Engineering Standard

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Synchronous Digital Hierarchy Transmission Systems

Document Responsibility: Communications Standards Committee

Saudi Aramco DeskTop Standards

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1 Scope

This standard covers mandatory requirements governing the design and implementation of digital transmission systems using Synchronous Digital Hierarchy (SDH) technology for fiber optic and digital microwave/radio systems that operate at speeds of 155 megabits per second and above.

The bit rates, interface specifications/requirements for transport of payloads [including digital signals of the Plesiochronous Digital Hierarchy (PDH) and Asynchronous Transfer Mode (ATM) cells], and multiplexing structures of the SDH line and terminal equipment are included in this standard.

This document can be attached to the purchase orders for procuring SDH equipment.

2 Conflicts and Deviations

Any deviations, providing less than the mandatory requirements of this standard require written waiver approval as per Saudi Aramco Engineering Procedure SAEP-302.

3 References

The selection of material and equipment, and the design, construction, maintenance, and repair of equipment and facilities covered by this standard shall comply with the latest edition of the references listed below unless otherwise noted.

3.1 Saudi Aramco References

Saudi Aramco Engineering Procedure

SAEP-302 *Instructions for Obtaining a Waiver of a Mandatory Saudi Aramco Engineering Requirement*

Saudi Aramco Engineering Standard

SAES-O-100 *General Requirements Safety and Security*

3.2 Industry Codes and Standards

International Telecommunication Union - Telecommunications Standardization Sector (ITU-T), formerly CCITT (The International Telegraph and Telephone Consultative Committee)

ITU-T Recommendation G.702 *Digital Hierarchy Bit Rates*

ITU-T Recommendation G703 *Physical/Electrical Characteristics of Hierarchical Digital Interfaces*

ITU-T Recommendation G.707 *Synchronous Digital Hierarchy Bit Rates*

ITU-T Recommendation G.708 *Network Node Interface for the Synchronous Digital Hierarchy*

ITU-T Recommendation G.709 *Synchronous Multiplexing Structure*

National Electrical Code

National Electrical Safety Code

4 Design Requirements

The latest recommendations of the International Telecommunication Union - Telecommunications Standardization Sector (ITU-T), as applicable, are hereby recognized as Saudi Aramco Engineering Standard SAES-T-360 "Synchronous Digital Hierarchy - Transmission Systems."

The ITU-T recommendations, as specified in Section 3.2, shall constitute a set of basic specifications of SDH equipment for deployment, interconnection and interworking between SDH network elements for transport of payloads including digital signals of Plesiochronous Digital Hierarchy (PDH) and ATM cells.

Any revision to ITU-T recommendations as listed in Section 3.2 shall automatically be deemed to change this standard to reflect the revision.

Commentary Note:

Subsequent Saudi Aramco Engineering Standards on other aspects of SDH, such as SDH network management, optical and microwave interface requirements, synchronization, etc., will be issued at a later date.

4.1 Digital Hierarchy Bit Rates

The following PDH bit rates shall be supported and carried by SDH transmission systems as lower level tributaries. The support of each individual or combination of bit rates should be based on specific Saudi Aramco application requirements.

Table-1

PDH Level	Bit Rates
1 (E-1)	2.048 Mb/s
3 (E-3)	34.368 Mb/s
4 (E-4)	139.264 Mb/s

In addition to the above PDH bit rates, the North American PDH bit rate of 44.736 Mb/s (T3) shall be supported.

4.2 Synchronous Digital Hierarchy Bit Rates

The transmission bit rate for the first-level of the synchronous digital hierarchy shall be 155.520 Mb/s and the higher SDH bit rates shall be obtained as integer multiples of the first-level bit rate of 155.520 Mb/s.

The higher SDH levels shall be denoted by the corresponding multiplication factor of the first-level rate.

