedly until the conditions are met or the command is cancelled manually.

Interlocking subsystem

The interlocking subsystem acts as a safety filter and prevents dangerous commands from the control system from being executed. The stored program control in the interlocking system uses an algorithm for this filter function, so that

- correct commands from the control system are safely transmitted to points, signals and level crossing equipment
- devices that are to be included in a train route are blocked against use in other routes
- blocked devices are relased when the train is clear of the route.

The processing in the interlocking computer is cyclic. The cycle time is approximately one second. During each cycle, fig. 6,

- all information concerning the state of the various devices is collected
- any commands from the control and supervision system are processed
- the interlocking data are processed in two separate program sequences
- commands to the devices are compiled and transmitted
- information concerning the yard status is transmitted to the control and supervision system.

Commands from the control and supervision system are transmitted in a background program and not as a part of the fixed cycle.

The data processing is duplicated for safety reasons. Two different program sequences each process the yard device data in accordance with the algorithm. The processing results in two commands per device, and check bits are added to both in order to ensure safe transmission. Finally the command message from one program sequence and the check part from the other are combined and sent via the concentrator to the interfacing equipment for the trackside device.

Interlocking conditions according to the geographical method

The interlocking conditions have been given a stringent mathematical descrip-

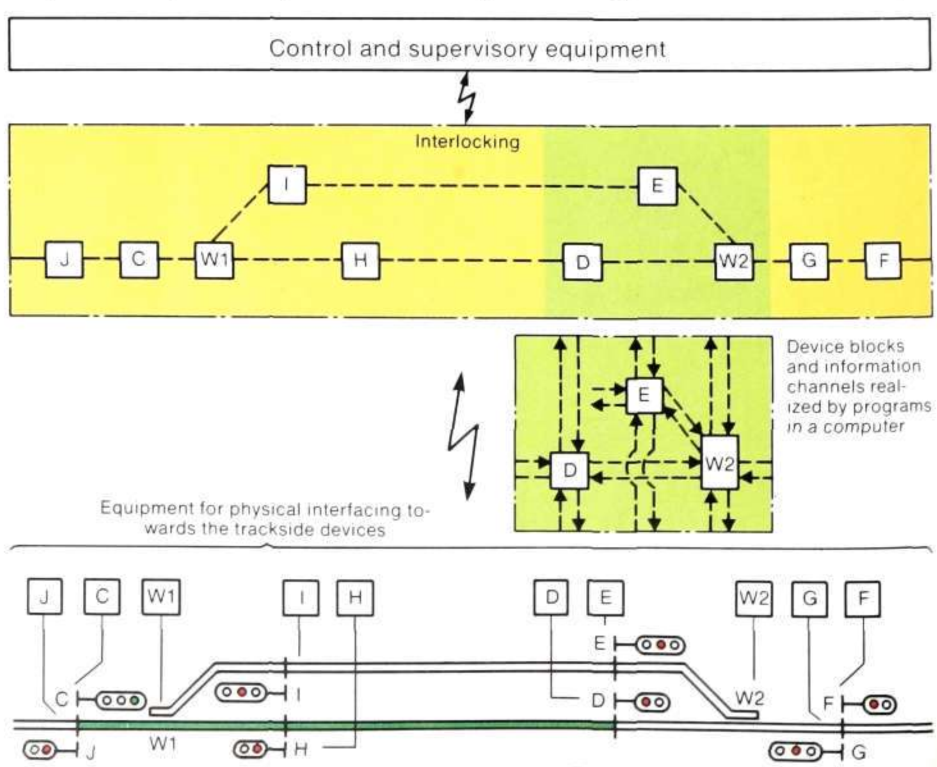


Fig. 7
The basic principle of the geographical method

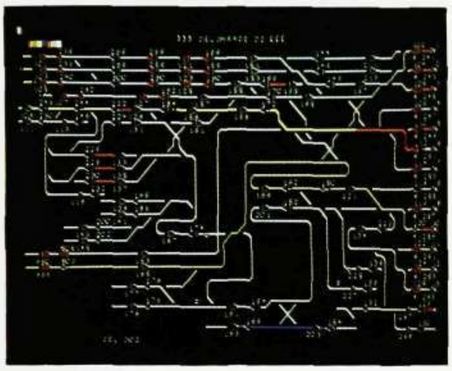


Fig. 8
A set train route is marked with a green line on the display screen and a shunting route is marked with yellow or blue alternatively

tion. The conditions are described in accordance with the geographical method, which means that they are related to the various trackside devices: points, signals, derailers etc.[1] For each device the conditions for every possible state and every possible change of state are set. Fig. 7 shows the geographical method in principle. Each device has an associated block with interfaces towards

- the control system
- the trackside device
- the blocks for the "geographical neighbours".

The interfaces towards the neighbours are the same for all devices, whereas the interfaces towards the control system and towards the trackside device are the same for each type of device.

When a train route is set up, figs. 7 and 8, the block for signal C receives an order from the control system to seek the necessary protection for the train route, so that command to show green light can be sent to the signal. At the same time the other blocks in the train route are ordered to assume states that form the conditions for establishing the route. For example, signal D is ordered to form the end point of the train route, which in its turn means that signal D must seek the necessary protection for the overlap area beyond the signal. Messages are then exchanged between the blocks in accordance with the program, and the blocks successively change state until the states of the whole chain of blocks in the train route agree with the interlocking conditions. The changes of state of the blocks also mean that the points in the train route and the flank protection are set and locked in the correct position etc. When all this has been completed, all conditions for the train route have been fulfilled and the block for signal C can send a command to set the signal to "clear".

The messages that are exchanged between blocks which are geographical neighbours can be divided into the following categories, namely messages that

- state the type of train route that is to be established, and which command the locking of the route
- indicate the type of flank protection and the length of the overlap area required for the train route
- inform that flank protection and overlap protection are achieved
- indicate clear track along the train route, in the overlap area and in the flank protection areas
- state the maximum speed for the train route
- control the level crossing devices
- release the devices in the train route when the train has passed.

Types of blocks

For each block there is a description of how the block must react to an incoming message, and which messages the block is to send to its neighbours, its own device and the control system.

The system contains the following eight types of blocks:

- signal blocks for signals
- advance signal blocks for independent advance signals
- point blocks for points and stop blocks
- crosssing blocks for track crossings
- road blocks for level crossing devices
- boundary blocks for the boundary towards areas without interlocking
- line blocks forming boundaries against lines between stations and against other signal box areas
- obstacle blocks, which add dependence on extra track circuits.

Processing of blocks

The conditions for each type of block are described by a number of equations in algebra that is similar to Boolean algebra, fig. 9. However, each variable can normally take up more than two values.

When processing a block, for example signal block D, the computer program uses the equations that apply for signalling blocks on the data of signal D, fig.

Fig. 9
An equation that describes a sub-condition for a device

```
IF (K.EQ.4.AND.(P1.EQ.2.OR.P1.EQ.3).AND.RØ.EQ.1.AND.
*(PK.NE.Ø.OR.R6.EQ.1.AND.(U2.NE.8.OR.
*I2Ø5.EQ.Ø.AND.T2.EQ.Ø)))R6=1.
```

Point block

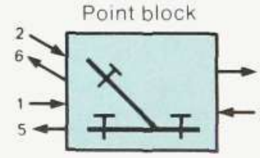
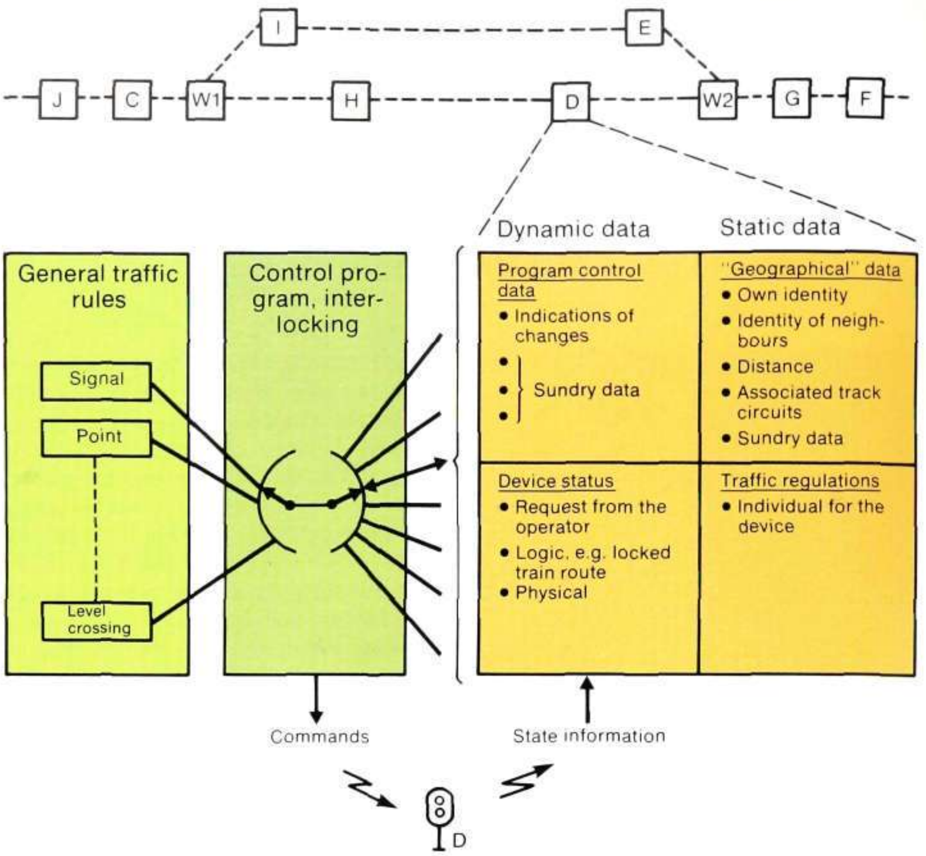


Fig. 10
The basic principle of the processing of the data concerning an object block



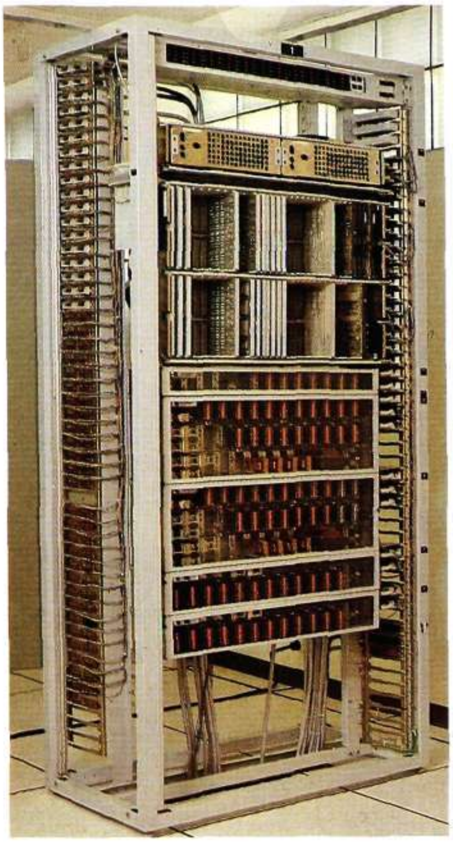


Fig. 11
Transmission terminal and interfacing relay units in a concentrator

10. The processing, including the exchange of messages with neighbouring blocks, continues until the equations have been satisfied and have resulted in
- a change of state for the block in question
- a change of state for the geographical neighbours
- the necessary commands to the device associated with the block
- information to the control system.

