60TDM, a 60-channel telex, time division multiplex equipment

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Summary The article describes an equipment with the capacity to connect 60 telex users to the synchronous digital network. Alternatively it can be used simply to give a cost effective connection to the existing telex network where normally the number of customers would be too small to warrant a local telex exchange. The equipment conforms to CCITT Recommendation R111 to form a 64kbit/s bearer for the 60 telex channels. This makes the multiplexer transparent to the code or speed (up to 300 baud) of the telex input. Dual independent bearers with automatic changeover facilities are provided to give space diversity for increased reliability.

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Introduction

The telex network, by far the largest data network in this country, has been in use since 1932. However, in the last few years the National Private Circuit Data Network (NPCDN) has come into being and is set to expand rapidly in the near future.[1,2,3] A method of interfacing the anisochronous telex signals to the synchronous data network serves to make the overall network more efficient.

This article discusses the design of a 60-channel Time Division Multiplex (60TDM) equipment which enables telex traffic to be carried over the NPCDN. Since the equipment is small it can be sited in remote exchanges, where the cost of providing a small number of telex lines over large distances would normally be prohibitive. It can also be used for point-to-point links. Figures 1 and 2 show some of the uses the equipment may be put to. It offers space diversity via dual independent 64kbit/s bearers and also code and speed (up to 300bit/s) independence for the telex interface. The means of achieving these system parameters are fully described below.

60-channel time division multiplex

The unit takes 60 telex (±12V telegraph) signals and multiplexes them into one 64kbit/s aggregate signal. It also converts the 64kbit/s aggregate into 60 telegraph signals. Figure 3 shows how the various functions required are carried out by the different units.

It should be noted that the equipment conforms to CCITT Recommendation R111. This lays down the rules for encoding the telegraph data, and defines the way in which the data bits and framing bits are structured to give an overall frame of 256 bits. Of this, 240 bits are encoded telegraph data bits, 12 bits are used for framing purposes, while the remaining four bits can be used for alarm and signalling information. Thus the 64kbit/s aggregate is divided as follows:

60kbit encoded data
3kbit frame word
1kbit alarm and signalling information

Mechanical construction

All the units which go to form 60TDM equipment are housed in a single TEP1E (Telecommunications Equipment Practice) 8VU shelf and all connections are accessed from the front. The system will normally be accompanied by a second shelf (Line Terminating Shelf) of the same dimensions which gives access to the 64kbit/s and 1·536/2·048Mbit/s bearers. This provides easy access for cross-patching and looping back of signals to aid fault finding but it is not described here as it does not form an integral part of 60TDM.

Telegraph data encoding

Telegraph data is inherently anisochronous (i.e. start-stop). For this to be sent over the synchronous data network it must be encoded in some form. One method is to sample the waveform at a much higher rate than the speed of the data and simply transmit a bit of data for each sampling pulse. This is very inefficient in terms of the bandwidth required for any given data rate. R111 recommends the use of transition encoding to reduce bandwidth requirements while keeping distortion to a minimum. A pictorial view of transition encoding is shown in figure 4, and a brief description follows.

The data is sampled at a rate of 4kHz, and the sample pulses are divided into groups of four. Each group gives rise to one bit of data to be sent as part of the R111 frame. When a transition occurs, the position is noted and the following three bits form a code word indicating in which quadrant the transition occurred. Three bits are enough to define any transition (+ve or −ve) in any quadrant. For correct