The following bit rates shall constitute the synchronous digital hierarchy (SDH). (Ref. ITU-T Recommendation G.707)

4.3 Basic Multiplexing Principle and Multiplexing Elements

Figure 1 shows the relationship between various multiplexing elements that are defined below, and illustrates possible multiplexing structures.

4.4 Definitions

4.4.1 Synchronous Digital Hierarchy (SDH)

SDH is a hierarchical set of digital transport structures, standardized for the transport of suitably adapted payloads over physical transmission networks.

4.4.2 Synchronous Transport Module (STM)

STM is the information structure, which consists of information payload and section overhead (SOH) information fields in a block frame structure which repeats every 125 microseconds. A basic STM (STM-1) is defined at 155.520 Mb/s. Higher-order STMs (STM-N) are formed at rates equivalent to N (N =1 or 4 or 16) times multiples of this basic rate. The standardized STMs are listed in Table 2.

Table-2

Synchronous Digital Hierarchy Level	Hierarchical Bit Rates
1 (STM-1)	155.520 Mb/s
4 (STM-4)	622.080 Mb/s
16 (STM-16)	2.488 Gb/s

Notes: 1. The specification of SDH levels higher than 16 (STM-16) is under study in ITU-T. Higher levels will be included in the future as and when standardization is completed.

2. For SDH radio systems, the bit rates of sub-STM-1 (below 155 Mbits/s) level will be standardized in the future. If applicable in Saudi Aramco, sub-STM-1 rates will be included in this standard.

4.4.3 Virtual Container (VC)

VCs are information structures used to support Path Layer Connections in SDH. It consists of information payload and path overhead (POH) information fields in a block frame structure which repeats every 125 or 500 microseconds.

Two types of VCs have been standardized:

- Lower-order VCs (VC-1s and VC-2s; VC-1s are further classified as VC-11 and VC-12) and
- Higher-Order VCs (VC-3 and VC-4).

A lower-order VC comprises a single container (C-11s, C-12s or C-2s), plus the POH appropriate to that level.

A higher-order VC comprises either a single container (C-3 or C-4) or an assembly of TUG-2s or TUG-3s, together with POH appropriate to that level.

4.4.4 Administrative Unit (AU)

An AU (AU-3 or AU-4) is the information structure which provides adaptation between the higher-order Path Layer and the multiplex Section Layer. It consists of an information payload (the higher order VC) and an AU pointer.

AU-4 consists of a VC-4 plus an AU pointer which indicates the phase alignment of the VC-4 with respect to the STM-N frame. AU-3 consists of a VC-3 plus an AU pointer which indicates the phase alignment of the VC-3 with respect to the STM-N frame. In each case, the AU pointer location is fixed with respect to the STM-N frame.

4.4.5 Administrative Unit Group (AUG)

One or more AUs occupying fixed, defined positions in an STM payload are termed an AUG. An AUG consists of a homogeneous, byte-interleaved assembly of AU-3s or an AU-4.

4.4.6 Tributary Unit (TU)

A TU is an information structure which provides adaptation between the lower-order and the higher-order Path Layer. It consists of an information payload (the lower-order VC) and a TU pointer which indicates the offset of the payload frame start relative to the higher-order VC frame start.

The TU-n (n=1,2,3) consists of VC-n together with a TU pointer. TU-1s are further classified as TU-11, which carries VC-11, and TU-12, which carries either VC-11 or VC-12.

4.4.7 Tributary Unit Group (TUG)

One or more TUs, occupying fixed, defined positions in a higher order VC payload, are termed a TUG. TUGs are made up of different-size mixed capacity payloads.

A TUG-2 consists of a homogeneous assembly of TU-11s or TU-12s, or a TU-2.

A TUG-3 consists of a homogeneous assembly of TUG-2s or a TU-3.

4.4.8 Container: C-n (n=1-4)

A container is the information structure which forms the network synchronous information payload for a VC. For each of the defined VCs there is a corresponding container. Adaptation functions have been defined for many common network rates into a limited number of standard containers. These rates are defined in ITU-T Recommendation G.702.

