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# DELTACS — a versatile tactical communication system

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*Summary*

*In the near future the Royal Netherlands Army will field its automatic digital communication system. This system is based on EUROCOM parameters. The modular construction in hardware and software allows a wide variety of applications. Major reductions in manual input of data have been achieved. The database of the switch is the tool by which both high system integrity and quick adaptation to changes in the network configuration are achieved.*

## 1 Introduction

The trend towards digital communication is clearly evidenced by the development of switches for the Integrated Services Digital Network. This trend is even stronger in the military environment, not only because of the need for technical enhancement, but because only a digital signal can be securely encrypted.
In the early seventies several NATO countries started to define integrated automatic communication systems to be used in the tactical area. It was recognised that the strength of NATO would be affected if the national systems would not interoperate. As standardisation within NATO was not progressing very rapidly, the European

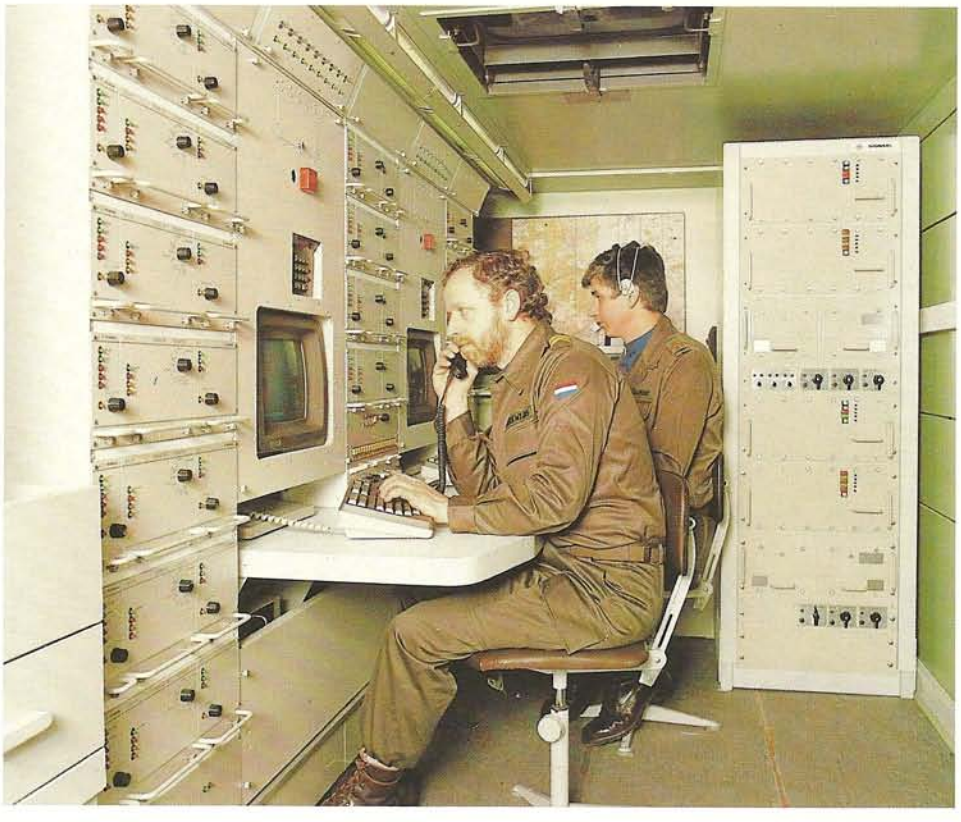


Fig. 1. The DELTACS switch

defence ministers, united in the EUROGROUP, decided to establish an ad-hoc body to mark out the architecture and interoperability parameters for tactical-area digital networks. This body, in which governments and industries of several European NATO countries are participating, is called EUROCOM.
EUROCOM has succeeded in defining the system parameters and has even taken the lead in realising additional NATO standards. The technical parameters for DELTACS have been derived from the EUROCOM D/1 document [1] and the relevant STAGNAGs (Standard NATO Agreement) [2].
ZODIAC is the acronym of the EUROCOM system for the Royal Netherlands Army. ZODIAC's heart consists of digital switches. These are the first of a family of Signaal-developed digital switching elements for military telecommunication networks. This family is called DELTACS and is the subject of this article.