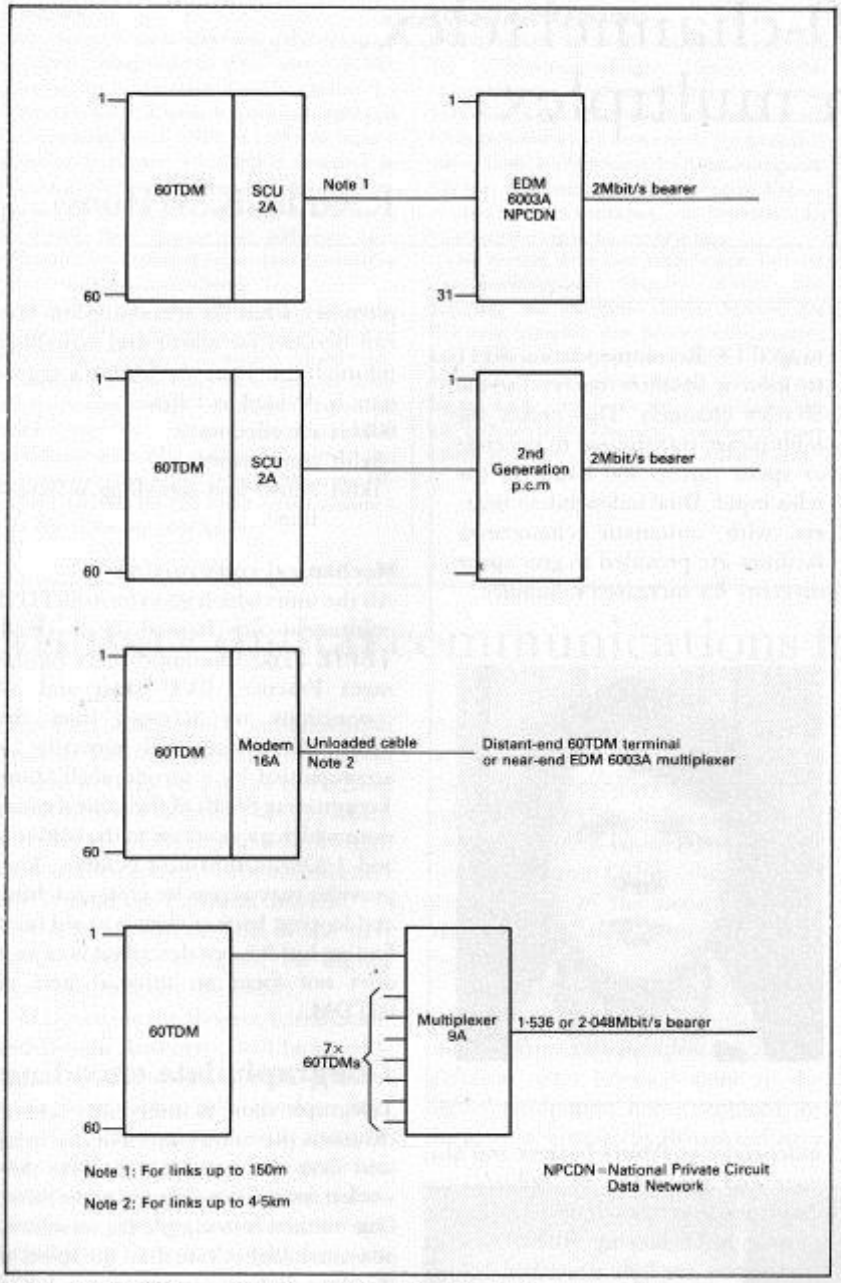


Figure 1. 60TDM as an interface to the national network

encoding of data the minimum time between transitions must be three groups of sampling pulses. Thus the maximum data rate which can be encoded with 4kHz sampling is:
$4000/(3\times4)=333\frac{1}{3}$bit/s
The maximum distortion which might arise from transition encoding is inversely proportional to the sampling rate. For 4kHz sampling the distortions produced are 7·5% maximum at 300 baud or 1·25% maximum at 50 baud.

The transition encoding is carried out by the Multiplexer 8A unit which is the heart of the 60TDM system. This unit also performs the multiplexing, demultiplexing and decoding functions. All the units required to make a complete system are described in the following sections. Also described are the three different types of interface which may be employed on the 64kbit/s aggregate signal, using the Miscellaneous Interface Conversion (MIC) units.