Container C-1s are further classified as C-11 which carries the North American rate of 1.544 Mbits/s (T-1), and C-12, which carries the European rate of 2.048 Mbits/s (E-1). The containers for the rates associated with Saudi Aramco applications, as specified in Section 4.1, are;

- C-12 for 2.048 Mbits/s (E-1)
- C-3 for European 34.368 Mbits/s (E-3) or North American 44.736 Mbits/s (T-3)
- C-4 for 139.264 Mbits/s

4.4.9 Pointer (PTR)

A Pointer is an indicator whose value defines the frame offset of a VC with respect to the frame reference of the transport entity on which it is supported.

4.5 Frame Structure

4.5.1 Basic Frame Structure

An STM-N frame is shown in Figure 2 which indicates the three main areas of a standard STM frame:

- SOH
- AU pointers
- information payload

4.5.2 Section Overhead

Rows 1-3 and 5-9 of columns 1 to 9 x N of the STM-N in Figure 1 are dedicated to the SOH. The presently unused bytes are reserved for future standardization and shall not be used for any other purpose by the vendor or the user.

4.5.3 AU Pointers

The entire Row 4 of columns 1 to 9 x N of the STM-N in figure-1 is assigned for AU pointers. The application of pointers and their detailed specifications shall be in accordance with ITU-T Recommendation G.709, Section-3.

4.5.4 AUs in the STM-N

The STM-N payload shall support N AUGs where each AUG may consists of one AU-4 or three AU-3s.

4.6 Interconnection of STM-Ns

SDH is designed to be universal, allowing transport of a large variety of signals of different types. However, different structures can be used for the transport of VCs. The following interconnection rule shall be used:

- The rule for interconnecting two AUGs (based upon two different types of AU, namely AU-4 and AU-3) shall be to use the AU-4 structure. Therefore, the AUG based upon AU-3 shall be demultiplexed to the TUG-2 or VC-3 level, according to the type of the payload, and remultiplexed within an AUG via the TUG-3/VC-4/AU-4 route.
- This SDH interconnection rule shall not modify the interworking rules for

networks based upon different plesiochronous digital hierarchies and speech encoding laws.

4.7 Overhead Functions

4.7.1 Section Overhead (SOH)

SOH information is added to the information payload to create an STM-N. It includes block framing information and information for maintenance, performance monitoring and other operational functions. The SOH information is further classified into the regenerator section overhead (RSOH), which is terminated at regenerator functions, and the multiplex section overhead (MSOH) which passes transparently through regenerators and is terminated where the AUGs are assembled and disassembled.

Rows 1 to 3 of the SOH are designated as RSOH while rows 5 to 9 are designated to be MSOH. This is illustrated in Figure 3 for the case of STM-1. The assignment of the various SOH bytes in the STM-1,4,16 frames is illustrated in Figures 3, 4 and 5.

4.7.7.1 SOH Bytes Location

The location of SOH byte within an STM-N frame shall be in accordance with ITU-T Recommendation G.708.

4.7.1.2 SOH Bytes Description

a) Framing: A1, A2

Two types of bytes are defined for framing:

- A1: 11110110
- A2: 00101000

b) Data Communication Channel (DCC): D1 - D12

A 192 kb/s channel is defined using bytes D1, D2, D3 as a regenerator section DCC.

A 576 kb/s channel is defined using bytes D4 to D12 as multiplex section DCC.

c) Order Wire: E1, E2

These two bytes shall be used to provide orderwire channels for voice communication. E1 is part of the

RSOH and may be accessed at regenerators. E2 is part of the MSOH and may be accessed at multiplex section terminations.

d) User Channel: F1

This byte is the part of the RSOH which shall be available to the user.

