Sub-multiplexers for 64K

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Summary The introduction of 64 kbit/s data channels in digital data networks has created a need for sub-multiplexers to achieve maximum utilization of the channel.

The article describes a family of time-division multiplexers designed to cater for various customer requirements. This includes a speech-plus-data multiplexer, a 5-channel multiplexer, and a range of extenders to increase this up to 20 channels, with data interfaces of X21 or X21 bis.

A segmented liquid-crystal display is used to provide status information on all channels, and to enable user options to be programmed via the front panel.

Introduction

The introduction to the data communications world of 64 kbit/s channels, through the medium of private digital data networks such as British Telecom's KiloStream service, has created a demand by users for multiplexers that will utilize these channels most efficiently. Furthermore, the development of good-quality speech encoders working at 32 kbit/s makes possible the integration of speech and data within one 64 kbit/s channel.

In the design of these multiplexers there are certain criteria to be observed:

a) they should be compatible with the data terminal equipment (d.t.e) currently used with data modems, i.e, have a CCITT X21bis equivalent interface at the data ports, but be adaptable to CCITT X21 protocols when terminals using these appear on the market,*

b) the availability of the equipment in service should be maximized by including comprehensive supervisory facilities such as test loops initiated by the user or by a centralized network management centre, centralized alarm reporting and continuous monitoring of the aggregate channel performance,

c) when a speech circuit is provided, provision should also be made for signalling,

d) the designs should be modularized such that a variety of systems can be configured which match the customer's terminal data rates and distribution,

e) as far as practicable, equipment should conform to CCITT Recommendations.

This article describes a family of digital multiplexers which has been designed in accordance with these criteria, and which is still being expanded to cover new requirements and advances in technology.

General

The current range of multiplexers available consists of:

a) S + 2TDM – speech plus two channels of data,

b) 5TDM – five channels of data,

c) 4TDM – extenders for use with the 5TDM which feed four channel inputs to each data channel.

They are housed in compact table-top units suitable for mounting alongside data terminals.

All the multiplexers, using time division multiplexing (t.d.m) techniques, sequentially allocate the aggregate to each user d.t.e in turn. In

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Joining Marconi Communication Systems as a Student Apprentice in 1977, Robert Bunce graduated from Southampton University in 1982 and joined Line Development at Writtle.

He worked as a Junior Development Engineer on data modem equipment, principally on software development.

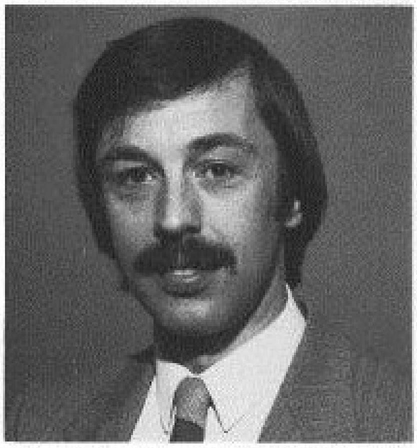
He then became a Development Engineer working as part of the 5 TDM development team, responsible for channel processor software.

He has since been responsible for the development of a successor to the S+2 TDM unit and is now working to develop a terminal adaptor for a 2 Mbit multiplexer.

B. Clare

Brian Clare joined Marconi Communication Systems as a Student Apprentice in 1969. Graduating from Brunel University in 1973 he joined Line Development at Writtle.

He worked as a Development Engineer on VFT equipment and then on designing gate arrays as part of data modems, before becoming a Section Leader responsible for data modems. He then became Project Leader responsible for the development of a family of sub-multiplexing equipment, and is now leader of a project to develop a 2 Mbit multiplexer.



* CCITT X21bis is the present European standard for digital data interfaces and CCITT X21 is a more recent European standard to give greater reach and/or higher data rates.

