REMOTE-CONTROL SYSTEMS
FOR TELEVISION PRODUCTION EQUIPMENT

Tech. 3245-E   December1984

CONTENTS

Introduction

The specification described in this document has been developed jointly with the SMPTE and is functionally identical to that encompassed by the following SMPTE documents,

ANSI - SMPTE 207M (equivalent to Chapter 5 of this specification).
Recommended Practice 113 (equivalent to Chapter 3 of this specification).
Recommended Practice 138 (equivalent to Chapters 2 of this specification)
Recommended Practice 139 (equivalent to Chapters 4 of this specification)

Publication in a single document has permitted a more concise presentation of some of the material.

In order to ensure that equipment obtained from different suppliers may be used to implement this system satisfactorily, it is necessary to standardize the messages to be transmitted. At the time of publication of this document, work on preparing the definitions of the admissible messages was still in progress. It is planned to publish these definitions in the form of supplements to this document as soon as possible. The first two supplements will define the messages common to all applications - common messages - and the system service messages. The other supplements, which should be read in conjunction with them, will define the admissible messages specific to particular applications -type-specific messages.

CHAPTER 1

System overview

1. General

The primary purpose of this specification is to define the <u>software characteristics</u> and the <u>hardware communication channel</u> of a remote-control system.

The system is designed principally for the remote control of broadcast equipment. It achieves this through the use of <u>intelligent processors</u> which, ideally, will be incorporated within the operational equipment. Nevertheless, it is envisaged that this specification will find more general application.

The specification does not cover the design of the remote-control system terminal hardware, beyond that directly associated with the system communication channel. The configuration and operational features of these aspects of the remote-control system are left to the discretion of manufacturers.

1.1. The function of any remote-control system is to establish connection between operational controlling and controlled devices.

This specification is based on the concept of <u>distributed intelligence</u> whereby each device, whether it be "controlling" (e.g. a remote-control panel for a telecine) or "controlled" (the corresponding telecine), is attached to the system by means of an intelligent interface, which will carry out the majority of local calculations and logical operations required by the device. The intelligent equipment will be called a <u>tributary</u> of the remote-control system.

The use of distributed intelligence within the control system offers a number of advantages for the broadcaster:

- the ability to modify elements of the configuration without affecting other users;
- high resilience (the majority of failures can be contained within a single tributary);

- the number of time-critical messages needing to be transferred between tributaries is minimized;
- the control system is Independent of the * type of device;
- the probable existence of microprocessors within future generations of equipment should minimize the cost of implementation.

1.2.   The basic functional unit of the remote-control system is the <u>local network</u>. The principal elements of the system are given in Fig. 1.

**LOCAL NETWORK IN
MULTIPOINT CONFIGURATION**

**LOCAL NETWORK IN
POINT-TO-POINT CONFIGURATION**
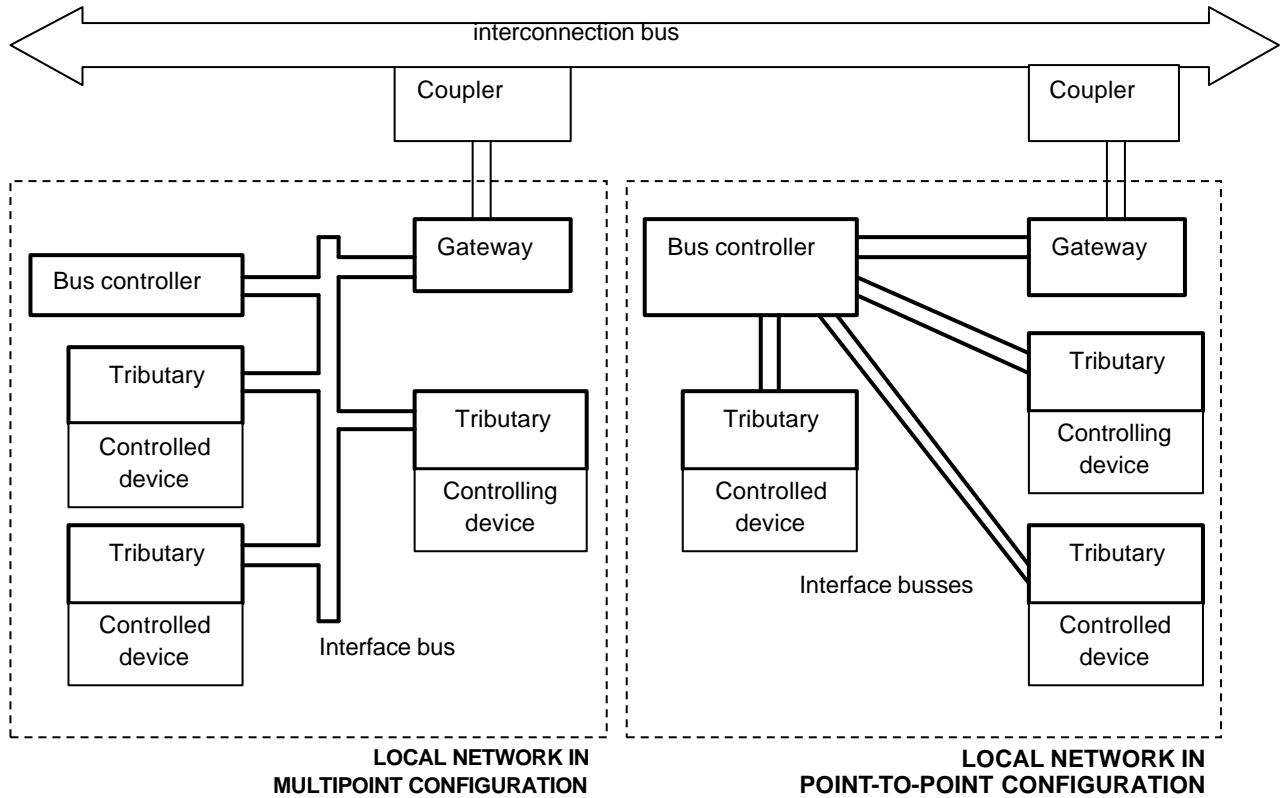
Fig. I.- System schematic

Only the system elements outlined in heavy line are within the scope of this specification

<u>Interface bus</u>

The interface bus is the hardware communication channel which carries the messages serially at 38.4 kbit/s between tributaries and the bus controller.

<u>Bus controller</u>

A bus controller is associated with each local network. It supervises communications between all other devices which are connected to the local network through the use of a predetermined procedure (the Supervisory Protocol). The bus controller may be incorporated into a device which performs additional functions (such as an operational control panel), but it is a distinct system component whose function is the delivery of control massages and the management of the control network. Although only one active bus controller may be a part of any one local network, it is recognized that an operational complex may make use of more than one local network.

Tributaries

Each operational device in a system connects to the network through a tributary. A tributary transfers the messages to and from an operational device as specified by the system supervisory protocol. The tributary may be a separate unit of equipment, or may be incorporated into an operational device, but in any event it is a distinct system component with the function of managing the network interface, synchronizing the network data flow, detecting errors and delivering control messages to and from the controlled equipment.

The number of tributaries on any one local network may range from one to a practical maximum of, say, 32, although typically the number will probably be less than 10.

If there is a requirement to transmit control messages from a tributary in one local network to a tributary in a different local network, a separate interconnection may be established between these networks. This comprises the following principal elements.

Interconnection bus

The interconnection bus is the communication channel which carries messages between local networks in order to permit interaction between tributaries located in different networks.

Gateway

A gateway will be provided to couple each local network to the interconnection bus. Its function will be to "translate" between the protocols under which the local network and the interconnection bus coupler operate.

1.3. As shown in Fig. 1, the local network may be arranged in a "point-to-point" or a "multipoint" configuration.

A point-to-point configuration is one in which an interface bus, in this case acting as a single communication channel, is connected to only one tributary. The bus controller may be connected to more than one bus, each having one tributary.

A multipoint configuration is one in which more than one tributary is connected to an interface bus which has one active bus controller.

The present specifications apply to both types of configuration and all equipment manufactured for use as tributaries should be able to operate within either.

The point-to-point configuration has the advantage of speed since the dedicated buses provide access to all tributaries simultaneously. The multipoint configuration has the advantage of reduced cabling costs and complexity but has the main disadvantage that messages to different tributaries must queue up and be sent serially on the bus. These configurations are therefore slower in response time than point-to-point systems.

The optimum configuration for any local network, and the number of tributaries which it can serve, will depend critically on the types of equipment controlled, typical message lengths and the required response time. Where response time is of paramount importance, it may be necessary to restrict the number of controlling devices on one local network to one, in which case the controlling device tributary and the bus controller (and, if necessary, the gateway) can be physically combined.

2.   System architecture

Progress in computer-controlled data-communication technology over several years has led to the development of a structured technique to describe communication systems. The terms such as "protocol" or "message" already used above are part of a vocabulary devised for this descriptive concept which is now in widespread use.

Data-communication systems are viewed as being logically composed of layers (Fig. 2).
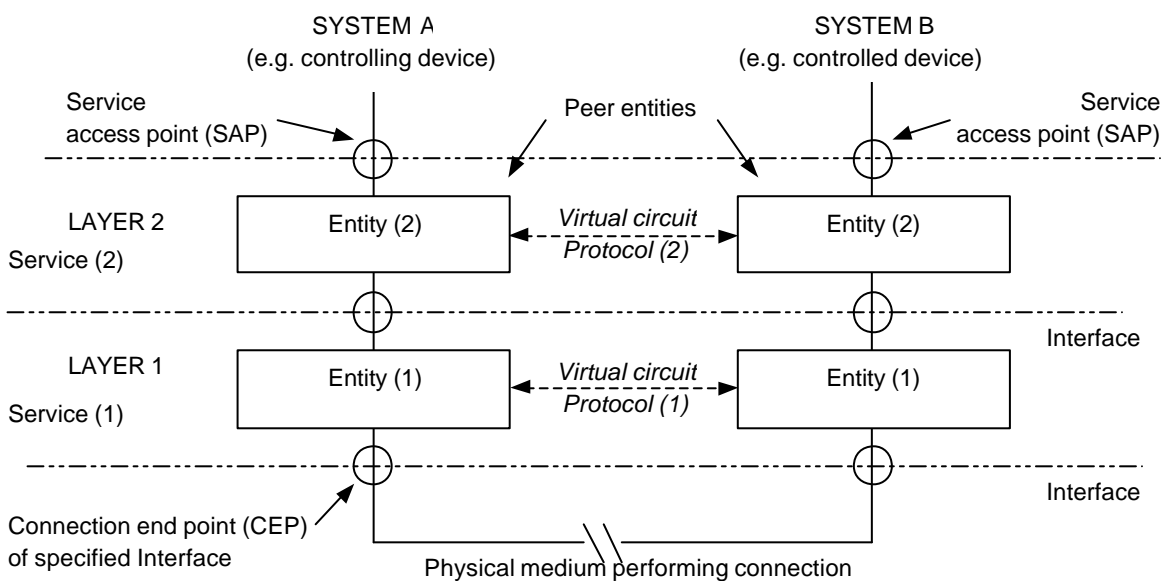
Fig. 2. - System architecture terminology

Layering divides the whole service offered by the system in such a way that each layer adds value to the service provided by the lower layers. This additional value is established by an entity residing in the layer. Two entities operating in the same layer, but in different parts of the network, are called peer entities.

The aim is to permit communication between peer entities and this communication is governed by a protocol. The route between peer entities using a protocol is only virtual - a virtual circuit; in reality, the communication path passes through lower layers and is completed over a physical medium, such communication being effected transparently.

The line separating two layers is called an interface.

The point where a communication path crosses an interface is called a <u>service access point</u> (SAP).

The SAP that provides a real connection is called a <u>connection endpoint</u> (CEP)

3.   The ISO model OSI

The International Organization for Standardization (ISO) has established a structured model for "open systems", these being data transmission systems that may be interconnected with other systems (which may be of differing types) to which the data may be communicated. This model has seven layers and is called the "Open System Interconnection" (OSI) architecture [1]

The seven layers have the following functions (left-hand side of *Fig. 3*):

<u>Layer 7</u>

Concerns those aspects of the system which serve the user directly and defines the required APPLICATION in abstract terms.

<u>Layer 6</u>

Concerns the PRESENTATION of those abstract terms as coded and formatted data.

<u>Layer 5</u>

Concerns SESSIONS involving more than one participant; it associates the coded and formatted data with each participant of those available in the session.

<u>Layer 4</u>

Defines the parameters of a system providing facilities for the <u>safe</u> TRANSPORT of system data. In particular, to eliminate any risk of congestion in the network, this layer commonly has the task of controlling data flow.

<u>Layer 3</u>

Dismembers and reassembles transported data into packets, with appropriate routing indications, to permit sequential transfer of information via a NETWORK system.

<u>Layer 2</u>

Defines the parameters of a DATA LINK that provides reliable <u>error-free</u> transmission despite disturbances that may be caused by the physical link; it includes, for this purpose, the fundamental protocols for the detection of errors, the correction of errors, etc. Where applicable, the association achieved in layer 5 is converted to an absolute system address.

<u>Layer 1</u>

Defines the hardware properties needed to set up a PHYSICAL LINK for the logically linked data.

OSI LAYERS   EBU/SMPTE LEVELS
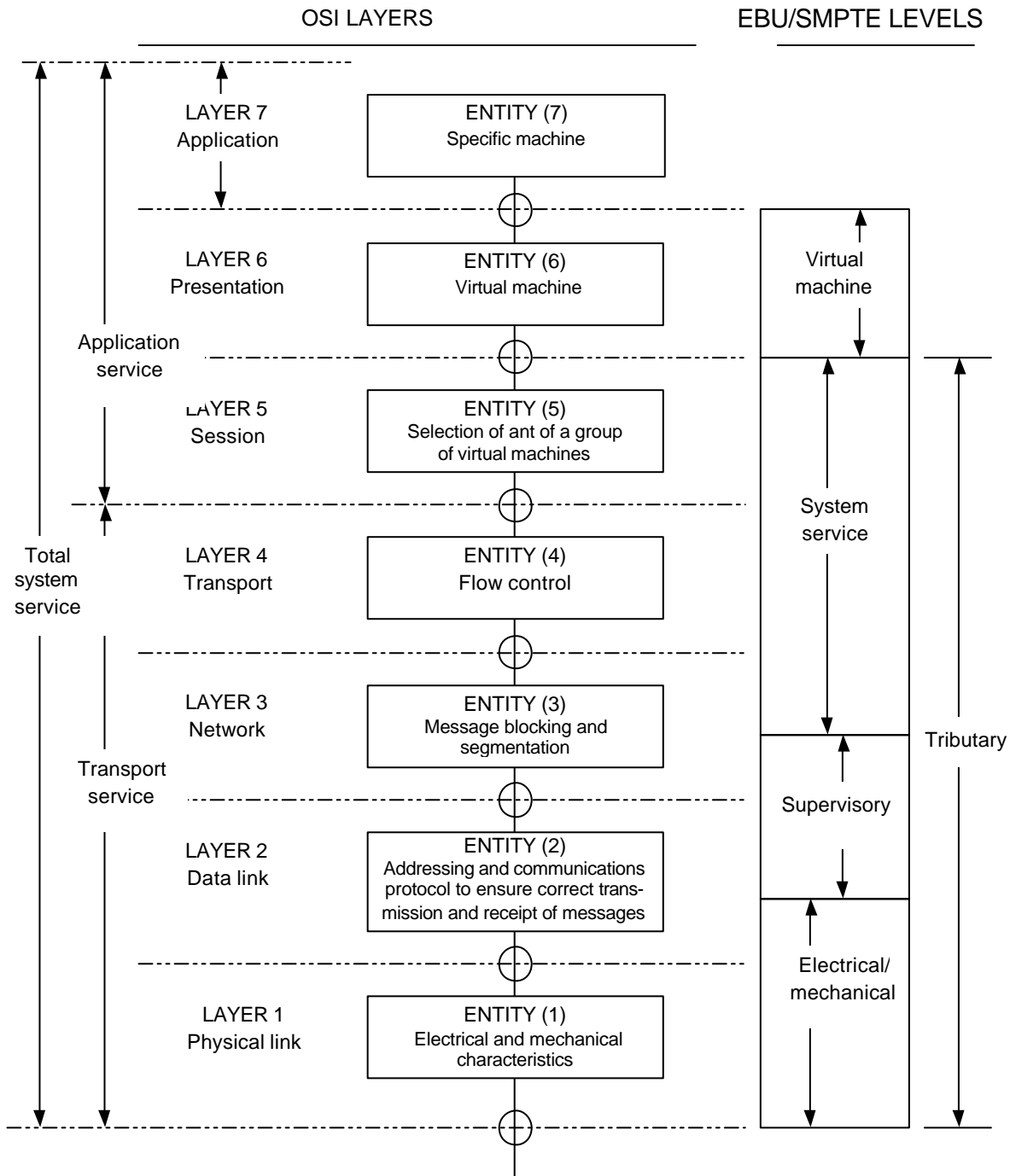
**Fig. 3.- The layers of the OSI model and their relationship to the levels
of the EBU/SMPTE remote-control system for broadcasting equipment**

It will be noted that layers 7, 6 and 5 are concerned with the specific application service; layers 4 to 1 relate to a general transport service.

