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Electrical and Mechanical Interface Characteristics and Line Control Protocol
Using Communication Control Characters for Serial Data Link Between a
Direct Numerical Control System and Numerical Control Equipment Employing
Asynchronous Full Duplex Transmission

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EIA STANDARD

Electrical and Mechanical Interface Characteristics and Line Control Protocol Using Communication Control Characters for Serial Data Link Between a Direct Numerical Control System and Numerical Control Equipment Employing Asynchronous Full Duplex Transmission

EIA-484-A

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JUNE 1995

ELECTRONIC INDUSTRIES ASSOCIATION
ENGINEERING DEPARTMENT



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**ELECTRICAL AND MECHANICAL INTERFACE CHARACTERISTICS
AND
LINE CONTROL PROTOCOL USING COMMUNICATION CONTROL CHARACTERS
FOR
SERIAL DATA LINK BETWEEN A DIRECT NUMERICAL CONTROL SYSTEM
AND
NUMERICAL CONTROL EQUIPMENT EMPLOYING ASYNCHRONOUS
FULL DUPLEX TRANSMISSION**

**(From EIA Standards Proposal Numbers: 1310-A for EIA-484 and 2956 for EIA-484-A,
formulated under the cognizance of EIA IE-31 Committee on Numerical Control Systems and
Equipment)**

Prepared by

**ELECTRONIC INDUSTRIES ASSOCIATION
IE-31 Committee on Numerical Control Systems and Equipment**

**ASYNCHRONOUS COMMUNICATIONS FOR NUMERICAL CONTROL
EIA-484-A**

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Electrical and Mechanical Interface Characteristics and Line Control Protocol using Communications Control Characters for Serial Data Link between a Direct Numerical Control System and Numerical Control Equipment Employing Asynchronous Full Duplex Transmission.

FOREWORD

The information and comments contained in this FOREWORD should not be considered part of the standard. They have been included for clarification and guidance purposes only.

The increasing use of computers and related equipment in Direct Numerical Control (DNC) Systems for storage and distribution of machine programs to numerically controlled machines and for communication between various components of DNC systems has demonstrated the need for a standard data communication link between the DNC and the numerical control unit. As a result, the EIA Committee IE-31 which is made up of representatives of numerical control system builders, machine builders and users has prepared this standard for use by people specifying, building and using DNC systems.

After reviewing the needs of NC and DNC users and system builders large and small, and taking into account the parallel standardization efforts in Europe under the cognizance of the International Standards Organization, it was concluded that the link described in this standard would meet the requirements of most users.

For Revision A of this standard a normative Annex A was added. This annex describes a communications architecture based, on the communications link and protocol described in this standard, and EIA-511. This revision is in response to a request from numerical control systems builders to create a relatively low-cost, easy to implement, point-to-point communications system using EIA-511.

The attributes of the link described in this standard is a full duplex, asynchronous link based on the use of control characters as described in the ANSI Standard X3.28-1976. While consideration was given to a synchronous link based on ANSI Standard X3.66 for Advanced Data Communication Control Procedures (ADCCP) and its bit oriented protocol, such sophistication was considered unnecessary for most applications. Consequently, the synchronous transmission under bit oriented protocol is not within the scope of this standard.

In order to reduce the possibility of misinterpretation and to provide continuity between ANSI X3.28 and this document, certain exact text and terminology have been excerpted from X3.28.

The protocol defined in this standard is not intended to interface directly to a complex multi-drop communication network. Complex types of communication networks such as CCITT's X.25 typically can be supplied with node controllers. This standard should be considered as the communications interface between the node controller and the NC equipment.

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The protocol defined in this standard has been designed in such a manner as to never allow undetected redundant data to be transmitted. Therefore, when a situation arises where undetectable redundant data may possibly be transmitted (that is, transmission of the same data block twice), the protocol defined in this standard shall abort rather than forcing the user to determine the validity of the data. Also, the loss of **STX** due to a transmission error or misinterpretation is an unrecoverable error. Lastly, the two octets following **ETX** always must be interpreted as CRC.

This standard defines initialization, message transmission, termination and error recovery at the line control level only. This standard does not address the use or control of the Information Field. User level protocol, which defines the data content and control of the Information Field, is the subject of EIA-511. Since Timer values are system and implementation dependent, a calculation procedure is presented in D.