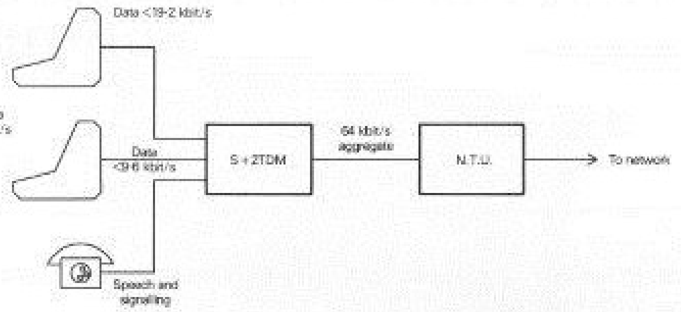


Fig. 1. S + 2TDM system configuration

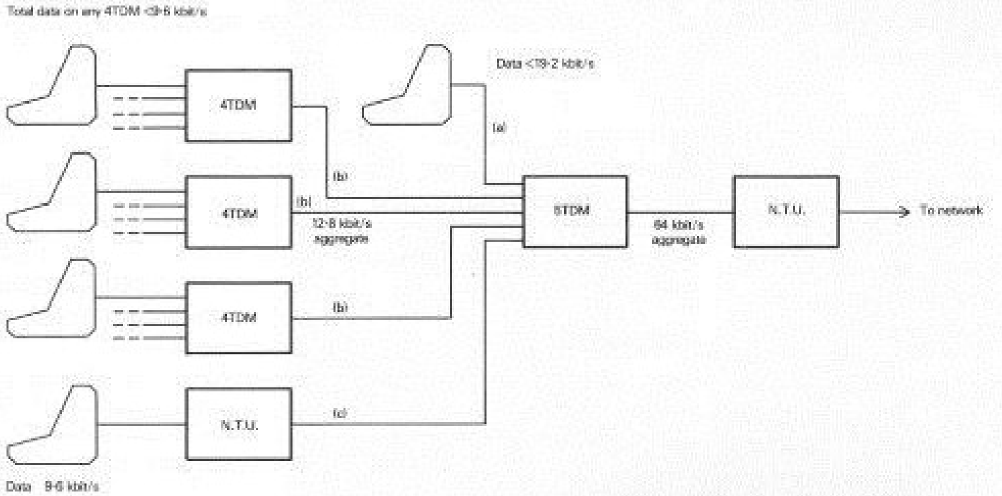


Fig. 2. 5TDM system configuration

addition to the user data, a frame pattern is added so that, at the far end of the link, the user data for each d.t.e can be demultiplexed correctly.

Figures 1 and 2 show typical system configurations of the equipments, as connected to a 64 kbit/s channel. In the KiloStream example the S+2TDM or 5TDM would be connected into an X21 network terminating unit (n.t.u).

The S + 2TDM provides local user access for two data channels at up to 9600 bit/s on X21bis, plus a speech channel with provision for simple signalling.

The 5TDM (figure 2) can provide local access at X21bis on up to five channels (a). Alternatively any channel may be extended up to a distance of 5km, using a local-line system, to a 4TDM extender (b).

These are available in three types to provide up to four channels each on either X21, X21bis synchronous data, or X21bis asynchronous data. A further option exists for customers wishing only to extend the reach of a single data terminal. This can be achieved by using the 12·8 kbit/s aggregate capability of a KiloStream n.t.u (c).

It is also possible to connect 4TDM units back to back. This provides short-range (5km) multiplex capability within customers' premises, without connection to a major network.

Speech + 2TDM

The speech-plus-data multiplexer provides a speech channel and two data channels. The speech port is designed for tie-line applications between PABXs but can also be used for point-to-point telephone connection and, with the