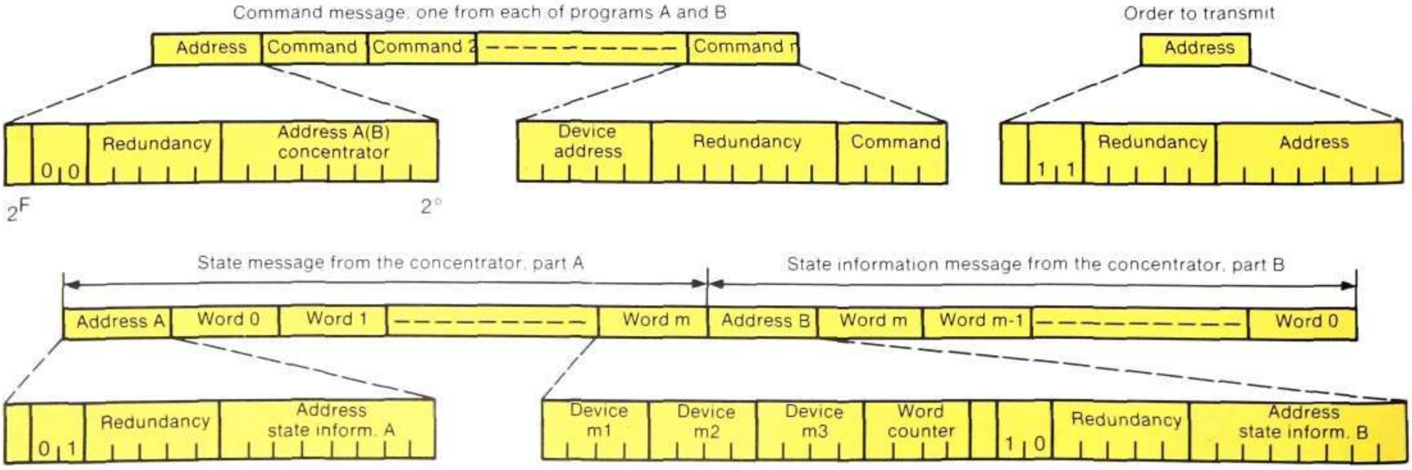
Transmission network

Concentrators are placed in the track area near groups of devices. Each concentrator contains interfacing equipment for the various devices and a transmission terminal, fig. 11. The system is dimensioned so that each terminal can serve 24 track circuits and 31 other devices. The system can address 64 terminals. However, the cycle time, one second, limits the number of devices that can be served to less than the total addressing capacity. Two important parameters in this connection are the interdependence of the devices and the number of simultaneous train movements in the track area served.

The exchange of messages between the interlocking computer and the concentrators is serial in half duplex form over two-wire circuits. The transmission rate is 4,800 bit/s. Two concentrators can be connected to each two-wire circuit. The transmission terminals can be reached from the computer via two alternative routes.

The exchange of messages must meet the fail-safe requirement. Each message therefore contains a number of check bits in addition to the actual information, which ensure that distorted messages cannot be misinterpreted and cause danger. Fig. 12 shows the struc-

Fig. 12
The format of telegrams between the interlocking computer and the concentrators



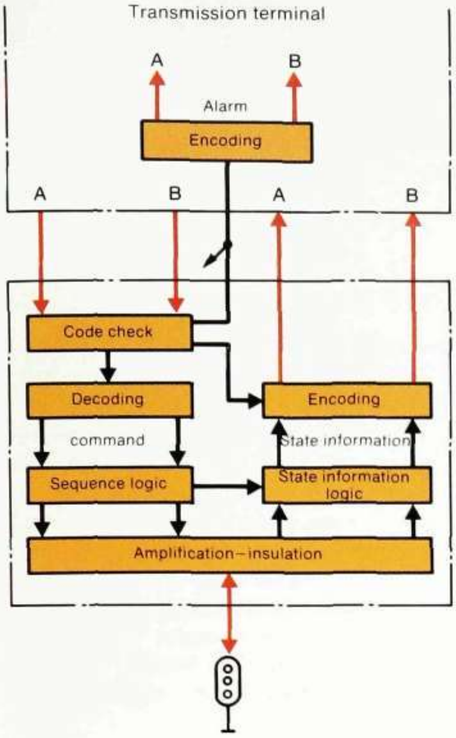


Fig. 13
Block diagram of the interfacing circuits for a trackside device

ture of the messages to and from the interlocking computer.

Trackside interfacing equipment

The equipment for interfacing towards the trackside devices is realized in conventional relay technology. It also includes relays for the decoding and checking of orders from the interlocking system. In addition it contains equipment for encoding the information about device states that has to be sent back to the interlocking system, fig. 13.

For example, for a point the following information is exchanged between the interlocking system and the interfacing equipment:

Commands
- release the locking of the point
- lock the point
- set the point to the reverse position
- set the point to the normal position
- release the point for local operation
- resume control of the point.

State information
- switching is taking place, or the position is not under control for some other reason
- the point is locked in the reverse position
- the point is locked in the normal position
- the point is released for local operation.

Fail-safe function

The use of computers in equipment with fail-safe function requires a system design that can never set the controlled devices in dangerous positions, even if faults occur in the hardware or the software. Thus the data processing that leads to such commands as "clear" for signals is always carried out in two separate program sequences, and the results must be compared outside the computer before the command can be executed, fig. 14.

The two program sequences have been designed by two separate programming teams and have both undergone careful examination and testing. The program sequences with the assocciated data are stored in different places in the computer memory, so that any hardware faults will also be discovered.

One prerequisite for the system is that the data to be processed are not too old. The stored information in the computer concerning the state of the different devices etc. is therefore updated every program cycle. Furthermore the data are labelled with the time, so that their age can be checked.

The mathematical description of the safety conditions, which forms the basis for the whole system, has been examined in detail by signal and traffic experts and has also been tested in a simulator. There is only one version of the description, but it is stored in the memory area of each of the two progam sequences, and will therefore be used in two different ways.

Individual data, which describe the various devices and their neighbours in each installation, also occur in only one version, but are also stored in both program areas.

The system contains further functions to ensure fail-safe operation. This problem has been discussed fairly comprehensively in a previous article[2].

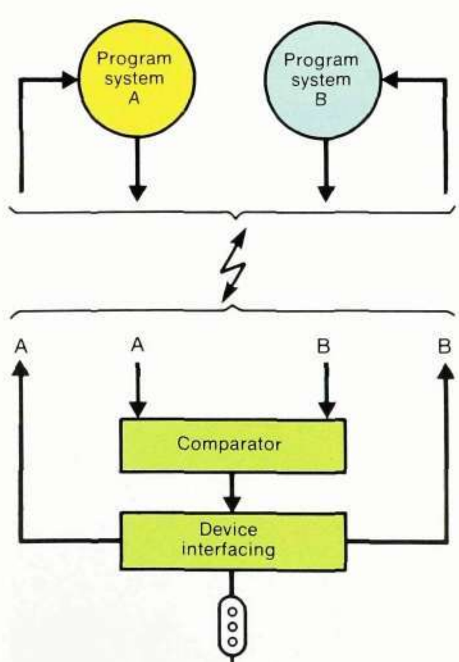


Fig. 14
Duplicated processing of commands to ensure fail-safe function

Fig. 15
The control office for Malmö railway yard area

Project planning system

A project planning system is used to prepare installation documents and the individual data for the control computers. An off line computer is used for the project planning system. The input data for this system are specified on standardized forms by the customer's project planners. The input data consist mainly of information concerning the structure of the track network and the individual characteristics of the yard devices.

The system provides
- data files for the control computers
- information for the installation of concentrators, cabinets, cables etc.
- materiel lists.

The project planning system is also used to plan extensions, handle version numbering etc. The data concerning each installation are stored in a data base.

Installations

Interlocking systems of the type described above are in operation in Gothenburg and Malmö yard areas.

Trial operation started in a small part of the Gothenburg yard area in May 1978. The results were satisfactory, and after minor modifications to the program system the installation was extended in November 1979 to include the central parts of the yard area.

The Gothenburg yard area is extensive and includes a large number of passenger stations as well as goods, harbour and industrial yards. Before the installtion of the new system the five passenger stations had individual signal boxes. These were worn and the operation was very personnel-demanding. The goods yards, and the tracks between them, lacked adequate safety arrangements, which meant that a large staff was required for the traffic handling and that the traffic capacity was low.

With the new system the traffic control and the safety interlocking have been centralized to one place, fig. 4. The trackside devices are successively being connected into the system. At present over 600 devices are under control, including 115 points, 216 signals and 203 track circuits. The central equipment communicates with the devices via 15 concentrators. When fully extended the installation will comprise about 1,200 devices.

The Malmö installation will comprise three passenger stations, two of which were completed in February 1981 and which contain about 330 trackside devices, including 40 points, 145 signals and 110 track circuits. The devices are connected to the central equipment via nine concentrators.

References

1. Andersson, H.S.: *Railway Signalling Systems*. Ericsson Rev. *57* (1980):4, pp. 118–123.
2. Sjöberg, A.: *Automatic Train Control*. Ericsson Rev. *58*(1981): 1, pp. 22–29.

A Rectifier for Large Plants

Leif Hansson and Renzo Santi

LM Ericsson are now introducing a new thyristor rectifier, BMT 343, for 48 V and 400 A. It forms part of a new power supply system, BZD 412, for large telecommunication plants. The authors describe how the rectifier functions in that system, its electrical and mechanical design, its control arrangements, its protection and alarm circuits and its installation, operation and maintenance features.

UDC 621.314.6:
621.311.4:
621.395.7

LM Ericsson's previous power supply system, BZD 101, was replaced for small plants by system BZD 112 in 1978. The product range is now also being updated for large plants by the introduction of system BZD 412. An important part of this new system is the thyristor rectifier, BMT 343, for 48 V and 400 A.

BMT 343, fig. 1, is intended primarily for feeding large electronic exchange systems for telephony, telex or data, such as the LM Ericsson systems AXE 10, AXB 20 and AXB 30.

The new rectifier

- meets the demands that are made on power supply units for electronic equipment as regards ability to withstand transients on the a.c. side and low transient and interference levels on the d.c. side
- is equipped with protective devices, which prevent damage or operational disturbances in the equipment which it supplies
- is suitable for connection to low quality mains, e.g. mains with large variations in voltage and frequency, or with frequent interruptions, or from low power high-impedance mains, e.g. local standby power plants
- contains few units, which makes for simple installation, testing and putting into operation
- has high reliability, is easy to handle and requires little maintenance. It can be remotely controlled as regards switching on and off, changing the voltage for battery charging etc. Alarms are automatically forwarded to central equipment. These features make the rectifier very suitable for unmanned exchanges
- is designed to ensure high personnel safety. Live parts have been made so inaccessible that accidental contact is impossible
- is dimensioned for natural cooling.

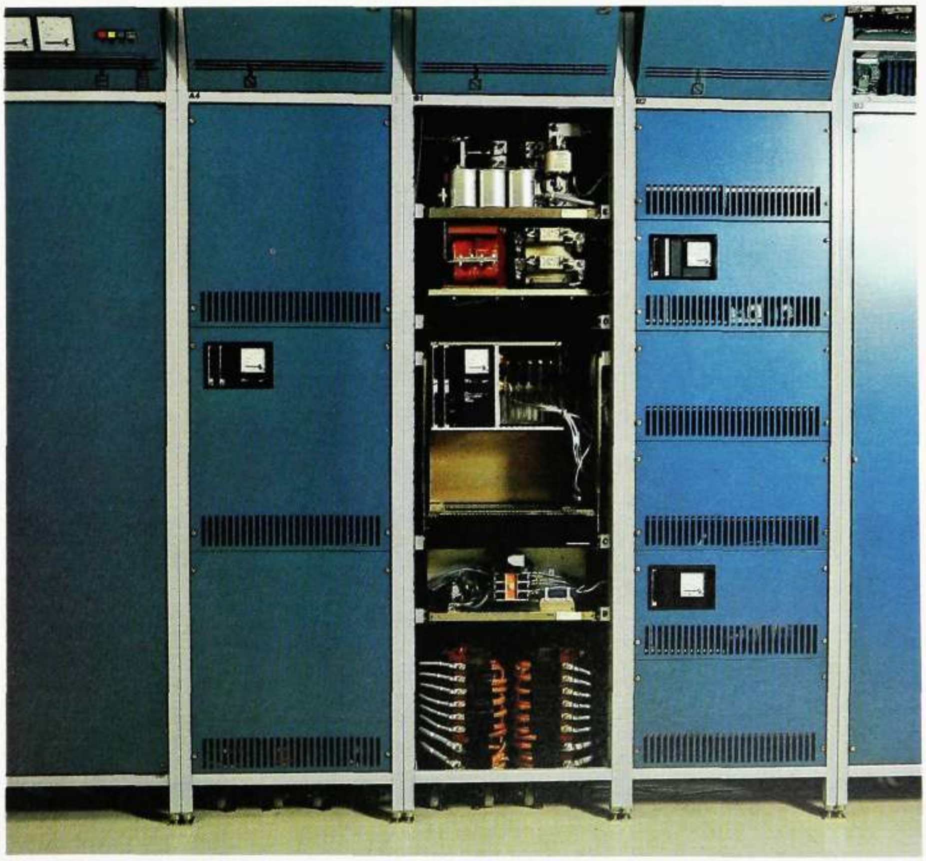


Fig. 1
Power supply system BZD 412.
The picture shows, from the left, distribution rack BMG 651, a rectifier BMT 343 with front cover, a rectifier without the front cover and two 400 A converters, BMR 273. Each rack has the dimensions 600×600×2200 mm

LEIF HANSSON
RENZO SANTI
Power Supply Department
Telefonaktiebolaget LM Ericsson

Function in the system

The rectifier, BMT 343, can be used in different power supply systems containing batteries, fig. 2. During operation the battery is float-charged in the conventional way. The rectifier voltage is kept so high that the self-discharge of the battery is compensated.