4.   The OSI model in relation to a broadcast control system

It is helpful to analyse a remote-control system for broadcast equipment by using such a layered technique. The EBU/SMPTE system described in the present specification is, however, defined in terms of only four levels: virtual machine, system service, supervisory and electrical/mechanical. The specific machine in OSI layer 7 is beyond the boundary of this specification.

The four levels incorporate all the necessary functions of the six lower layers of the OSI model in the same ascending (or descending) relationship. It has not been found necessary in the broadcasting application to divide the functions so rigorously.

Fig. 3 illustrates the distribution of OSI layer services among the four EBU/SMPTE levels.

The VIRTUAL MACHINE LEVEL contains the VIRTUAL MACHINE, which responds to defined data, the CONTROL LANGUAGE, in a defined manner regardless of the characteristics of the physical machine used at the application level. Each type of virtual machine utilizes a distinct dialect within the overall control language.

The SYSTEM SERVICE LEVEL provides such services as mapping logical addresses to physical addresses, identification of the dialect required for each type of machine used, message segmentation and assembly, blocking and error recovery, etc.

The SUPERVISORY LEVEL establishes communication between physical units connected to the network and provides data synchronization, data transfer and error-recovery services. Local networks include an ACCESS sub-level within the data link which apportions use of the network among several connected entities. The access method used in this system is polling, initiated by the bus controller.

The ELECTRICAL/MECHANICAL LEVEL consists of the electrical and mechanical specifications which define the actual communication channel, including the bus operating speed of 38.4 kbit/s.

The specification set out in the following chapters conforms to the above interpretation of the OSI model. By means of this structure, the requirements of the network configuration depicted in *Fig. 1* can he met. The elements defining the virtual machine are contained within the highest level whilst those defining the functions of the tributary are distributed among the three remaining levels. A schematic representation of this functional distribution is shown in *Fig. 3*.

Chapter 2.describes the generalized virtual machine for a broadcast equipment control standard. The relevant protocol is referred to as the control message architecture. Each equipment type (video tape-recorder (VTR), audio tape-recorder (ATR), telecine, vision mixer etc.) is allocated a specific subset of messages - a dialect - which takes account of all necessary controllable functions. The subset list appropriate to each equipment type and details of the corresponding bit representations will be issued in separate supplements to this specification.

Chapter 3 describes the supervisory level for the interface bus in the basic local network.

Chapter 4 deals with tributary interconnections both within the local network and through an interconnection bus, utilizing facilities in the system service level. It is not within the scope of this specification to define the operation of the interconnection bus itself beyond that which is inherent in the definition of the gateway. The list of messages pertaining to the system service level together with details of their bit representations will be issued as a separate supplement to this specification.

Chapter 5 describes the electrical and mechanical characteristics of the interface bus.

5.   Definitions

The following notes are included for the benefit of broadcasters who may not be familiar with some of the terms and conventions used in this specification.

<u>Byte</u>

A byte,is a set of eight information bits.

Byte pairs are represented here by their hexadecimal notation followed by "h".

<u>Word</u>

In this document a word means the combination of a byte with its start, stop and parity bits.

<u>State diagrams</u>

The effect of messages on the state of tributaries or of operational equipment is indicated by means of state diagrams. In this document, the following conventions will be used.

Each state (condition) that a tributary can assume is represented graphically as a circle; major states are identified by an upper case label or mnemonic within the circle.

All possible transitions between states are represented by arrows between the states; each transition is qualified by an expression (Exp) which will produce the transition.
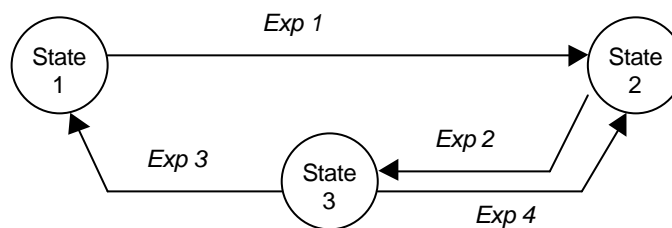
Expressions can be messages received from or transmitted to the interface bus orlocal messages generated within the tributary:

a)   Received messages are represented by R followed. by the received message in parionthesis.

indicates transition from state ONE to state TWO on receipt of the message GRP.

b)   Transmitted messages are represented by T followed by the transmitted message in parentheses:
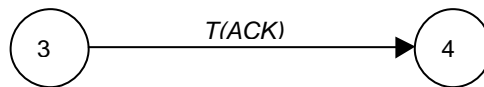
indicates transition from state THREE to state FOUR after transmitting the message ACK.

c)   Local messages are represented by lower case labels:
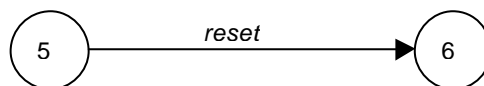
indicates transition from state FIVE to state SIX when reset occurs.

CHAPTER 2

Control message architecture

1.   General

1.1.   Language

In common with human language, the control message language is composed of three elements:

- vocabulary: a sequence of conventionally-agreed labels for things (concrete or abstract), actions
              etc.;
- syntax :   a conventionally-agreed grammatical structure defining the manner in which
              elements of the vocabulary are used together to describe specific concepts;
- semantics :   conventionally-agreed relationships between messages (constructed using the
              vocabulary and the syntax) and practical realities.

The primary purpose of this chapter is to establish the syntax of the message language. The content of the vocabulary and its semantics are specific to individual types of operational equipment and will be defined in supplements to this specification.

1.2. Definitions

For the purposes of this chapter the following definitions apply:

Virtual machine :   a logical device consisting of a single device or a combination of devices that
              respond in essence or effect as a generic type of equipment (e.g. VTR, video
              switcher, telecine etc.).

Virtual circuit :   a transparent, unidirectional, logical communications connection between virtual
              machine entities. The communication path, in reality, passes through other levels and
              is propagated over a physical medium.

2.   Message structure

The message architecture described in this chapter is prepared broadly in accordance with the principles of communications layering. This architecture follows a logical structure and is defined in terns of a virtual machine.

Messages are of variable length according to their function. Complex functions may be divided into basic functions, transmitted as a-sequence of shorter messages for execution in the virtual machine.

All messages pertaining to generic types.of equipment shall be defined in terms of the virtual machine. Use of the virtual machine concept in defining messages provides a message architecture that is independent of machine specific characteristics.

3.   Message classification

3.1.   General

Control messages are classified as follows (Fig. 4).

Fig. 4.- Message Classification
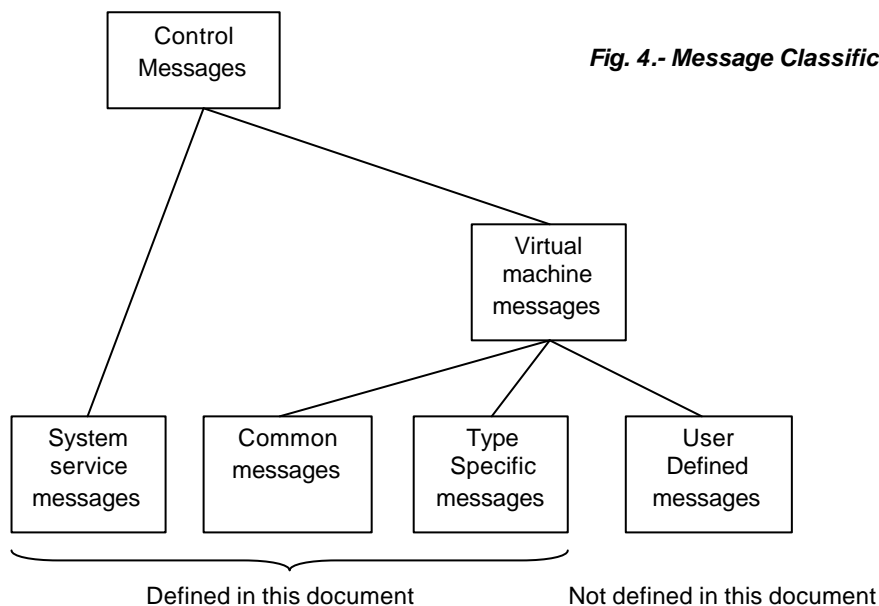
Virtual machine messages

These are used to pass commands and responses between virtual machines. They are initiated by a controlling device; responses originate in the controlled device. The receipt of a virtual machine message shall result in a defined action and/or response by the virtual machine.

System service messages

These are all control massages other than virtual machine messages. The functions and definitions of messages of this type will be dealt with in chapter 4, 5 3, and in a supplement to this specification.

3.2. Virtual machine messages

These may be sub-divided into:

Common messages, whose coding is reserved to provide for functions of general application, e.g. procedures, reference time functions, reset.

Type-specific messages, which are applicable to specific generic categories of equipment.

User-defined messages, which implement special functions which are not included in the type-specific message set.

A separate and distinct sub-set of virtual machine messages shall be specified for each type of virtual machine (VTR, telecine, audio tape recorder, graphics generator, etc.). Each sub-set constitutes a "dialect" and shall comprise common, type-specific and, optionally, user-defined messages.

Common messages, which are in all virtual machine dialects but not necessarily operative in all virtual machines. These messages are defined in a supplement to this specification.

Type-specific messages, which are defined in individual virtual machine supplements to this specification.

User-defined messages, which are unique to the type (manufacturer, model, version, serial No. etc.) of the specific machine. While their definition and/or documentation is considered outside the scope of this specification, their structure shall conform to the message architecture as defined herein.

4. Message construction

System service and virtual machine massages are uniformly constructed with the following syntax:

MESSAGE = KEYWORD (+ ARGUMENT)

where the keyword characterizes the function to be performed and the argument contains the parameters, where necessary, to perform that function.

A parameter has the following syntax:

PARAMETER = (NAME +) VALUE(S)

The name may be implied, with the use of specific keywords and in such cases is therefore not required. The length and format of the value (or values) is defined by the name (or implied name). No restriction is placed on the possible concatenation of parameter values.

4.1.   Message formats

All control messages are formed as groups of integral bytes. The first byte of each message is the keyword. A keyword specification defines the format of its argument, although no mathematical relationship is intended between the bit pattern of the keyword and the format.

Messages are constructed in one of the following formats:

Format 1	Message = (keyword)
Format 2	Message = (keyword) (parameter list)

where	(parameter list) can be (parameter)
or	(parameter list) can be (begin) (parameter group) (end)

where	(parameter group) can be (parameter)
or	(parameter group) can be (parameter group) (parameter)

where	(parameter) = (parameter value) . . . . (parameter value)
or	(parameter) = (parameter name) (parameter value) . . . . (parameter value)

The message formats are illustrated in Fig. 5.

Fig. 5 -Message formats
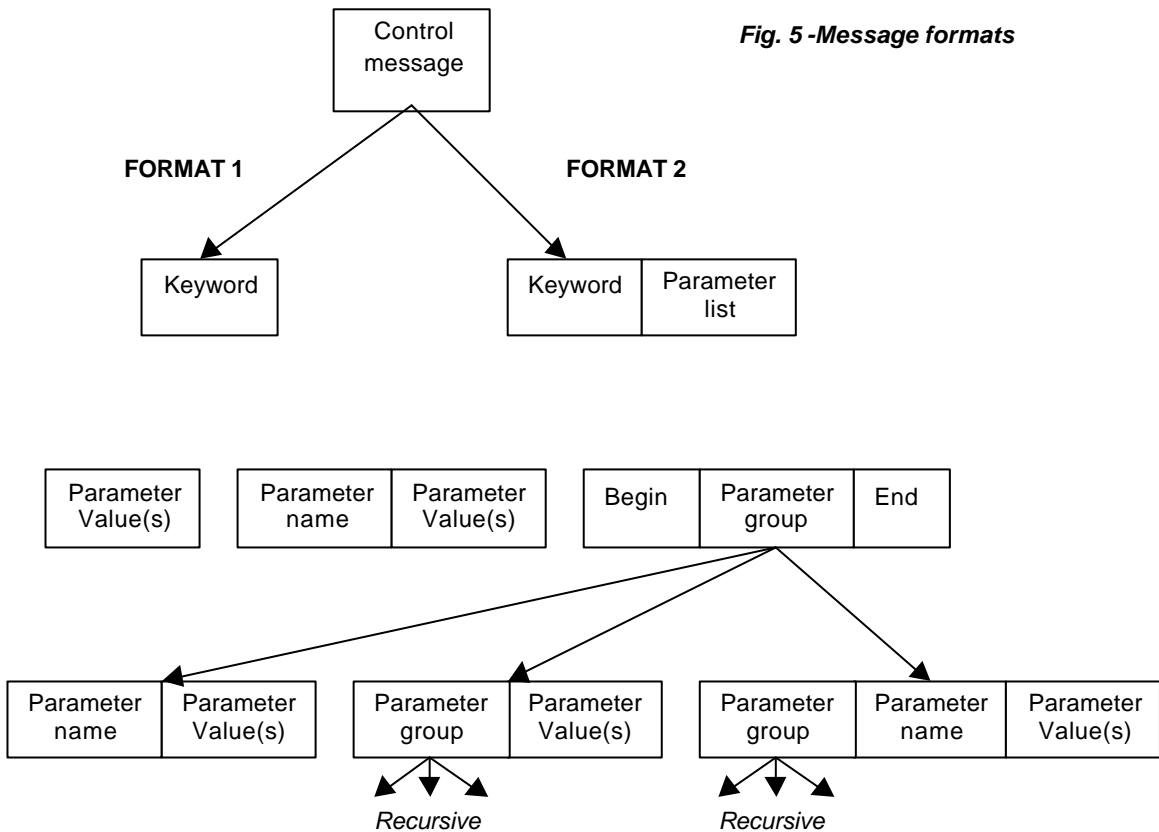
5.   Message coding

Identical or similar functions on equipment of different generic types should be effected by the same keyword bit pattern.

5.1.   Parameters

Messages may contain parameters as an essential part. All parameters are classified as follows.

5.1.1.   Logical Parameters

These parameters represent any abstract function(s) that may be expressed by a simple binary state of 1 (true) or 0 (false), such as tally ON/OFF or YES/NO.

The minimum code length for a single logical parameter is one byte. Individual logical parameters can be assembled, where applicable, into groups to form bit-specific bytes for transmission purposes.

5.1.2.   Numerical parameters

These parameters represent a numeric value and consist of the following:

- Unsigned-number parameters: parameters representing any numeric value without polarity.
- Signed-number parameters: parameters representing any numeric value with polarity.
- Time parameters: parameters representing hours, minutes, seconds and frames expresssed in that order as a 4-byte quantity in BCD.

    The hex "40"-bit of the "frames" byte will be set to one in drop frame compensated mode. In non-drop frame, uncompensated mode and all other time code standards, this bit will be zero.

    In all standards, the hex "80"-bit of the "seconds" byte will be set to zero to indicate monochrome field 1 or colour fields 1, 3, 5 or 7. This bit set to one will indicate monochrome field 2 or colour fields 2, 4, 6 or 8 (see Fig. 6a).

    All unused bits are reserved and shall be set to zero until they are assigned.