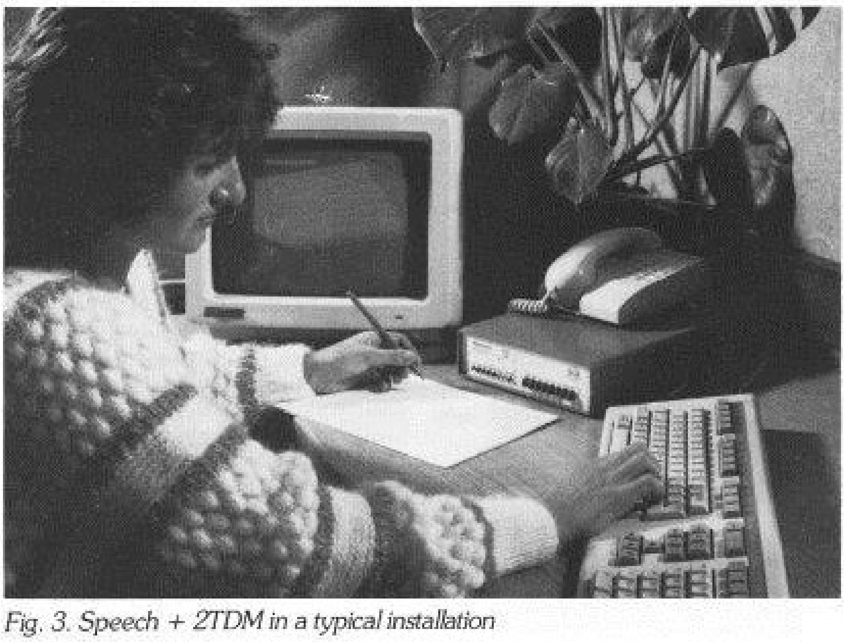


Fig. 3. Speech + 2TDM in a typical installation

correct signalling converter, telephone-to-exchange connection. The two data ports are X21bis synchronous, independently strappable for 1200, 2400, 4800 or 9600 bit/s operation. Optionally a single channel at 19200 bit/s can be provided.

The speech is digitized using Continuously Variable Slope Delta modulation (CVSD) into a 32 kbit/s stream. The speech port provides a 600Ω balanced connection and can be used for 2-wire or 4-wire connection to an exchange without line wetting current. Alternatively it can provide a 2-wire connection to a local telephone with current-limited power feed. The speech port also provides a signalling channel sampled at 1600 bit/s. This channel is terminated in earth ON – earth OFF signalling (E and M) converters for tie-line applications, but can be strapped for point-to-point telephone connection.

Semi-custom integrated circuits (IC) are used to provide X21bis interchange circuit control and data formatting. The data stream is formatted into a 6 + 2 envelope (6 data bits + 1 status bit + 1 frame pattern bit), and the resulting serial data stream is then bit-iterated up to 12·8 kbit/s. In the receive direction, the customer data is recovered from the 12·8 kbit/s stream. The stream is first bit-deiterated, then the frame pattern bit found, enabling the status and data bits to be extracted.

A semi-custom IC is used to multiplex the speech, two data streams and speech signalling into the 64 kbit/s aggregate. A 20 bit frame is used, this frame comprising one frame bit, ten speech bits, four data bits for each data channel, and one bit speech signalling. In the receive direction, the frame pattern bit is found to enable the stream to be demultiplexed into its component parts.

The front panel provides locking key switches for: local loop, local loopback, remote loopback, lamp test, binary 0 data clamp, CNR data clamp, and UNR data clamp. An additional switch is used to select between the two data channels. Light-emitting diode (l.e.d) indicators are used to show: loop active, test mode, UNR data pattern received, CNR data pattern received, aggregate fault, RDY pattern received, carrier detect, and received data. Internal option straps are used to select channel data rate, clamps on interchange circuit, and interchange circuit response time.

The next generation of this multiplexer, now in design, will incorporate Adaptive Differential Pulse Code Modulation (ADPCM) speech encoding, improved speech signalling, more efficient multiplexing to provide more data channels, and greater ease of programming.

5TDM multiplexer family

The 5TDM multiplexer family comprises four multiplexers that enable the customer to obtain from three to 20 data channels from the 64 kbit/s (e.g. KiloStream) link. The channels can be provided with a range of interface standards; X21, X21bis, synchronous and asynchronous. T.D.M techniques are used throughout and provide the customer with a maximum of 48 kbit/s data capacity.

All members of the family share the intelligent front panel described below.