After a heavy battery discharge, for example after a mains failure, the rectifier output voltage is raised to the recharging level. When the battery is fully recharged, the voltage is decreased to the float level. The state of the battery is monitored continuously by automatic charging equipment, previously described in Ericsson Review[2].

Several rectifiers can be connected in parallel and the current load is then shared equally between them. Step-connection equipment can also be used, which connects and disconnects rectifiers according to the load. This step-connection equipment is only provided where the current consumption varies considerably.

Special Master Voltage Control (MVC) equipment is used in very large systems if the power supply is sectioned. MVC is connected to the rectifier group in each section and provides them with correction signals, so that the different parts of the powered telecommunications plant receive exactly the same voltage from each rectifier group. The rectifier design also allows for control from a centralized microcomputer supervision system.

Technical description

The rectifier consists of the following units:

- d.c. controlled contactor for connection to the a.c. mains
- two transformers for transforming down to a twelve-phase secondary voltage
- thyristors with control circuits for the rectifying function
- interphase transformers for connecting together the neutral points in the star windings of the secondary sides
- a filter for smoothing the d.c. voltage.

The rectifier also contains devices for operation and alarm, mounted on the front, and circuits for receiving and executing remote control commands. There are also internal protective devices which disconnect the rectifier in the case of overvoltage and then automatically start it up again. In addition the rectifier contains phase failure protection and electronic fuse alarms.

Rectifier circuit

The three primary windings are star-connected in one transformer and delta-connected in the other, fig. 3. The secondary windings of each transformer are connected as two three-phase stars with 180° phase shift between them. In this way each transformer gives six phases with 60° shift relative to each other. The different connections of the respective primary windings to the mains mean that the two six-phase stars have a phase shift of 30° and thus the overall result is a twelve-phase star with 30° between the phases.

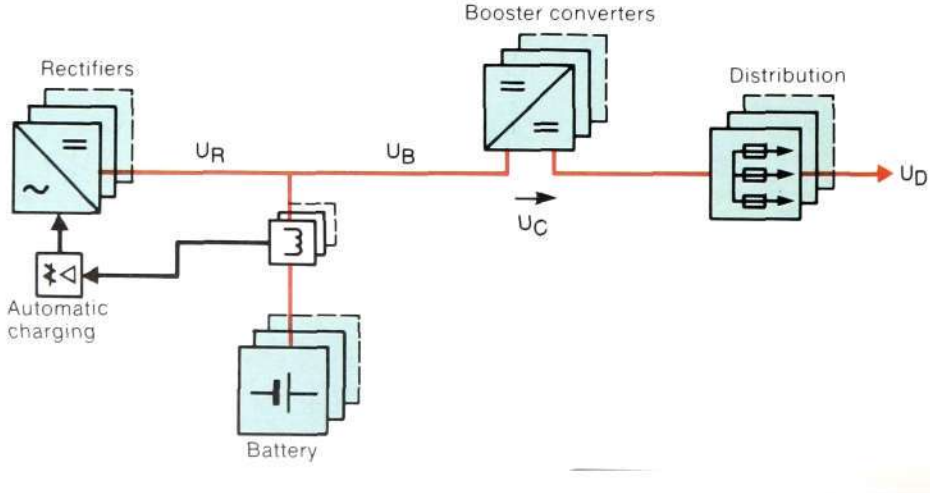


Fig. 2
Power supply system BZD 412 with thyristor rectifiers BMT 343 and high-frequency booster converters.
The block diagram shows the position of the various units in the system

On the secondary side the neutral points of the two stars in each transformer are connected to an interphase transformer. The centre points of the two interphase transformers are then connected to a third interphase transformer, the centre point of which constitutes the negative pole of the rectifier.

The interphase transformers maintain the voltage differences that occur between the neutral points of the stars and constrain the current to divide equally between the two halves of the windings. This means that each three-phase star will contribute a quarter of the total current. There is no d.c. magnetization of the interphase transformers since the currents in their two winding halves are equal and oppositely directed.

The rectifier consists of twelve thyristors, one for each phase. Each thyristor normally conducts for a third of the mains cycle, i.e. the conducting angle is 120°. This means that four thyristors, one in each three-phase star, conduct simultaneously. The peak current through each thyristor is thus a quarter of the output current.

The output voltage from the inter-connected thyristors is a d.c. voltage with a ripple frequency that is twelve times the mains frequency, namely 600 Hz. This high ripple frequency means that the smoothing filter that follows can be made with small mechanical dimensions. The filter is a T-type low pass filter with chokes in the series branches and two electrolytic capacitor banks with fuses in the shunt branch, an LCL filter. The a.c. voltage component is attenuated in two steps in the filter, first by the choke nearest the interphase transformer and the capacitor banks, then by the second choke and the battery. The chokes limit the ripple current, and the capacitor and battery shunt the current, so that the resultant noise voltage at the output across the battery is very low.

A fuse which also functions as an isolator is included in the rectifier output. When the rectifier is to be connected to the battery, the filter capacitors must be charged before the fuse is inserted. This charging is carried out automatically by a special circuit. An LED indicates when the charging is completed. Slow charging is necessary, otherwise the large capacitor banks would experience a current surge that could shorten their life. Furthermore the filter capacitor fuses would not withstand a rapid charging.

On the d.c. side the rectifier satisfies the radio interference requirements of CISPR Recommendation No. 43. On the mains side, radio interference suppression filters are not standard but can be included in the rectifier as optional extras.

Control circuits

Voltage-control of the rectifier is effected by changing the trigger phase angle of the thyristors so as to keep the output voltage constant. When the output current exceeds the rated value, the

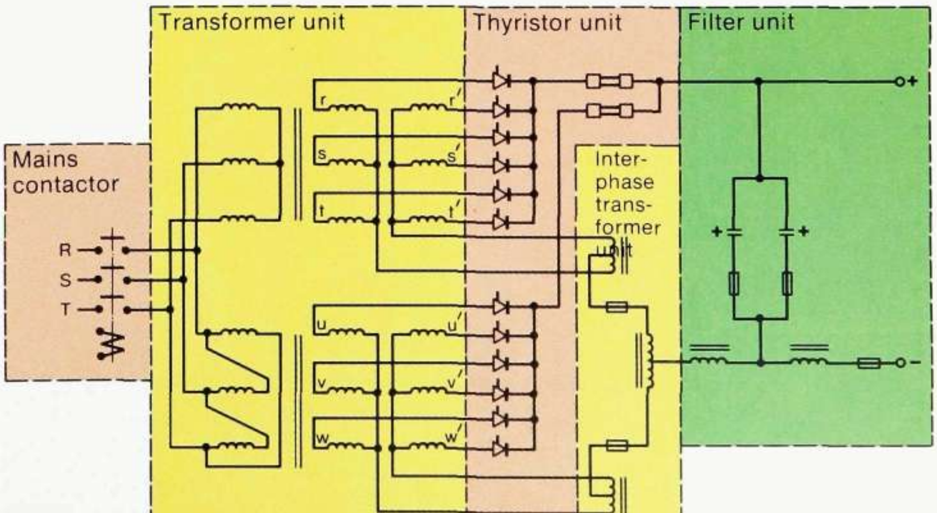


Fig. 3
The rectifier circuit.
Three-phase mains voltage is fed to the two transformers via the mains contactor. The thyristors in the thyristor unit rectify and control the voltage, which is then smoothed in the filter unit. The thyristors receive trigger pulses at the correct instants so that the output voltage is kept constant

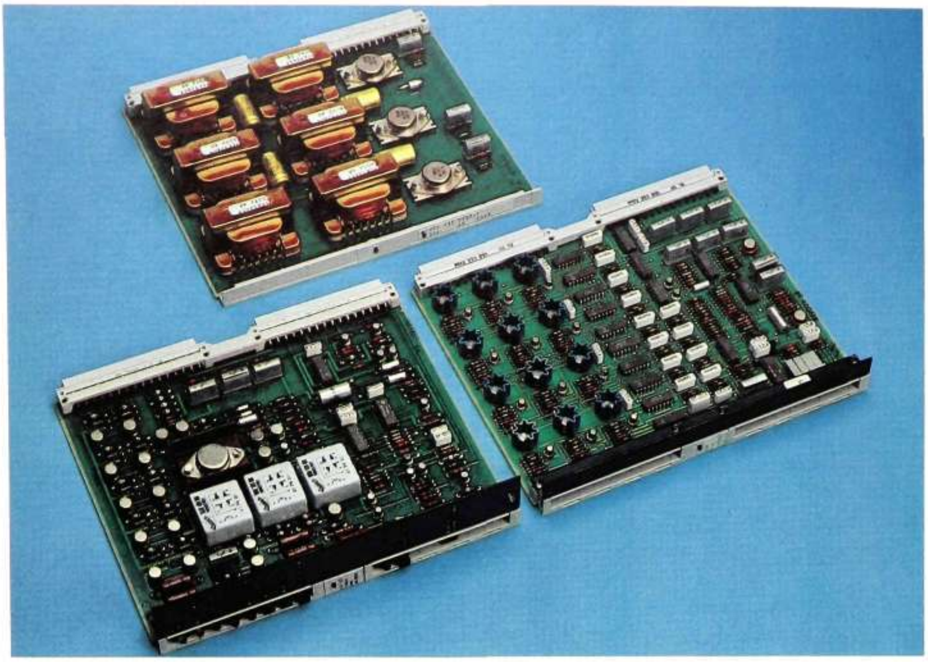
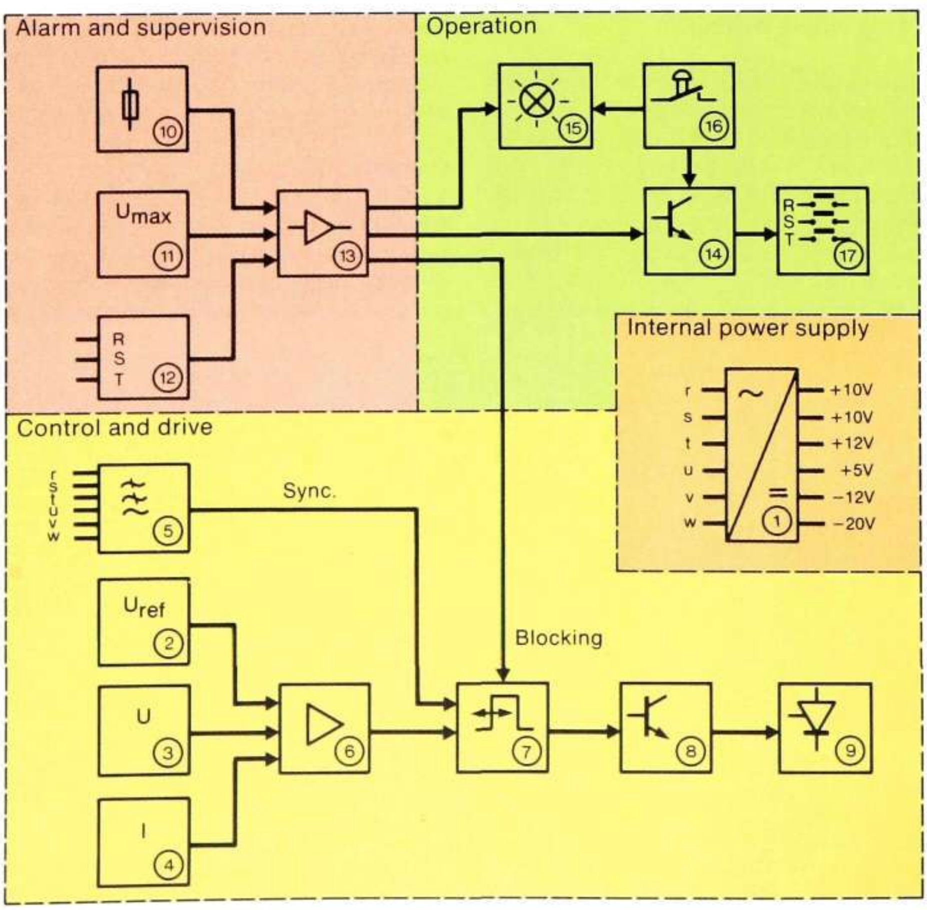