- High resolution time parameters: high resolution time is enumerated as a 6-byte quantity. The first 4 bytes are exactly the same as time parameters. The two remaining bytes express fractions of frames as a 16-bit binary unsigned number (see Fig. 6b).

a) Time parameter format
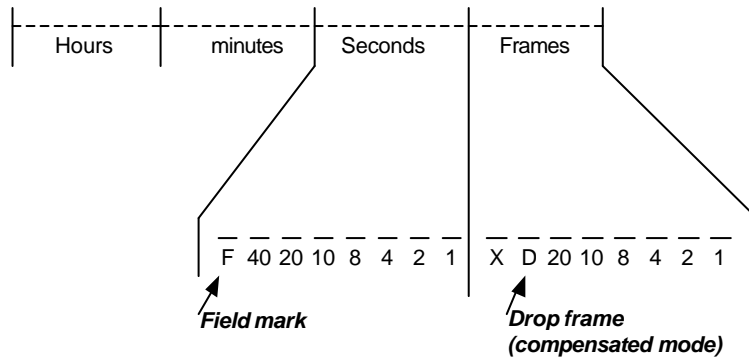
b) High resolution time parameter format
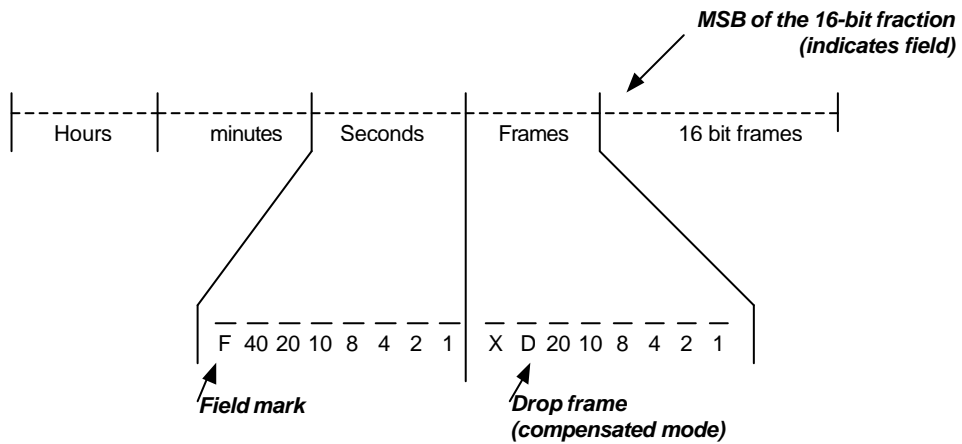
Fig. 6 - Time parameter format

5.1.3.   Literal parameters

These are parameters based, in general, on ASCII[*] characters.

5.1.4.   Raw data parameters

These are parameters based on a free-form data stream. Raw data parameters must provide for byte transparency to the lower layers. The first byte of a raw data parameter shall be a byte count.

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[*] The North American version of ISO Standard 646.

CHAPTER 3

Supervisory protocol

1.   General

This chapter specifies the supervisory protocol used within the communication channel operating over the interface bus. The protocol is the sequence of characters used to transfer messages between the bus controller and tributaries, provide recovery from error conditions, and generally supervise the usage of the channel.

The supervisory protocol is illustrated by means of a state diagram; this method of representation and the symbols used are explained at the end of Chapter 1.

2.   Message types

Two types of messages shall be transmitted on the channel:

-   Supervisory messages to supervise the channel and direct the flow of message blocks.

-   Control messages to control operation of equipment functions. This type of message shall be transmitted only within standard message blocks or during non-standard communications modes. The content and format of control messages are the subject of Chapter 2 and supplements.

3.   Tributary addresses

Tributary addresses shall consist of two bytes; the most significant byte, which is transmitted first, and the least significant byte.

The most significant bit of each byte shall be set to binary 1. This provides an address range starting at 8080h.

Each tributary shall be assigned two unique addresses, a SELECT address and a POLL address.

3.1.   Select address

An address in which the least significant bit of the least significant byte equals binary 0 is a SELECT address.

3.2.   Poll address

An address in which the least significant bit of the least significant byte equals binary 1 is a POLL address.

3.3.   Group addresses

Address pairs 8080-8081h and 8082-8083h to 81FE-81FFh are reserved as GROUP SELECT addresses. The addresses in which the least significant bit of the least significant byte equals binary 1 (POLL address) shall not be used but are retained in the address numbering scheme for software considerations.

3.4.   Discrete addresses

Tributary addresses shall start at 8280-8281h.

Precisely 8064 discrete tributary address pairs are available.

3.5.   Address allocation table

8080-8081h	Group select	- all call
8082-80FFh	Group select	- groups 1 to 63
8180-81FFh	Group select	- groups 64 to 128
8280-82FFh	64 tributaries	
8380-83FFh	64 tributaries	
up to		
FF80-FFFFh	64 tributaries	

4.   Tributary operational states

A tributary shall be in one of five major operational states:

IDLE   :   The tributary shall not perform any communications. It shall leave this state only in response to BREAK.

ACTIVE   :   Prerequisite for transition to other operational   states. The tributary shall enter this state whenever BREAK is received.

POLL   :   The tributary shall transmit a single status byte to the bus controller.

SELECT   :   A single tributary shall enter a communications mode with the bus controller.

GROUP SELECT :   All tributaries or a selected group of tributaries shall enter a communications mode with the bus controller.

5.   Supervisory messages

Tributaries shall be directed to operational states through various communications sequences by supervisory messages as shown in Fig. 7. Supervisory messages consist of the following elements:

BREAK   : Shall drive all tributaries to the ACTIVE state
                         (see Chapter 5, § 1.4.4 for detail of BREAK character).

(ADDR-POLL)   : A tributary poll address (ADDR-POLL) shall drive the addressed tributary to the POLL state.

(ADDR-SELECT)   : A tributary select address (ADDR-SEL) shall drive the addressed tributary to the SELECT state.

(GROUP ADDR-SEQ   : A group select address shall drive a group of tributaries to the GROUP SELECT state.

Supervisory characters

Supervisory characters identify communications sequences and provide status information. These characters are single bytes within the range 00h-7Fh. Supervisory characters shall consist of:

    01h   (GRP)   Group assign
    02h   (STX)   Start of message
    03h   (ESC)   Escape
    04h   (ACK)   Acknowledge
    05h   (NAK)   Negative acknowledge
    06h   (BSY)   Busy
    07h   (RST)   Reset
    08h   (SVC)   Service request from controlled equipment
    09h   (TEN)   Transmit enable

All other supervisory characters are reserved. The use of other characters for tributary supervision is prohibited within this specification.
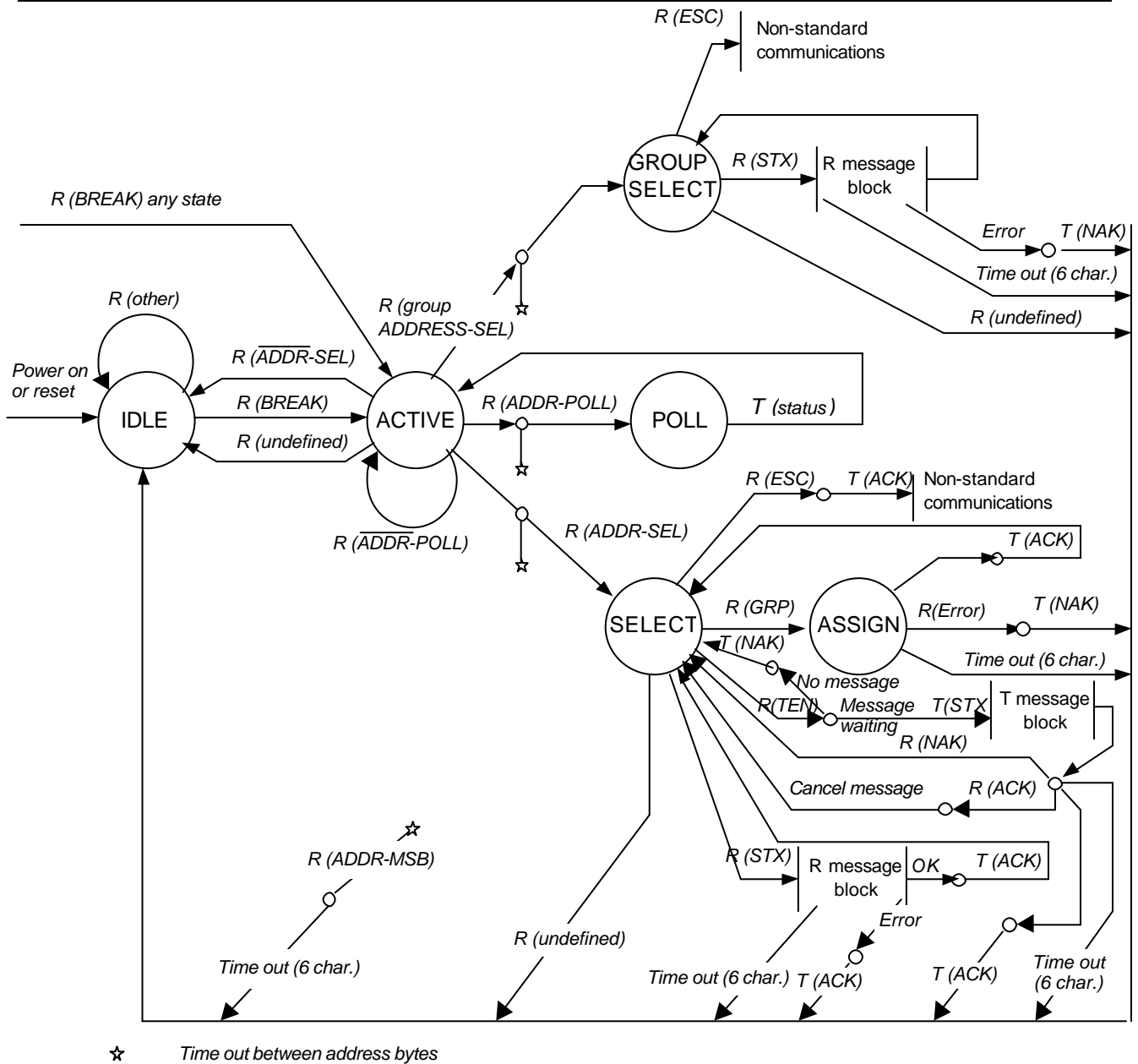
Fig. 7.- Tributary supervisory protocol

6.   Operational sequences (see Fig. 7)

6.1.   IDLE

Tributaries in the IDLE state shall not perform any communications sequences.

6.1.1.   IDLE state shall be entered under the following conditions:
- tributary power on or reset;
- upon receipt of an (ADDR-SEL) not assigned to the tributary;
- upon receipt of a (GROUP ADDR-SEL) not assigned to the tributary;
- when a specified time-out of six words duration occurs;
- on receipt of an undefined byte;
- on encountering a transmission error or an ambiguous condition.

6.1.2.   A tributary shall leave the IDLE state only on receipt of BREAK.

6.2.   ACTIVE

A tributary in the ACTIVE state shall perform communications sequences as directed by the bus controller.

6.2.1.   All tributaries shall enter the ACTIVE state whenever BREAK is received and on completion of a poll sequence.

6.2.2.   A tributary shall leave the ACTIVE state on receipt of an address which directs it to the POLL, SELECT, or GROUP SELECT states. A time-out between the two address bytes shall cause the tributary to enter the IDLE state.

6.3.   POLL

The POLL state shall be used to determine the presence and status of a tributary.

6.3.1.   A tributary shall enter the POLL state on receipt of its poll address (ADDR-POLL)

The tributary shall transmit one supervisory character to indicate its status, then return to the ACTIVE state. Tributaries not addressed shall remain in the ACTIVE state.

Supervisory characters transmitted shall be selected from the following:

RST   (07h) :   tributary has been powered up or been reset since last poll;
NAK.   (05h) :   an exception (time-out, undefined byte etc.) condition has occurred since last poll
                              or select;
BSY   (06h) :   tributary not available to receive messages;
SVC   (08h) :   service request from controlled equipment;
ACK   (04h) :   available.

These characters rank in priority according to the order shown above.

6.4.   SELECT

6.4.1.   Entry into the SELECT state

A single tributary shall enter the SELECT state on receipt of its select address (ADDR-SEL). All other tributaries shall revert to the IDLE state.

A tributary in the SELECT state shall execute the communications sequences detailed in 55 6.4.1.1 to 6.4.1.4, as directed by the bus controller.

6.4.1.1. Receive message

Supervisory character STX (02h) shall be followed by a message block containing the following characters:

Byte 1:   byte count of bytes 2 to n (0 - 256 bytes)

Bytes 2 to n   (256 bytes maximum): control message

Byte n + 1:   checksum (defined as 2's complement of the least significant byte of the sum of bytes 1 to n).

The tributary shall indicate error-free reception by responding with ACK and shall then return to the SELECT state.

On encountering an error during reception, the tributary shall respond with NAK, then revert to IDLE.

If transmission from the bus controller is interrupted for more than the time-out period (six words), the tributary shall return to IDLE.

The tributary shall transfer the byte count and control message (bytes 1 to n specified above), and a "block ready" flag indication to the entities using the system for control purposes (see Fig. 8).
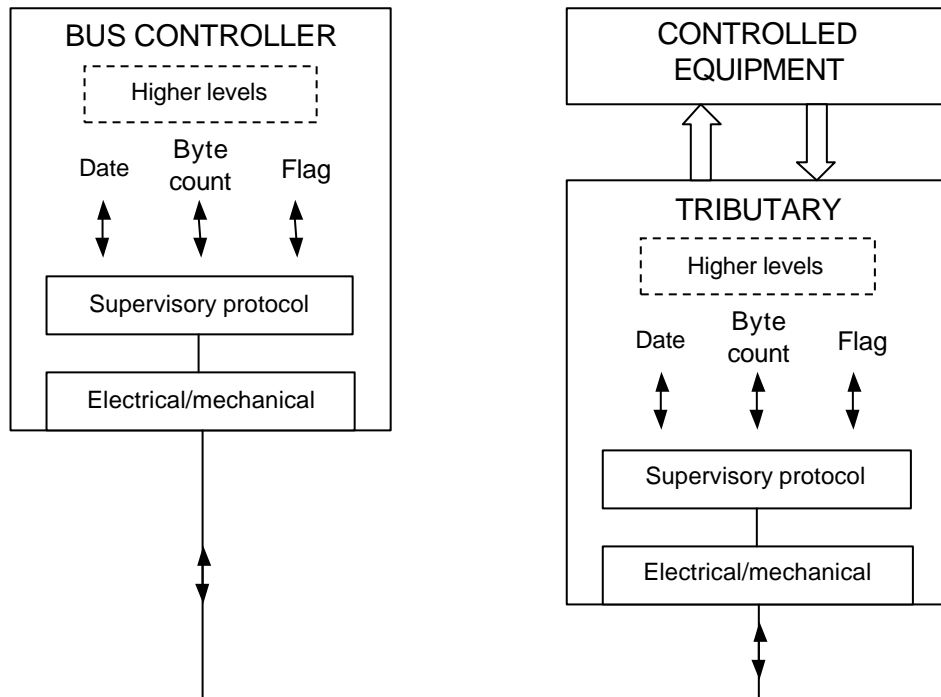
Fig. 8. - System elements

6.4.1.2. Transmit message

A tributary shall notify the bus controller that a message is waiting by transmitting SVC (08h) during POLL. On receipt of TEN (09h) while in SELECT, the tributary shall transmit a standard message block as defined in § 6.4.1.1.

6.4.1.3. Assignment of a tributary to a group

Supervisory character GRP (01h) shall be followed by a single byte:

00h - deletes all previous group assignments;

GRP (01h), followed by a byte whose most significant bit is zero (01-0Fh), deletes the assignment of the tributary whose address is represented by the subsequent 7 bits (1-127);

80h - assigns the tributary to all groups 1-127;

GRP (01h), followed by a byte whose most significant bit is one (81-FFh), assigns the tributary whose address is represented by the subsequent 7 bits (1-127).

A tributary may be removed from, or assigned to, more than one group by repeating the assignment sequence.

If transmission from the bus controller is interrupted for more than the time-out period between receipt of GRP and the group assignment byte, the tributary shall return to IDLE.

All group addresses except "all call" (8080h) shall be deleted on tributary power-up or reset.

6.4.1.4. Non-standard communications

Supervisory character ESC (03h) shall release a tributary to nonstandard communications sequences. The tributary shall respond with ACK; it shall leave ESC mode only in response to BREAK.

6.4.2. Leaving the SELECT state

The tributary shall leave SELECT on receipt of BREAK or in response to the exceptional conditions noted in §§ 6.4.1.1 and 6.4.1.3 above.

6.5.   GROUP SELECT

6.5.1. Entry into the GROUP SELECT state

Groups of tributaries shall enter the GROUP SELECT state on receipt of their group select address (GROUP ADDR-SEL). All tributaries not assigned to the group shall return to IDLE.

Tributaries in the GROUP SELECT state shall execute the communications sequences detailed in §§ 6.5.1.1 and 6.5.1.2 as directed by the bus controller.

6.5.1.1. <u>Receive message</u>

Supervisory character STX shall be followed by a message block as defined in § 6.4.1.1.

Each tributary returns to GROUP SELECT state after error-free reception of the block; no response shall be transmitted.

On encountering an error during reception, a tributary shall respond with NAK, then return to IDLE.