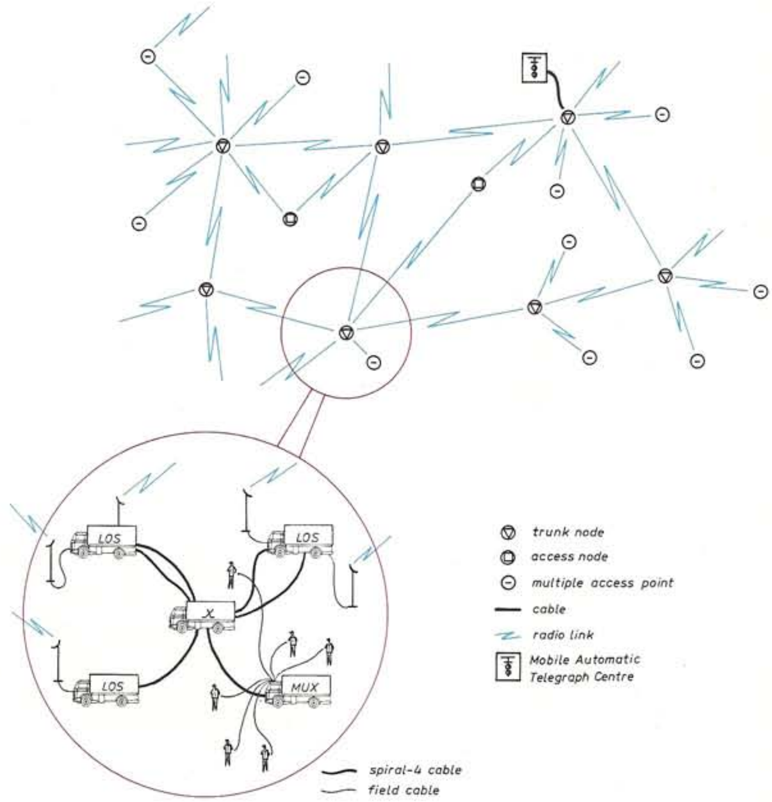



Fig. 2. Typical tactical network configuration

## 2 Grid network

A EUROCOM network is a fully digital grid-type network which consists of a number of mobile circuit switches, located in trunk nodes and access nodes, interconnected by line-of-sight radio links. The network supports the operational area of an army corps (Fig. 2). The communication centres of the various HQs are connected to this network by line-of-sight links or cables via switches or multiplexers. A EUROCOM system is mobile in the sense that it is movable, for the elements are operational only when stationary.
For a tactical mobile communication system the following elements are essential:
- very short set-up and tear-down times
- a modest requirement for not highly-qualified operating personnel

- automatic adaptation to continually changing deployment
- a distributed database to give independence from a vulnerable central database.

### 2.1 Gateways

In the EUROCOM philosophy every army corps deploys and controls its own network. Adjacent army corps networks are interconnected by gateways. A gateway is defined to provide interconnection of two systems without special interface equipment, cable or radio. To realise this, the parameters of a gateway are unambiguously defined in spite of national responsibilities for network control, subscriber administration, routing, etc.

### 2.2 Interfaces

Although DELTACS (the EUROCOM system developed by Signaal) is a fully digital network conforming to EUROCOM standards, it often has to operate in environments where many interfaces and terminals are analog. For this reason the multiplexers in DELTACS can be equipped with digital EUROCOM interface cards as well as analog interfaces such as central-battery rotary-dial telephone sets, local-battery ringdown telephone sets, analog data modems, and PTT as well as other analog tactical networks [3]. The signalling of the analog peripherals is forwarded by the multiplexers in the form of digital signals that can be handled by the switch. Thanks to the added analog interfaces a DELTACS system is much more versatile than a mere EUROCOM system.

### 2.3 Numbering plan

The numbering plan in the DELTACS network is based on 13 digits: 6 for the routing indicator and 7 for the subscriber number. Within a network the 7-digit number suffices to establish a connection. To permit inter-network calls the 6-digit routing indicator is required.
The subscriber number is not geographically but functionally organised. A subscriber moving through the network keeps the same number. This means that the subscriber number does not contain any routing information and the network has to keep book of all subscriber locations. The network will present itself to its subscribers as a distributed switch.
For the composition of the 7-digit subscriber number a deducible directory [4] has been chosen. The subscriber's function determines his number. All that is needed for telephone calls in the NATO communication system is a deduction matrix of visit-card size. The 6-digit area code is deducible as well.

### 2.4 Delta modulation

Analog signals such as speech are digitised by delta modulation at 16 kb/s. Delta modulation is preferred over PCM for two reasons:
- it has an acceptable error immunity: all bits have the same weight, and speech is still intelligible at 10% bit error rate,
- at low bitrates the quality of delta modulation is superior to that of PCM.

The delta modulation principle adopted is known diversely as Digitally Controlled Delta Modulation (DCDM) and as Continuous Variable Slope Deltamodulation (CVSD) [5, 6].

### 2.5 Multiplexing

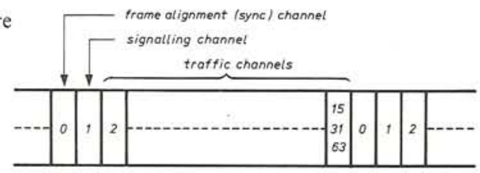
The signals between a multiplexer and an exchange or between two exchanges are organised in multiplex groups comprising 16, 32 or 64 one-bit timeslots (channels). At a channel speed of 16 kb/s, the group bitrates for 16, 32 and 64 channels are 256, 512 and 1024 kb/s respectively.
A straightforward bit-by-bit TDM structure can be chosen on account of the equal

weights of all bits. See Fig. 3.
Time slot 0 is reserved for a constant 15-bit frame synchronisation pattern, which is to maintain synchronisation even at high bit error rates and permits independent resynchronisation for each direction of transmission.
Time slot 1 contains the common signalling channel for inter-exchange communication. The common-channel transmission proceeds under an ARQ protocol using a fixed blockstep-back based on a (31,21) BCH code. Consequently, the maximum effective throughput of the signalling channel is 8 kb/s.

## 2.6 Network synchronisation

Plesiochronous network synchronisation is used to make the network less vulnerable. Each exchange (node) is autonomous and uses its own high-stability atomic clock as reference for the outgoing bit streams. Differences between the clocks of the nodes are absorbed by an elastic buffer store for incoming bit streams. The buffer capacity selected is such that short-term jitter and long-term drift over at least a 24-hour period are compensated, with full bit-count integrity being safeguarded.