Fig. 5
The printed board assemblies with the control circuits. At the top the printed board assembly for the internal power supply, below those for all control circuits

Fig. 4, below
Block diagram of the control circuitry, which is divided into four blocks. The control and drive circuits provide the thyristors with trigger pulses phased so that the output voltage and current are kept constant. The alarm and supervision circuitry consists of drive circuits for the mains contactor and push-button switches for external control of the rectifier.
The internal power supply provides the feeding voltages for the control circuitry

1 Internal power supply
2 Reference voltage
3 Voltage sensing
4 Current sensing
5 Integrator
6 Comparator
7 Pulse generation
8 Thyristor drive
9 Thyristors
10 Fuse sensing
11 Overvoltage sensing
12 Phase sensing
13 Supervision and alarm
14 Contactor drive
15 Indication
16 Operation
17 Mains contactor



constant voltage control is changed into constant current control in order to avoid overloading the rectifier, fig. 4.

The control circuits, with their alarm and supervision circuits, are mounted on two printed boards, fig. 5. A third printed board holds transformers for synchronizing, trigger pulse feeding and circuits for the internal power supply.

The interal power supply is stabilized by voltage regulators. The reference voltage consists of the voltage across a zener diode with compensated temperature dependence. A resistive voltage divider is used to sense the voltage and a shunt to sense the current. The difference between the actual and desired d.c. voltage values is fed to the control amplifier.

The output signal from the control amplifier, together with the synchronization voltages, are fed to comparators, which give twelve trigger pulses per period with a phase shift of 30°. The phase position of the control pulses relative that of the a.c. voltage is affected by the output signal from the control amplifier, so that constant voltage or constant current control is obtained. There is an amplifier stage for each trigger pulse to ensure large control pulses with a rectangular shape and steep flank, which is necessary for triggering large thyristors. The control current is constant and independent of the thyristor characteristics.

The current control circuits in all rectifiers that are connected in parallel are connected via special amplifiers, one in each rectifier, in such a way that they share the total direct current equally.

When the rectifier is started, the current and voltage are increased slowly (walk-in start). This method avoids voltage transients towards the load and current shocks towards the battery.

The rectifier output voltage can be adjusted to between 44 and 61 V using potentiometers. The upper limit for the rectifier output current is normally 400 A. With manually controlled rapid charging of the battery, this current can be limited to other values below 400 A by means of another potentiometer.

The main features of the control system are:
- correct function even with large mains waveform distortion
- even current sharing by the 12 thyristors in the rectifier
- the regulation level is not sensitive to variations in temperature
- even load sharing between rectifiers that work in parallel.

Protection and alarm circuits
The rectifier is protected against excess current by the current limiting of the control system and by the fuse on the output, which will blow for the current surge that occurs with a short circuit.

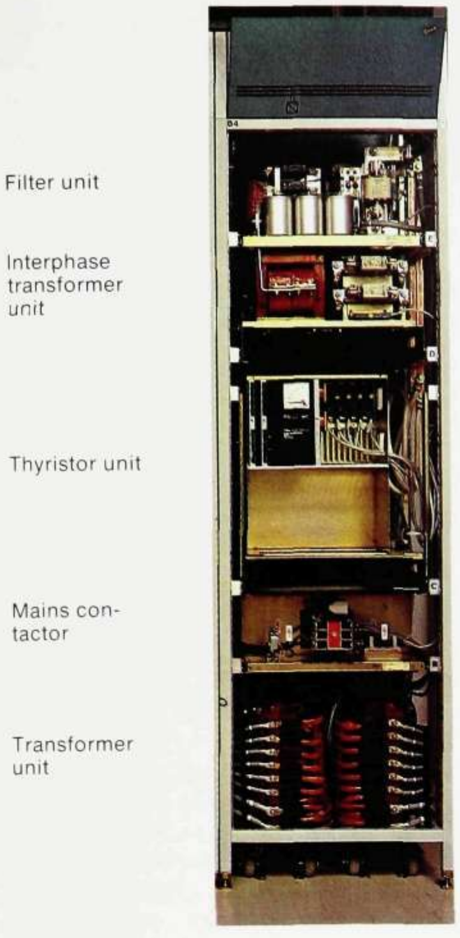


Fig. 7
A complete rectifier.
The units are installed and the cabling is done from the front

Further short-circuit protection is provided by two cartridge fuses, which protect the transformers and current measuring shunts against short circuits in the thyristor unit.

The rectifier has a selective overvoltage protection combined with automatic restart, fig. 6. If the output voltage exceeds a predetermined level, the thyristor trigger pulses will be momentarily blocked, thereby cutting off the power output from the rectifier. The rectifier is then restarted in the walk-in mode. If the overvoltage recurs and at the same time the current from the rectifier exceeds a certain value, the rectifier will be completely switched off via the mains contactor and an alarm given. Current sensing is carried out in order to achieve selectivity. The rectifier that causes the overvoltage will be delivering all of the current to the load. This means that the rectifiers which have overvoltage on their output but do not deliver current have not caused the overvoltage. These rectifiers therefore do not have to be disconnected.

Automatic restart effectively prevents spurious shut-downs due to voltage transients of external origin, for example caused by a fuse blowing.

If an interruption occurs in one phase, the rectifier would work as a single-phase rectifier with a risk of overloading the thyristors. Moreover the noise voltage at the rectifier output would increase. This is prevented by a phase failure protection, which blocks the thyristor trigger pulses and gives an alarm if there is an interruption in any of the phases. Restart is carried out automatically when the fault has been cleared.

All fuses in the rectifier are supervised by an electronic circuit, which disconnects the mains contactor and gives an alarm for a blown fuse.

Operation

The rectifier can be operated directly or remotely.

Direct operation is by means of pushbotton switches placed on the front of the rectifier. With direct operation it is possible to
- connect and disconnect the rectifier
- increase the output voltage for battery charging
- reset alarms
- test the overvoltage protection.

Remote operation is carried out over a cable plugged into the rectifier. WIth remote operation it is possible to
- increase the rectifier output voltage for battery charging
- control the rectifier output voltage so that it follows an external voltage (MVC)
- block the thyristor trigger pulses and thus obtain momentary disconnection
- operate the rectifier mains contactor, for example with control from a step connection device.

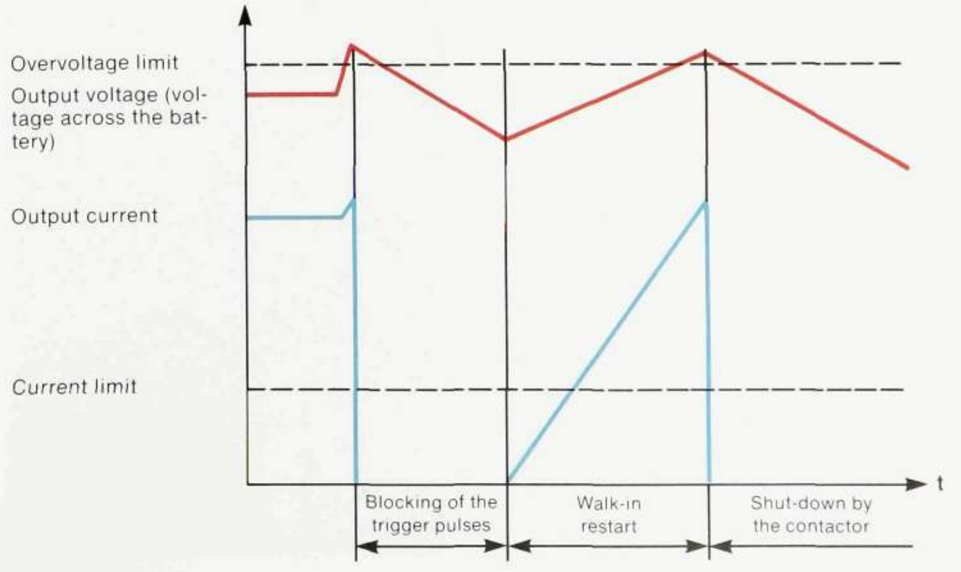


Fig. 6
The operation of the overvoltage protection.
If the rectifier output voltage becomes too high, the rectifier is first blocked momentarily, then restarted. If the overvoltage recurs, and at the same time the current exceeds a certain preset value, the rectifier is completely disconnected. However, no disconnection takes place if the rectifier operates normally after the restart. Thus transients cannot cause disconnection

Fig. 8
The transformers are equipped with wheels, which simplifies their handling during installation. The front cross-member of the rack is removed when the transformers are installed. Clear labelling ensures correct connection to the secondary side. The fixed cables on the primary side are connected direct to the mains contactor

Mechanical construction

The rectifier is mounted in a rack, BAF 201, with dimensions 600×600×2200 mm, fig. 7. It is covered with three front plates. The six units in the rectifier rack are mounted in the following order (from the bottom): transformers, mains contactor, thyristor unit, interphase transformers and filter unit. The rack sides are equipped with guide rails, so that the units, with the exception of the transformers, can be slid in and out of the rack. The units are cooled in accordance with the parallel cooling principle, which means that there are several air inlets in the front panels.

The transformers are placed direct on the floor, fig. 8. They are mounted on wheels, which simplifies installation and reduces acoustic noise (hum) during operation. Fixed cables on the primary side of each transformer are connected to the mains contactor. The secondary side has a terminal strip with screws to fix cable lugs.

The thyristor unit contains four heat sinks on which the twelve thyristors are mounted, fig. 9. At the front of the unit a cassette is mounted which holds the three printed board assemblies for the control electronics, an ammeter and all secondary circuitry for the plug in connection of the other units.

The interphase transformer unit contains the three transformers and two fuses. The filter unit contains the two chokes, the electrolytic capacitors, the 500 A output fuse and the capacitor charging circuit.

Installation, operation and maintenance

Simple and quick installation was one of the main aims when designing the rectifier. It is delivered from the factory in fully tested, easy-to-handle units. The rectifier is connected to the system busbars by means of bar contacts, fig. 10.

The installation only requires ordinary hand tools, and the installation testing is reduced to a visual inspection to detect any transport damage, followed by a functional test.

The rectifier works wholly automatically and all operational changes take place without any manual intervention.