If transmission from the bus controller is interrupted for more than the time-out period, tributaries shall return to IDLE.

6.5.1.2. <u>Non-standard communications</u>

Supervisory character ESC shall release a group to non-standard communications in accordance with 6.4.1.4.. Tributaries shall leave this mode only in response to BREAK.

6.5.2. Leaving GROUP SELECT

Tributaries shall leave GROUP SELECT on receipt of BREAK or in response to the exceptional conditions noted in 6.5.1.1.

7. Bus controller operation

7.1. System synchronization

The bus controller shall transmit BREAK when power is turned on and after being reset.

7.2. Tributary response time-out

The bus controller shall transmit BREAK when a tributary fails to respond, within a six-word time-out, to ADDR-POLL, GRP (#), ESC, TEN, End of message block.

8. Guidelines

8.1. General

The following paragraphs are intended to give guidance to system designers in the interpretation of this chapter.

8.2.   Channel synchronization

Data density is maximized by allowing the transmission of binary data in all message blocks. This means that there must be no combination of transmitted bytes which can be interpreted as a channel synchronization command. The channel synchronization command is a unique transmission sequence called BREAK. This sequence cannot be accidentally generated by normal communications. Tributaries receiving BREAK are required to transfer immediately to the ACTIVE state regardless of what they are currently doing in relation to the communication channel. On power up, a tributary enters the IDLE state and ignores all bus transactions until it receives BREAK. Electrical specifications appropriate for use with this supervisory protocol assure that BREAK cannot be generated accidentally.

8.3.   Supervisory message components

The protocol uses BREAK, tributary addresses, and a small number of predefined supervisory characters to manage the communication channel. Since the addresses and supervisory characters, like control messages, are eight-bit binary bytes, they can only be recognized by some special sequence. This is the BREAK instruction and it is the only supervisory message that is unconditionally recognizable.

8.3.1.   Tributary addresses

Tributary addresses consist of two bytes. Up to 8064 tributaries can be addressed uniquely. A one-byte addressing scheme would have served most small system applications with a saving in channel overhead, but complex reassignment strategies would have to be employed in order to accommodate larger users.

The address bytes are characterized by a 1 in the most significant bit. Each tributary is assigned two addresses, a SELECT address and a POLL address. The least significant bit of the least significant byte is set to 0 for SELECT and 1 for POLL.

A unique two-byte address serves as an all-call SELECT address. When this address is transmitted all tributaries in a multi-point system simultaneously receive and act on system messages.

Tributaries can be assigned to one or more of 127 GROUP SELECT addresses. These addresses allow simultaneous operation with selected groups of tributaries in multi-point systems similar to all-call.

During all-call or group operation, transmission by the tributaries is allowed only when an error condition is encountered, since other transmissions could cause channel errors when several tributaries attempted to transmit at the same time. When error conditions are encountered, tributaries transmit the supervisory character NAK; reception of the NAK, or an error, indicating channel contention, alerts the bus controller to an error condition in one or more tributaries. The bus controller must transmit BREAK and then poll individual tributaries to determine which have encountered an error and the nature of the error.

8.3.2.   Supervisory characters

The only supervisory characters used are those given in § 5. Supervisory characters are single eight-bit bytes in which the most significant bit is 0. Implementations of this protocol must not use any other supervisory characters for non-specified functions as such use would render a tributary incompatible with other systems and could occasion serious operational failures if other supervisory functions are added to this specification in the future.

8.4.   Poll sequence

The POLL sequence is used to verify tributary presence and status. In multi-point systems, the POLL sequence allows all tributaries to be scanned quickly to see if servicing or attention is required by any of them.

Status characters transmitted by a tributary inform the bus controller of the tributary's current condition. Characters associated with specific conditions are detailed in § 6.3.1. The tributary is required to send the highest priority status character applicable to its condition if more than one applies. All status characters except service request (SVC) apply to conditions within the interface function. SVC is a pass-through condition which indicates a service need by the equipment controlled through the interface. Control messages are used to identify and provide the service required.

8.5.   Message block receive/transmit sequences

Message blocks are received or transmitted by a tributary by means of the message receive/transmit sequence, from the SELECT state. This sequence offers control message lengths of 1 to 256 bytes with checksum protection. Groups of tributaries can receive message blocks from the GROUP SELECT state.

All equipment control and status information is exchanged by means of control messages. On receipt of a message, the bus controller will transmit an ACK or NAK. It will then wait for 6 characters for any exception condition (see *Fig. 7*).

Control messages have been dealt with in Chapter 2. Only control messages which conform to this specification should be transmitted via the control message receive/transmit facilities. Non-standard messages should be transmitted via the escape sequence.

8.6.   Escape sequence

The escape sequence is provided for those users who wish to remain compatible with the electrical and supervisory protocol characteristics of the interface system but require non-standard operational sequence or messages. Single tributaries or groups of tributaries may be placed outside the normal protocol limits using this sequence. The only protocol requirement which must be observed by devices while using this sequence is the requirement to enter the ACTIVE state whenever a BREAK is received from the communication channel.

8.7.   Switched tributaries

This specification considers the operation of bus controllers and tributaries to be within one communication channel. If tributaries are transferred between channels, the system designer must provide means to place them in an appropriate state before connection to a new channel. It is recommended that the tributaries be forced to the IDLE state with all group address assignments cleared before connection. Procedures for notifying a bus controller of the attachment of a tributary will generally be required; these procedures are dependent on the nature of the system and are left to the designer's discretion.

CHAPTER 4

Tributary interconnection

1.   General

All communication in the interface bus takes place under the control of, and through, the bus controller. Chapter 3 described the protocol governing the transfer of control messages between a tributary and the bus controller at the supervisory level.

The present chapter, which is primarily concerned with system service level functions, provides for the completion of this process to allow control messages to be transferred between tributaries.

2.   Interconnection within a local network

2.1   General

The mechanism for message transfer between tributaries is based broadly on the principles of communications layering and makes use of virtual circuits. This allows for the establishment and breaking down of multiple links between the tributaries. System service messages perform this function.

A linkage directory is established within the bus controller for each working session. The directory is considered to be a system service feature, and provides for the establishment of multiple virtual circuits through the network.

2.2.   The linkage directory

The linkage directory shall establish a relationship between virtual machines, i.e. a virtual circuit. The establishment of the linkage directory shall be completed as the initial task in each working session. The linkage directory resident within the system service level of the bus controller binds message "sources" and "destinations".

Linkage information may originate in any application level and shall effect directory construction within the system service level of the bus controller. Linkage messages are reserved messages within the system service message set; they establish and disconnect virtual circuits within the network.

The bus controller, on receipt of a transmission request from the supervisory level of any tributary, will identify the destination tributary by reference to the linkage directory; acting as an intermediary it will forward the message as directed.

2.3.   Multiplexing within tributaries

Tributaries, in general, have a single supervisory level address, and a single physical connection end point to the bus.

Alternative multiplexing mechanisms, as described below, enable multiple virtual circuits to pass through any single connection end point.

2.3.1.

Multiple, logically independent virtual machines, each with a unique supervisory level address, may be attached to the communications channel through a common connection end point. Multiplexing is then performed by multiple polling of the addressing entity residing with the supervisory level (*Fig. 9*).
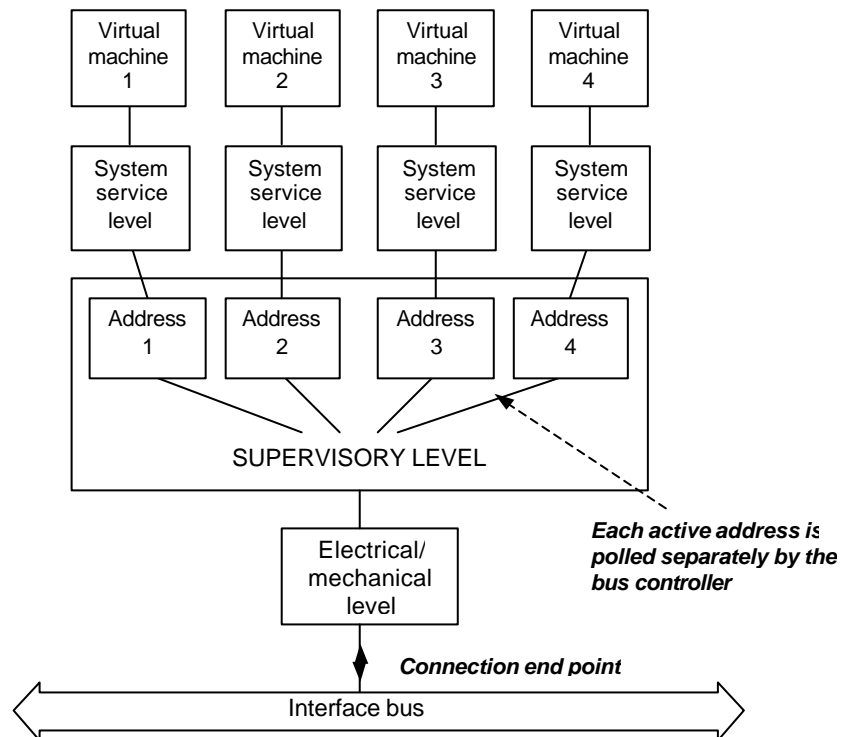
Fig. 9. - Multiplexing within supervisory level

It may be noted that any individual tributary address may achieve a higher priority - and hence an improved response time at the expense of that of the remaining tributaries - by being allocated more than one poll within each poll sequence.

2.3.2.

Alternatively, a single supervisory level address may be Multiplexed to multiple logically independent virtual machines, with selection being performed by a logical switch residing within the entity of the destination tributary system service level (see *Fig. 10*).
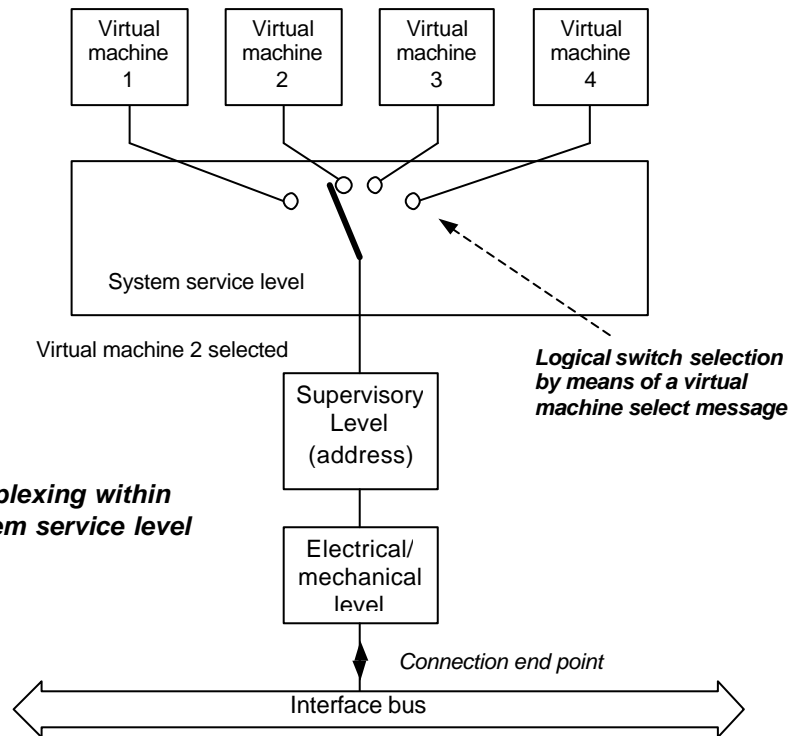

Fig 10. - Muitiplexing within system service level

The required virtual machine is selected from those associated with the single supervisory level address, by means of a system service "virtual-machine select" message (see § 3.4 below). This is transmitted from the bus controller under the direction of the linkage directory held within its system service level, to the destination tributary system service level, immediately prior to the transmission of any control message, or sequence of control messages, destined for that specific virtual machine.

The selected routing will remain in existence until receipt, by the system service level, of a new virtual-machine-select message, thereby minimizing the message traffic on the communications channel.

2.3.2.1. The reverse route of each virtual circuit, when required, will be selected similarly by the logical switch resident within the entity of the system service level of the multiplexed tributary. This selection is performed on receipt of a control or response massage from any one of the virtual machines attached to the system service level of the tributary. The system service level will then instruct its supervisory level to transmit the appropriate "virtual-machine-select" message to the supervisory level, and hence the system service level of the bus controller..

2.3.2.2. System service level virtual group "assign" and "deassign" commands shall be used to
assemble/desassemble groups of virtual machines within the system service level, from those
associated with a single supervisory level tributary address, for simultaneous control purposes.

Virtual circuits employing virtual group identifiers shall be recorded as additional entries within the
bus controller linkage table.

2.3.3.

It should be noted that a bus overhead exists in each method of virtual circuit multiplexing. Where
the multiplex is to take place within the supervisory level (§ 2.3.1), the overhead will take the form of
additional polls in each cycle.

S ystem service level multiplexing (5 2.3.2) introduces an additional control message (a
virtual-machine-select message) prior to each virtual machine message, or series of virtual machine
messages, destined for an alternative virtual machine.

The choice of multiplexing mechanism, where used, rests with the system designer taking account of
specific design considerations.

2.4.   Forbidden configurations

Some virtual circuit configurations may be forbidden due to the function of the particular tributary,
i.e. the functions of the tributaries are incompatible. Checking mechanisms should be employed to ensure
that illegal virtual circuits cannot be established. Most of the checking would be performed in the system
service level according to predefined rules within the particular network. Some rules could be readily derived
from the type of tributary (built in) while others may be imposed by the user or system designer.

3.   System service messages

System service messages shall be used to command the performance of system functions; they are
fully defined in a supplement to this specification. These functions include, but are not limited to, the
following.

3.1.   Segmentation and re-assembly

These processes enable the transfer of messages which exceed the maximum supervisory level
message block length (see *Fig. 11a*).

The parsing mechanism for segmentation and blocking is described by the state diagram given in
Fig. 12.

3.1.1. A data segment shall take the following, form (see *Fig. 11b*):

lst byte : keyword SEGNIMIT (initial or subsequent).

2nd byte : number of segments remaining; last segment is 0; segment count shall be sent in sequentially descending order.