The main 5TDM multiplexer is the interface to KiloStream. It provides five user ports that can be configured for X21bis data or local line system to an expansion multiplexer, 4TDM.

The 64 kbit/s aggregate is presented at X21 (V11) standards.

Frame alignment

Frame alignment throughout the 5TDM multiplexer family is carried out using microprocessors. In all cases the following features are provided:

a) persistence on frame pattern errors before loss of frame alignment declared,

b) fast frame alignment process after initial loss of alignment,

c) after three frames of loss of alignment, critical loss of alignment is declared. Only an error-free pattern will then be realigned to,

d) recognition of multiple-frame pattern positions, caused by frame pattern mimics in the data field. Frame alignment prevented until single-frame pattern position identified,

e) alarm recognition and generation where supported. Some frame patterns provide a signalling bit that is used to indicate aggregate faults from local to remote unit.

5TDM multiplexer

This 5-channel multiplexer is the heart of the family. The 64 kbit/s aggregate is used to carry customer data framed to CCITT Rec. X50 div 2. This provides an 80-envelope frame, each envelope structured in 6 + 2 format. The 80 envelopes are allocated sequentially to each channel provided by the multiplexer, as shown in Table 1.

Table 1: Envelope allocation for 5 TDM multiplexer

Channel	Envelopes
1	1, 6, 11............76
2	2, 7, 12............77
3	3, 8, 13............78
4	4, 9, 14............79
5	5, 10, 15............80

Thus each channel is allocated a 12·8 kbit/s slot within the 64 kbit/s aggregate.

Each channel can be configured, through front panel switches, to provide either an X21bis data port or a 4-wire local line termination.

Each X21bis port can be independently programmed for 600, 1200, 2400, 4800, or 9600 bit/s.

The user data is formatted into 6 + 2 envelope structure. Data rates below 9600 bit/s leave empty envelopes in the allocated channel, i.e, 4800 bit/s uses every other envelope, 600 bit/s uses one envelope in 16. The first five

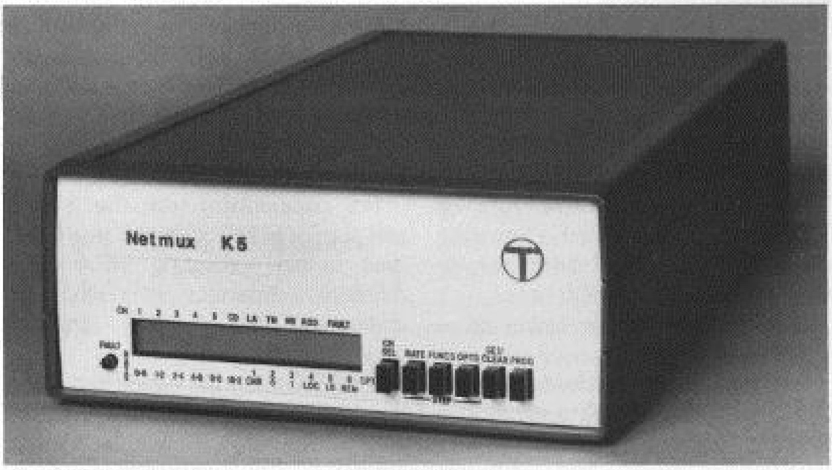


Fig. 4. 5TDM, as supplied to British Telecom

envelopes in the 80-envelope pattern always contain data to allow easy identification of the remaining data envelopes.

The local line system uses WAL2 coding at 12·8kHz. This gives a reach of approximately 5km. The 6+2 structured data format allows a maximum of 9600 bit/s user data. Although each channel is allocated 12·8 kbit/s capacity of the 64 kbit/s aggregate, one bit in every eight is overwritten by the X50 framing pattern bit. Thus the frame pattern bit in the 6+2 formatted local link is overwritten by the X50 frame pattern used on the aggregate link. By careful choice of the frame pattern, it is possible to align the local frame pattern to the channel envelopes in the X50 structure, such that the local frame pattern can be regenerated correctly at the remote 5TDM.

5TDM implementation

The heart of the design comprises an aggregate interface frame-alignment processor and 5-channel multiplexer/demultiplexer.