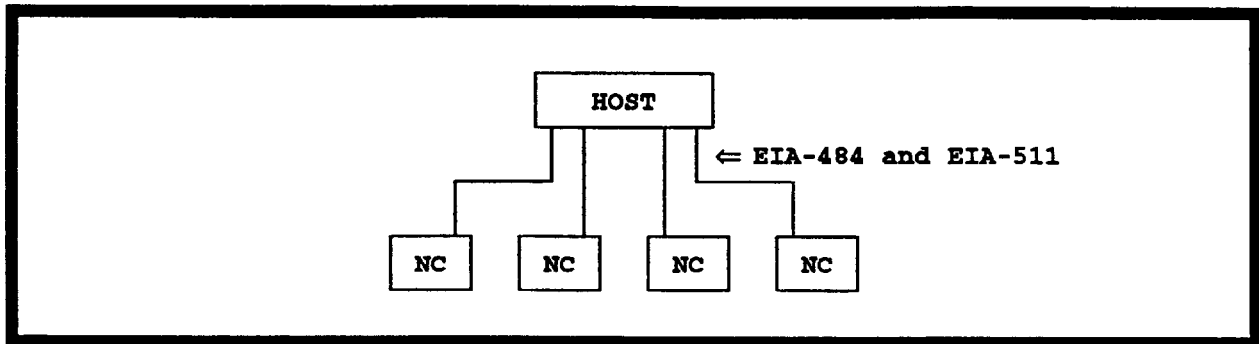
There are many possible applications of the protocol defined in this standard. The following examples illustrate possible uses.

The first example illustrates a method showing how one or more numerical control units can be connected to a DNC host computer.

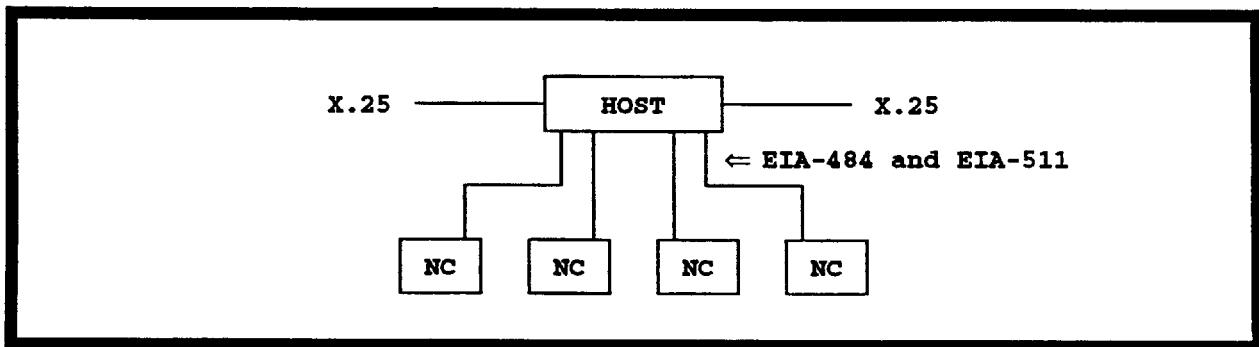
The second example illustrates a method showing how one or more numerical control units can be connected to a DNC host computer and where the host computer is also the interface to a higher level communication link, such as X.25.

The third example illustrates a technique used to connect a numerical control to a node controller in a high level communication system, such as X.25.