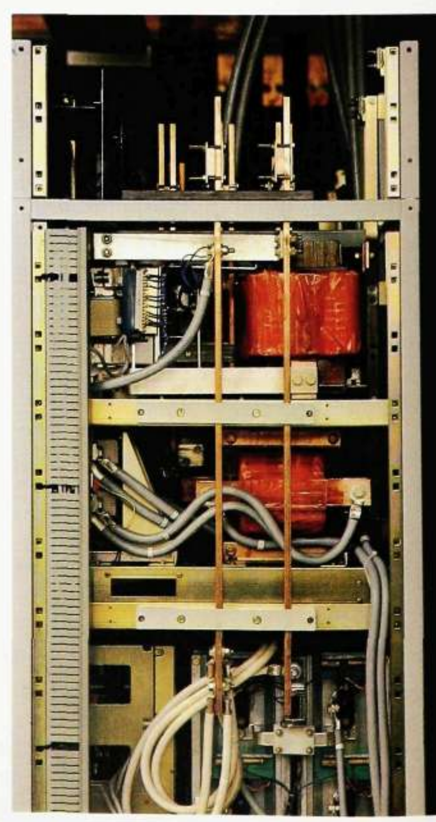


Fig. 9, left
The thyristor unit, the control circuitry and cable connections to the other units can easily be pulled out from the rack. The components are then accessible for measurements and service

Fig. 10, right
This side view of the rectifier shows the vertical positive and negative busbars. These bars are connected to the horizontal system busbars at the top of the rack by means of bar contacts

Technical data

Input data		
Mains voltage, 3-phase, standard	V	380, 220
Permissible voltage variation	%	−15 to +10
Do. with 2 % regulation accuracy	%	−20 to +20
Permissible frequency variation	Hz	47 to 63
Permissible mains distortion	%	30
Primary current with nominal input voltage and maximum output current	A	41
Power factor with nominal input voltage and 75 % output current	cos φ	0.88
Efficiency with nominal input voltage and 60–100 % output current	%	≥92
Radio interference on the mains side (relative 1 μV) measured in accordance with CISPR Recommendation No. 43, using additional radio interference suppression filters		
0.15–0.50 MHz	dB	<66
0..50–30 MHz	dB	<60
Output data		
In parallel operation with a battery of	Ah	1600
System voltage	V	48
Output current	A	400
Static regulation over the whole permissible variation range for mains voltage, mains frequency and output current	mV	100
Dynamic regulation with step changes of the output current from 50 % to 75 % and back to 50 %		
response time	ms	35
voltage deviation	V	1
Noise voltage		
psophometric	mV	<1
peak value	mV	<6
Radio interference on the d.c. side (relative 1 μV) measured in accordance with CISPR Recommendation No. 43		
0.15–0.50 MHz	dB	<80
0.50–30 MHz	dB	<74
Adjustable levels		
Voltage		
normal float level	V	44 to 53
charging level	V	55 to 56
rapid charging	V	44 to 61
Current limiting	A	*0 to 400*
General data		
Ambient temperature		
operation	°C	0 to +45
non-destructive	°C	−10 to +55
Reliability, MTBF	years	17
Acoustic noise level measured at a distance of 1 m	dBA	<60
Dimensions		
width	mm	600
depth	mm	600
height	mm	2200
Weight	kg	680

The valuse given above are normal values and are subject to alteration.

In order to reduce the risk to personnel working on the rectifier, all parts at mains voltage have been shielded. The rectifier can easily be taken out of operation for work on the units without the staff having to come close to any live parts.

Reliability

Rectifiers for telecommunications plants must have high reliability. This has been achieved in the design of BMT 343 by

- choosing only components of high quality and subjecting them to extensive testing before acceptance
- applying dimensioning rules with wide safety margins,

when engineering the system, by

- always ensuring that standby rectifiers are available
- designing each rectifier as an independent unit, i.e. ensuring that its function does not depend on a central control unit and that selective disconnection can take place autonomously.

The MTBF (Mean Time Between Failures) is calculated to be 17 years. The life of the rectifier is estimated to be 40 years under normal operating conditions.

References

1. Michelsen, S. et al.: *A New Generation of Power Supply Equipment, Type BZD 112.* Ericsson Rev. *55* (1978):2, pp. 46–57.
2. Lind, H.: *Computer-Controlled, Automatic Battery Charging.* Ericsson Rev. *56* (1979):2, pp. 84–88.
3. Boije af Gennäs, C.: *Optimization of Power Supply Equipment for Modern Telecommunications Systems.* Ericsson Rev. *53* (1976):3, pp. 142–151.

Central Expert Support for Maintenance and Installation

Lars Estberger

LM Ericsson's stored program controlled telephone exchanges are equipped with a fault diagnosis system which gives detailed information on how to clear any faults that may occur in the exchange hardware. The fault clearing is usually simple and a matter of routine. However, expert assistance may be necessary for rare faults of a complicated nature. Such assistance is normally organized centrally within the country, but during an introductory stage it may be desirable to be able to consult an external group of specialists. In this article a description is given of the expert support provided by LM Ericsson in Stockholm, Sweden, in the form of guidance for complicated fault tracing. The expert support can also include regular inspections of telephone exchanges to determine the condition of the equipment and to locate any faults. Assistance can also be provided for processor installation and extensions.

UDC 621.3.95.34.004.5

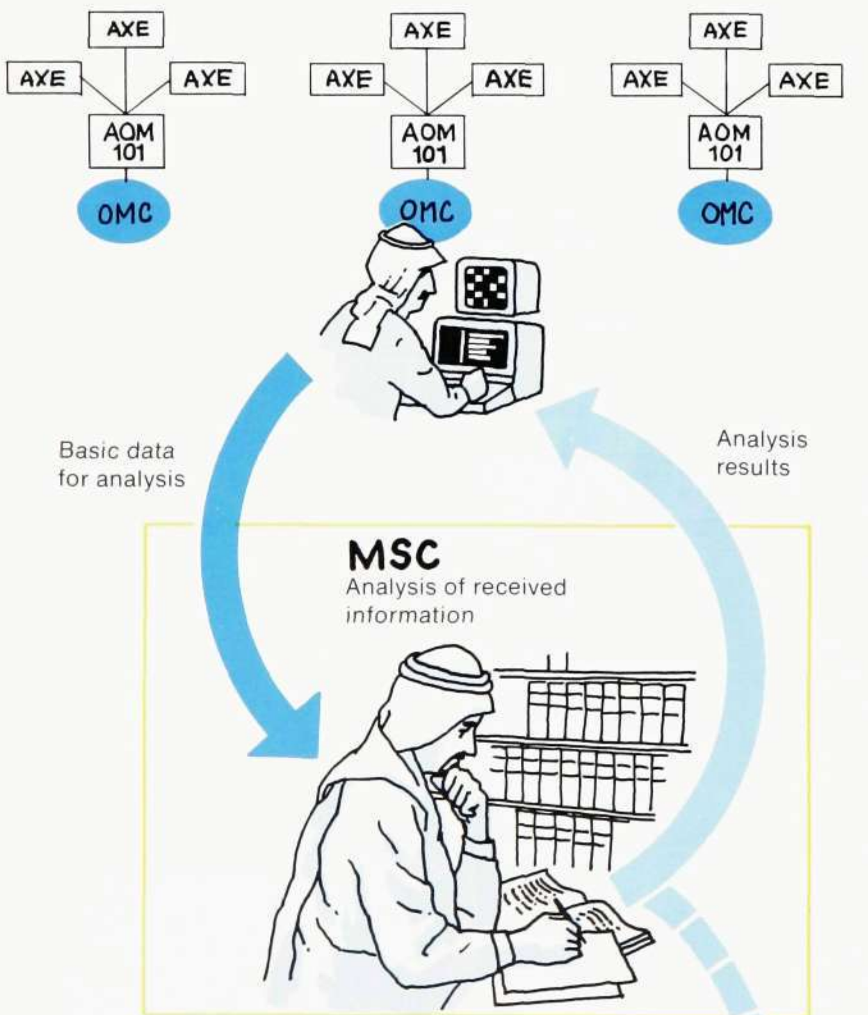


Fig. 1
An expert located at the MSC (Maintenance Support Centre). The illustration indicates the working philosophy. As necessary, the expert goes to the OMC or the exchange to give the appropriate assistance. Fig. 9 shows alternative means of communication.

AOM 101 Operation and maintenance system for the network
OMC Operation and maintenance centre
MSC Local maintenance support centre
MIPSC Central maintenance support from LM Ericsson in Stockholm, Sweden

LM Ericsson's telephone exchange systems have long been well-known for the small amount of effort needed to maintain the equipment. High reliability and comprehensive supervision equipment with good coverage permit controlled corrective maintenance[1]. The introduction of stored program control (SPC) has led to further improvement of the maintenance functions. LM Ericsson's SPC exchanges have a very extensive maintenance system, with automatic analysis and reporting of equipment behaviour. The maintenance functions in system AXE 10 and the centralization of the maintenance functions in a telephone network have been described previously[2,3].

This centralization has reduced the maintenance work further. For example, a normal telephone network with AXE 10 exchanges requires only about 0.05 hours per subscriber line and year for the maintenance of the exchange equipment. At the same time the maintenance work has changed, and this necessitates some changes in the way the work is organized. Experience has shown that it is suitable to use a hierarchic organization which distributes the tasks to different personnel groups with different training.

SPC technology simplifies the ordinary maintenance work

The increasing demands for reliability, flexibility and services have led to increasingly advanced technology being applied in the exchange equipment.

Before the introduction of SPC the exchange control functions were incorporated in the mechanical construction or in electrical circuitry. With the aid of the corresponding diagrams an experienced technician could follow all individual stages in the operation of the telephone system and this enabled him to carry out his job without knowing the system in all its details. Traditionally all technical maintenance work in telephone exchanges has therefore been carried out by "all-round" technicians with an ability to improvise, and thus only the minimum of external assistance has been required.

LARS ESTBERGER
Telephone Exchange Division
Telefonaktiebolaget LM Ericsson

In SPC exchanges the control functions are primarily realized in software. The powerful processors run extensive diagnostic programs. Normally only a limited number of faults occur in such exchanges, and the majority of these are automatically identified and reported to the maintenance staff. This has simplified the maintenance work considerably, and it is comparatively easy to train maintenance staff for these routine tasks. At same time, the possibility to improvise the maintenance work has largely disappeared, and hence it is suitable to divide the tasks among personnel groups with different training.

Team of experts within the country

The main part of the maintenance work in a network with AXE 10 exchanges can be centralized to one or more operation and maintenance centres, OMC. The OMC staff can localize most faults. However, if a complicated fault should occur, it may be necessary for this staff to have access to experts with a thorough knowledge of both the hardware and the software. Seldom occurring faults, for instance in the fixed exchange cabling, could be very difficult to localize. The expert assistance should therefore be concentrated to a common support centre for an administrative area such as an entire country. Such a maintenance support centre (MSC) is equipped with all necessary documentation and the special instruments and test equipment required for complex fault localization.

Having a centralized team of experts makes it easier for the specialists to keep their system knowledge up to date, since it gives them the opportunity of more regular fault localization. This is very important, since there are otherwise few opportunities for practical training in complex fault localization, either during the installation or the operation of SPC exchanges. During the short installation time the functions of the equipment are tested mainly by means of special automatic test programs and this results in there being few opportunities for normal fault tracing. Moreover the equipment is delivered from the factory so thoroughly tested that the processors usually work perfectly from the beginning and no fault tracing is necessary.

Fig. 2
LM Ericsson have established a Maintenance, Installation and Production Support Centre, MIPSC, in Stockholm. The picture shows an AXE 10 exchange in MIPSC. It is employed for detailed analysis of complex problems

Central expert support from LM Ericsson in Stockholm

Scope and organization

A previous article has described several systems which have been developed to aid the work on LM Ericsson's telephone exchange systems[4]. These systems have now been supplemented by the Maintenance, Installation and Product Support Centre, MIPSC, which LM Ericsson have established in Stockholm, Sweden. The centre, which is also used for normal production, was set up in connection with the introduction of SPC technology. MIPSC consists of five separate units, which are responsible for

1. AXE and AXB exchanges
2. ARE exchanges and subsystems, such as toll ticketing, operator and I/O systems
3. AKE exchanges
4. PABX systems with SPC
5. Test equipment for SPC exchanges.

The units, figs. 2, 3, 6, 7, 8, 11 and 12, are organized to provide assistance in maintenance and installation work at short notice. The organization is flexible enough to ensure that the appropriate

```
PW        MIPSC6-02/1     R3A*0915    TW-4     TIME 791214 1017
ALARM A2/APT
SEIZURE QUALITY SUPERVISION
DEV             STATE  BLS
BJ-128          BLOC   ABL
END
```

The exchange gives an *alarm, type A2*, and indicates a *quality fault for BJ number 128*.