Three processors, two serving dual channels, the other a single channel, provide the channel interfaces. These processors perform all functions associated with each interface: X21bis interchange circuit control and data structuring, local-line system frame alignment and alarm monitoring. Discrete hardware is used to provide the X21bis interface, while semi-custom ICs and analogue circuitry are used to provide the interface for the local-line system.

The front panel is controlled by a fifth processor, which also acts as supervisor/controller to the other four processors.

4TDM multiplexers

The 4TDM synchronous expansion multiplexers each provide up to four data ports, and a single 12·8 kbit/s local-line output.

4TDM synchronous

These units provide either X21 or X21bis data ports, with either four data channels at 600, 1200, 2400 bit/s or two data channels at 4800 bit/s.

The multiplexers are based on a single-processor design.

Each d.t.e port is provided by a Universal Synchronous Asynchronous Receiver Transmitter (USART) used in synchronous mode, and additional

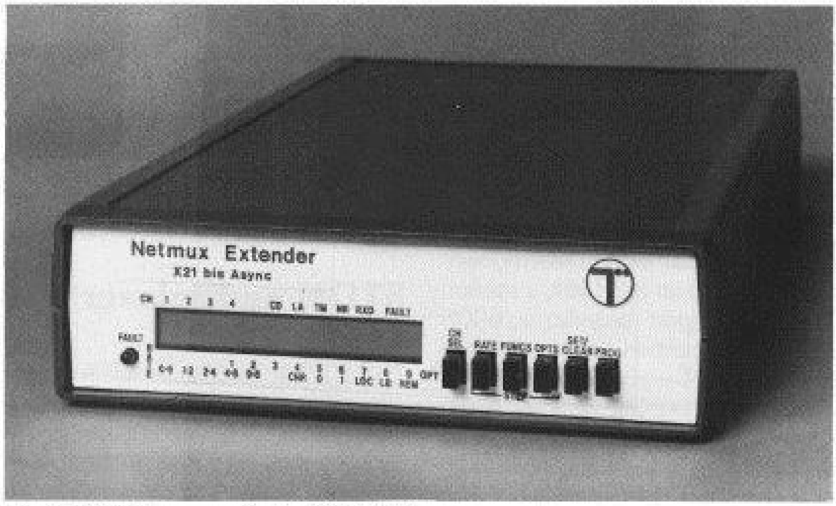


Fig. 5. 4TDM, as supplied to British Telecom

discrete hardware. The processor provides the appropriate interchange circuit control and data structuring.

A fifth USART is used to connect the processor to the semi-custom IC and analogue circuitry that comprises the local-line system interface. The processor performs all frame alignment associated with this interface, as well as the multiplexing of each d.t.e port into the aggregate.

4TDM asynchronous

The asynchronous unit is similar to the synchronous X21bis unit, but additionally provides a single channel at 9600 bit/s.

The mutliplexer is based on a single-processor design.

Each d.t.e port is provided with a USART used in asynchronous mode. Asynchronous operation implies no clock, so it is not possible to multiplex each d.t.e port directly into the aggregrate.

Characters from each d.t.e are placed into buffers. Each buffer is then sequentially sent through the local line as a HDLC (High-level Data Link Control) message. The advantage of HDLC is that each message is self contained, comprising start and end of message flags, channel identification and error detecting checksum in addition to the data characters.

For compatibility with the 5TDM unit the local line must still use 6+2 data format, providing 9600 bit/s message capacity, although the additional status and framing information is redundant.

A HDLC controller is used to provide the message handling. This is provided with a 9600 bit/s channel by a semi-custom IC that frames and structures the data into a 12·8 kbit/s stream. This connects to the local-line interface used by the synchronous expansion multiplexers.

To allow 9600 bit/s of user data plus HDLC message overhead to be fitted into a 9600 bit/s channel, the start and stop bits, associated with asynchronous character format, are not passed in the message. Provided that the boundary between characters in the message is known, and this can be found from character format programmed into the units, then the start and stop bits are redundant information.