Telegraph interface

The unit accepts and returns ±12V (V28) telegraph signals. This is a commonly found interface in telex exchanges and it is also reasonably simple to implement, so that four send and return channels can be accommodated on one 4VU card (this is half the size of all the other units in the system). Thus only 15 Channel Card 1A units are required to service all 60 channels. Each telegraph input uses two opto-isolator devices to convert the ±12V signals to the TTL levels required to interface to the Multiplexer 8A. One is used to detect positive transitions and the other negative transitions. This reduces distortion that would occur if only one device were used to detect both transitions, because the switch-on time of the opto-isolator device is much faster than its switch-off time. Should the input go open-circuit the signal sent to the Multiplexer 8A can be pre-programmed to a logic 1 or 0 by means of a link. Each channel has this programmed separately. The unit also performs the inverse function of converting TTL levels to telegraph signals. Should the multiplexer fail, these outputs can be individually programmed to return a mark or space condition to the customer.

Facilities are provided so that any of the telex interfaces can be examined by a separate unit in the system, the Monitoring Unit 29A. This is to aid fault finding of the telegraph interface and is discussed more fully in the Telegraph Monitoring Facilities section.

The Multiplexer 8A

This performs most of the functions required to form an R111 multiplex. As well as the multiplexer/demultiplexer functions for two 64kbit/s aggregate bearers, it monitors the incoming signals for errors or faults. It also performs the automatic changeover from a faulty line to a good line. The two 64kbit/s bearers are known as the main and standby lines. Both lines are identical except for certain alarm bits in the frame structure, explained fully later. When a fault occurs causing a changeover from the main line, the other bearer assumes main line status. When the faulty line comes back into service it assumes standby line status. A manual method of changing the status of the lines is provided by means of a push-button.

At the heart of the system are three single-chip micro-computers. These are Intel 8051 devices. They require a clock at 12MHz and contain 4Kbytes of mask programmed ROM (read-only-memory) and 128bytes of RAM (random access memory) for use during program execution. Extensive use was made of in-circuit emulators and EPROM versions of the 8051 device during development to check