The location of SOH bytes within an STM frame, and the applications and specifications of the SOH, shall be in accordance with ITU Recommendation G.708.

e) Network Note Interface (NNI)

NNI is defined as the interface at the network node for interconnecting with another network node. The specifications for physical electrical characteristics of the NNI are contained in ITU-T Recommendation G.703.

4.7.2 Virtual Container Path Overhead (VC POH)

VC POH provides for integrity of communication between the point of assembly of a VC and its point of disassembly. There are two categories of VC POH:

- Lower-order VC POH (VC-1/VC-2 POH)
- Higher-order VC POH (VC-3/VC-4 POH)

Lower-order VC POH is added to the container (C-1/C-2) when the VC-1/VC-2 is created. Among the functions included in this overhead is VC path performance monitoring, signals for maintenance purposes and alarm status indications.

VC-3 POH is added to either an assembly of TUG-2s or a C-3 to form a VC-3. VC-4 POH is added to either an assembly of TUG-3s or a C-4 to form VC-4. Among the functions included within this overhead is VC path performance monitoring, alarm status indications, signals for maintenance purposes and multiplex structure indications (VC-3/VC-4 composition).

POH descriptions and specifications shall be in accordance with ITU-T Recommendation G.709.

4.8 Basic Multiplexing Structure

The relationship between the various multiplexing elements is shown in Figure 6.

4.9 Multiplexing Method

4.9.1 Multiplexing of AUs into STM-N

The arrangement of N AUGs multiplexed into STM-N (multiplexing of AU-4s and AU-3s into STM-N via AUG) shall be in accordance with ITU Recommendation G.709.

4.9.2 Multiplexing of TUs into VC-4 and VC-3

The arrangement of TUG-3s multiplexed in VC-4, multiplexing of TU-3s via the TUG-3, multiplexing of TUG-2s via TUG-3, multiplexing of TUG-2s into a VC-3, multiplexing of TU-2s via TUG-2s and multiplexing of TU-1s via TUG-2s into STM-N frame shall be in accordance with ITU-T Recommendation G.709.

4.9.3 Maintenance Signals

An alarm indication signal (AIS) is a signal sent downstream as an indication that an upstream failure has been detected and alarmed.

Maintenance signals (the bit positions and code assignments for section and path AIS) shall be in accordance with ITU-T Recommendation G.709.

4.9.4 Timing Recovery

A suitable bit pattern which prevents a long string of 1s and 0s is required to maintain sufficient bit timing at the interface. This is provided by using a scrambler.

The requirement, operation, functional specifications and the limitations of the scrambler shall be in accordance with ITU-T Recommendation G.709.

4.10 Pointers

4.10.1 AU Pointer

The AU pointer provides a method of allowing flexible and dynamic alignment of the VC within the AU frame. The location, value, frequency justification, new data flag, generation and interpretation of the Au pointer shall be in accordance with ITU-T Recommendation G.709.

4.10.2 TU-3 and TU-1/TU-2 pointer

The TU-3 pointer provides a method of allowing flexible and dynamic alignment of VC-3 within the TU-3 frame, independent of the actual content of the VC.

The TU-1 and TU-2 pointers provide a method of allowing flexible and dynamic alignment of the VC-1/VC-2 within the TU-1 and TU-2 multiframes, independent of the actual contents of the VC.

The location, value, frequency justification, new data flag, generation and interpretation of the TU pointer shall be in accordance with ITU-T G.709 Recommendation.

4.11 Mapping of Tributaries into VCs

For Saudi Aramco applications, the SDH virtual containers (VCs) shall be capable of mapping the following PDH tributaries for transport through the SDH network:

- Asynchronous mapping of 139.264 Mb/s into VC-4
- Asynchronous mapping of 44.736 Mb/s (North American) into VC-3
- Asynchronous mapping of 34.368 Mb/s into VC-3
- Asynchronous mapping of 2.048 Mb/s into VC-12

The mapping of PDH tributaries shall be in accordance with ITU-T Recommendation G.709.