Front panel – control and configuration

The front panels of existing data communications equipment have traditionally comprised locking switches for control and l.e.d indicators, additional options being available on straps (wire links or switches) internal to the equipment.

Requirements

The advent of multichannel equipment presents the designer with the problem of providing control and indication for more than one data channel.

For the Speech + 2 Data multiplexer, described above, an additional switch was used to select between data channel 1 and data channel 2, as the front panel area prevented the duplication of controls for each channel. Internally the option straps are duplicated for each channel.

This solution poses a number of problems, which get more difficult as the number of channels provided by the equipment increases.

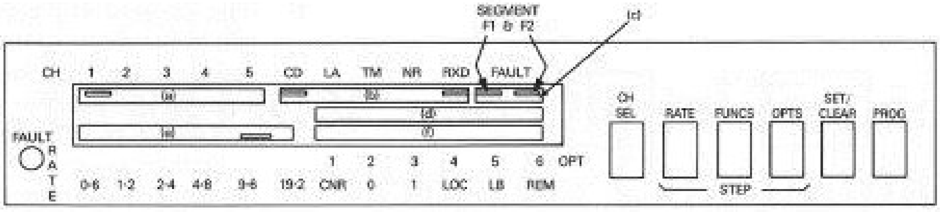


Fig. 6. 5TDM front panel

The channel selector used on the front panel must allow the user to identify the channel currently allocated easily. Control facilities are available only on the channel currently allocated to the front panel, and are transferred to the new channel if the channel selector is changed. Internally the duplication of option straps uses up valuable printed-circuit board area, and can cause confusion in identification of the correct strap for a given channel and option. In multi-board designs some straps may be accessible only by disassembly of the unit.

Implementations

Most multichannel equipments make use of microprocessors, with all options and control functions being passed through the processor. The addition of extra software, and modifications to the front panel design, allow most of the problems identified above to be overcome.

The internal strap options either interface directly to the processor, or control inputs to ICs that could be provided by latches off the processor data bus. To eliminate the straps, an indication of their present setting and a method of alteration must be provided via the front panel. The processor stores the state of options for channels not on the display. Also some method of storing the strap settings during power-off is required so that re-programming on power up is not required.

The number of indicators on the front panel can be increased, without the power requirement increasing, by using l.c.d technology to provide a simple multi-segment display. Separate locking switches, to select test modes, are also replaced by programmable l.c.d segments.

Access to all programmable segments on the display is provided by a movable cursor, controlled by a small number of switches rather than individual switches for each segment. This display replaces all indicators, except for one l.e.d used to attract operator attention to the unit in case of aggregate alarm. The power-off storage can be provided by an electrically erasable programmable read-only memory (EEPROM) which provides both non-volatile storage and easy alteration.

General-purpose intelligent front panel

The display, comprising three rows of 12 segments, is divided into six areas (figure 6):

Channel, used to identify selected channel (a),

Status, status of selected channel (b),

Aggregate, status of aggregate link irrespective of selected channel (c),

Options, current setting of all option straps on selected channel (d),

Rate, data rate of selected channel (e),

Functions, test functions set on selected channel (f).

The front panel is controlled by a bank of six non-locking switches.

One switch, CH SEL, is used to step sequentially round the available channels. Some multiplexer configurations may disable certain channels and the front panel will not allow access to disabled channels. As each new channel is selected, the display changes to reflect its configuration.

To alter the configuration of a channel, program mode is entered by pressing the PROG switch. In program mode a flashing cursor is used to indicate the current position on the display.

The switches RATE, FUNCS, and OPTS are used to access the alterable areas of the display. Repeated operation of the switch steps the cursor on to the next position on the display in a cyclic manner.

Changes are made on the display by the SET/CLEAR switch which toggles the state of the position under the cursor.

Changes made in program mode take effect only when the PROG switch is pressed. It is possible to abort programming mode without making any alteration by pressing the CH SEL switch.

These features allow the configuration of each channel to be checked and altered rapidly. Additionally, the software driving the front panel was written to prevent the simultaneous setting of conflicting rates, options and functions.