Fig. 3. Multiplex structure




## 2.7 Signalling

For the data that has to be sent between exchanges to establish connections between subscribers and to update the network status, a so-called processor network is established, for which one channel of each trunk group is reserved. This common channel serves the out-band signalling and other types of data communication between switches.
Loop signalling on the digital subscriber channels is in-band, using 8-bit cyclically permutable code words (CPCs). This signalling is compelled, which means that a code word is repeated until the opposite end asks for the next code word. This renders the system extremely error-resistant and relaxes the real-time requirements imposed on the signalling receivers.

## 2.8 Type of connections

The system employs normal dialled circuits where the connection to the called subscriber is construed on the basis either of dial information provided by the calling subscriber or of preprogrammed dialling data (switched hot-line).
The system also includes sole-user circuits, i.e. circuits of which the termination points are defined by the operating staff.
Such a sole-user circuit is automatically rerouted in case of disturbance, and may operate at 16, 32, 48 or 64 kb/s (multi-rate switching). Owing to this multi-rate sole-user capability, the network of circuit switches may serve as a medium for overlay structures, such as a message-switching telegraph network or a packet-switching data network.

*Circuit-switched transmission*

The network sets up dialled circuits from subscriber to subscriber for operation at 16 kb/s. These circuits are suitable not only for speech (delta modulated) but also for other types of digital traffic (telegraphy, facsimile, data). The latter can be slotted

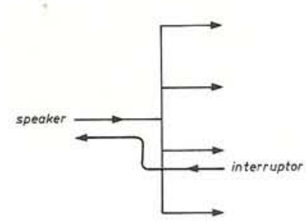
into the 16 kb/s bitstream without the intervention of a modem.
Dialled connections established in speech mode may change over to data transmission and vice versa, but it is also possible to directly establish a connection for data transmission without prior speech. In the signalling information two digits (the mode digits) specify the traffic characteristics and the transmission class.

## 2.9 User facilities

Many user facilities in the DELTACS network are similar to those in modern civil networks, notably:
- dialled connections
- switched hot-line circuits
- conference
- broadcast
- call hold
- call forward
- follow me (call transfer)
- abbreviated dialling
- trunk barring
- call waiting
- line grouping.

But there are also facilities specific to military applications.
- Precedence and pre-emption. The system recognises and handles three levels of precedence for direct traffic: special priority, priority and routine. To each connection a precedence level is assigned by the calling terminal. Pre-emption is effected without delay, an indication being given to the interrupted subscribers.
- The step-up feature provides for transfer of command from the operational to the leap-frog staff. It permits the co-existence of operational and reserve commands within the same network.

Fig. 4. Conference is performed by way of duplex switched broadcast




The implementation of conference as defined in the EUROCOM document is of particular interest. The conference bridge does not use an analog mixing technique but operates on the duplex switched-broadcast principle. This permits a full digital conference in which speech and other signals can be exchanged. See Fig. 4.
The conference bridge switches the speaker's signal to all listening subscribers and switches the signal produced by the first interruptor back to the speaker. All telephone sets are provided with a press-to-talk switch to control the conference bridge through in-band signalling.

## 3 The switch

The DELTACS switch is designed in such a way that it can be implemented as a trunk switch or as an access switch, using the same hardware and software. This offers a major logistic advantage.
Fig. 5 shows the main parts of the ZODIAC switch:

- the terminating subsystem,
- the matrix subsystem,
- the control subsystem.

All the signals originating from subscribers or other switches are inputted in the form of digital multiplex groups of 16, 32 or 64 channels. The bitrate may be set at 16, 32 or 64 kb/s, individually per channel.

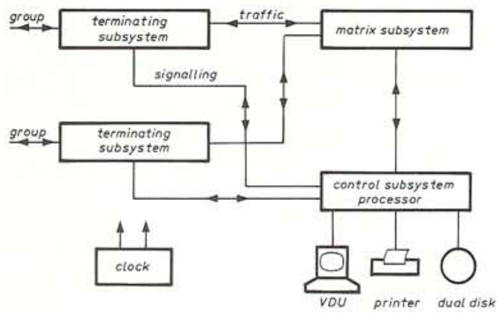



Fig. 5. Block diagram of switch

### 3.1 Terminating subsystem

Each terminating subsystem consists of a line terminating unit (LTU), link encryption equipment (LE) and a universal junctor (UJ). The terminating subsystem caters for the coupling between digital multiplex channels (subscriber or trunk channels), the matrix subsystem and the control subsystem. For maximum operational flexibility, the various elements are selectable for compliance with the EUROCOM and/or STANAG requirements.

### 3.2 Line terminating unit

The line terminating unit is to regenerate a multiplex group at an aggregate bitrate of 256, 512 or 1024 kb/s. For all these bitrates automatic equalisation takes place for cables of up to 2.4 km. HDB3 or CDS line coding can be accommodated by change-over. The LTU also gives access to the phantom of a quad cable for the engineering order wire (EOW) signal.