Remaining bytes : segment data. No further message shall follow a data segment message within a single supervisory level message block.

a) Supervisory level block
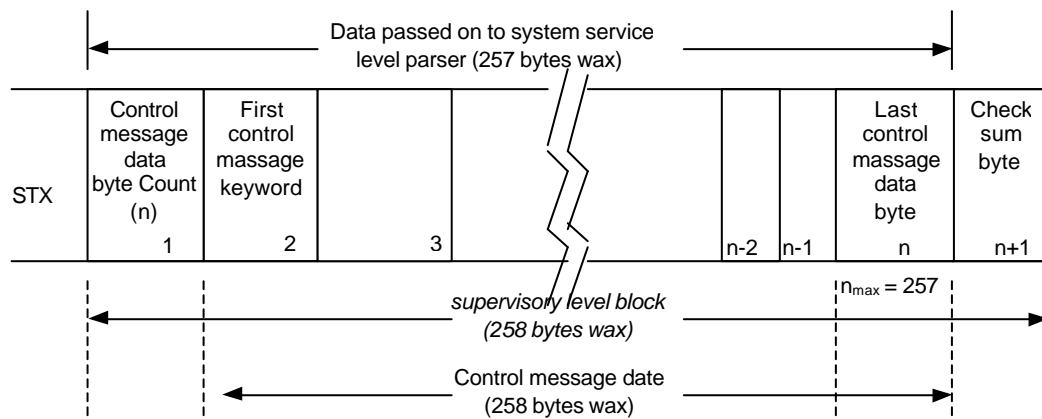
b) Format of data segment
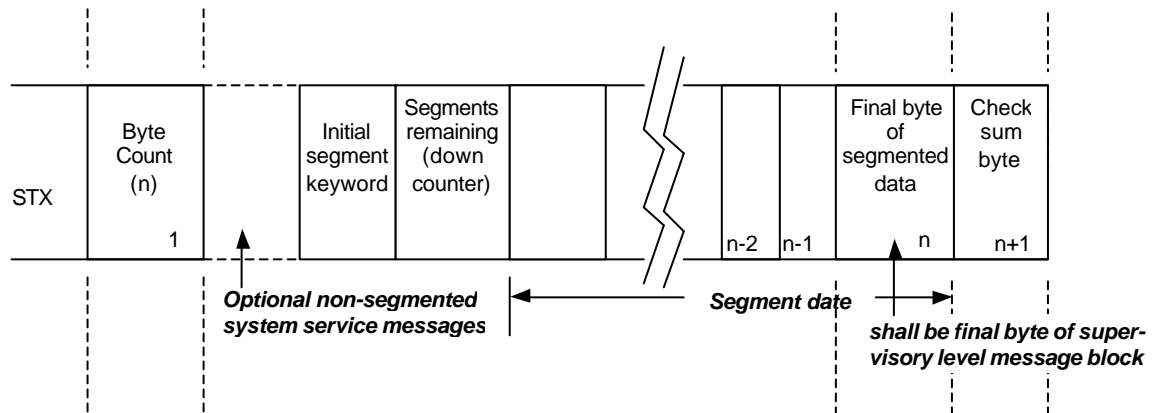
c) Format of date blocks
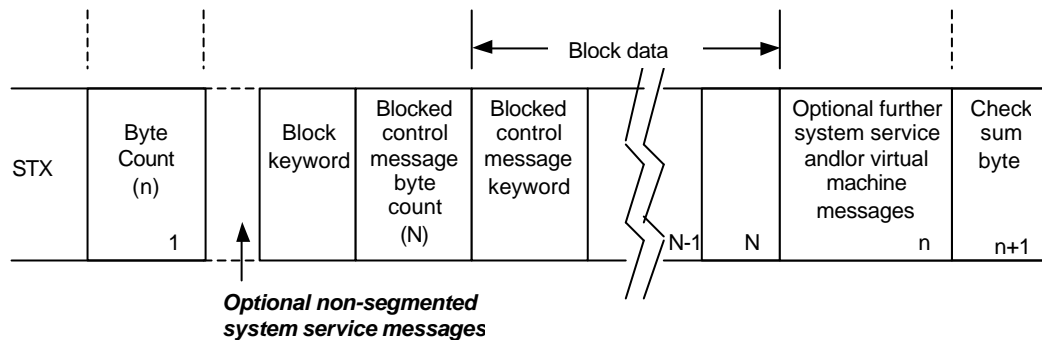
Fig. 11- Data segments and blocks

3.2.   Blocking and deblocking

These processes enable the concatenation of messages within a single supervisory level message block.
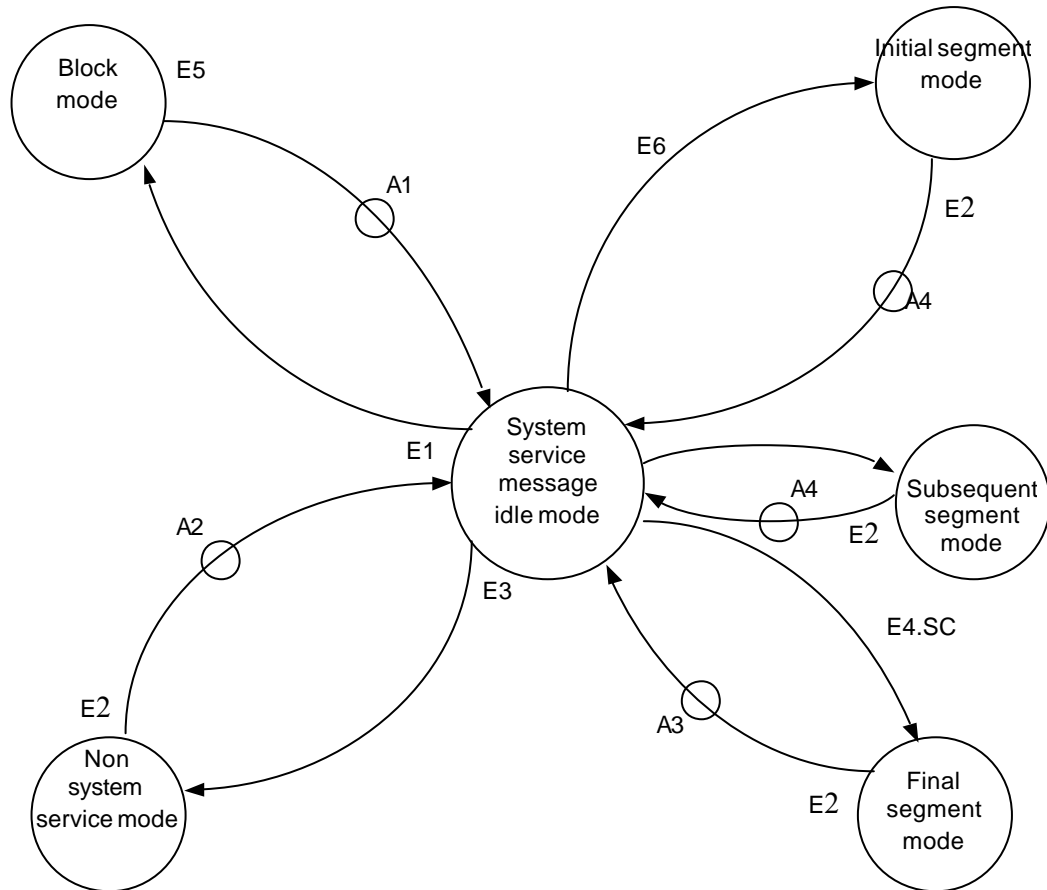
Events

    E1 =   Block keyword
    E2 =   Lost byte of supervisory level message
    E3 =   Keyword not system service message: i.e.: ≠ Block: ≠ Segment
    E4 =   Subsequent segment keyword
    E5 =   Lost byte of block data
    E6 =   Initial segment keyword

Conditions

    SC =   Segment count ≠ 0
    SC =   Final segment: segment count = 0

Actions

    A1 =   Pass data block transparently for higher level parsing
    A2 =   Pass data transparently, no parsing required on message level
    A3 =   Pass concatenated segments transparently
    A4 =   Store incoming segment.

Fig. 12. - Segmentation / blocking state diagram

3.2.1. A data block shall take the following form (see Fig. 11a)

1st byte   :   keyword BLOCK.

2nd byte   :   byte count (N), where N in the number of bytes in the block data.

Remaining bytes :   block data.

3.2.2. The supervisory level shall transfer the byte count to the system service level.

3.3.   The establishment of virtual circuits

This process is effected through the management of the linkage directory contained within the bus controller.

3.4.   The selection of a virtual machine

This process enables the selection of a virtual machine from those previously assigned to a tributary.

3.5.   System service level reset

This command returns the system service level to its power-up default state, i.e.:

1) virtual machine zero,
2) error flags reset,
3) segmentation cancelled,
4) virtual groups cancelled.

3.6.   Group assign/de-assign

These commands establish/break down supervisory level groups of tributaries for joint control purposes.

3.7.   Virtual group assign/de-assign

These commands establish/break down system service level groups of virtual machines for joint control purposes.

4.   Interconnection of local networks

4.1.   The interconnection bus

The interconnection of Individual local networks shall be by means of an interconnection bus (Fig. 13). The linking of the local network to the Interconnection bus shall be by means of a gateway.
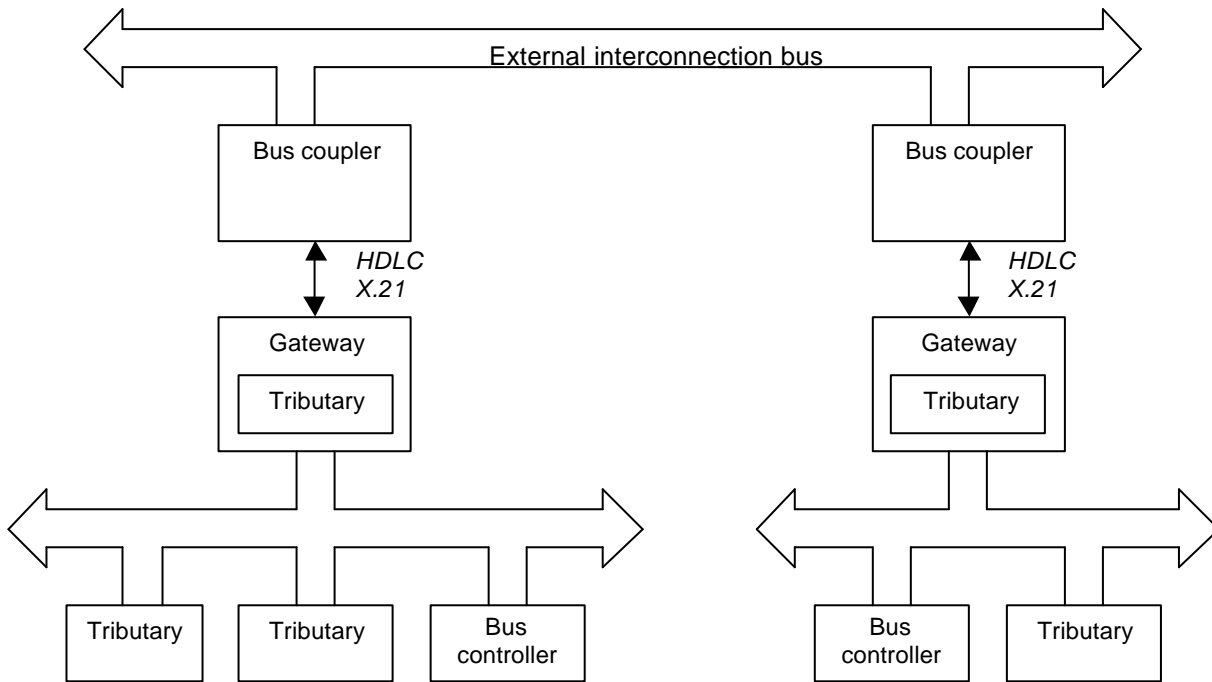
Fig. 13. - Local network Interconnection

ISO Standards 3309 and 4335 (HDLC), in accordance with CCITT Recommendation X.25 LAPB, shall be used for the data link layer protocol between the gateway and the bus coupler; the physical link layer shall be as specified in CCITT Recommendation X.21.

4.2.   The gateway

The gateway Is a logical device whose task is to transfer messages between a local network and an external interconnection bus coupler. The gateway provides for the interchange of messages between multiple local networks.

The gateway will maintain a linkage directory in its system service level. The linkage table will allow the gateway to be seen by the bus controller as a set of "virtual" tributaries linked by virtual circuits.

The gateway will provide for all protocol conversions required to convert from the interface bus supervisory and electrical/mechanical level standards as specified in Chapters 3 and 5 respectively, to the HDLC data link and X.21 physical link layers.

The gateway will provide decoding of group addresses provided for in the. supervisory level (Chapter 3) and will forward messages addressed to these groups over the interconnection bus as discrete individual select addresses. Where more than one "external" tributary is addressed by a group message, the individual messages to all such tributaries shall be dispatched sequentially as individual messages from the gateway. Translation takes place in the system service level of the gateway. The functional structure of the gateway is shown in *Fig. 14*.
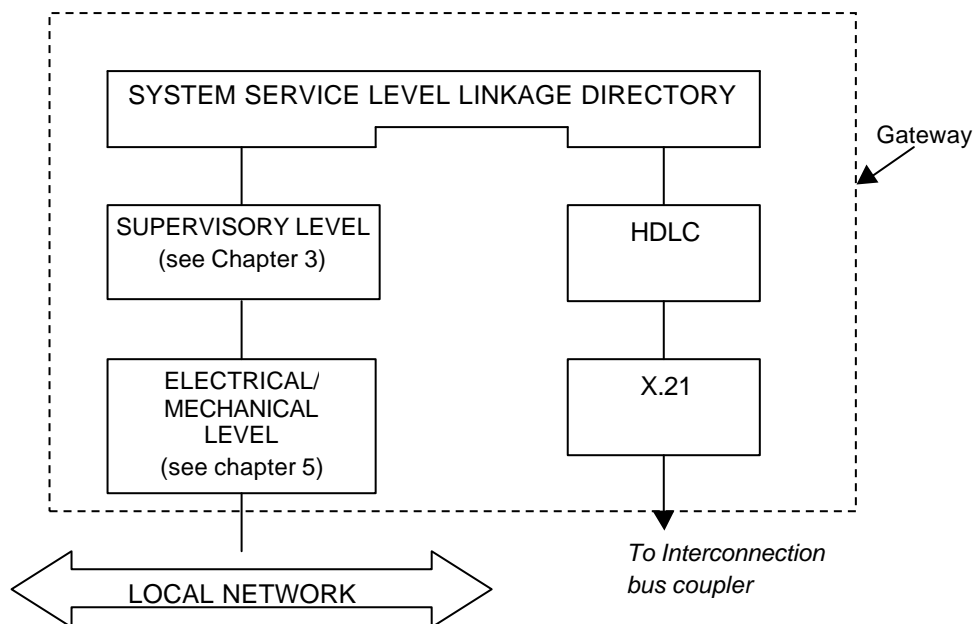
Fig 14. - Gateway functional structure

Note: The HDLC/X.21 definition is in accordance with the CCITT X.25-LAPB specification

5.   Guidelines

This section gives a typical example of virtual machine selection when using the multiplexing technique detailed in § 2.3.2 of this chapter. It encompasses operations in both the system service and supervisory levels and thus also includes features described in Chapter 3.

In § 5.1 the procedure is described in broad outline; in § 5.2 the same example is dealt with in more rigorous detail.

5.1.   In this broad outline, the form of the messages is not defined precisely but is given only as an illustration of the function to be performed.

a)   Assume that three control panels are linked to the local network through a single tributary address and connection end point as shown in *Fig. 15*.
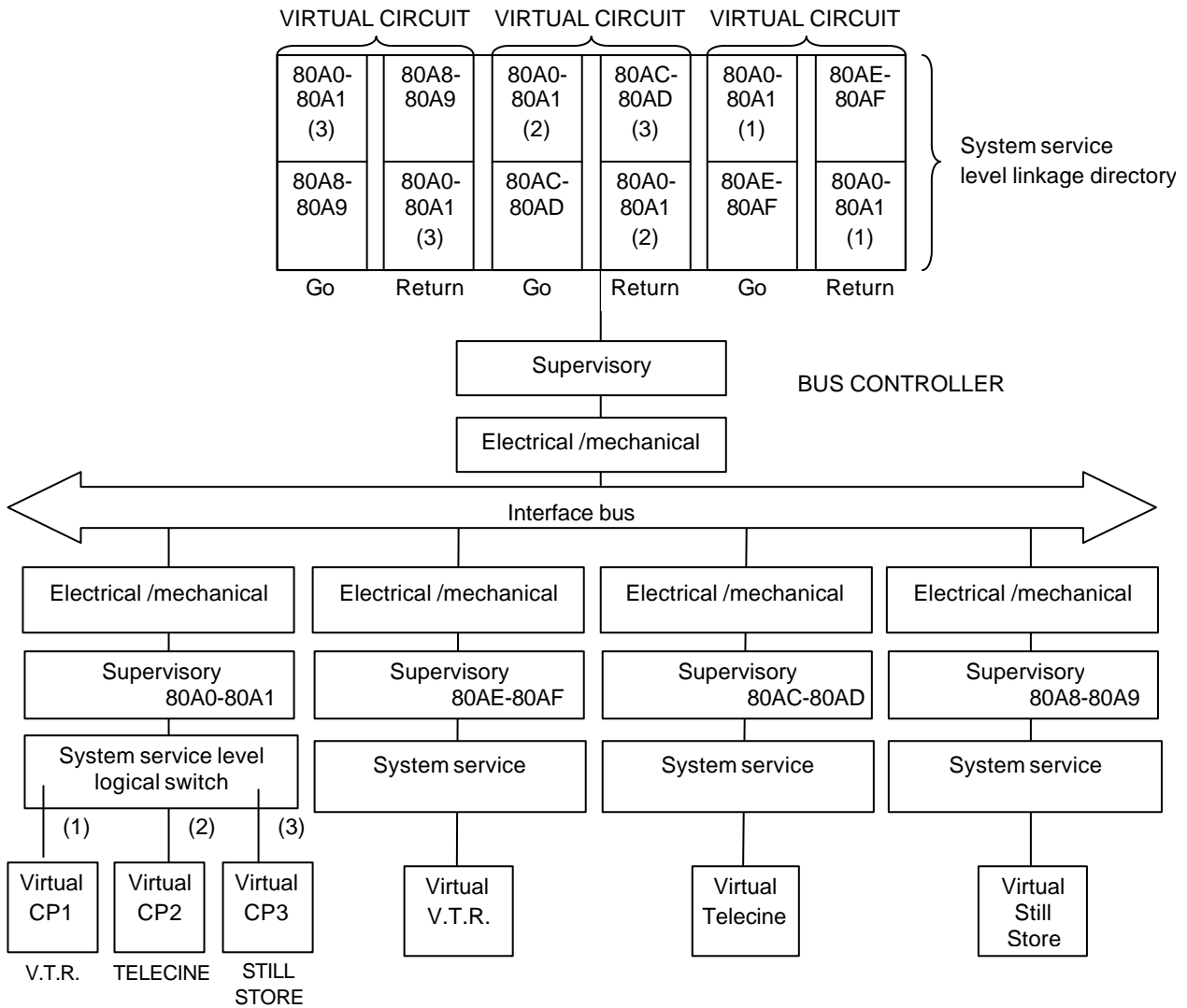
Fig. 15- Example of virtual machine select mechanism

During the assignment process, the control panels CP1, CP2 and CP3 have been associated with VTR, telecine and still-store respectively via virtual circuits (1), (2) & (3).

b)   Assume further that a VTR <u>command </u>has just been issued *by* CP1 and a telecine PLAY command is now required.

c)   The following linkage message must be issued by the system service level of the control panel tributary:

(Virtual-machine-select) (2)

This changes the virtual machine selection from virtual machine (1), (VTR); to virtual machine (2), (telecine)

d)   The control panel virtual machine then issues the control message:

(PLAY)

This causes the telecine virtual machine to change to Play state.