System status

The use of the front panel described above enables the system status to be continuously monitored. Two fault segments are provided to give information of various system failures, with an l.e.d to attract the operator's attention. For example, the faults shown in Table 2 are indicated on the 5TDM unit.

The controls can also be used, in addition to normal channel signals, to set up local loops, remote loops, or loopback (figure 7), to aid diagnostics.

Table 2: 5TDM fault indications

LED	F1	F2	Fault
ON	OFF	OFF	Aggregate alarm from remote 5TDM
ON	ON	OFF	Loss of aggregate frame pattern alignment
ON	ON	ON	Loss of aggregate clock
ON	FLASH	ON	Local line fault, not on selected channel
ON	FLASH	FLASH	Local line fault, on selected channel
OFF	OFF	OFF	Normal operation

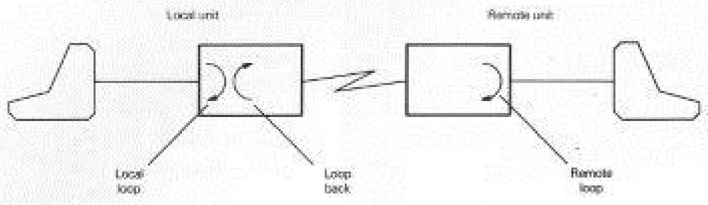


Fig. 7. Test loops

Conclusions

The equipment described makes full use of the channel capability of digital services such as KiloStream, offering as many as 20 channels of low-rate data, or a speech-plus-data facility.

Further development will improve the service being offered (as in the case of speech encoding) and offer a wider series of interfaces, such as G703 aggregate, to interface directly to a 2 Mbit/s primary multiplexer.

RÉSUMÉ

L'introduction de voies de transmission de données à 64 kbit/s dans les réseaux de données numériques a créé un besoin pour les sous-multiplexeurs de réaliser une utilisation maximale de la voie.

L'article contient une description d'une famille de multiplexeurs temporels conçus pour satisfaire les différentes exigences des clients. Cela comprend un multiplexeur de parole plus données, un multiplexeur à cinq voies de transmission, et une gamme d'unités d'extension en vue de porter le nombre de voies à 20, avec des présentations de données X21 ou X21 bis.

Un affichage fractionné à cristaux liquides est utilisé pour assurer des informations d'état sur toutes les voies, et pour permettre la programmation des options de l'utilisateur par l'intermédiaire du tableau frontal.

RESUMEN

La introducción de canales de datos con velocidad de transferencia de 64 kbit/s en redes de datos digitales, ha creado la necesidad de submultiplexores para lograr la utilización máxima del canal.

El artículo describe una familia de multiplexores por división de tiempo, diseñados para satisfacer las varias exigencias de los clientes. Ésta comprende: un multiplexor de voz más datos, un multiplexor de cinco canales, y una gama de extensores para aumentar éste hasta 20 canales, con formatos de datos de X21 ó X21 bis.

Se utiliza un panel de presentación segmentado a base de cristal líquido para proporcionar información de situación en todos los canales, y permitir que el usuario pueda programar opciones vía el panel frontal.

ZUSAMMENFASSUNG

Die Einführung von 64 kBit/s Datenkanälen in digitale Datennetze führte zu einer Forderung nach Sub-Multiplexgeräten, um maximale Nutzung des Kanals zu ermöglichen.

Dieser Aufsatz beschreibt eine Reihe von Zeit-Multiplexgeräten, welche bestimme Kundenforderungen erfüllen, einschließlich einen Sprache/Daten-Multiplexer, einen Fünfkanal-Multiplexer und eine Reihe von Erweiterungsgeräten, um die verfügbare Kanalanzahl auf 20 zu erhöhen, u.zw. mit X21 bzw. X21 bis Datenformaten.

Eine segmentierte Flüssigkristallanzeige gibt Zustandsinformation über alle Kanäle und ermöglicht das Programmieren von Benutzeroptionen von der Frontafel aus.