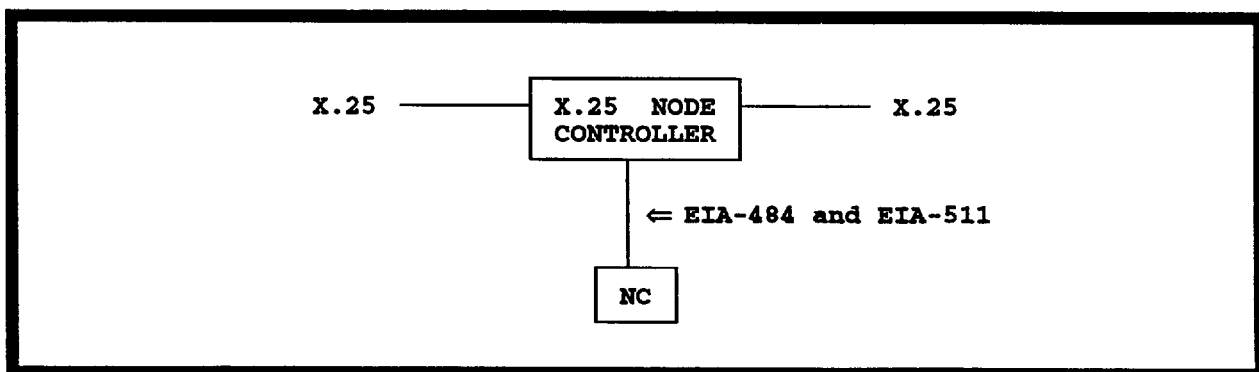
EXAMPLE 1



EXAMPLE 2



EXAMPLE 3



The following is a list of standards referenced by this document:

EIA-232-C	Interface Between Data Terminal Equipment And Data Communication Equipment Employing Serial Binary Data Interchange
EIA-274-D	Interchange Variable Block Data Format Positioning For Contouring, And Contouring/Positioning Numerically Controlled Machines
EIA-358-B	Subset Of American National Standard For Information Interchange For Numerical Machine Control Perforated Tape (EIA-358-B-79)
EIA-422-A	Electrical Characteristics Of Balanced Voltage Digital Interface Circuits
EIA-423-A	Electrical Characteristics Of Unbalanced Voltage Digital Interface Circuits
EIA-449	General Purpose 37-Position And 9-Position Interface For Data Terminal Equipment And Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange
EIA-511 1989-24-03	Manufacturing Message Specification - Service definition and Protocol
EIA-566	Numerical Control Message Specification
ANSI X3.4-1977	American National Standard Code For Information Interchange (ASCII)
ANSI X3.15-1976	Bit Sequencing Of The American National Standard Code For Information Interchange In Serial-By-Bit Data Transmission
ANSI X3.16-1976	Character Structure And Character Parity Sense For Serial-By-Bit Data Communication In The American National Standard Code For Information Interchange
ANSI X3.28-1976	Procedures For The Use Of The Communication Control Characters Of The American National Standard For Information Interchange In Specified Data Communications Links
IEEE Std 802.2-1985	Logical Link Control
ISO 7498 1984-10-15	Information Processing Systems - Open Systems Interconnection - Basic Reference Model
ISO 8649 1988-12-15	Information Processing Systems - Open Systems Interconnection - Service definition for the Association Control Service Element
ISO 8650 1988-12-15	Information Processing Systems - Open Systems Interconnection - Protocol specification for the Association Control Service Element

ISO 8824 1987-11-15 Information Processing Systems - Open Systems Interconnection -
Specification of Abstract Syntax Notation One (ASN.1)

ISO 8825 1987-11-15 Information Processing Systems - Open Systems Interconnection -
Specification of Basic Encoding Rules for Abstract Syntax Notation One
(ASN.1)

1. INTRODUCTION

1.1 Purpose

This standard is intended to serve as a guide in the coordination of design and implementation of digital data communication links between Direct Numerical Control (DNC) Systems and Numerical Control Units in the machine shop and the automated factory. It is intended to meet the present and future needs of such links requiring:

- Two way simultaneous message transfer
- Error Protection
- Noise rejection
- Transparency to the data
- Independence from higher level protocols
- Point to point communications
- Switched or non-switched links¹
- Transmission via Modems

An additional facet of the purpose is to establish standards to permit DNC systems and Computer Numerical Control units of the same or different vendor source and having a common messaging syntax and protocol. EIA-511 is such a standard.

The intended communications may include but are not limited to:

- EIA-274 Format Machine Programs
-
- ISO 6582 ESSI Format Machine Programs
- EIA-494 Binary CL (BCL) Exchange Data
- BINARY Data including CNC executives and diagnostic programs
- EIA-358 Code ("ASCII" NC subset)
- GRAPHICS Data
- EIA-511 Manufacturing Messaging Syntax and Protocol

¹ NOTE: "Switched links" may require an EIA-232-C or EIA-423-A interface until EIA-422-A is generally implemented.

1.2 Scope

1.2.1 This standard specifies services whose architecture can be described in the context of the physical layer architecture (1) and the data link layer architecture (2) of the ISO Open Systems Interconnection Basic Reference Model - ISO 7498.