Any subsequent messages   from the control panel to the telecine will be transferred   without any   further linkage messages, e.g. control   message (STOP).
A (NEXT SLIDE) command for the still‑‑‑store virtual machine would, however, require:
1. (Virtual‑machine‑select) (3) and
2. (NEXT SLIDE)
in order to reselect the virtual machine CP3.

5.2.   In this more rigorous treatment of the example given in 5.1, it is assumed that the three control panel virtual machines, CP1, CP2 and CP3, are linked to the interface bus through the single tributary address (80A0-80A1) and connection end point.

5.2.1.   A (START) command from the telecine control panel virtual machine CP2 attached to tributary 80A0-80A1 is to be sent by virtual circuit (2) to the telecine virtual machine connected to tributary 80AC-80AD. A possible message exchange might be:

a)   Telecine control panel virtual machine, (CP2), passes (START) command to system service level of tributary 80A0-80Al.

b)   80A0-80A1 system service level instructs supervisory level to raise the service request flag (SVC).

c)   The bus controller, as part of its normal poll sequence, polls 80A1 and receives (SVC).

d)   The bus controller issues select address 80A0: it then sends (TEN) to 80A0-80A1 supervisory level.

e)   80A0-80A1 supervisory level sends:

(STX) (byte count (BC)) (virtual-machine-select) (2)
(Block check (B.CK))

to the bus controller (see Note 1).

f)   The bus controller responds with (ACK) and a further (TEN). (Since the last message was a "virtual‑ntachine‑select" message, a further virtual machine control message is expected by the bus controller. See Note l.)

g)   The supervisory level of the tributary 80A0-80A1 sends:

(STX) (BC) (START) (B.CK)

to the bus controller (see Note 1).

h)   The bus controller system service level identifies the destination of (80A0-80A1 - virtual machine 2) from its linkage directory. The address is found to be 80AC-80AD.
i)   The bus controller issues (BREAK).

j)   The bus controller issues select address 80AC

k)   The bus controller then sends:

        (STX) (BC) (START) (B.CK)

        to tributary 80AC-80AD.

l)   The supervisory level of tributary 80AC- 80AD responds with (ACK) and passes the control
        message to the system service level parser.

m)   The system service level parser passes the (START) command to the telecine virtual machine.

Note 1:   The messages in (e) and (g) might be concatenated Into the single hybrid   command:

(STX) (BC) (virtual-machine-select) (2) (START) (B.CK)

        *in order to limit protocol overhead. In this case, the messages contained in (f) would not be
        necessary.*

5.2.2.   A tally response (STARTED) from the telecine virtual machine tributary 80AC-80AD is to be sent
to telecine control panel virtual machine CP2 attached to interface bus through tributary 80A0-80Al.

a)   The telecine virtual machine passes the (STARTED) tally to system service level of tributary
        80AC-80AD.

b)   The system service level instructs the supervisory level of 80AC-80AD to raise service request flag
        (SVC).

c)   The bus controller, as part of its normal poll sequence, polls 80AD and receives (SVC).

d)   The bus controller issues the select address 80AC, followed by (TEN) to the supervisory level of
        80AC-80AD.
e)   The bus controller receives the tally:

        (STX) (BC) (STARTED) (B.CK)

        from 80AC-80AD.

f)   The bus controller system service level determines the destination (80A0-80A1 - virtual machine 2)
        from its system service level linkage directory.

g)   The bus controller issues (BREAK).

h)   The bus controller issues select address 80A0.

i)   The bus controller sends:

        (STX) (BC) (virtual-machine-select) (2) (B.CK)

        to tributary 80A0-80A1 (see Note 2).

j)   The tributary 80A0-80A1 responds with (ACK), and sets the logical switch In its system service
        level to select telecine control panel virtual machine CP2.

k)   The bus controller sends tally..

(STX) (BC) (STARTED) (B.CK)

to tributary 80A0-80A1 supervisory level (see Note 2).

1)   The supervisory level of tributary 80A0-80A1 responds with (ACK) and passes control message to system service level parser.

m)   The system service level parser passes (STARTED) tally to the telecine control panel virtual machine CP2.

Note 2: The messages in (1) and (k) might be concatenated into the single hybrid command:

(STX) (BC) (virtual-machine-select) (2) (SMRTED) (B.CK)

in order to limit protocol overhead.

5.2.3   It should be noted that further commands to the same virtual machine, and which follow immediately on the sequences detailed in § 5.2.1, will omit steps "e" and 'f' since no further changes are needed in the virtual machine selection.

Similarly, § 5.2.2 steps "i" and "j" will be omitted under the same circumstances.

CHAPTER 5

Electrical and mechanical characteristics

1.   General

1.1.   This chapter defines the electrical and mechanical characteristics of the communication channel and the associated interface device(s). to the exclusion of design specifications, performance requirements, safety requirements, and the communications protocol used in or by such equipment. The EBU has published guidelines relating to certain of these aspects.

1.2.   For the purposes of this chapter, "equipment" shall be taken to mean either a single device which connects to the interface system or a group of interconnected devices, providing a specified operational function, having one common connection to the interface system.

1.3.   The intent of this chapter is to:

-    specify equipment-independent electrical, mechanical, and functional interface characteristics which permit equipment to connect and communicate unambiguously via the interface system;

-    specify terminology and definitions related to the electrical and mechanical portion of the interface system;

-    enable the interconnection of independently-manufactured equipment into a single functional system;

-    permit equipment with a wide range of operational capabilities to be connected to the interface system simultaneously;

-    define a system which is user configurable;

-    define a system based on readily obtainable standard components.

1.4.   This chapter defines a system which has the following characteristics:

-     a full-duplex four-wire communications channel;
-     a nominal maximum bus length of 1220 m;
-     data is transmitted asynchronously, bit serial and word serial;
-     standard transmission rate on the interface bus is 38.4 kbit/s;
-     data exchange between devices is digital.

The function of the interface system is to provide an effective communications link over which messages are carried in an unambiguous way among a group of interconnected devices.

The basic message path and the bus structure shall be as follows.

The basic message path utilizes asynchronous, bit seriallword serial transmission via a balanced wire pair. The interface bus is a four-wire configuration which will effect two-way communication using a separate wire pair for each transmission direction.

The data word and BREAK character utilized by the interface system shall be as follows.

The standard serial data word includes an eight-bit data byte.

The complete serial data word consists of one start bit (SPACE), eight data bits (ONE BYTE), a parity bit (EVEN), and one stop bit (MARK). The least significant bit is transmitted first.

A BREAK character, comprising 20 bits SPACE followed by a minimum of 2 bits MARK, is utilized to synchronize all devices connected to the interface bus.
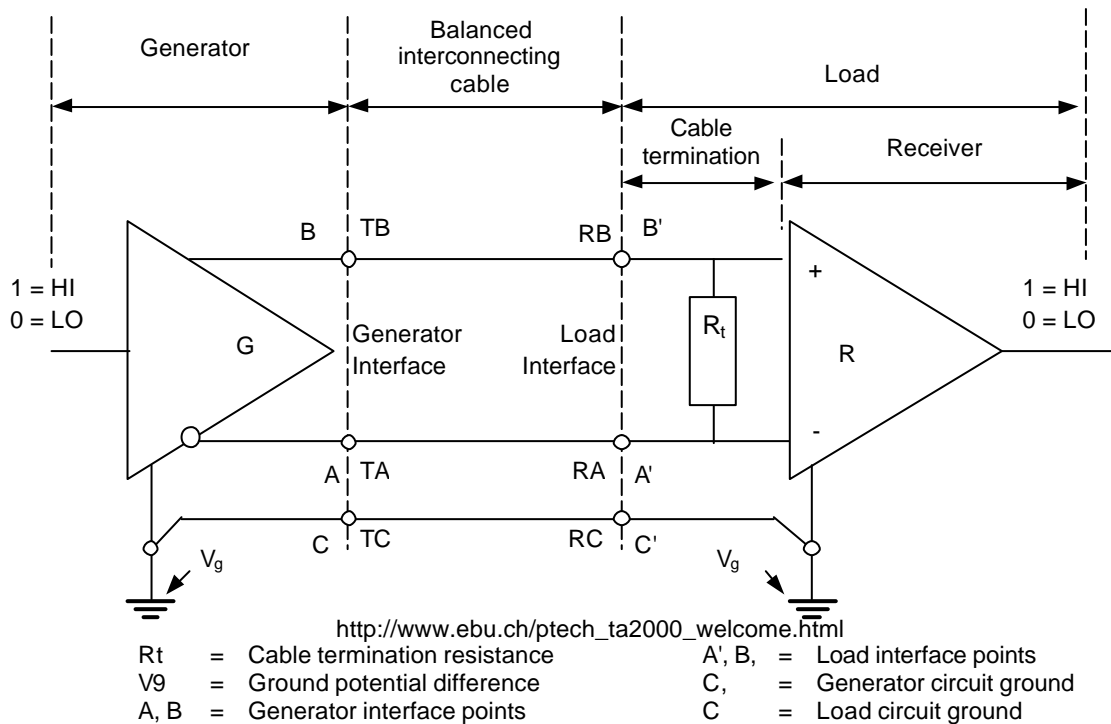

2.   Electrical characteristics

2.1.   Interface circuit

The balanced voltage digital interface circuit is shown in *Fig. 16.* The circuit consists of three parts: the generator, the balanced interconnecting cable and the load. The load may consist of one or more receivers (R) and an optional cable termination resistance (R_t). The electrical characteristics of the generator and receiver are specified in terms of direct electrical measurements, while the interconnecting cable is specified in terms of its electrical and physical characteristics.

2.2.   Generator characteristics

The electrical characteristics of the generator are specified in accordance with measurements described below in §§ 2.2.1 to 2.2.6 and illustrated in *Figs. 17* and 18. A generator circuit meeting these requirements results in a low Impedance (100 O or less) balanced voltage source producing a differential voltage applied to the interconnecting cable in the range from 2 to 6 V. The signalling sense of the voltages appearing across the interconnecting cable is defined as follows:

Rt = Cable termination resistance   A', B, = Load interface points
V9 = Ground potential difference   C, = Generator circuit ground
A, B = Generator interface points   C = Load circuit ground
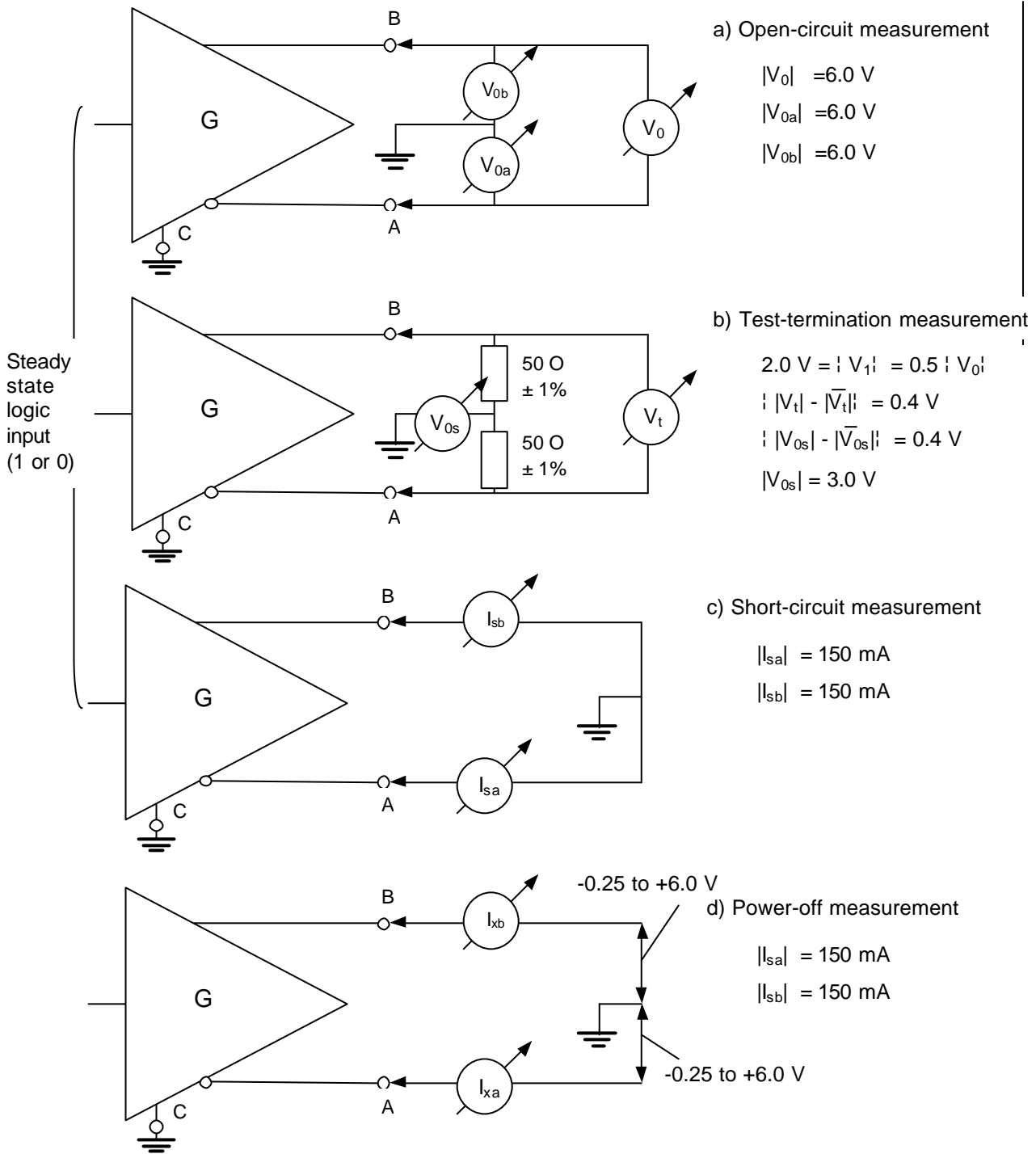
Fig. 16- Balanced digital interface circuit

- the *B* terminal of the generator shall be positive with respect to the A terminal for a binary 1 (MARK) state;
- the *B* terminal of the generator shall be negative with respect to the A terminal for a binary 0 (SPACE) state.

2.2.1. Open circuit measurement for either binary state shall be made in accordance with *Fig. 17a*. The results of this measurement shall be as follows:

- the magnitude of the differential voltage (V_0) measured between the two generator output terminals shall not be more than 6.0 V;
- the magnitude of the voltage between either of the generator terminals and generator ground (V_{oa} and Y_{ob}) shall not be more than 6.0 V.