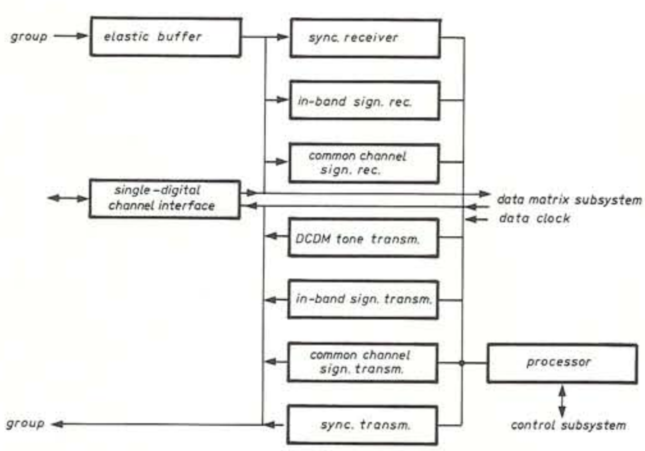



Fig. 6. Block diagram of Universal Junctor

### 3.3 Universal junctor

The UJ handles the coupling of the matrix subsystem, the control subsystem and the LTUs. The universal junctor is a front-end unit equipped with a microprocessor (Fig. 6).

When a UJ is put into operation, software commands will specify which functions are to be fulfilled by that particular UJ in view of the nature of the multiplex group attached.

*Signalling*

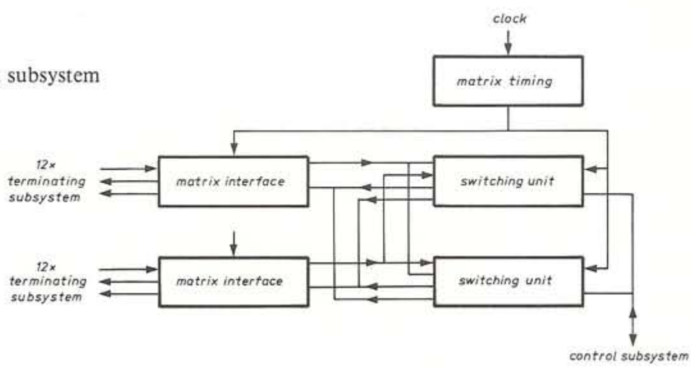
All the signalling protocols required for signalling in the various channels are supported by the UJ. The signalling systems used in ZODIAC networks are:
- common-channel signalling with ARQ for the inter-switch connections,
- loop signalling with cyclically permutable code words (CPCs) in a compelled protocol for digital telephone sets,
- loop signalling with a ringdown protocol via a 15-bit pattern for a local battery (LB) analog set,
- loop signalling with a pulse protocol via a 15-bit pattern for a central battery (CB) analog set,
- loop signalling with an E&M pulse protocol via a 15-bit pattern for STANAG 5040 B interfaces [3].

In principle, the UJ converts the different types of signalling to a uniform protocol for the information exchange with the control subsystem.

*Receiving*

The incoming multiplexed signal is synchronised to the switch clock by means of an elastic buffer store. With this buffer and a synchronisation receiver capable of detecting both EUROCOM and STANAG 4208 sync patterns, frame alignment of the received signal is effected.
If a channel (usually the second) in a group functions as a common signalling channel, the messages are exchanged with an ARQ block protocol. The individual channels are checked for the presence of CPCs used for in-band signalling.
The 15-bit patterns which convey the ringdown signalling and pulse signalling of analog sets will also be detected.
After synchronisation, the channel is no longer necessary. It is then available for use as a single digital channel.

Fig. 7. Matrix subsystem




*Transmitting*

The channel information in the multiplexed signal coming from the matrix subsystem is replaced with the synchronisation pattern required. This information is fed to the single digital channel via the interfacing circuit. If necessary, the channel subsequent to the synchronisation channel is used as a common channel. In-band signalling may be inserted in the individual channels as required; if so, the user information is not passed on.
To enable tone signals to be sent to the analog sets, the DCDM-coded tone signals are added to a channel.

The junctor is connected to the matrix subsystem via a data transmit line, a data receive line and a synchronisation line. The UJ and the control subsystem are coupled through a full duplex circuit using an HDLC LAP B (LAP = link access protocol) operating at 9.6 kb/s.
A special version of the UJ enables the system to interface with PCM networks operating with a T1 carrier at 1.536 Mb/s or with a CEPT multiplex system operating at 2.048 Mb/s.

### 3.4 The matrix subsystem

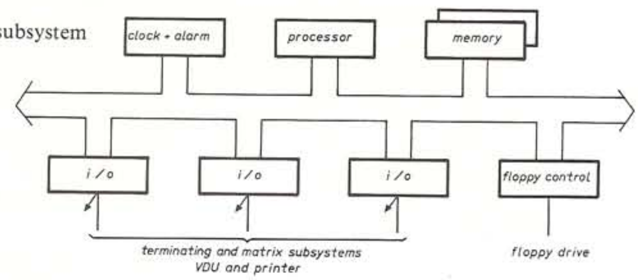
The matrix subsystem is a single-stage purely time-switching circuit. Its design is modular. The basic module consists of three printed circuit boards: a matrix interface, a matrix timing circuit and a switching unit. The switching capacity of the unit is 384 channels. Up to 12 UJs can be attached.
The capacity is extendible by multiples of 384 channels up to a maximum of 3072 channels, by adding sets of matrix interface and switching unit PCBs. The switching subsystem is shown in Fig. 7.
The matrix subsystem is capable of switching bit-interleaved multiplexed signals as well as PCM multiplex structures (CEPT and T1). Processing PCM signals does not reduce the capacity of the switch.