1.2.2 This standard specifies the electrical characteristics of the interface, the mechanical characteristics and pin assignment of the connectors, the signal names, the line control protocol using communication control characters, and the means for error recovery for a bit serial digital data link employing asynchronous full duplex transmission. This standard does not address the user level language or protocol (reference EIA-511) except for the requirement that it shall be transparent to the user level information.

1.2.3 The definitions of terms used in this standard are in accordance with EIA Automation Bulletin 3C "Glossary of terms for Numerically Controlled Machines". Additional terms are defined in Annex C.

1.2.4 The electrical characteristics of the interface are in accordance with EIA-422-A "Electrical Characteristics of Balanced Voltage Digital Circuits". EIA-232-C or EIA-423 may be optionally used to interface MODEMS.

1.2.5 The mechanical characteristics of the interface are defined as a subset of EIA-449 "General Purpose 37-Position and 9-Position Interface for Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange".

1.2.6 The line control protocol is based on ANSI Standard X3.28-1976 "American National Standard Procedures for the use of the Communication Control Characters of American National Standard Code for Information Interchange¹ in Specified Data Communication Links". A method is defined in this standard to permit transmission of binary data.

The specific protocol in this standard is a composite protocol based on subcategories D1 and F1 as defined in ANSI X3.28-1976. The protocol description in terms of ANSI X3.28 is: "Two Way Simultaneous Operation, Message Independent Blocking, Cyclic Checking, Alternating Acknowledgements, and Transparent Heading and Text".

¹ NOTE: ASCII-ANSI X3.4-1977

1.2.7 The Line protocol specified in this standard addresses the following:

- Establish and terminate transmission
- Transfer of messages between stations
- Acknowledgement of messages
- Order of bits
- Error detection and recovery

1.3 Transmission Characteristics

1.3.1 Transmissions shall occur asynchronously serial-by-bit and serial-by-character.

1.3.2 The character structure for asynchronous data communication shall consist of ten signal elements having equal time intervals: one "Ø" (spacing) start element, eight data bits, and one "1" (marking) stop element. Data Transmission is in accordance with American National Standard Code for Information Interchange in Serial-by-Bit Data transmission, ANSI X3.15-1976 which specifies the least significant bit shall be transmitted first.

2. LINE CONTROL PROCEDURES-GENERAL

2.1 Communication Control Characters

2.1.1 The control characters referenced in this standard are those defined in ANSI X3.4-1977 "Code For Information Interchange". The control characters are coded as shown in the following table:

Table 2.1.1
Communication Control Character Encoding

DLE	X'90'
ENQ	X'05'
ETX	X'03'
STX	X'82'
NAK	X'95'
EOT	X'84'
;	X'BB'
1	X'B1'
Ø	X'30'

2.1.2 The communication control character sequences **DLE STX** and **DLE ETX** are defined for use as Information Field delimiters and are, therefore, integral parts of a message.

2.1.3 The communication control character sequences **DLE EOT**, **ACKN** and **DLE** are defined for use on each link independent of their use on other links and, therefore, are not required to be propagated through successive links in a multiple-link system. In multiple-link systems, however, the functional properties of these control characters may be required to be passed through the system. This standard does not describe means for the propagation of such information beyond the defined DNC to CNC link.

2.2 Code Extension Sequences Using **DLE**

This section specifies the method of providing additional communication control functions through the definition of code extension sequences using **DLE**. The method is a subset of that specified in ANSI X3.28-1976. For examples see 3.1.1.

2.2.1 The character **DLE** is used as a prefix to one additional ASCII character to form a sequence representing a communication control function not directly represented by a single control character.

2.2.2 A code extension sequence begins with **DLE** and is immediately followed by one ASCII character. The code extension sequence characters are limited to those defined in 3.1.

2.3 Aborts and Interrupts

The sending station may need to end a transmission in an unusual manner such that the receiving station disregards that portion of the transmission which has been received. These procedures are called sending station aborts.

The receiving station may need to cause the sending station to stop sending, either temporarily or permanently. These procedures are called temporary interrupts and receiving station aborts respectively.

2.3.1 Sending Station Abort Procedures

2.3.1.1 Description

The sending station, in the process of sending several messages, decides to prematurely terminate transmission to the particular station. Such a procedure is called a sending station abort.