2.2.2. The test termination measurement shall be made with a test load of two resistors, 50 O ± 1%, connected in series between the generator output terminals as shown in *Fig. 17b*. The results of this measurement shall be as

- the magnitude of the differential voltage (V_t) measured between the two output terminals shall not be less than either 2.0 V or 50% of the magnitude of V_o, whichever is greater. For the opposite binary state, the polarity of V_t shall be reversed;

- the magnitude of the difference between V_t and $\overline{V}_t$, shall not be greater than 0.4 V;

a) Open-circuit measurement

$|V_0|$ = 6.0 V

$|V_{0a}|$ = 6.0 V

$|V_{0b}|$ = 6.0 V

Steady state logic input (1 or 0)

b) Test-termination measurement

50 Ω ± 1%

50 Ω ± 1%

$2.0\ V = |V_1| = 0.5\ |V_0|$

$\big||V_t| - |\overline{V_t}|\big| = 0.4\ V$

$\big||V_{0s}| - |\overline{V_{0s}}|\big| = 0.4\ V$

$|V_{0s}| = 3.0\ V$

c) Short-circuit measurement

$|I_{sa}|$ = 150 mA

$|I_{sb}|$ = 150 mA

-0.25 to +6.0 V

d) Power-off measurement
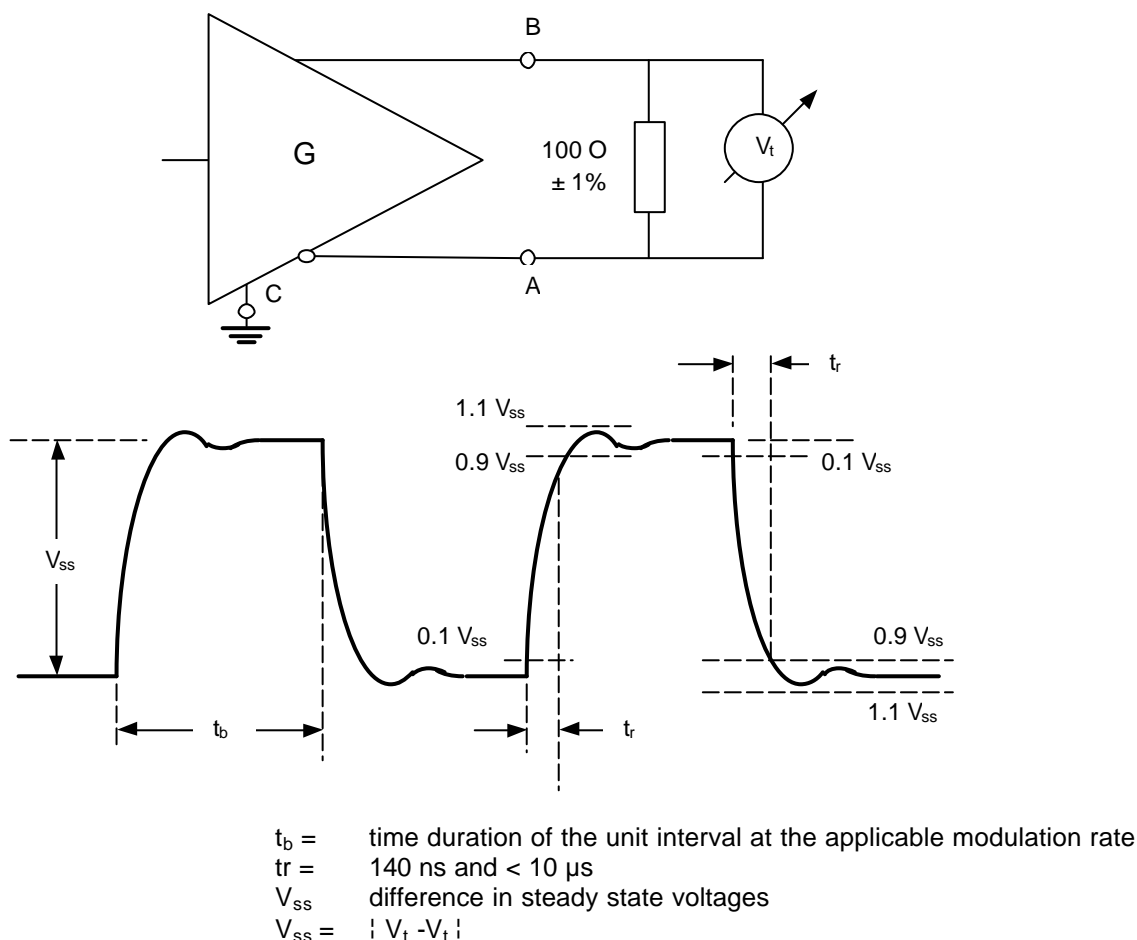
$|I_{sa}|$ = 150 mA

$|I_{sb}|$ = 150 mA

-0.25 to +6.0 V

Fig. 17.. Generator Parameter measurement

- the magnitude of the difference between V_{os} for one binary state and V_{os} for the opposite binary state shall not be greater than 0.4 V;

- the magnitude of the generator offset voltage, V_{os}, measured between the centre point of the test load and generator circuit shall not be greater than 3.0 V.

2.2.3. The short-circuit measurement shall be made with the generator output terminal short-circuited to the generator circuit ground as illustrated in *Fig. 17c*. The magnitudes of the currents flowing through each generator output terminal during this test shall not exceed 150 mA for either binary state.

2.2.4. The power-off measurement shall be made under power-off conditions and as illustrated in *Fig. 17d*. The magnitude of the generator output leakage currents *(I$_{xa}$ and I$_{xb}$)*. with voltages ranging between +6.0 and -0.25 V applied between each output terminal and generator circuit ground, shall not exceed 100 µA.

2.2.5.   The outpuit signal wave form measurement shall be made using a test load consisting of a non-inductive resistor with a value of 100 O ± 10% connected between the generator output terminals, as illustrated in *Fig. 18.*

t$_b$ =   time duration of the unit interval at the applicable modulation rate
tr =   140 ns and < 10 µs
V$_{ss}$ difference in steady state voltages
V$_{ss}$ =   ¦ V$_t$ -V$_t$ ¦

Fig. 18. - Generator output signal waveform

During transitions of the generator output between alternating binary states (one-zero-one-zero. etc.), the differential signal measured across the test load shall be such that the voltage monotonically changes between 10% and 90% of V$_{ss}$ in not less than 140 ns and not more than 10 µs. Thereafter, the signal voltage shall not vary more than 10% of V$_{ss}$ from the steady state value, until the next binary transition occurs. At no time shall the instantaneous magnitude of V$_t$ or V$_t$ exceed 6.0 V nor be less than 2.0 V. V,, is defined as the voltage difference between the steady state value of the generator output.

2.2.6.   The generator shall be capable of being placed in a high-impedance state and when in such state shall withstand a common-mode voltage swing of up to 7 V.

2.3.   Load characteristics

The load consists of one or more receivers (R) and an optimal cable termination resistance (R_t) as shown in Fig. 16. The electrical characteristics of a single receiver excluding both cable termination and fail-safe provision are specified in terms of the measurements described in §§ 2.3.1 to 2.3.7 and illustrated in *Figs. 19* to *21*. A circuit meeting these requirements results in a differential receiver having a high input-impedance.(> 4 kO), a small input threshold-transition region between -0.5 and +0.5 V and allowance for an internal bias voltage not exceeding 3 V in magnitude.

2.3.1.   The input current/voltage measurements shall be made with the voltage V_{ia}, (or V_{ib}) ranging between -10.0 and +10.0 V, while V_{ib} (or V_{ia}) is held at 0.0 V (ground). This measurement shall be made with the power supply to the receiver in both the power-on and power-off condition. The resultant input current I_{ia} (or I_{ib}) shall remain within the shaded region shown in *Fig. 19*.
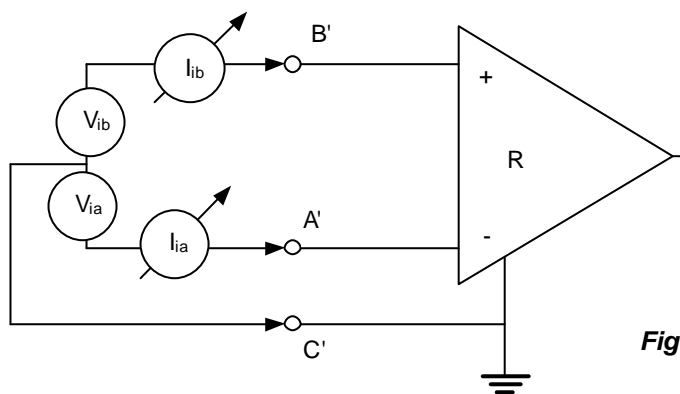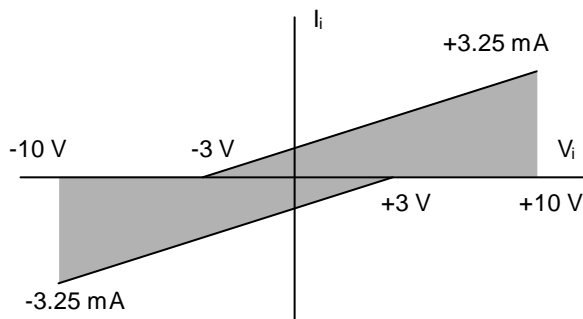

**Fig. 19. - Receiver input
current-voltage measurement**

2.3.2.   The input sensitivity measurement shall be made as illustrated in *Fig. 20* over the entire common mode voltage (V_{cm}) range of -15 to +15 V. The receiver shall not require a differential input voltage of more than 500 mV to correctly assume the intended binary state. Reversing the polarity of V_i shall cause the receiver to assume the opposite binary state. The receiver is required to maintain correct operation for differential input signal voltages ranging between 500 mV and 6 V in magnitude. The maximum voltage (signal plus common mode) present between either receiver input terminal and receiver circuit ground shall not exceed 25 V in magnitude. Application of Voltages less than the maximum voltage (signal plus common mode) of 25 V or a maximum differential signal of 15 V at the receiver input terminals shall not result in operational failure of the receiver. The common mode voltage (VCM) is defined as the algebraic mean of the two voltages appearing at the receiver input terminals (A' and B') with respect to the receiver circuit ground (C').
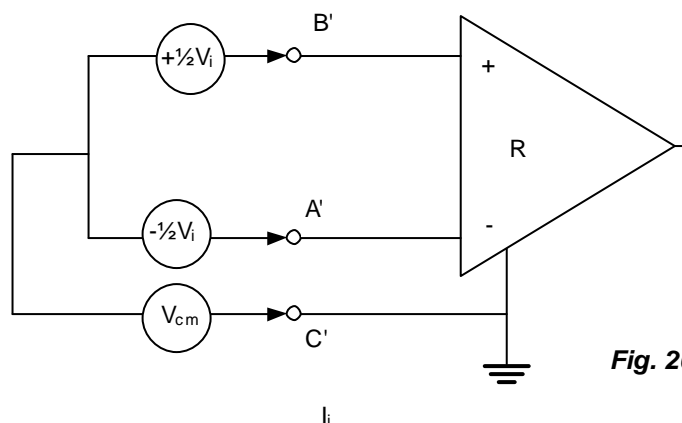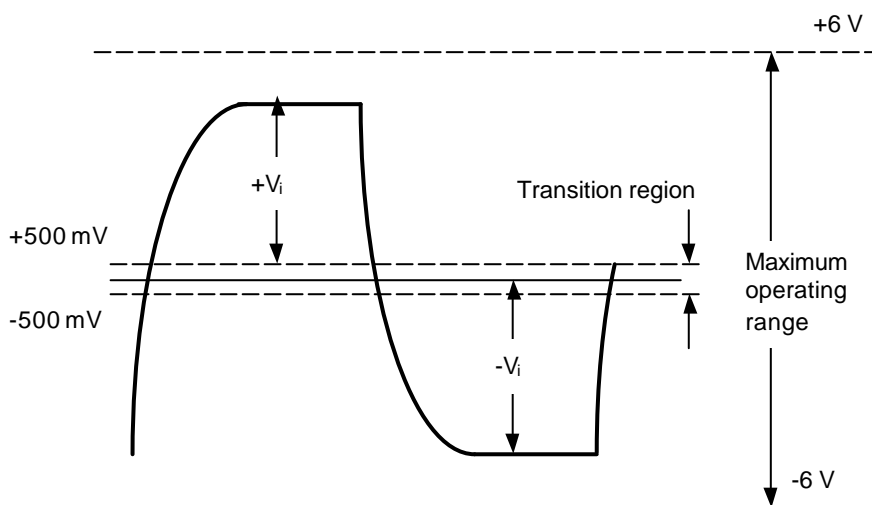
**Fig. 20. - Receiver Input sensitivity measurement**

Designers of terminating hardware should be aware that slow signal transitions with noise present may give rise to instability or oscillatory conditions in the receiving device and appropriate techniques should be implemented to prevent such behaviour; for example, adequate hysteresis may be incorporated into the receiver to prevent this condition.

2.3.3. The input balance measurement shall be made as illustrated in *Fig. 21*. The balance of the receiver input voltage/current characteristics and bias voltages shall be such that the receiver will remain in the intended binary state when a differential voltage (V_i) of 500 mV is applied through $500O \pm 1\%$ to each input terminal and V_{cm} is varied between -15 and +15 V. When the polarity of V_i is reversed, the opposite binary state shall be maintained under the same conditions.

2.3.4. The use of a non-inductive cable termination resistance (R_t) is recommended. A distributed resistive load or a combined R/C load may be required in some cases (see § 4.2.1) and the use of an active cable termination resistance is desirable for the purpose of reducing cross coupling when the bus controller is placed in a high-impedance state (see § 4.2.2). Care must be taken not to exceed the limits on total load resistance or sensitivity. Refer to § 2.3.7 for limits on the total load resistance.

2.3.5. The use of Multiple receivers is permitted. Caution must be exercised to avoid performance degradation due to signal-reflection effects from stub lines emanating from the load interface point to the receivers.

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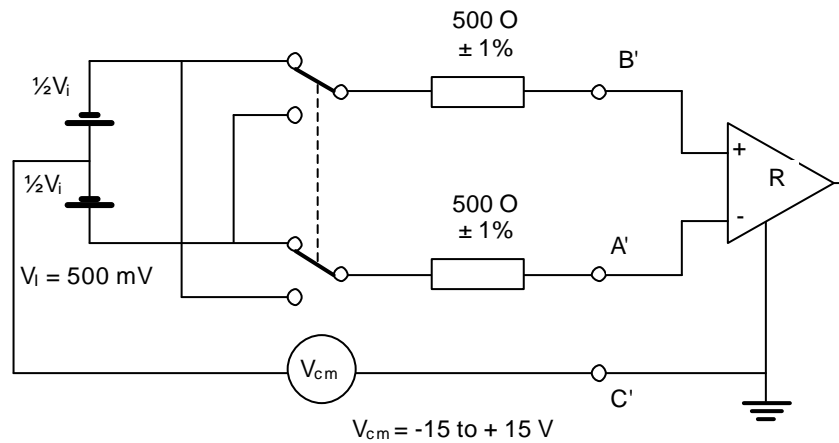
Fig 21 Receiver Input balance Measurement

2.3.6.   The interface system shall fail safe. This shall be accomplished by automatic disconnection of a tributary from the interface system in the event of a malfunction or power failure and incorporating in the receiver provisions to provide a steady binary MARK to protect against the following conditions:

- generator power off,
- generator in high-impedance state,
- both signal wires open or shorted (signal common return still connected),
- generator not implemented (signal leads may or may not be present),
- open connector (both signal leads and the common signal return are open simultaneously).

2.3.7.   The total load characteristics, including multiple receivers, failsafe provision, and cable termination shall have a combined resistance greater than 90 O between its input points (A' and B', *Fig. 16*) and shall not require a differential input voltage of more than 500 mV for all receivers to assume the intended binary state.

2.4.   Interconnecting cable characteristics

The physical and electrical characteristics of the interconnecting cable are given in §5 2.4.1 to 2.4.4; additional guidance is given in § 4. An interconnecting cable conforming to this standard will result in a transmission line with a nominal characteristic impedance of the order of 100 O at frequencies greater than 100 kHz, and a DC series loop resistance not exceeding 240 O over an operational loop length of nominally 1220 m. The cable may be composed of twisted or non-twisted (flat cable) conductors possessing the characteristics described in §§ 2.4.1 to 2.4.4. Most commonly-available cable used for telephone applications (non-loaded) will meet these specifications.

2.4.1.   Each conductor of the interconnecting cable shall be composed of either stranded or solid copper wire with a uniform overall diameter of at least 0.5 mm. The use of non-copper conductors is allowed provided they are of sufficient size to yield a DC wire resistance not exceeding 10 O per 100 m per conductor.

2.4.2.   Mutual pair capacitance, that is the capacitance between one wire in the pair and the other wire in the pair, shall not exceed 65 pF/m, and the value shall be reasonably uniform over the entire length of the cable.

2.4.3.   Stray capacitance, the capacitance between one wire in the cable and. all others In the cable sheath, with all others connected to ground, shall not exceed 130 pF/m, and shall be reasonably uniform over the entire length of the cable for any given conductor.

2.4.4.   Pair-to-pair balanced crosstalk is defined as the crosstalk between one pair of wires and any other pair of wires in the same cable. This crosstalk shall be attenuated by a minimum of 40 dB when measured at 150 kHz with each cable pair terminated in its characteristic impedance.

2.5.   Environment

A balanced voltage digital interface circuit conforming to this specification will perform satisfactorily at a data rate of 38.4 kbit/s providing that the following operational constraints are simultaneously observed.