4.11.1 Mapping of ATM cells

In addition to the PDH tributaries, the ATM (Asynchronous Transfer Mode) cells shall be capable of being mapped into the SDH transport system. At present, mapping of ATM cells into VC-4 only has been standardized. The SDH equipment shall be capable of mapping of ATM cells into VC-4 and, in the future, into other VCs as the standards are finalized.

4.11.2 Mapping of ATM cells into VC-4

The ATM cell stream is mapped into C-4 with its octet boundaries aligned with the C-4 byte boundaries. The C-4 is then mapped into VC-4 with the VC-4 POH. The ATM cell boundaries are thus aligned with the VC-4 byte boundaries. Since the capacity of C-4 (2340 bytes) does not match exactly with the integer multiple of the ATM cell length (53 bytes), an ATM cell may cross the C-4 boundary.

The H4 byte in the AU pointer field shall be used for indicating the frame offset as multiframe indicator for mapping of ATM cells.

The information field (48 bytes) of the ATM cell shall be scrambled before mapping into the VC and descrambled at the termination of the

VC signal before being passed to the ATM layer. A self-synchronizing scrambler shall be used which will operate for the duration of the cell information field only, and shall remain suspended during the 5-byte ATM header field.

The generator polynomial of the self-synchronizing scrambler and the coding, operation and permissible range of values of the multiframe indicator (H4) shall be in accordance with ITU-T Recommendation G.709.

5 Installation

The installation of SDH equipment and system for fiber optics and digital microwave radio systems shall comply with this standard, SAES-O-100 (General Requirements, Safety and Security), The National Electrical Code, National Electrical Safety Code and other referenced and applicable standards and specifications.

The instructions issued by manufacturers shall also be complied with, to avoid the possibility of violating manufacturer's equipment warranty conditions.

6 Certification and Acceptance

The vendor of SDH products is required to certify that the equipment delivered meets ITU-T/CCITT specifications. If and where applicable, the vendor shall also certify that the equipment shall be modified to comply with future enhancements of ITU-T Recommendations through upgrade or replacement.

Revision Summary

8 November 2010	Revised the "Next Planned Update". Reaffirmed the contents of the document, and reissued with no other changes.
8 June 2011	Editorial revision to change the document's Primary Contact Person.
3 June 2012	Editorial revision to change the primary contact.