2.3.1.2 Application

2.3.1.2.1 Sending station abort procedures may be used by a sending station when, in the process of sending multiple messages, it determines that it should prematurely terminate transmission to the particular receiving station. Such a determination would be caused by the processor's not receiving the remaining messages in time from a peripheral device or another communication line; the need for a higher priority message to be transmitted to the same or another station; the temporary inability of the sending station to continue transmission; etc.

2.3.1.2.2 Sending station abort procedures may be used to accomplish a transmission abort condition; that is the sending station prematurely terminates the transmission.

2.3.1.3 Procedures

Sending station abort procedures are accomplished by the sending station transmitting a **DLE EOT** at any time. The receiving station detects this sending station abort procedure by recognizing receipt of **DLE EOT**. Receipt or transmission of **DLE EOT** resets all stations on the link. Refer to 4.2 for re-establishing the link.

In issuing **DLE EOT**, a reply from the receiving station is not required.

When termination occurs, both receiving stations and both sending stations are simultaneously disconnected.

2.3.2 Receiving Station Abort Procedure

2.3.2.1 Description

The receiving station, in the process of receiving several messages, causes the sending station to cease transmission. Such a procedure is called a receiving station abort.

2.3.2.2 Application

Receiving station abort may be used by the receiving station to cause the transmission to be aborted because it is not in condition to receive.

2.3.2.3 Procedures

Receiving station aborts are accomplished by the receiving station transmitting **DLE EOT** at any time. The **DLE EOT** resets all stations on the link.

2.3.3 Temporary Interrupt Procedure--**WACK**

2.3.3.1 Description

After receipt of a message, the receiving station affirmatively acknowledges the information received and also indicates that it is temporarily unable to receive additional data by transmitting the **WACK** control function. The sending station must then delay transmission of any subsequent messages to that station until it has determined that the receiving station is once again ready to receive. Such a procedure is called temporary interrupt.

2.3.3.2 Application

Temporary interrupt may be used by a receiving station to delay the receipt of additional data until it has the opportunity to allocate a buffer to contain the next message.

2.3.3.3 Procedures

Temporary interrupt is accomplished by the receiving station transmitting the **WACK** control character sequence consisting of a **DLE** character followed by a semicolon character. It is transmitted in lieu of the appropriate affirmative acknowledgment (**ACKN**). The **WACK** response indicates that the receiving station received the last message correctly, but that it is temporarily unable to accept additional data.

Upon receipt of **WACK**, the sending station may release the information just transmitted from storage and prepare for transmission of the next message. However, before actually initiating such a transmission, the sending station must first determine the state of readiness of the receiving station by transmitting the control character sequence **DLE ENQ** to the receiving stations.

The receiving station shall respond to **DLE ENQ** with the **WACK** sequence if it is still unable to receive. The sending station may then repeat the **DLE ENQ** query. The receiving station shall continue to transmit the **WACK** sequence in response to **DLE ENQ** until it is ready to receive

additional data, at which time it shall respond with the appropriate **ACKN** (see 2.4.2.2). Upon receipt of the appropriate **ACKN**, the sending station shall resume sending additional data.

If a response to **DLE ENG** is not received during the **DLE ENG/WACK** interchange, the sending station shall exit to the Response Timer Time-Out error recovery procedure (see 2.4.2.1.4).

If an invalid response to a **DLE ENG** is received during the **DLE ENG/WACK** interchange, the sending station shall transmit **DLE ENG** up to five additional times with appropriate timeouts between transmissions in order to solicit a valid response. After six unsuccessful attempts, the sending station shall transmit **DLE EOT**.

Alternatively, upon receipt of the **WACK** sequence from the receiving station, the sending station may, as appropriate:

- initiate a sending station abort function, or
- transmit a **DLE ENG** sequence.

2.4 Recovery Procedures

2.4.1 General

Recovery procedures are system guidelines that should be used by all stations, as applicable. In some cases these recovery procedures can only detect the error condition and then notify the operator or the processor program, or both. In more sophisticated cases automatic recovery is partially or completely possible. In still other cases only operators can perform the recovery procedures. Operator recovery procedures are not part of this standard. See 5 for Error Recovery Procedures.

2.4.2 Timers

2.4.2.1 Response Timer

2.4.2.1.1 Purpose

The Response Timer is used by a sending station to protect against an invalid response or no response.