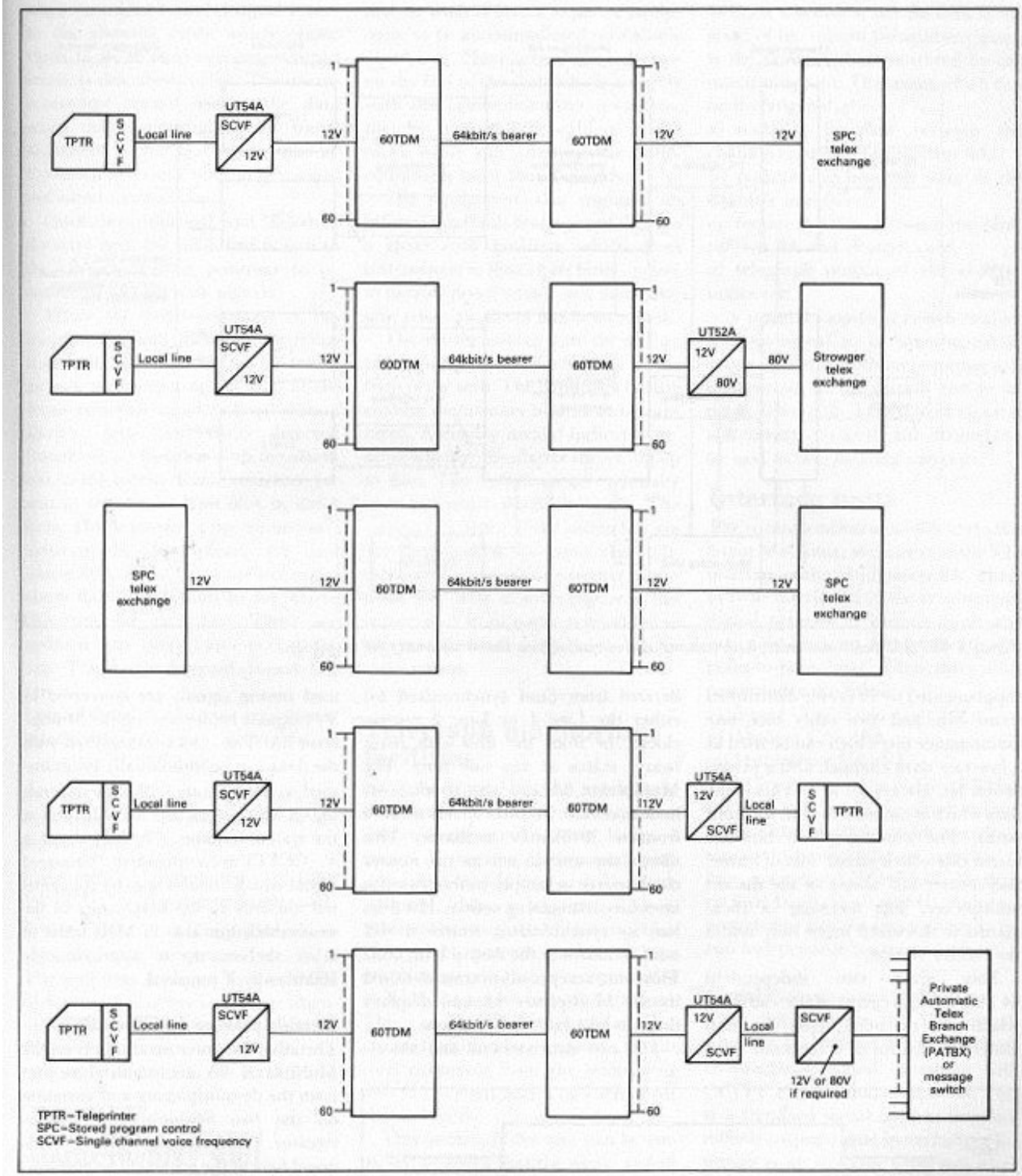


Figure 2. 60TDM as a point-to-point telex link

the operation of the software. All three devices contain identical programs even though they perform different functions on the Multiplexer 8A. This is achieved by the device assuming a different status depending on where it is used on the Multiplexer 8A and means that the device is not fully utilized in any one position. Some of the software written into the device will be redundant but manufacturing costs are greatly reduced since only one mask is required, and the total numbers of the single device are increased, reducing the unit cost still further. Assembly is also made easier since the device cannot be put into the wrong socket.

The arrangement is such that two 8051 micro-computer devices are used in identical roles to de-multiplex the received 64kbit/s data. The other device is used to perform the transmit processing. The functioning of the devices is more fully explained in the following sections.

Encoding and multiplexing

One micro-computer is required to process all the data appearing at the 60-channel inputs. The data is sampled at 4kHz, as previously stated, and transition encoding is carried out by the software in the device. The 60 transition encoded channels give rise to 240 bits of the data frame. These are