Table 1 Digital signals with their channel bitrates

| | 16 channels | 32 channels | 24 channels |
|---|---|---|---|
| 16 kb/s | 256 kb/s EUROCOM trunk/loop group | 512 kb/s EUROCOM trunk/loop group | |
| 32 kb/s | 512 kb/s EUROCOM trunk/loop group | 1024 kb/s EUROCOM trunk/loop group | |
| 64 kb/s | | CEPT 2048 kb/s PCM group | T1 1536 kb/s PCM group |

Like the communication between the UJ and the control subsystem, the information exchange between the matrix subsystem and the control subsystem takes place via a connection using an HDLC LAP B protocol.

Fig. 8. Control subsystem

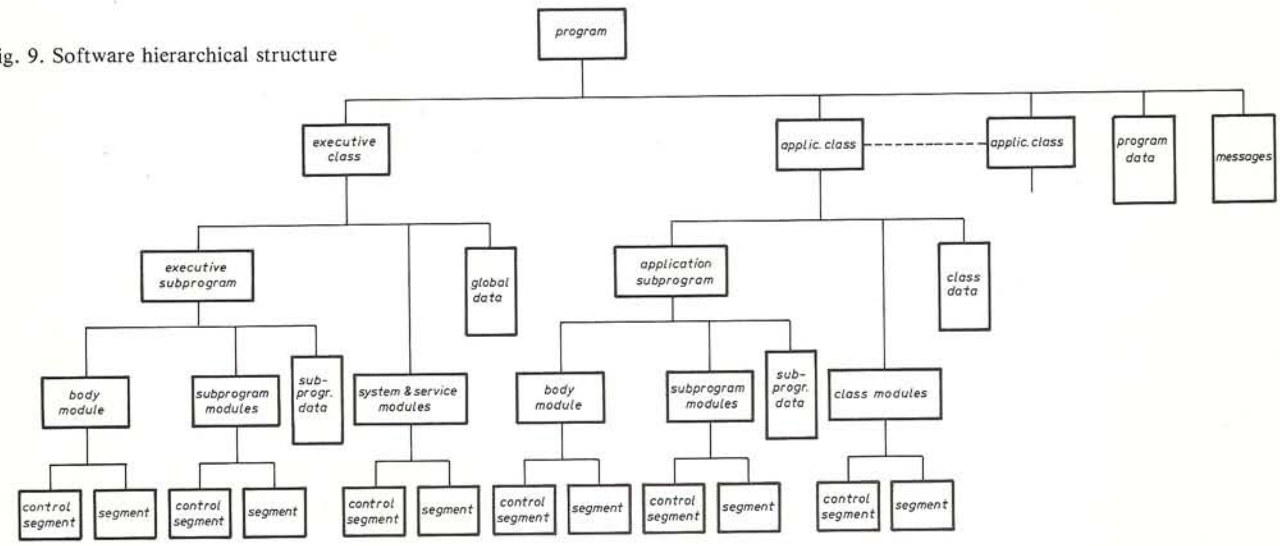



### 3.5 The control system

The control subsystem coordinates the operation of all the elements in the switch and, in conjunction with the other switches, the operation of the total communication network. As shown in Fig. 8, the control subsystem is built around a microprocessor PCB accommodating an MC 68000 $\mu$p operating with an 8 MHz clock. The memory for the storage of programs, instructions and data is of the RAM type. It occupies five PCBs, each having a 256 kbyte memory capacity. The programs are loaded from a floppy disc back-up store. The data needed in a particular location is also retrieved from the back-up store. To enable quick restarting, all the data

specific for a certain switch is copied from a permanent data disc to a temporary data disc. The data is read from the latter as and when required.
Each I/O PCB, using its own microprocessor, is capable of handling six channels. Several transmission protocols may be set.
The visual display units and the printer utilise a standard start-stop protocol for information exchange on a character-by-character basis. An HDLC protocol operating at a bitrate of 9.6 kb/s is also used on the connections to the Universal Junctors and the lines for the Matrix subsystem.
A special PCB controls the data exchange with the floppy disc. A direct memory access (DMA) facility links the disc drive to the memory.
The clock-and-alarm PCB monitors the Control Subsystem and produces an alarm signal if necessary. The clock signals generated are applied to the various subunits.
The Control Subsystem is provided with two display units, of which one may be used for making amendments to the data base, whereas the other is to monitor the switch operation. The two visual display units have a protected screen area for the presentation of alarm details.

Fig. 9. Software hierarchical structure




## 4 Software

Since the microprocessor of the control system has to execute complicated real-time tasks, the proper working of the switch and the complete network depends on the degree of perfection of the software. The structural top-down approach to the software development ensures a high-quality, maintainable product [8]. This is illustrated in Fig. 9. For the high-level language PASCAL was chosen (ISO dp 7185, second draft) [9].
During system development, special development programs were used to monitor the start and the completion of the various development phases. These phases were: function specification and architectural analysis, high-level design, detail design, coding, unit testing, hardware-software integration test, system integration test, and acceptance test.
The software is divided into an operating system and several classes. The characteristic of a class is that it has no data in common with another class. Each class is divided into subprograms, class 'procedures and functions', and class data. Class 'procedures and functions' will be called only by subprograms of the same class.

Each subprogram consists of modules, subprogram 'procedures and functions', and subprogram data. Each module may call any service 'procedure and function' in the operating system. A module consists of one or several segments. A segment is the lowest level that can be compiled; it consists of 25 to (max.) 100 high-level statements.

The data exchange between the various classes and between subprograms within a class is achieved by messages.

The software for the control subsystem is divided into 10 classes, one of these being the operating system. About 40% of the entire software consists of data.