Repair

```
PW        MIPSC6-02/1     R3A*0915    TW-4     TIME 791214 1018
SEQAR:DEV=BJ-128!
EXECUTED
```

The printed board has been exchanged and *the alarm is acknowledged*.

```
PW        MIPSC6-02/1     R3A*0915    TW-4     TIME 791214 1018
ALARM CEASING A2/APT
SEIZURE QUALITY SUPERVISION
DEV             STATE  BLS
BJ-128          BUSY
END
```

The exchange confirms that the *alarm condition has ceased* and *BJ has been put into operation*.

Fig. 4
When a fault occurs, the AXE 10 exchange normally indicates the faulty unit. The quality supervision gives an alarm and carries out blocking if the number of unsuccessful connection attempts via a device exceeds a preset percentage

type of assistance can be given on every occasion. This assistance can vary form telephone consultation to active aid on site.

Since the technicians in OMC or the exchanges will normally contact their national MSC for assistance with complex fault clearing, the MIPSC staff in Stockholm will be approached only if the MSC staff need assistance. Contact with MIPSC can therefore be considered as an extra safeguard in the case of rare and especially complicated faults.

Access to such expert assistance can be particularly important during an introductory stage, before the maintenace staff have acquired sufficient experience.

The services offered by MIPSC for AXE 10 exchanges are indicated in the following. Firstly, the normal procedure for clearing faults in an AXE 10 exchange is described together with some examples of how the OMC or exchange staff carry out such work.

Typical fault clearance in AXE 10

The maintenance functions in AXE 10 (see the previous article on this subject[2]) cover the various subsystems in the exchange. When a fault occurs, the fault report received is normally so specific about the nature of the fault that the repair work is more routine. In most cases the faulty printed board assembly is indicated directly, fig. 4, and can be replaced by a spare one from the spares store.

Sometimes the caracteristics of the fault are such that there could be more than one possible cause. In such cases a fault printout is obtained that lists the possible faulty printed board assemblies together with the fault probability for each one, fig. 5. The repair work starts by replacing the printed board assembly with the highest fault probability. If the fault remains the next printed board assembly is replaced and so on.

In certain cases the alarm printout information may be insufficient to directly identify the fault, and fault tracing with the aid of built-in test functions must be carried out. The procedure is described in the operation and maintenance man-

```
PW        MIPSC6-02/1     R3A*0915    TW-4     TIME 791214 1053
ALARM A2/APZ

RP FAULT

RP    FCODE  INF1     INF2     INF3
 68   H'4    H'4      H'54     H'23
 68   H'11   H'0      H'0      H'0

MAG        CARD          WEIGHT
P-RP- 68                    1
RP- 68     EMBU             2
RP- 68     OBU              5
RP- 68     IBU              5

RP- 68     PSH              3
RP- 68     DSH              3
RP- 68     MIG              3
RP- 68     MPSU             2
RP- 68     PS-4&  5        10

END
```

The exchange gives an *A2 alarm* and indicates that *RP (Regional Processor) number 68* has a check sum fault on *program page 4*. (The fault code is explained in the exchange manual.) *PROM boards 4 and 5* are listed as having a high probability of being faulty.

Repair

```
EX-A      MIPSC6-02/1     R3A*0915    TW-4     TIME 791214 1056
DIRPI:RP=68!
RP CHECK PASSED
END
```

The printed board assemblies have been changed and a *test of RP no. 68* is ordered. The response confirms that RP is working properly.

```
EX-A      MIPSC6-02/1     R3A*0915    TW-4     TIME 791214 1056
BLRPE:RP=68!
BLRPE:RP=68!
!
EXECUTED
```

Deblocking of RP is ordered. This command has been classified as an important one and is therefore repeated by the processor. After acceptance the order is executed.

```
PW        MIPSC6-02/1     R3A*0915    TW-4     TIME 791214 1057
ALARM CEASING A2/APZ

RP FAULT

RP    FCODE  INF1     INF2     INF3
 68   H'4    H'4      H'54     H'23

END
```

The exchange informs that the *alarm condition for RP no. 68 has ceased*.

Fig. 5
If there are possible alternative fault causes, the fault diagnosis system in the AXE 10 exchange will list all printed board assemblies involved, together with the fault probability for each one

Fig. 3
The MIPSC unit dealing with the telex exchange systems, AXB 20

Fig.6
Work on toll ticketing equipment in the MIPSC unit dealing with the ARE systems

ual for the exchange. The fault localization is usually carried out from OMC, as has been described in a previous article[3].

The maintenance functions cover faults in the switching network, and associated devices, faults in memories and power supply equipment and faults in maintenance circuits and switch-over functions. The hardware in the AXE 10 control system is supervised by comparing the output of the duplicated, synchronous working processors. If a comparison fault is detected, a test program is automatically started to identify the faulty processor side. This side is automatically blocked and then the faulty unit is pinpointed and an alarm is given.

Som incidental faults are not reported to the maintenance staff until the same fault has occurred several times. This avoids unnecessary investigation of circuits where the faulty state no longer exists. However, the maintenance staff can at any time request a printout of the stored information concerning such incidental faults.

Fig. 7
Measurements on the processor part of control system ANA 30 in the MIPSC unit dealing with the ARE system

The powerful automatic recovery capabilities of AXE 10 mean that MIPSC need seldom be called upon
The automatic blocking of faulty devices limits the effects of faults and consequently the traffic handling ability is not noticeably impaired by a small number of individual faults. Furthermore, faults in the common sections of the exchange do not normally affect the traffic. This is because such sections are at least duplicated, and the faulty unit is automatically blocked until the repair has been carried out.

Even if an incidental fault in, for example, a processor does not immediately result in a positive identification, the fault diagnosis proceedure continues in a predetermined way. The executive side of the duplicated processor continues the traffic handling and the standby side is stopped. If the fault occurs again within ten minutes, a changeover is carried out and the standby side now takes over the traffic handling and the executive side is stopped. The net result is that automatic blocking of a faulty processor side is achieved.

Whenever there is a processing failure, not involving hardware faults, the system recovers automatically with the aid of a minor restart. In most cases the effects of a software fault are thus eliminated as result of the central processor being cleared of all work in progress. Connections that have already been established are not affected, but the limited number of calls that are in the register stage are disconnected, and the subscribers in question receive a new dialling tone.

If a further processing failure occurs within ten minutes of a minor restart, a major restart is initiated. All variable data are reset and all established connections are released. If this action does not rectify the situation, degeneration of programs or data has probably occurred. Another processing failure within ten minutes therefore automatically initiates reloading of both programs and data from a magnetic tape unit.

Whenever a restart occurs the exchange records details of the sequence of events, and a printout of this information is obtained automatically. Fault localization with the aid of this information requires a thorough knowledge of the system. MSC normally provides the required assistance, but help can also be obtained from MIPSC in Stockholm. The printout gives very detailed information so that the necessary corrective measures can be carried out at an early stage.

Commmunication with MIPSC as and when required

A request for assistance is normally sent to MIPSC via telex, fig. 9. The disturbances should be described in sufficient detail to enable the system expert to analyze the situation. The MIPSC staff can also simulate the fault situation in a model exchange. The result of the analysis and a recommendation for suitable action are then sent back via telex.

In certain cases a technician may need guidance for fault localization in a telephone exchange. It is then possible to telephone MIPSC, where a system expert is available to give advice.

If assistance is required outside normal working hours, the MIPSC staff can be reached via an alarm centre equipped with telex and telephones. Whenever a request for help is received at the alarm centre, the staff on duty will notify an

Fig. 8
Processors of type APZ 130 and APZ 150 in the MIPSC unit dealing with the AKE system

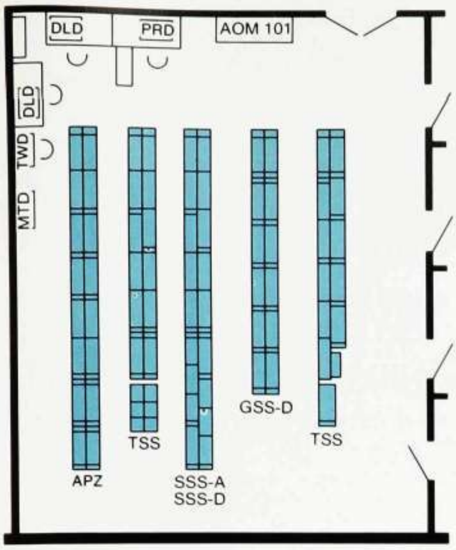


Fig. 10
The AXE 10 model exchange in MIPSC contains sufficient hardware to permit simulation of several exchange variants

APZ	Control subsystem with duplicated synchronous-working central processors
TSS	Trunk and signalling subsystem, adaptable to different markets
SSS-A	Analog subscriber stage
SSS-D	Digital subscriber stage
GSS-D	Digital group selector
AOM 101	Operation and maintenance subsystem
DLD	Digital display unit
PRD	Line printer
TWD	Typewriter
MTD	Magnetic tape unit

MIPSC system expert, who will then make the required contact as quickly as possible.

Certain fault situations require analysis of long printouts. It is extremely important that every single figure is exact when this information is transmitted to MIPSC. Experience has shown that telex is not suitable for this purpose. MIPSC is therefore equipped with telefax, which gives rapid and reliable transmission of written data over a normal telephone circuit. After detailed analysis of the printout the MIPSC staff can recommend suitable action to the exchange staff.

It is possible to send a system expert to an exchange at short notice if it proves impossible to give sufficient assistance from a distance. However, the need of such visits is expected to be very small.

Model exchange for simulating different variants of AXE 10

MIPSC contains a model exchange of type AXE 10, fig. 2. The model exchange contains a fully equipped, duplicated central processor and sufficient switching equipment to simulate several exchange variants, fig. 10. The store capacity is so large that the exchange configuration can be changed by reloading programs. This makes it possible to carry out detailed analysis of complicated faults, which are reported by the installation and maintenance staff in the field.

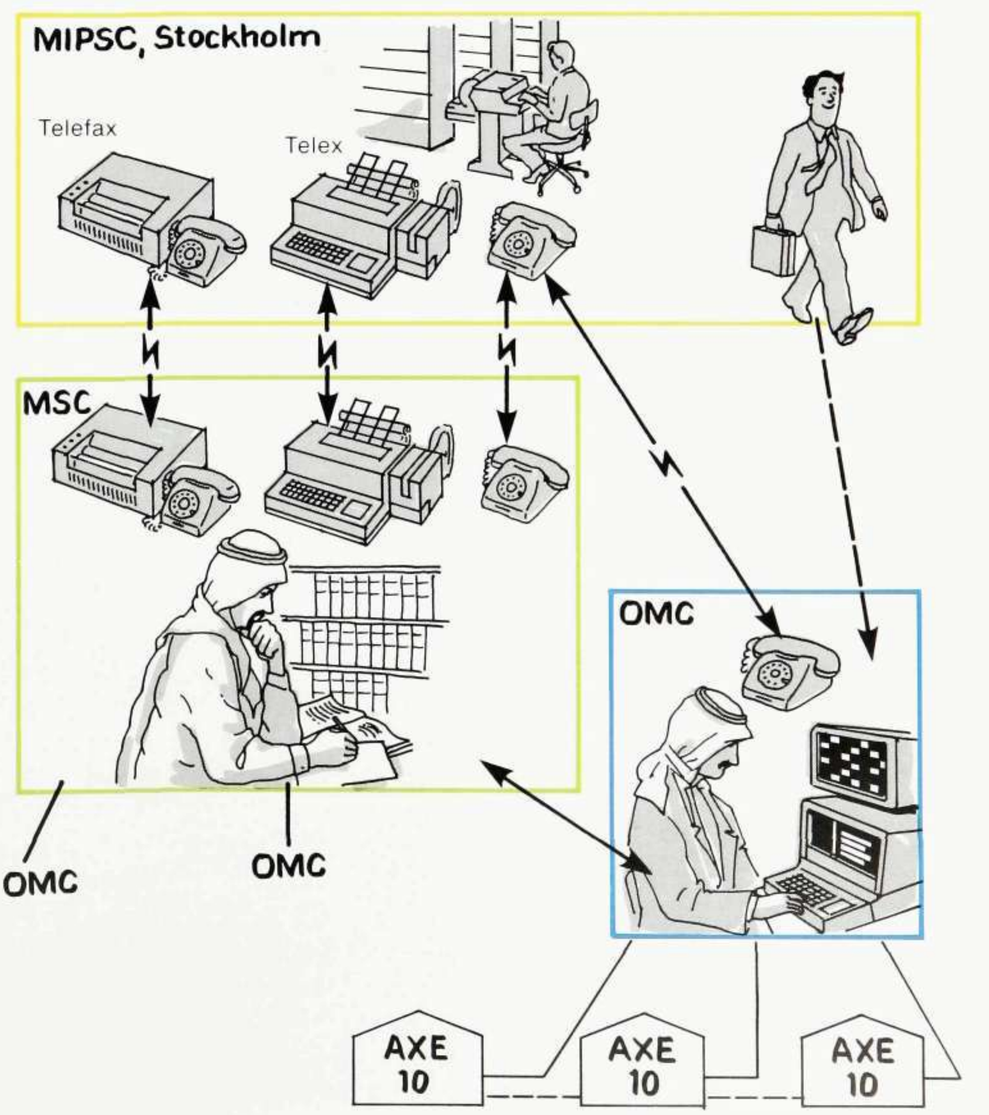


Fig. 9
Communication with MIPSC can take place via telephone, telex, telefax or personal visits