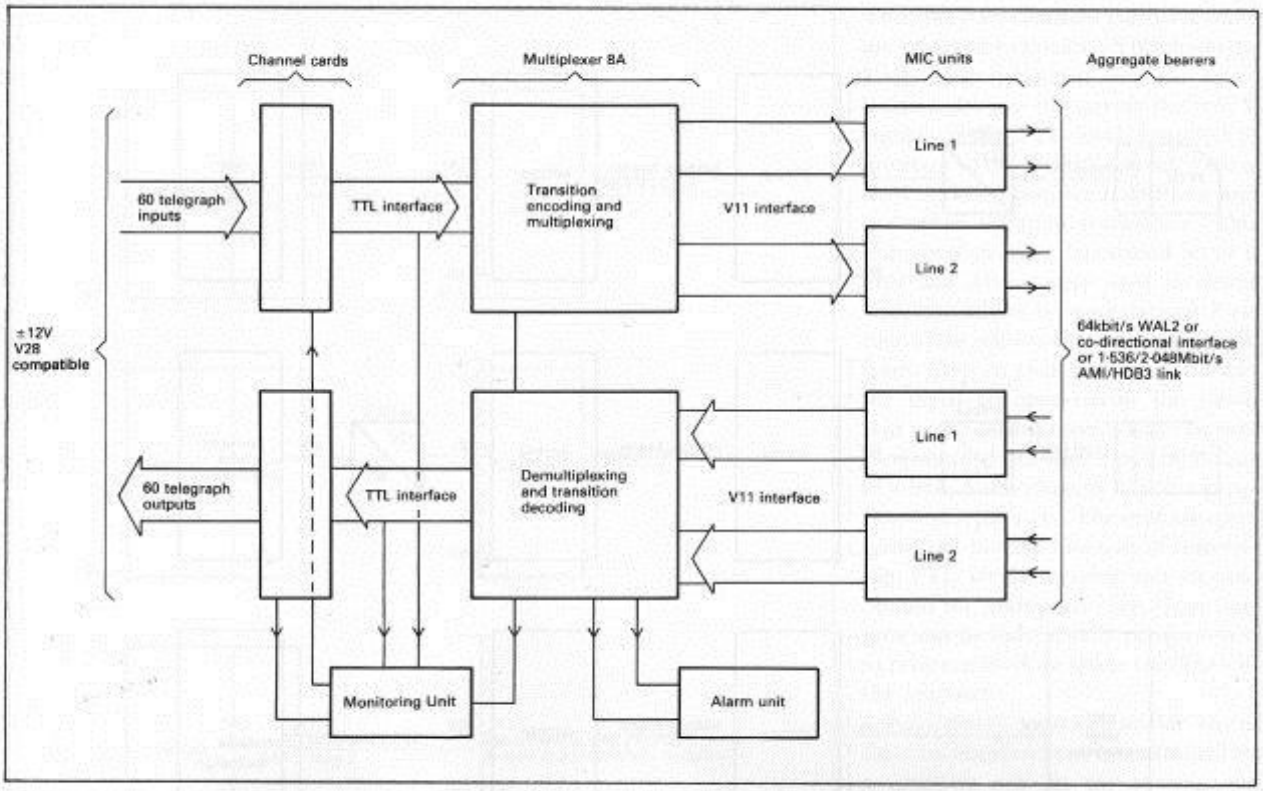
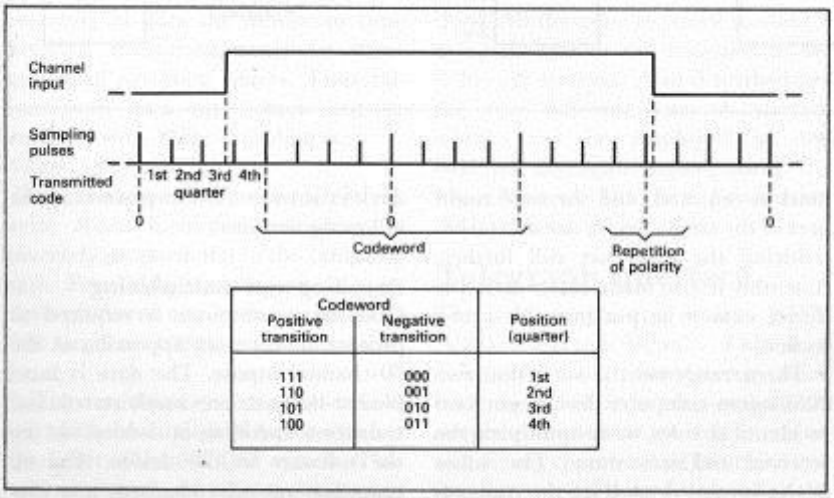


Figure 3. 60TDM functional units, with transmit and receive sections shown separately for simplicity

supplemented by 12 evenly distributed frame bits and two other bits, one maintenance bit, which can be used as a low-rate data channel, and a justification bit, always set to 1. This is the data which is common to both transmit paths. The remaining two bits are alarm bits which signal 'loss of frame' and 'bearer fail' status to the distant multiplexer. The meaning of these alarms is discussed more fully under the receive section.