In the development stage special attention has been paid to the administration class, which also contains the man-machine communication. This communication takes place through the display-keyboard combination. A menu structure, suitable for use in a guided or unguided mode, ensures efficient data exchange between operator and system even under conditions of stress.

The program for the Universal Junctor is not written in a high-level language but in assembler to meet the stringent real-time requirements and spare the limited memory capacity (32 kbytes). A table-driven structure is used for the software to provide a simple method for later changes or additions to signalling protocols.

### 4.1 Arrangement of the DELTACS data base

DELTACS subscribers may frequently change their location. At each location they are connected to the nearest switch. Irrespective of the terminal selected, each subscriber retains his own function-related subscriber number. The switches are mobile as well, and are regularly moved. The result of such movements is that both the subscriber file and the network topology are subject to continuous change.

Despite the dynamically changing character of DELTACS, it is necessary to have an accurate picture of the network and the subscriber configuration available. This should be achieved without having to carry out operator actions other than initiation. It is therefore necessary to have the disposal of the static data of subscribers and switches and to keep the current subscriber and switch status up to date. This is accomplished through the arrangement of the DELTACS data base as a conglomerate of permanent and temporary data files.

The permanent files use the conventional structure of files, records and fields. They contain the initial characteristics of all the switches, group types, and subscribers, which potentially form part of the DELTACS system. Of the permanent files there is only one version, of which each switch dumps an identical copy in a back-up store.

The temporary files consist of tables generated, as required, in the main memory of an active switch. They contain the current characteristics of the switches, groups and subscribers, which take an active part in a system in a given configuration. These files also contain data from which the desirable routing can be derived for a circuit required between subscribers, and data about the actual status of such circuits. The temporary files are unique for each switch and each active period of the switch. An active switch keeps a copy of its temporary files in the back-up store.

### 4.2 Permanent files

The permanent files comprise the Node File, Group File, Unit File, Subscriber File, Profile File, Number Set File and Compressed List File. A switch operator is unable to make changes in these files, but can use them when initialising his switch and group equipment, and when affiliating subscribers.

The Node File contains all data needed to initialise a switch as a uniquely recognis-

able element in the network.
The Group File contains all details needed to initialise group equipment for use as a subscriber group. These details include the number and type of circuits, frame structure, etc. The data are grouped for each unit in the Group File. A unit is understood here to mean the identity of a tactical unit (staff) to whose subscriber terminal the circuits can be connected.
Also the Unit File contains data, viz. that which concerns the collection of subscriber numbers assigned to members of the tactical unit. This data is grouped for each unit.
The Subscriber File is a collection of individual subscriber numbers which cannot be assigned permanently to a tactical unit defined in the Unit File. Each subscriber number entered in the Unit or Subscriber File is associated with a subscriber profile. Such a profile specifies the physical characteristics of the subscriber equipment and the special facilities initially assigned to the subscriber. Several subscriber numbers may share the same profile. The collection of defined profiles is entered in the Profile File.
Finally, several collections of subscriber numbers are entered in the Number Set and Compressed List Files. The subscriber profile makes reference to these collections if the subscriber has access to line group, preset conference, broadcast or abbreviated dialling facilities.
Fig. 10 illustrates the references from and to the various files.

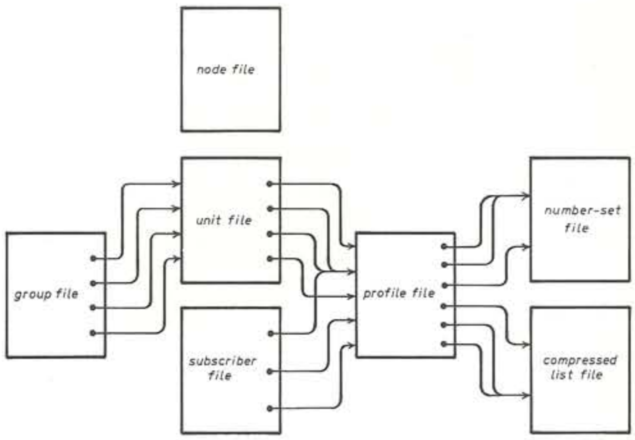



Fig. 10. Relations between permanent files

All these data form a picture of the nature and the arrangement of the elements of which the network may be composed. This picture reflects the organisation for which the network is designed; the permanency of the data is therefore the same as that of the organisation itself.

## 4.3 Temporary files

The temporary files consist of tables with data used for the routing functions, status determination and status monitoring of the switch, the subscriber circuits and the network. The initial filling of the tables is obtained from the permanent files; the tables may be supplemented with data entered manually by the operator or derived from other temporary files. Table updating is effected by software processes executed in the switch. These processes are initiated by subscriber and switch operator actions, or by an external interference, impeding or prohibiting the traffic between switches or between switches and subscriber terminals.

In the following paragraphs only those tables which play a part in changing the configuration of subscribers and the network will be considered in more detail. The tables involved in this are the Affiliated Network Table (ANT), the Affiliated Subscriber Table (AST), the Expected Subscriber Table (EST), the Subscriber Location Table (SLT), the Route Table (RT) and the Connectivity Map Table (CMT).
An AMT is created exclusively in a DELTACS switch having circuits connected to elements belonging to a network other than DELTACS. The remaining tables are produced in each active DELTACS switch.