Fig. 11
PABX type ASB 900 installed in the MIPSC unit dealing with stored program controlled PABXs

Special test equipment makes it possible to load the exchange with concentrated traffic, so that problems which only appear in such circumstances can be investigated. The load is then considerably greater than any load that can occur in a telephone exchange. This simulation facility is particularly useful for testing system revisions before they are introduced in exchanges that are already in operation.

Testing of programs and data before installation

Programs and data for an SPC exchange are normally compiled independently of each other and are then tested separately in automatic test equipment. However, it is possible that certain faults remain in newly designed software in spite of such tests. Further testing can be carried out by loading the programs and the exchange data in the MIPSC model exchange, and then checking that the programs are correct. This procedure means that any remaining faults are detected at a sufficiently early stage to permit correction before the software is needed for testing of the exchange on site.

Testing of hardware and software before complicated extensions

Additional hardware has to be installed when an SPC exchange is to be extended and this means that new data, and sometimes new programs, must also be introduced. The various stages in an extension have been described in a previous article[2]. In the case of a complicated extension, or when the staff who are to carry out the extension have limited experience, it may be advantageous to first simulate the extension in the model exchange. The methods used are the same as in the actual extension work, and the staff thus receive on-the-job training. At the same time the software is checked and any faults are cor-

Fig. 12
Calibration of stored program controlled traffic generators in the MIPSC unit dealing with test equipment

rected before the actual extension is carried out. The MIPSC staff can also provide assistance on site if necessary.

Help with processor installation

The MIPSC staff are prepared to help with the starting up of the control system for a new exchange if the local staff lack the necessary experience. The starting-up process takes very little time, since the control system is thoroughly tested at all levels before delivery. The extensive test programs included in the control system are then used to test the telephone system, thereby taking advantage of all the fault detecting facilities provided by the control system[5].

A similar service can be provided when changing program packages in an exchange which is in operation. Such assistance may be considered an extra safeguard, but it may be of value if the exchange staff have not sufficient experience.

Service contract

MIPSC can be used in different ways. A suitable way would be for a telecommunications administration to enter into a service contract, which could comprise all or some of the following services:

- consultation via telephone or telex
- telephone assistance in tracing complicated faults
- regular service visits 1–4 times per year
- visit by an expert if a particularly complicated fault should occur.

Such a contract also promotes the building up of an efficient maintenance organization by providing the administration's staff with continuous information concerning general practices and improvements in maintenance methods. In the long run it will therefore enable the telecommunications administrations to become completely self-sufficient in respect of the installation and maintenance of AXE 10 exchanges.

References

1. Eriksson, V.: *CCM–A Well-Tried and Economic Maintenance System*. Ericsson Rev. *53* (1976):3, pp. 134–137.
2. Söderberg, L.: *Operation and Maintenance of Telephone Networks with AXE 10*. Ericsson Rev. *59* (1979):3, pp. 104–115.
3. Nordqvist, G.: *AOM 101, an Operation and Maintenance System*. Ericsson Rev. *56* (1979):3, pp. 116–123.
4. Svenle, I.: *Auxiliary Systems for AXE 10 Networks*. Ericsson Rev. *56* (1979):4, pp. 170–178.
5. Hagberg, P.-O. et al.: *Installation of AXE Exchanges*. Ericsson Rev. *56* (1979):1, pp. 14–21.

ERICARE

Anders Lennström and Curt Sundmalm

LM Ericsson Telematerial AB have developed a telephone system, ERICARE, which provides old-age pensioners and handicapped people who live alone with the means of calling for help in various situations. The system registers alarms from the subscribers, automatically sets up telephone connections to an alarm centre and transmits alarm and identity messages. The system also permits speech communication with the person who has requested help, without the caller having to lift the handset. A message is given via a loudspeaker, and the speech of the person in distress is transmitted by microphones in the flat or house. Alarms can be originated in different ways, for example from small, portable radio signal transmitters. Transmitters and receivers for this type of alarm have been developed by SRA Communications AB, a subsidiary company of LM Ericsson. In this article the equipment in the subscriber's home and at the alarm centre are described, followed by a description of the course of an alarm call and, finally, technical information.

UDC 621.395.721:
654.938

Many old-age pensioners and handicapped people have to live alone, without access to nearby aid. ERICARE has been developed for this steadily increasing category of people. Technical aids can never replace personal care, but they can help to make life safer for the elderly and the handicapped people who have to live alone. ERICARE enables the lonely person to send an alarm in an emergency and then speak to somebody who can arrange help.

The basic equipment in the suscriber's home is easy to install. It can be put in and tested by non-specialists and is easy to move. The system can have a few or several hundred pensioners and handicapped people connected to one and the same alarm centre. Public institutions, such as old people's homes, nursing homes, health centres and fire stations, can be used as alarm centres.

The main function of the system is to sence an alarm from a subscriber's home, automatically set up a telephone connection to the alarm centre and transmit alarm and identity information. When an alarm has been received, the staff on duty at the alarm centre can speak to the person via a units placed in the subscriber's home which contains a microphone and a loudspeaker.

Home equipment

The basic equipment in the subscriber's home consists of a telephone base unit and a box with electronic equipment. The base unit contains a microphone, a loudspeaker and an amplifier for loudspeaking calls. A large alarm button is mounted on a panel on the base unit. Extra alarm buttons can be wall-mounted to give added opportunities for initiating alarms. Extra units with microphone and loudspeaker can be installed in other rooms in the subscriber's home in order to make speech communication possible in all rooms.

A portable alarm button with a radio signal transmitter has several advantages over fixed buttons. In the case of an accident—a fall in the bathroom—a touch on the portable button will give an immediate alarm. There is no need to crawl

Fig. 1
Loudspeaking calls provide information and aid the decisionmaking, and thus reduce the number of emergency visits to the old-age pensioners and handicapped people.
The person on duty at the alarm centre learns what has happened, can advise and reassure the pensioner and arrange help when necessary.
It is not possible to set up a loudspeaking call from the alarm centre for listening-in on the pensioner. It is only when an alarm has been sent that the loudspeaking two-way speech circuit is opened

ANDERS LENNSTROM
CURT SUNDMALM
LM Ericsson Telematerial AB

over to a wall button, which would often be impossible, for example if the person had a fractured thigh. The portable alarm button is available as a bracelet or as a medallion on a band round the neck.

The range of the radio signal transmitter is sufficient to penetrate reinforced walls and reach the receiver even in a large house, and it is the best and safest method for a pensioner etc. to send an active alarm.

A person cannot set off an active alarm if he or she is unconscious or cannot reach the alarm button. For this reason supplementary equipment for passive alarm is often also installed. This type of alarm is released when a normal activity is not repeated within a certain time. ERICARE has an electronic clock which measures the time, for example from the last time the toilet was used. After, for example, 12 hours a passive alarm is sent to the alarm centre.

Alarm centre equipment

In the telephone exchange a group number for three or more lines is reserved for the alarm centre and used only for alarm calls. The person on duty can switch between incoming alarms and deal with them according to urgency. A separate telephone line at the alarm centre is used for outgoing calls. The staff on duty can use this line to call an ambulance, a doctor, a caretaker etc., or make ordinary calls to the pensioners.

The central equipment is mounted in a wall rack and consists of the standard printed board assemblies used in telephone attendance system AVE 100.

The control equipment at the alarm centre consists of a telephone base with two units. The lower one has buttons for connecting up 3–6 alarm lines. The upper unit has six control buttons and a digit indicator. One of the buttons is used to change the speech direction in the home equipment. The button is depressed for speech and released for listening. In the home equipment there is corresponding switching between microphone and loudspeaker.

The telephone set at the alarm centre can be a standard set, e.g. DIALOG or DIAVOX. However, it is more convenient if the switching of speech direction can be done with a key in the handset instead of a panel button. If the telephone set has a carbon microphone, changing it to a dynamic microphone with amplifier will give better sound quality in the loudspeaker in the home equipment.

Theoretically, 10,000 alarm sources can be identified with a four-digit indicator. A recorder can be connected to the central equipment to record the time and identity of incoming alarms.

The alarm centre does not have to be manned. It can be equipped with an ERICALL radio transmitter which, when an alarm comes in, automatically pages the person in charge, who is thereby called to the alarm centre.

Fig. 2
The telephone base unit has a large red button for alarms. A second button gives easy, single-handed calling of an optional telephone number, usually to a close relative.
The button at the far left cancels an initiated alarm call

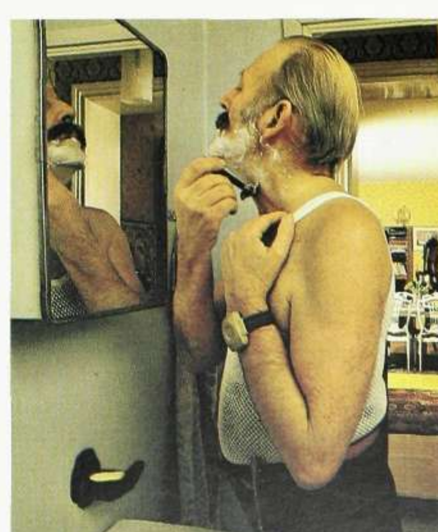


Fig. 3
The portable alarm button gives a wireless alarm signal to a radio receiver built into the telephone base unit. The receiver then automatically initiates a call to the alarm centre.
The portable alarm button is worn as a bracelet or as a medallion on a band round the neck.
The radio signal transmitter is equipped with automatic battery checking. When a change of battery is due, a special signal is sent to the receiver in connection with an alarm or test signal. The green diode lamp in the telephone base unit starts to flash. Moreover the digit indicator in the alarm centre displays the letter C, which indicates that the battery should be changed

Alarm procedure

When an alarm is initiated the telephone exchange is called automatically, and the alarm centre number is transmitted. For about 10 seconds the pensioner will hear, via the loudspeaker, the signals and tones that are sent out during the calling process. During this time the call can be cancelled by depressing the button marked Reset.

If the alarm centre lines are engaged, or if the exchange is congested or connects up to a wrong number, this call attempt is abandoned and the call is automatically repeated until the alarm centre is reached. If the alarm centre does not answer within about 90 seconds the call is disconnected and a new call is again automatically repeated until the alarm centre answers. The person in duty there answers the call by lifting the handset and depressing the line button whose call lamp is flashing. A tone code is sent to the home equipment and releases tone transmission of alarm type and identity number.

The alarm code and identity are displayed on the digit indicator used by the person on duty. He can request new transmission of the information, by depressing the button New code, if it is not shown or is shown distorted.