This gives two independent 64 kbit/s aggregate data streams which are extended from the unit under the control of a common clock derived from (and synchronized to) either the Line 1 or Line 2 receive clocks, or from the line with main bearer status at any one time. The Multiplexer 8A can also produce its own accurate 64kbit/s clock derived from a 2048kbit/s oscillator. This allows the unit to act as the master clock source or simply to free-run if it loses a synchronizing source. If it does lose its synchronizing source it will send an alarm to the Alarm Unit 68A. This unit accepts all alarms detected by the Multiplexer 8A and displays them to give fault information.

The two data streams and associated timing signals are converted to V11 signals before leaving the Multiplexer 8A. The clocks transmitted with the data can be individually programmed to 64kbit/s or 128kbit/s depending on which clock rate the MIC unit in the system requires. The V11 signal is a CCITT-recommended balanced signal which enables it to be transmitted not only to the MIC units in the same shelf, but also to MIC units in other shelves, up to approximately 100m away if required.



Codeword		
Positive transition	Negative transition	Position (quarter)
111	000	1st
110	001	2nd
101	010	3rd
100	011	4th

Figure 4. R111 transition encoding

Demultiplexing and decoding

The other two micro-computers on the Multiplexer 8A are required to perform the demultiplexing and decoding on the two 64kbit/s receive data streams. Only one line will be considered here as the other will be performing exactly the same function.

At switch-on the unit must first gain frame alignment. It does this by storing a whole frame of data and searching it for the frame word. Once this has been achieved successfully it searches the next frame of data for the frame word in the same place. When it has found a third correct frame word it assumes it has gained frame alignment. Whilst this is happening the data from the other line will be sent to the channel cards. If the other microcomputer is also searching for frame

alignment then a control signal is sent to the channel cards which causes them to go to their pre-programmed levels as described earlier. The micro-computers cannot decode the data while they are searching for frame alignment as the procedures take up too much processor time to be carried out simultaneously.

Once demultiplexed and decoded, the data from the main line is sent to the correct channel positions to be converted to telegraph signals.

While the micro-computer is de-multiplexing and transition decoding it can still monitor the line for faults, as well as monitoring the bits in the frame structure which indicate distant alarms. Any local faults detected (listed below) together with the alarm bits in the receive frame structure are sent to the Alarm Unit 68A in serial form. This is to reduce the connections between the Multiplexer 8A and Alarm 68A units. There are two serial alarm data connections to the Alarm 68A, one for each line. These are updated once every frame period, i.e. 4ms. The alarms detected on each line are:

Loss of signal transitions	when no data transitions occur in a frame,
Receive Alarm Indication Signal (AIS)	when all data in receive frame is set to 1,
Error ratio $>1{\cdot}10^{-3}$	calculated from errors in frame word,
Bearer Fail	set if any of the above are set.

The unit also indicates to the Alarm 68A when a line has lost frame alignment. This alarm together with the Bearer Fail alarm are used to set the relevant alarm bits in the R111 frame structure.

Alarm display unit

In order to aid fault finding of mis-operating equipment, the Alarm Unit 68A displays all the alarms detected on the Multiplexer 8A, together with alarms forwarded by the MIC units. The conditions which may cause a MIC alarm are discussed under the relevant MIC unit description.

The unit also interfaces the alarms to the alarm bus system in the rack. Since the equipment is housed in TEP1E equipment practice it must connect to the 10-way alarm bus found in this type of rack. This enables the alarms from different types of equipment to be accommodated on a single alarm bus. There is an alarm indicator on the end of the shelf which is visible with the equipment front covers on, thereby reducing the cabling in the racks while still allowing the faulty equipment to be found quickly.