The interconnecting cable length is a nominal maximum 1220 m and the cable is appropriately terminated. The common-mode voltage at the receiver shall lie within the range -15 to +15 V.

2.6.   Circuit protection

The balanced voltage digital interface generator and receiver device, in either the power-on or power-off condition and complying with this specification, shall not be damaged under the following conditions:

- generator open-circuit,
- short-circuit across the balanced interconnecting cable,
- short-circuit to any other lead having electrical characteristics in compliance with this standard,
- short-circuit to ground.

(The above faults may cause the power dissipation in the interface device to approach the maximum power dissipation tolerable for a typical integrated-circuit (IC) package. Caution should, therefore, be exercised when multiple generators or receivers are implemented in a single IC package, since only one fault per package may be tolerated at any one time without experiencing IC failure. It should also be noted that the generator and receiver device(s) complying with this specification may be damaged by spurious voltages applied between the input/output terminals and circuit ground. In applications where the interconnecting cable may be subject to a **severe** electro-magnetic environment or the possibility exists that it may be inadvertently connected to circuits not In compliance with this specification, additional protection should be employed as may be appropriate.)
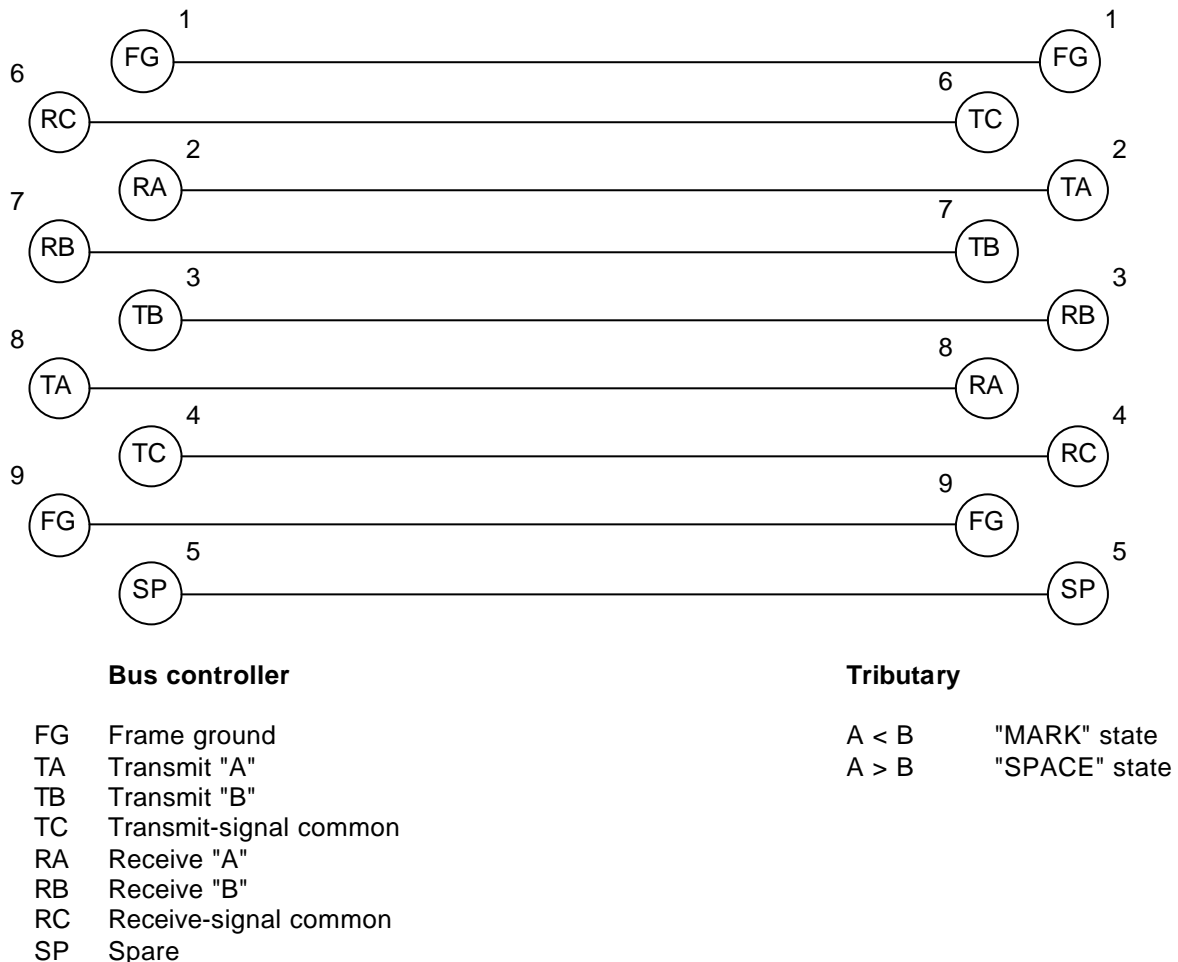
3.   Mechanical characteristics

3.1.   Interface. connector

The interface connect or shall be a 9-pin D-subminiature female (DE-9S with metric (M3) female screwlock). A single interface connector shall be associated with any particular tributary device. Multiple interface connectors may be utilized on a bus controller in the case of a multi-point system or when the bus controller must communicate with more than one interface system.

3.2.   Pin assignment

The pin assignments for the bus controller and tributary shall be as shown in *Fig. 22.* Use of the spare pin for unspecified communication or supervision is not in compliance with this specification. If used, it may not interfere with the normal operation of the standard interface system.

Bus controller   **Tributary**

FG   Frame ground   A < B   "MARK" state
TA   Transmit "A"   A > B   "SPACE" state
TB   Transmit "B"
TC   Transmit-signal common
RA   Receive "A"
RB   Receive "B"
RC   Receive-signal common
SP   Spare

Fig. 22.- Connector pin assignment

4.   Guidelines

When interconnecting equipment using the interface system described in this specification, consideration should be given to some of the problems that may be encountered due to the characteristics of the interconnecting cable, cable termination, the number of devices in use, and grounding arrangements.

4.1.   Cable

The interconnecting cable electrical characteristics are specified in § 2.4. The following is intended to be used as additional guidance when considering the operational constraints placed on the system by the cable parameters.

4.1.1.   The maximum length of cable separating the generator and receiver (load) is a function of modulation rate (influenced by the tolerable signal distortion), transmission losses, the amount of longitudinally-coupled noise, and ground potential difference introduced between the generator and receiver circuit grounds, as well as by cable balance. Increasing the physical separation and interconnecting cable length between the generator and receiver (load) interface points increases the system exposure to common-mode noise, signal distortion, and the effects of cable imbalance. Users are advised to restrict cable length to the minimum consistent with the generator/receiver (load) separation requirements, and whenever possible to utilize cable specifically designed for balanced data circuits.

4.1.2.   The nominal maximum cable length of 1220 m is based on empirical data for non-loaded, twisted-pair telephone cable with copper conductors 0.5 mm in diameter, terminated in a 100-11 resistive load. This length assumes a load signal-quality of:

- signal rise and fall time equal to, or less than, 10 gg;
- a maximum voltage loss between the generator and receiver (load) of 6 dB.

(The user is cautioned that the nominal limit of 1220 m does not take into account cable imbalance or common-mode noise beyond the limits set in this specification. Operation within the limit of 1220 m should result in a degradation of signal quality that will not exceed a zero-crossing ambiguity of 0.05 unit interval. It is recognised that many applications can tolerate a timing and amplitude distortion greater than this amount and in these cases correspondingly greater cable lengths may be employed. The use of cables specifically designed for the transmission of balanced data signals can also result in the ability to operate over substantially increased cable lengths.)

4.2.   Cable termination

The characteristics of the cable termination are specified in 5 2.3.4. The following is intended to be used as additional guidance when considering the operational constraints placed on the system by the termination resistance.

4.2.1.   The determination of the type of cable termination utilized and its value must take into account the characteristic impedance of twisted-pair cable; this is a function of operating frequency, wire size, wire type and the kind of insulating materials used. The characteristic impedance of non-loaded plastic-insulated twisted-pair telephone cable with copper conductors 0.5 mm in diameter is of the order of 100 O when measured at 100 kHz with a sine wave.

The characteristic impedance of any cable typically contains an inductive component which could adversely affect the wave shape aver extended cable lengths. Use of a composite R/C cable termination with a time constant of approximately three times the propagation delay of the cable may result in a significant improvement in the wave shape and a reduction in driving power requirements.

4.2.2.   The presence of stray capacitance between the interconnecting cable and any adjacent cable *(Fig.* 23) can result in interference being coupled to an adjacent cable when a transition occurs that is other than balanced. During normal operation, inter-cable coupling is at a minimum due to the use of a balanced transmission mode along with control of signal rise-times (see 5 2.2). When the driving device is placed in a high-impedance state, however, this control is no longer applied and the conductor in the pair that was at a positive value will go to a less positive value. This transition, being uncontrolled and of an unbalanced type, may be coupled into adjacent cables.
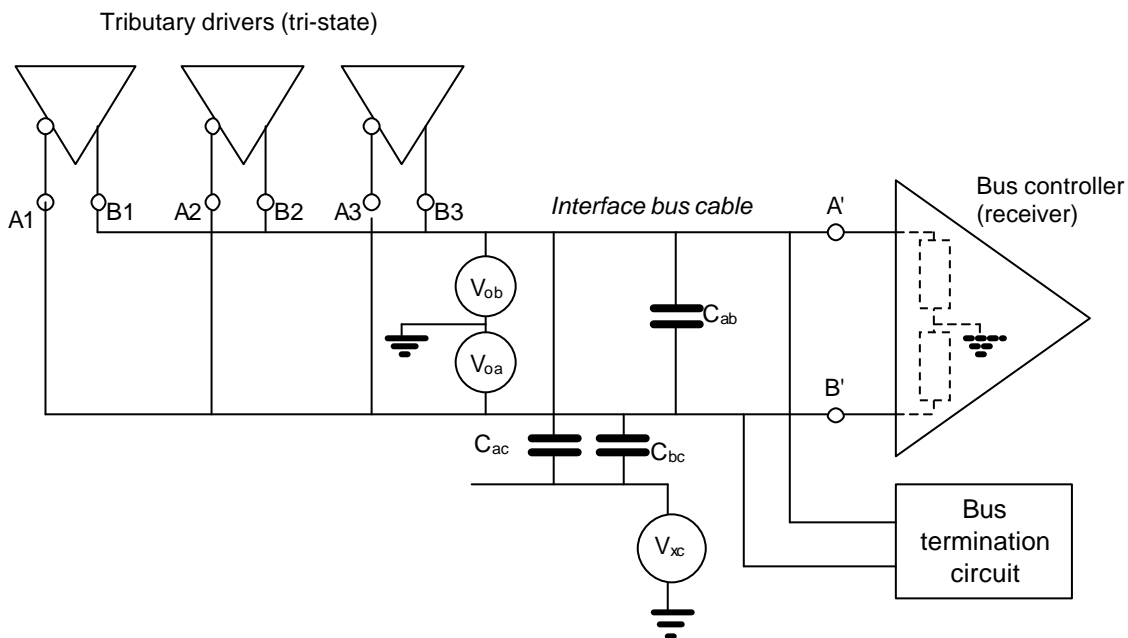
Fig. 23 - Cable model

Capacitive coupling of this type can be reduced or eliminated by utilizing shielded cables specifically designed for the transmission of digital data information. Although this approach is practical when installing the interface system in new plants, it may not be possible with existing facilIties. When utilizing non-shielded cable, the use of an active termination is recommended. An active termination of the type shown in *Figs. 24.*and *25* will result in a balanced transition to a voltage that is equal on both conductors of the cable pair. The circuit shown in *Fig.* 24 also provides a fail-safe bias on the bus an allows for higher impedance terminations, while the circuit shown in *Fig.* 25 is balanced with respect to the interface bus and does not introduce a differential bias on the line.
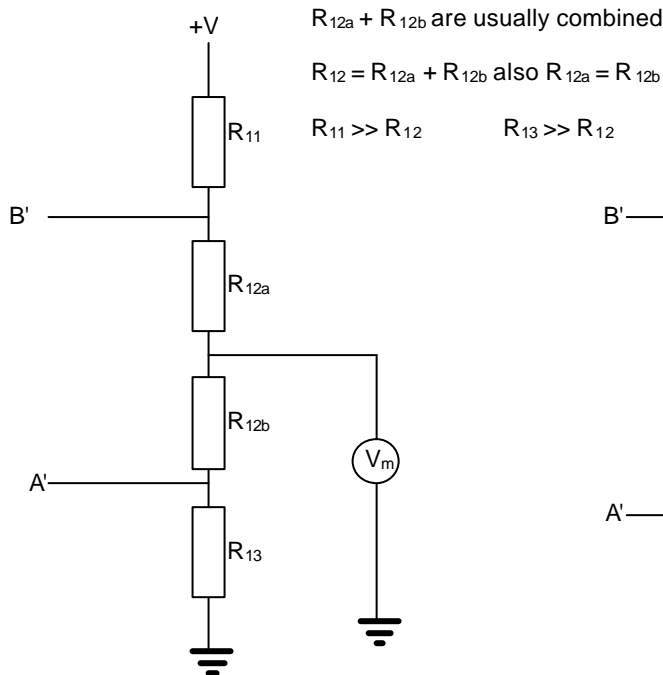
R$_{12a}$ + R$_{12b}$ are usually combined

R$_{12}$ = R$_{12a}$ + R$_{12b}$ also R$_{12a}$ = R$_{12b}$

R$_{11}$ >> R$_{12}$ R$_{13}$ >> R$_{12}$

R$_{22}$ = R$_{23}$

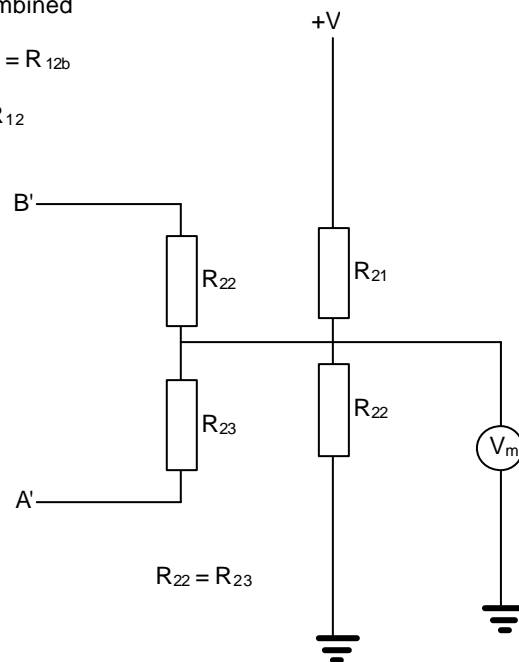**Fig. 24.- Terminator circuit 1**   **Fig. 25.- Terminator 'Circuit 2**

4.2.3.   In general, reliable operation of the balanced interface circuit is not particularly sensitive to the presence or absence of the cable termination resistor when operating at 38.4 kbit/s. The termination of the cable with a, non-inductive load of the order of 90 to 250 O tends to result in the preservation of the rise time in the generated signal and a reduction of line noise. Caution must be exercised in selecting the value of termination, as too low a value would result in a reduction in signal amplitude to the point where reliable operation of the system would be affected.

4.3. The data rate of 38.4 kbit/s can result in a system response time within the equivalent of one television picture period when the total number of tributaries is not excessive. Higher data-rates may be used when the operation of a specific system indicates this need. When higher data-rates are used, the device(s) shall first establish communication at 38.4 kbit/s. Operation at data-rates lower than 38.4 kbit/s is expressly prohibited due to the possible confusion of certain data-patterns with the BREAK sequence.

Bibliography

[1!   *Data processing - Open Systems Interconnection - Basic reference model.*
        International Standard ISO/DIS 7498, 1982.

[21   *Data communication - High-level data link control procedures - F11ame structure.*
        International Standard ISO 3309, 2nd edition, 1979.

[31   *Data communication - High-level data link control procedures - Elements of pro   cedures.*
        International Standard ISO 4335, 1st edition, 1979.

[41   *Data communication networks - Services and facilities, terminal equipment and interfaces.*
        CCITT Recommendations X.1 to X.29, Yellow Book, VIIth Plenary Assembly, Geneva 1980, Volume
        VIII, Fascicle VIII.2.

[51   *Guiding principles for the design of electronic equipment.*
        EBU document Tech. 3215, 2nd edition, 1980.

[61   *Data communication - 37-pin and 9-pin DTE/DCE interface connectors and pin   assignments.*
        International Standard ISO 4902, 1980.