### *Connectivity Map Table*

The CMT gives a picture of the actual DELTACS network configuration in each switch. It contains the identity of each DELTACS switch. This serves as index for the table, the entry indicating the switches with which a direct connection is made.

### *Route Table*

The RT indicates in each switch the preferred route of a circuit to each of the other switches of the DELTACS network. 'Route' is here understood to be the trunk link through which the local switch is exited. Besides this, a maximum of nine alternative routes may be indicated.
The RT contains the identity of each DELTACS switch, which serves as index for the table; the entry concerned gives the primary and the alternative routes.
The RT is updated on the basis of the connectivity map. The preferred route is that involving the least number of trunk links between source and destination. The alternative routes are determined in the sequence of a rising number of links; with an equivalent number the routes are selected in the order in which they have been written in.

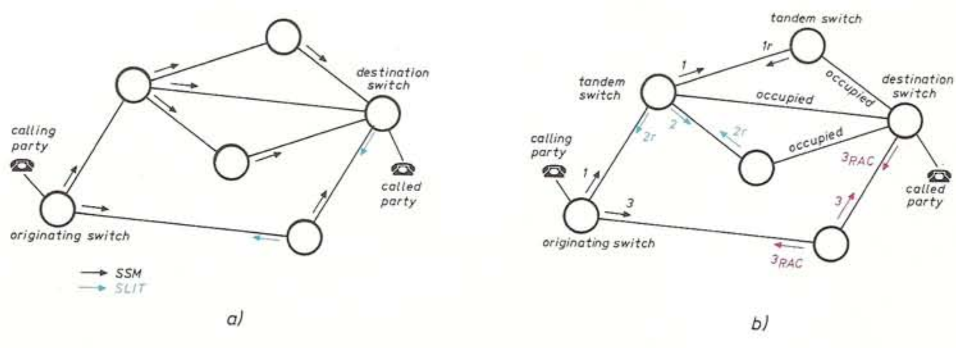



Fig. 11*a*. Saturation search; *b*: Deterministic routing: First and second attempts of intermediate switch result in 'number unobtainable' (*1* and *1r*, *2* and *2r*, respectively); called subscriber reached in final attempt (*3*).

With the actual switching of the circuits, each switch forming part of the trajectory re-determines the preferred route on the basis of its own local RT. Such a spill-forward system [10] adapts itself automatically to changes of the connectivity during the build-up of the circuits, but it entails the risk of circuits being endlessly switched without ever reaching the destination. To prevent such a situation, the source switch also gives an indication concerning the permissible maximum number of trunk links. This maximum number is decreased through each switch on the route. If in a given switch the minimum number of trunk links required to reach the destination is found to be greater than the permissible maximum, the switch abandons further attempts and returns a 'number unobtainable' signal. On receiving this signal, the source switch makes another attempt over the next alternative route. If there are no more alternatives available, the process ends with 'number unobtainable' tone to the caller.

## 4.4 Subscriber reconfigurations

The complete collection of potential DELTACS subscribers is laid down in the permanent files. The current subscriber configuration, however, is determined by the sub-collection of subscribers actually affiliated at each of the switches.
Only the subscriber configuration data of local importance to the switch are laid down. The Expected Subscriber Table indicates the subscribers eligible for local affiliation according to the rules; the Affiliated Subscriber Table gives the locally affiliated subscribers, and the Subscriber Location Table the non-local subscribers most frequently called.
To be able to switch a circuit to a called subscriber, the location of this subscriber should be known first. To this effect that switch must be identified whose AST contains the called subscriber. If the AST or the SLT of the originating switch does not list the called subscriber, a 'saturation search' is conducted to determine the destination switch. In such a case, the originating switch transmits a Subscriber Search Message (SSM) via the processor network. The SSM contains the identity of the calling switch and the number of the required subscriber.
Each switch receiving an SSM makes a search through its AST for the called subscriber. If the table does list the subscriber, the switch returns a Subscriber Location Message (SLM) to the searching switch. The SLM contains the identity of the destination switch and the number of the called, and now located, subscriber. Fig. 11*a* illustrates this saturation search process.
The calling switch updates its SLT by means of the received SLM. In the absence of an SLM, the call attempt is terminated with the 'number unobtainable' signal.
For calls destined to subscribers listed in the local AST, circuits can be directly connected to the terminal indicated in this table. Calls for subscribers entered in the SLT can be directed to the found destination by the deterministic spill-forward routing process. The identity of the destination switch serves as index for the Route Table. Fig. 11*b* illustrates the deterministic process. The diagram shows that each of the intermediate switches re-attempts to reach the desired destination on the basis of its own RT and over the preferred route.

Fig. 12. Terminal subsystem drawer

It may happen that a subscriber listed in the SLT has meanwhile left the location indicated in the table. In such a case, the switch listed as destination in the SLT will answer a call to this subscriber by 'number unobtainable'. The calling switch will still initiate the search procedure, but when this fails to locate the called subscriber, the number of this subscriber will be deleted from the SLT.

### 4.5 Traffic capacity

The switch has a maximum capacity of 96 groups, where each group may consist of either trunks or subscribers. The maximum number of channels is 3082.
The data base is so designed that for the time being a maximum of 5000 users can be connected. The number of user profiles is confined to 2000. The number of lists for preprogrammed broadcast, conference and line group, with a maximum of seven users per list, is limited to 250. A number of 128 military units can be registered beforehand.