Figures 1 – 6

Figure 1 – Generalized Multiplexing Structure

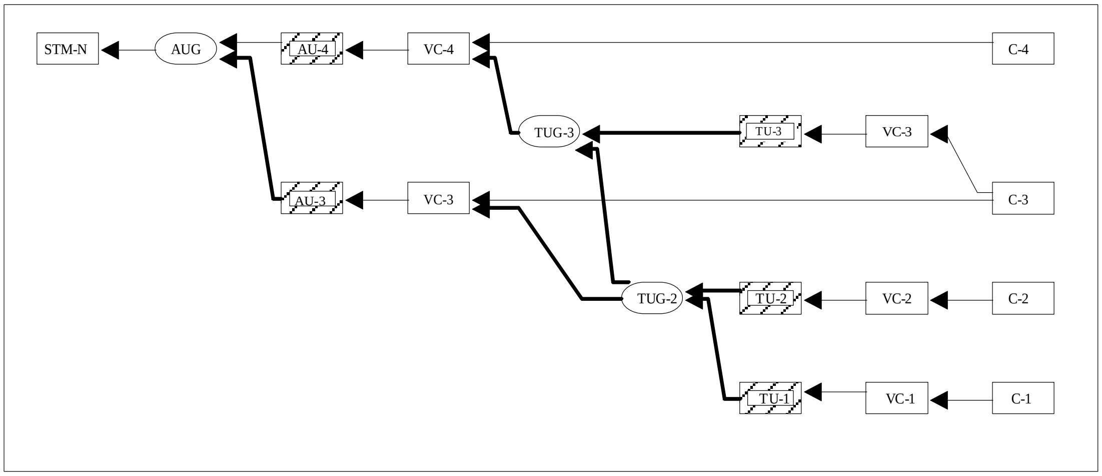


Figure 2 – STM-N Frame Structure

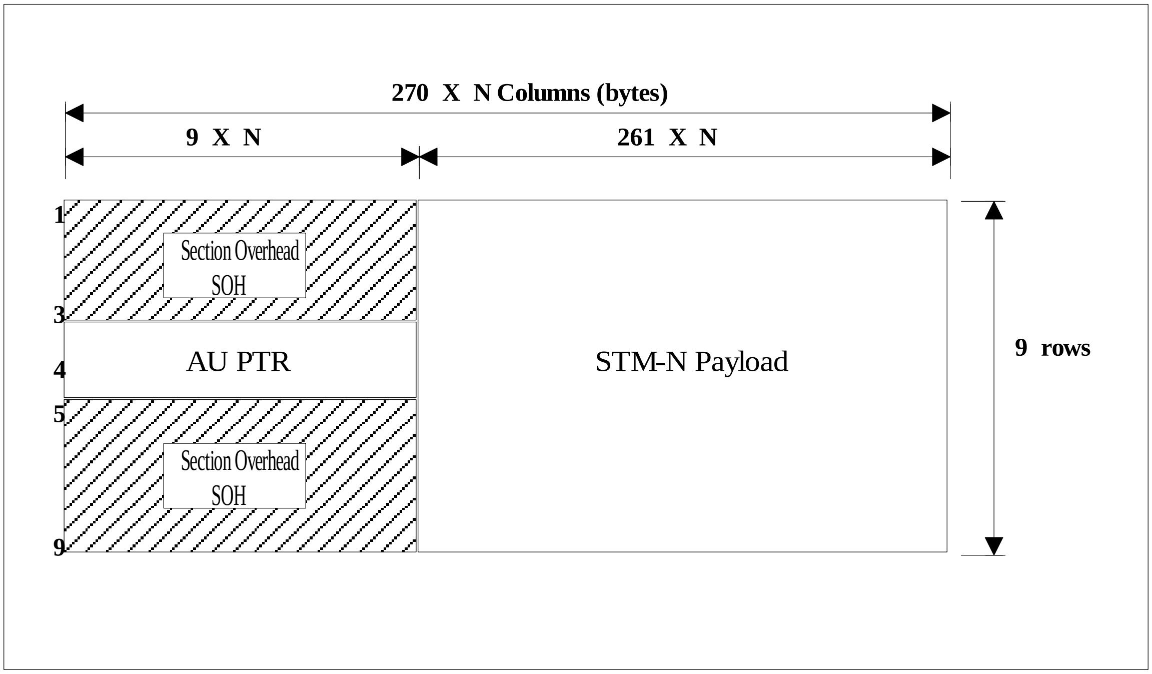
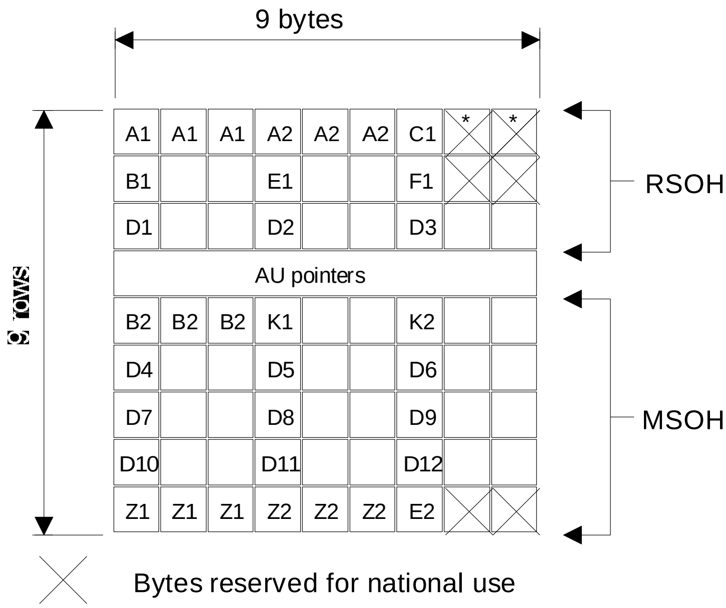