2.4.2.1.2 Start

The Response Timer is started at its initial value immediately after the transmission of any ending character where a reply is expected, for example, **DLE ENG** or after the CRC pair.

2.4.2.1.3 Stop

The Response Timer is stopped upon receipt of a valid reply from the communication line, for example, **DLE Ø**, **DLE 1**, **DLE NAK**, or **DLE EOT**.

2.4.2.1.4 Time-Out

When time-out occurs, transmit **DLE ENG** up to five additional times with timeouts between transmissions; if a response is not received, transmit **DLE EOT**. See Annex D for suggested implementation procedure.

2.4.2.2 WACK Timer

2.4.2.2.1 Purpose

The **WACK** Timer is used by the sending station to determine the time interval between attempts to continue sending messages to a receiving station which has assumed the **WACK** state.

2.4.2.2.2 Start

The **WACK** Timer is started at its initial value after the sending station receives a **WACK** character sequence from the receiving station.

2.4.2.2.3 Time-Out

When time-out occurs, the sending station queries the receiving station to determine if the receiving station is prepared to continue receiving. The query is accomplished by transmitting **DLE ENG**. If the receiving station is capable of resuming transmission, the receiving station responds with the appropriate **ACKN** sequence (see 4.4.5). If The receiving station is unable to resume transmission, it responds with **WACK**.

3. COMMUNICATION CONTROL CHARACTERS-DEFINITIONS

3.1 Communication Control Characters

The communication control character encoding is shown in Table 2.1.1

All transmissions shall be transparent.

3.1.1 **ENG (Enquiry)**

3.1.1.1 Definition

DLE ENG is a communication control character sequence used as a request for a response.

3.1.1.2 Function

DLE ENG is used to solicit a retransmission of the last reply (**ACKN/DLE NAK**).

3.1.2 **NAK (Negative Acknowledge)**

3.1.2.1 Definition

DLE NAK is a communication control character sequence transmitted by a receiver as a negative response to the sender.

3.1.2.2 Function

DLE NAK is transmitted by a receiving station as a negative reply to a sender.

3.1.3 **ACKN (Acknowledgment N)**

3.1.3.1 Representation

ACKN represents:

ACKØ - a **DLE** character followed by a zero (Ø) character, or

ACK1 - a **DLE** character followed by a one (1) character.

3.1.3.2 Definition

ACKN is a set of communication control sequences transmitted by a receiver as affirmative responses to a sender.

3.1.3.3 Function

ACKN is transmitted by a station as a numbered affirmative reply (**DLE Ø** or **DLE 1**). See 4.2.1 for **ACKN** initialization state.

Embedded acknowledgements are not permitted within the scope of this standard, that is, **ACKN** must be an independent message, **ACKN** can never appear between **DLE STX** and **DLE ETX**. However, **DLE EOT** can be transmitted and recognized at any time, that is, **DLE EOT** may appear between **DLE STX** and **DLE ETX**.

3.1.4 **STX (Start of Text)**

3.1.4.1 Representation

Start of Text is represented by the character sequence **DLE** followed by **STX**.

3.1.4.2 Definition

DLE STX is a communication control sequence that initiates the beginning of the Information Field.

3.1.4.3 Function

3.1.4.3.1 **DLE STX** delimits the start of an Information Field.

3.1.4.3.2 **DLE STX** places the data link in a condition to transmit the Information Field.

3.1.4.3.3 **STX** is used in the Cyclic Redundancy Check procedure as described in 3.2.2.1.

3.1.5 **ETX (End of Text)**

3.1.5.1 Representation

End of Text is represented by the character sequence **DLE** followed by **ETX**.

3.1.5.2 Definition

DLE ETX is a communication control sequence that terminates an Information Field.

3.1.5.3 Function

3.1.5.3.1 **DLE ETX** delimits the end of an Information Field.

3.1.5.3.2 **DLE ETX** is used in the Cyclic Redundancy Check procedure as described in 3.2.2.2.

3.1.5.3.3 **DLE ETX** signals that the two characters immediately following constitute a CRC.

3.1.5.3.4 **DLE ETX** calls for a reply from the station receiving the message.

3.1.6 **DLE (Data DLE in Transparent Data)**

3.1.6.1 Representation