The person on duty can carry out a conversation with the pensioner by means of the key on the handset or the button Speech control. If he finds it difficult to hear or to make himself heard, he can connect in extra amplification in both speech directions by depressing the button Sound amplification.

The digit indicator shows the letter A for an active alarm and B for a passive alarm. The letter C is shown for alarms or alarm tests from the portable alarm button if the battery needs changing.

The person on duty carries out the appropriate action on the basis of the information received during the call. The call is then disconnected by depressing the button Reset and replacing the handset.

Technical description

CMOS circuits have been used to obtain high reliability, low power consumption and small volume. Standard circuits have been used for supplementary functions, such as tone encoding and decoding and also number sending. The electronic circuits in ERICARE, fig. 4, are used for the following functions:

In the subscriber's home:
- registering an alarm situation
- automatically calling when an alarm is given
- sending predetermined telephone numbers
- receiving control signals from the alarm centre
- sending an identity number
- loudspeaking communication, simplex.

Fig.4
The block diagram for ERICARE

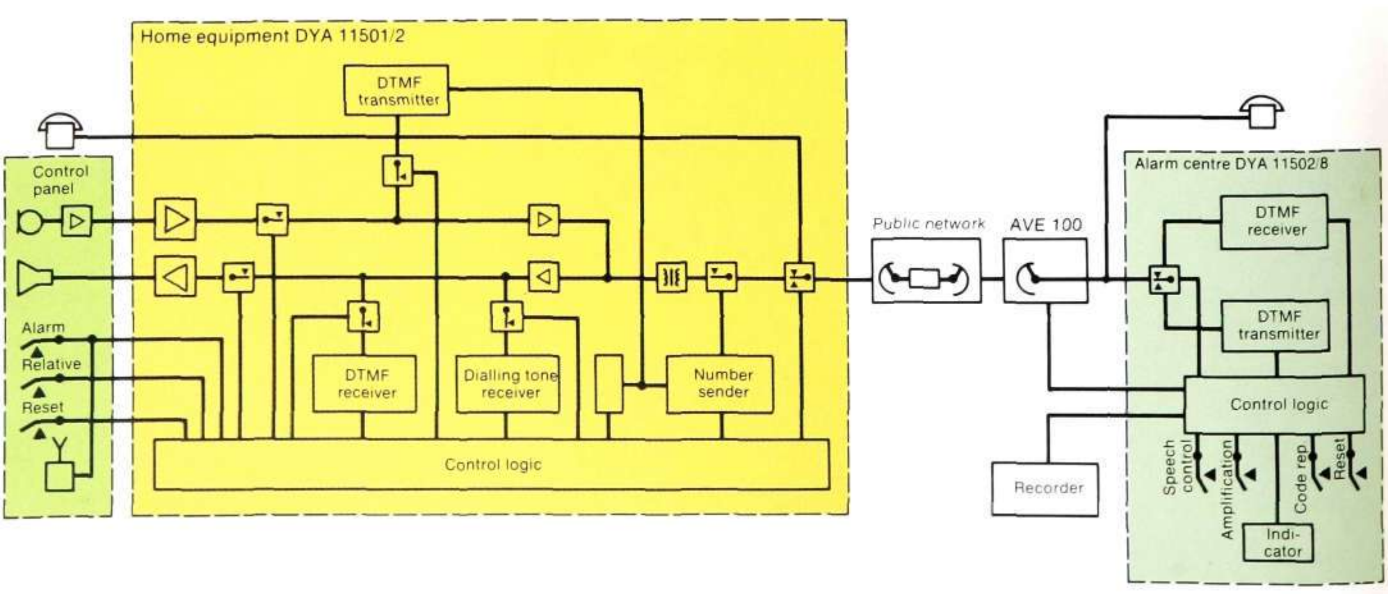


Fig. 7
Four figures show the identity of the person sending the alarm. The letters A–F give the type of alarm

Fig. 5, left
The digit indicator in the telephone base unit at the alarm centre shows the identity of the pensioner and whether the alarm is active or passive. The person on duty has a file with notes on the person, his or her name, telephone number, doctor, medicine requirements, nearest neighbour, caretaker, relative etc.
An important facility in this system for caring for people is that the person on duty can easily switch over from one alarm line to antoher, and thus for example park a "conversation alarm" in order to attend to a real alarm

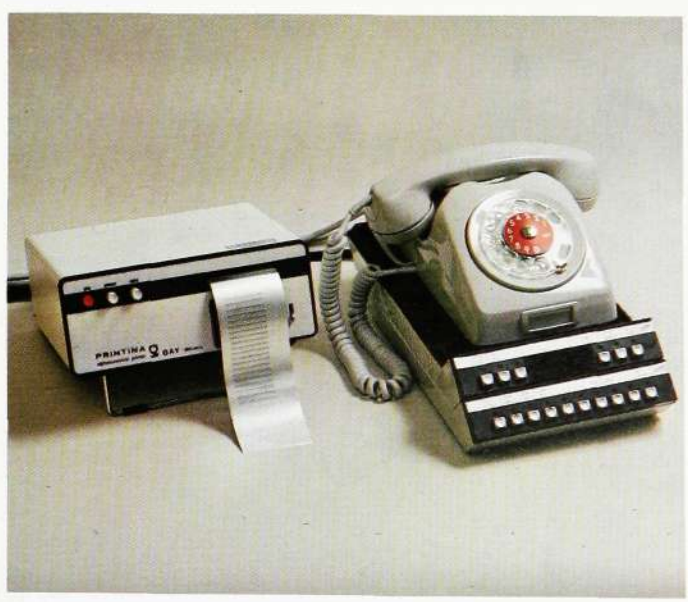


Fig. 6, right
A recorder can be connected to the alarm centre to record the time of each incoming alarm and the identity of the caller

In the alarm centre:
- receiving and registering the identity number of the home equipment
- sending control signals to the home equipment.

Active alarms are initiated from fixed alarm buttons or radio signal transmitters. The receiver, ERICALL CONTACTOR, for the wireless alarm is placed in the telephone base unit in the home equipment. The receiver and radio signal transmitter have both been developed by SRA Communications AB. The transmitter contains a special circuit for signal encoding.

A special signal is sent in connection with alarms or alarm tests when the battery needs changing. This signal is forwarded to the alarm centre where it gives the alarm code C on the digit indicator. Thus the transmitter itself indicates when it is time to change the battery, and it is not necessary to check the battery manually.

Alarms can also be initiated by special time supervision equipment; passive alarms.

The type of alarm is registered in the home equipment, and is transmitted and indicated by a letter on the digit indicator at the alarm centre:

A. active alarm, initiated from an alarm button or a portable transmitter
B. Passive alarm
C. Active alarm, initiated from a transmitter with a low battery voltage
D. Alarms from other objects, fire alarm
E. or burglar alarm
F. Fault alarm, caused by a break in an external alarm loop.

When an alarm is registered, a relay disconnects the telephone line from the telephone set in the subscriber's home and connects the line to the amplifier circuits in the home equipment. A loop call is made to the exchange and the dialling tone is detected by a tone receiver. If the tone is accepted, the number sender starts sending the alarm centre number. The number is obtained from a progammable memory with a capacity of 8×32 bits. The memory also contains the telephone number of a relative and the identity number of the equipment within the system.

Supervision is carried out during and after the number sending, and a new call is made if the home equipment receives the busy tone or the call is not answered within a reasonable time, fig. 8. The supervision function is blocked during calls to the relative.

The transmission of control signals to the home equipment, and of alarm type and identity number to the alarm centre, is carried out using DTMF signalling over the established telephone circuit. A filter and detection circuits, each in a standard package, are used for the

Technical data

Home equipment		
Mains voltage	V a.c.	220
Maximum power consumption		
– idle	W	5
– during an alarm	W	10
Maximum output power for the loudspeaker	W	1.5
Microphone sensitivity	dB rel. 1 V/Pa	–45
Maximum line level		
– with speech transmission	dBm	0
– with signalling	dBm	–10
Maximum line attenuation, home equipment		
– alarm centre	dB	30
Line matching	ohm/nF	600/15
Return loss	dB	>9
Impulsing	pulses/second	10
Temperature limits	°C	0 and +55
Air humidity limits	%	40 and 90
Alarm centre		
Voltage	V d.c.	24
Power consumption		
– idle	W	2.5
– during an alarm	W	20
Signal level during transmission	dBm	–10
Line matching		
– minimum during recieving	kohms	10
– during transmission	ohm/nF	600/15
Return loss	dB	>9
Temperature limits	°C	0 and +55
Air humidity limits	%	40 and 90
Radio signal transmitter		
Frequency	MHz	26.855
Output power	mW	>1
Digital code	bits	12
Weight with battery and bracelet, approx.	g	40
Battery life, approx.	years	3
corresponding to alarms, approx.	times	1,400
in the button is kept depressed	sec./alarm	10

DTMF signalling. The filter is of the switched capacitor type.

When the call is answered at the alarm centre an acknowledgement signal is sent to the home equipment, which then initiates the sending of identity number and alarm type. This information is registered in the alarm centre and is displayed on the digit indicator. Signals can then be sent from the alarm centre for controlling the speech direction, for increasing the amplification in the home equipment in both speech directions and for requesting repetition of the identity number.

Time supervision of the speech control is arranged in order to prevent the signalling being blocked if the sound level in the subscriber's home is too high as can be the case if, for example, a radio or TV set placed near the microphone is switched on. When the speech direction is set for listening, the sound from the radio or TV will go out on the telephone line at a level of nearly 0 dBm. If the line attenuation is high, the received DTMF signal will be about 30 dB below the level of the disturbing signal. This can prevent the two-tone signal from being received.

The time supervision automatically changes the speech direction and connects in the loudspeaker in the home equipment if the home equipment does not receive any speech control signal for about 20 seconds. The person on duty at the alarm centre hears when the speech direction is switched over, and can then take the opportunity of informing the pensioner that the alarm has been received and what action is being taken etc.

When the call is completed, a disconnection signal is sent from the alarm centre to the home equipment. The disconnection is also supervised. If there is no signalling for about 5 minutes, the home equipment is automatically disconnected.

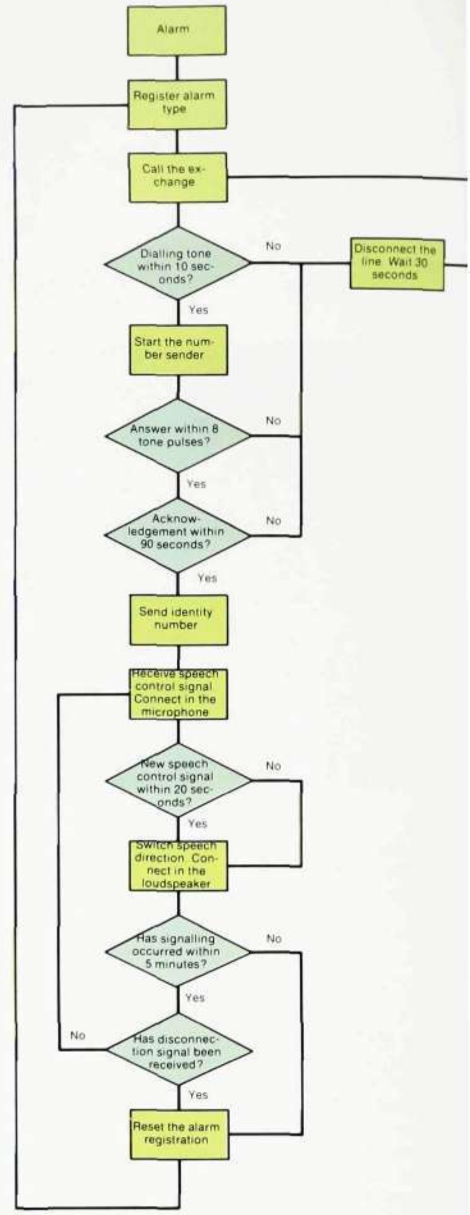


Fig. 8
Sequence diagram for ERICARE

TELEFONAKTIEBOLAGET LM ERICSSON

ISSN 0014-171

Printed in Sweden. Ljungföretagen, Örebro 19