## 5 Mechanical Design

All DELTACS switch equipment is accommodated in an air-conditioned shelter. The equipment is housed in 19″ drawers, resulting in a modular and well-maintainable design. Each drawer has its own DC/DC converter, which operates from 24 V DC obtained from a rectifier with a buffer battery, so that a failure can be bridged for a limited period. The rectifier is fed with 220/110 V AC.
Fig. 12 shows the 19″ drawer of a Terminal Subsystem, showing from left to right the line terminating unit, the encryption unit and the universal junctor. The DC/DC converter is mounted to the rear of the drawer.
The various units which slide into the drawer are fully shielded to minimise crosstalk and electromagnetic interference, both between the units and with the remaining equipment. To permit cooling in spite of the shielding, the units contain double walls with air openings in the inner and outer walls staggered. The construction is clearly visible in Fig. 13, which shows a line terminating unit.


Fig. 13. Line terminating unit

The complete Terminating subsystem and the operator positions for the man-machine communication are installed at one side of the shelter (see Fig. 1). The digital telephone sets of the operators are connected to the single digital channel interface of the Universal Junctor. At the other side of the shelter are the Matrix Subsystem, the Control Subsystem, the isolating transformer, the rectifiers and the associated distribution system.
The cable connections for groups and power supply are located in the entry panels at both sides of the door. Protective devices against lightning surges and other voltages on the cables are fitted to the connectors.

## 6 Multiplexer

Since the connection to the switch can only be made with a multiplexed signal, the users are connected through a multiplexer. Various users can be accommodated by a selection of printed circuit boards. The channel PCBs supply the electrical interface parameters needed for the user signalling.
The units that can be connected are:
- digital subscriber set (16 kb/s) with cyclically permutable code words for signalling,
- local-battery analog set with ring-down signalling,
- central-battery analog set with pulse signalling,
- 6-wire STANAG 5040 interface with E&M signalling,
- data equipment with V.24-V.11 characteristics,
- data equipment with current loop characteristics.

To transmit data signals having a lower bitrate than the line speed, the 'Multiple Sampling Majority Voting' principle is applied to the channel PCBs for data equipment. This equipment is operable at a maximum asynchronous bitrate of 2400 bauds.

### 6.1 Digital subscriber set

A digital subscriber set is also available for use in DELTACS. It has a 2-wire con-

Fig. 14. Typical subscriber set

nection to the system and operates at 16 kb/s in full duplex mode.
The set also has provisions for the connection of analog or digital peripherals; this makes it an Integrated Services station rather than a telephone set.
Connections from this subscriber set can be built up in voice or directly in the peripheral mode. Fig. 14 shows the digital subscriber set.

## 7 A look into the future

Besides the fact that the DELTACS system is able to operate jointly with Combat Net Radio Systems [12] and the Mobile Automatic Telegraph System [13], provisions have been made in its design for the future addition of Single-Channel Radio Access systems for mobile users.
In the latter case, the subscribers will enjoy the same facilities as subscribers using wire-connected terminals.
Because the DELTACS system is able to make multi-slot connections, provisions are incorporated to accommodate a Packet-Switching overlay network.

## 8 Editor's note

The information presented in this article was earlier given in a combined meeting of the Nederlands Electronica en Radiogenootschap, the KIVI, Section Telecommunicatie-techniek, and the IEEE, Benelux Section, on military telecommunication [14].

## 9 References

1 EUROCOM D/1: Tactical Communication Systems, basic parameters, September 1982
2 Drafts-STANAG 4206-4214: The NATO multi-channel digital gateway, 1983
3 STANAG 5040: NATO Automatic and Semi-automatic Interface between the National Switched Telecommunications Systems of the Combat Zone and between these systems and the NATO Integrated Communications Systems (NICS), June 1981
4 STANAG 5046: The NATO military communications directory system, 1978
5 F. de Jager: Delta Modulation, a method of PCM transmission using the 1-unit code, *Philips Research Reports*, Vol. 7, 1952, 442-466
6 J. A. Greefkes, K. Riemens: Code modulation with digitally controlled companding for speech transmission, *Philips Technical Review*, Vol. 31, 1970, 335-353 (No. 11/12)
7 J. W. Glasbergen: This versatile IC digitises speech, *Philips Telecommunication Review*, Vol. 39, 1981, 147-154 (No. 3)
8 E. Erickson, J. Roder: A Generic Approach to Software Validation, 1982 Conference Proceedings, First Annual Phoenix Conference on Computers and Communications
9 B. W. Ravenel: Towards a Pascal Standard, *Computer Magazine*, April 1979
10 P. M. Lin, B. J. Leon, C. R. Steward: Analysis of circuit-switched networks employing originating office control with spill-forward, *IEEE Transactions on Communication*, Vol. COM 26, 1978, 754-765 (No. 6)
11 C. Ziekman, P. Zwaal: Deltamux, a design element for military communication networks, *Philips Telecommunication Review*, Vol. 32, 1974, 78-89 (No. 2)
12 A. de Waard: PRC/VRC 4600 VHF combat area radio equipment, *Philips Telecommunication Review*, Vol. 35, 1977, 120-133 (No. 3)
13 R. W. Bruins, G. J. Oostenenk: A military Mobile Automatic Telegraph System, *Philips Telecommunication Review*, Vol. 39, 1981, 187-200 (No. 4)
14 Subjects by P. van der Vlist, A. J. W. van Daal and J. F. H. Pacanda (*in Dutch*), *Tijdschrift van het NERG*, Vol. 49, 1984, No. 3.