The equipment also contains an information/fault finding card, kept in a spare card position, which gives instructions in flow chart form on how to narrow down a fault to a particular unit when an alarm has been raised.

The alarms coming onto the unit go to lamp-locked l.e.d indicators at the front of the unit. The lamp-lock facility enables momentary alarms to be captured. A display invalid indicator signifies whether the alarms shown are up to date. The indicators are manually reset by means of a push-button. The alarms forwarded to the alarm bus are not lamp-locked. The unit also indicates which bearer is operating as the main line and if a changeover has occurred. A front panel is provided to give some indication of what each indicator means.

Telegraph monitoring facilities

Since the Alarm Unit 68A provides the user only with an indication of 64kbit/s aggregate receive faults, a means of checking the transmit path up to the 64kbit/s level and the return telegraph data is required. This is achieved by use of the Monitoring Unit 29A, which generates a known telegraph message (QKS as recommended in R111) at approximately 210 baud. This can then be patched into any channel position by means of a simple cord connector from the monitoring unit to the front access on each of the channel cards.

This achieved, the unit can be employed to check that the signal at four separate stages in the system is still correct. The channel that the signal has been sent to is selected on the monitoring unit by means of thumb-wheel switches indicating 0 to 60. A four-position rotary switch then enables separate stages of the system to be investigated. Only one channel is affected during this procedure so that the other 59 are still available to carry traffic. Two l.e.ds indicate the presence of data on the transmit and receive highways between the channel card and Multiplexer 8A. Two further l.e.ds indicate whether or not the data at the stage of the system being investigated is the same as that generated by the monitoring unit. The stages which can be investigated are:

a) transmit interface between the channel card and Multiplexer 8A,
b) multiplexed transmit data at the 64kbit/s interface,
c) receive interface between the Multiplexer 8A and channel card,
d) telegraph output of the channel under test.

A manual loop-back switch enables the test signal to be investigated at stages c) and d) without requiring any connections at the distant end to be made. Thus if the looped back signal is still correct at stage d), the channel can be said to be operating correctly.

Interface units

The equipment has available three different MIC units to connect to the V11 interface of the Multiplexer 8A. These provide interfacing to the synchronous digital network at various levels and can also be used independently for point-to-point links. These three units come under the titles:

a) Signal Conversion Unit 2A,
b) Modem Unit 16A,
c) Multiplexer Unit 9A.

The first two units offer differing 64kbit/s links while the third enables up to eight Multiplexer 8A aggregate signals to be multiplexed together to form a single 1·536/2·048Mbit/s digital link. In all cases two MIC units are provided to give the space diversity for two independent bearers.

Signal Conversion Unit 2A

This unit converts the V11 signals from the Multiplexer 8A to a 64kbit/s co-directional signal compliant with CCITT Recommendation G703. This is a standard signal used to interface different equipments in exchanges for distances up to 150m. Only two wires are required to send information in each direction as timing can be extracted from the data. The interface can be used to connect to the KiloStream (NPCDN) network or 2nd Generation 30-channel p.c.m equipment, when they are situated in the same exchange building. If power to the unit is lost, a MIC alarm is extended to the alarm unit.

Modem Unit 16A

Where the 60TDM equipment in, say, an outlying exchange has to connect to

the national network, the Modem 16A may be used. This is a 64kbit/s baseband modem using WAL2 diphase modulation. WAL2 refers to the coding carried out on the data before being filtered, amplified and sent over a pair of wires.[4] Four wires are required for bothway transmission.

The unit requires no manual or automatic equalization to accommodate different line characteristics, and can be used for distances up to 4·5km. It is compatible with the modem used on KiloStream network multiplexers. If the input level falls below −45dBm the unit extends AIS to the Multiplexer 8A and a MIC alarm to the alarm unit.

Multiplexer Unit 9A

This unit will take the 64kbit/s aggregates from up to eight 60TDM equipments and multiplex them together into one 1·536/2·048Mbit/s digital signal.