Figure 3 – STM-1 SOH

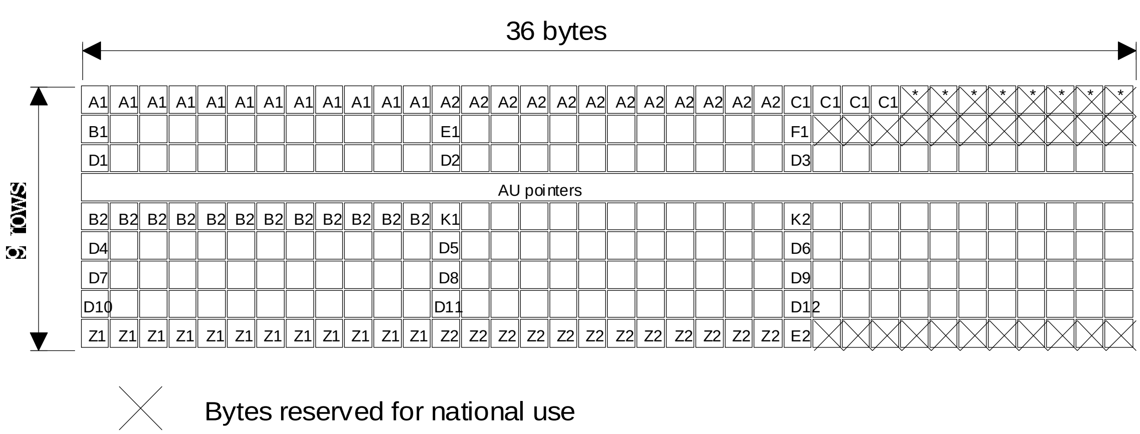


Bytes reserved for national use

* Unscrambled bytes. Therefore care should be taken with their content

Note - All unmarked bytes are reserved for future international standardization

Figure 4 – STM-4 SOH

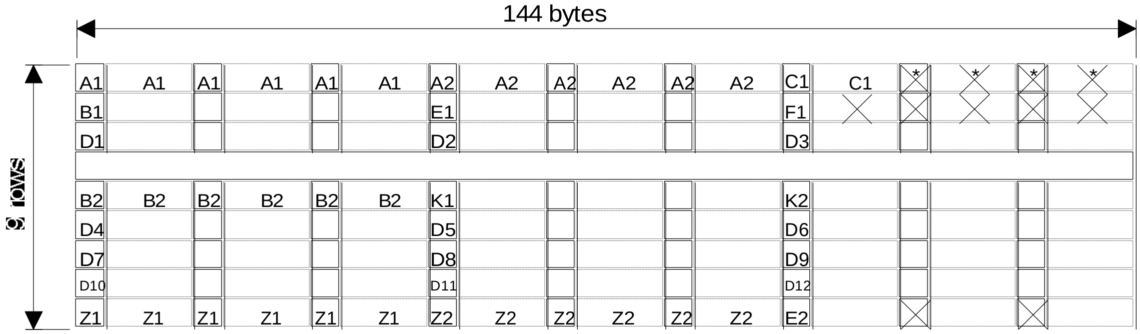


Bytes reserved for national use

* Unscrambled bytes. Therefore care should be taken with their content

Note - All unmarked bytes are reserved for future international standardization

Figure 5 – STM-16 SOH



Bytes reserved for national use

* Unscrambled bytes. Therefore care should be taken with their content

Note - All unmarked bytes are reserved for future international standardization

Figure 6 – Multiplexing Structure