A frame word and spare bits are added since the full capacity of the digital link is not utilized either at 1·536Mbit/s or 2·048Mbit/s. The 2·048Mbit/s signal is G703 compatible so that it can use the network as it stands. The 1·536Mbit/s signal is also compatible with older parts of the British Telecom line system.

The unit has its own fault detection circuitry, and indicates when the received signal has a high error rate, or if it loses frame alignment. These conditions cause AIS to be sent to the Multiplexer 8A and a MIC alarm to the alarm unit. The unit can synchronize to the network in various ways. It can synchronize to the recovered receive clock or to a separate synchronizing input. Should the synchronizing source be lost an alarm is indicated.

A MIC alarm is extended to the alarm unit if it is due to the loss of the receive clock. The unit can also free run accurately at 1·536/2·048Mbit/s in which case it is considered to be the master clock of the system.

Power supplies

A single D.C-D.C Converter 44A supplies all the power requirements for the equipment in the shelf. It converts the 24V/50V d.c supply, standard in exchanges, to the +5V and ±12V required by the units. The power unit has automatic shutdown protection on its outputs. If any of the outputs cause an overload, all the outputs are shut down. They are then restored periodically (every 250ms) to see if the overload is still present. If a faulty unit causing the overload is removed, the supplies will automatically be restored.

Conclusions

The 60TDM equipment is a versatile, cost-effective interface between the telex and data networks as they exist today, as well as being equally suitable for combining small numbers of users into the telex network. The uses for the equipment can only increase as the NPCDN expands to cover more of the business community across the country. The compliance with international regulations makes it equally suitable for use in other countries with expanding data networks.

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RÉSUMÉ

L'article décrit un matériel capable d'effectuer le raccordement de 60 utilisateurs télex au résau numérique synchrone. Par ailleurs, il peut être utilisé tout simplement pour réaliser un raccordement peu coûteux au réseau télex existant dans les cas où le nombre de clients se trouve être selon la norme trop petit pour justifier un central télex local. Le matériel se conforme aux recommandations R111 du CCITT pour constituer une porteuse 64 kbit/s pour les 60 canaux télex. Ceci rend le multiplexeur transparent au code ou à la vitesse du signal d'entrée télex (justu'à 300 bauds). Des porteuses indépendantes doubles avec fonction de commutation automatique sont disponibles de façon à offrir une diversité d'espacement permettant d'améliorer la fiabilité.

ZUSAMMENFASSUNG

Dieser Aufsatz beschreibt ein Gerät, welches 60 Telexteilnehmer an das synchrone Telexnetz vermitteln kann. Wahlweise ermöglicht es auch einen kostengünstigen Anschluß an das bestehende Telexnetz, bei dem die Anzahl der Teilnehmer normalerweise zu klein ist, um ein Orts-Telexamt zu rechtfertigen. Das Gerät entspricht der CCITT-Empfehlung R111 und stellt einen 64 kbit/s Träger für die 60 Telexkanäle dar. Dadurch wird der Multiplexer für den Kode bzw. die Rate (bis zu 390 baud) transparent. Doppelte unabhängige Träger mit automatischer Umschaltung sind vorgesehen, um durch Raumdiversity die Zuverlässigkeit zu verbessern.

RESUMEN

El artículo describe un equipo con la capacidad de unir a 60 usuarios del télex con la red digital sincrónica. Por otra parte, peude emplearse simplemente para dar una conexión rentable a la red télex existente, donde normalmente el número de clientes sería sumamente pequeño para justificar una central local de télex. El equipo se ajusta a la recommendación del Comité Consultivo Internacional Telegráfico y Telefónico (CCITT) R111 para formar un portador de 64 kbit/s destinado a los 60 canales télex. Esto hace al multiplexor transparente al código o velocidad (hasta 300 baudios) de la entrada télex. Se suministran portadores independientes dobles con instalaciones de conmutación automática para dar diversidad espacial y lograr así mayor fiabilidad.