SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

SAE AS5652

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10 Megabit/sec Network Configuration
Digital Time Division Command/Response Multiplex Data Bus

RATIONALE

AS5652 has been reaffirmed to comply with the SAE five-year review policy.

FOREWORD

This standard was developed in conjunction with the Miniature Munitions Interface Standard in order to support a distributed RT point-to-point network configuration.

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1. SCOPE:

This SAE Aerospace Standard (AS) contains requirements for a digital time division command/response multiplex data bus, for use in systems integration that is functionally similar to MIL-STD-1553B with Notice 2 but with a star topology and some deleted functionality. Even with the use of this document, differences may exist between multiplex data buses in different system applications due to particular application requirements and the options allowed in this document. The system designer must recognize this fact and design the multiplex bus controller (BC) hardware and software to accommodate such differences. These designer selected options must exist to allow the necessary flexibility in the design of specific multiplex systems in order to provide for the control mechanism, architectural redundancy, degradation concept, and traffic patterns peculiar to the specific application requirements.

1.1 Purpose:

This document establishes requirements for digital, command/response, time division multiplexing (Data bus) techniques. It encompasses the data bus line and its interface electronics illustrated on Figure 1, and also defines the concept of operation and information flow on the multiplex data bus and the electrical and functional formats to be employed.

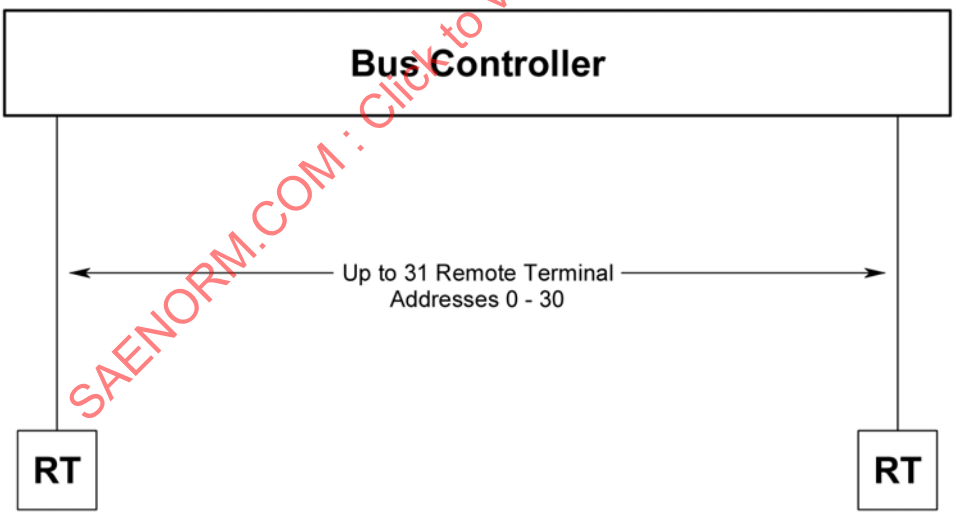


FIGURE 1 - Data Bus Network Configuration

1.2 Field of Application:

When invoked in a specification or statement of work, these requirements shall apply to the multiplex data bus and associated equipment which is developed either alone or as a portion of a Miniature Mission Store weapon system or subsystem development. The contractor is responsible for invoking all the applicable requirements of this standard on any and all subcontractors he may employ.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

ARP4242	Electromagnetic Compatibility Control Requirements, System

2.1.2 U.S. Government Publications: Available from Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/

MIL-STD-1553B	Digital Time Division Command/Response Multiplex Data Bus
MIL-STD-464	Electromagnetic Environmental Effects, Requirements for Systems

2.1.3 TIA Publications: Available from TIA, Standards and Technology Department, 2500 Wilson Boulevard, Arlington, VA 22201, www.tiaonline.org/standards/

TIA/EIA-485-A 21 (ANSI/TIA/EIA-485-A-98)	Electrical Characteristics of Generators and Receivers for Use in Balanced Multipoint Systems

2.2 Definitions:

ASYNCHRONOUS OPERATION: For the purpose of this standard, asynchronous operation is the use of an independent clock source in each terminal for message transmission. Decoding is achieved in receiving terminals using clock information derived from the message.

BIT RATE: The number of bits transmitted per second.

BIT: Contraction of binary digit: may be either zero or one. In information theory a binary digit is equal to one binary decision or the designation of one of two possible values or states of anything used to store or convey information.

BROADCAST: Operation of a data bus system such that information transmitted by the bus is addressed to more than one of the remote terminals connected to the data bus.

Bus Controller (BC): The terminal assigned the task of initiating information transfers on the data bus.

BUS MONITOR (BM): The terminal assigned the task of listening to Logical Hub activity with ability to extract selected information, to be used at a later time. Bus Monitor may be stand alone or incorporated into another terminal.

COMMAND/RESPONSE: Operation of a data bus system such that remote terminals receive and transmit data only when commanded to do so by the bus controller.

COMPOSITE BUS MONITOR (cBM): The cBM provides a time correlated transmission of all activity entering and departing the Logical Hub, including all BC and RT valid, invalid, legal and illegal words.

DATA BUS: Whenever a data bus or bus is referred to in this document it shall imply all the hardware including twisted shielded pair cables, required to provide a single data path between the bus controller and each associated remote terminal resulting in a Star Topology, as seen in Figure 2.

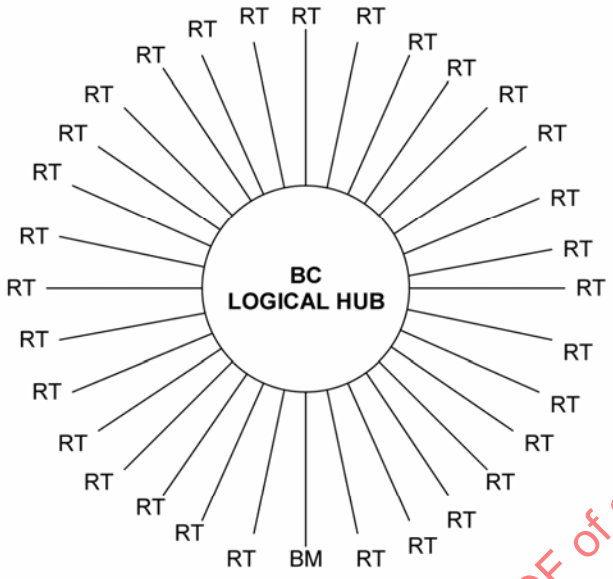


FIGURE 2 - BC Logical Hub - Star Architecture

HALF DUPLEX: Operation of a data transfer system in either direction over a single line, but not in both directions on that line simultaneously.

LOGICAL LEVEL HUB: In this document, the Logical Level Hub or just Logical Hub is a set of Hardware and/or software providing logical communications from the BC to and from each implemented RT, authorized by command word RT address bits, thru the RS-485 transceivers. The hub architecture is known as an Active Star Configuration; where the active function limits responses from the Remote Terminals so that the BC receives communications from only one RT at a time. The Logical Hub also supplies a composite Bus Monitoring traffic line out, to allow monitoring of all activity within the Logical Hub. See Figure 2 and Figures 3.

MESSAGE: A single message is the transmission of a command word, status word, and data words if they are specified.

MODE CODE: A means by which the bus controller can communicate with the multiplex bus related hardware, in order to assist in the management of information flow.

MULTIPLEX DATA BUS: A communications pathway, based on a physical media, where Time Division Multiplexing is employed in order to manage the transfer of information to and from terminals located across the physical media.

PULSE CODE MODULATION (PCM): The form of modulation in which the modulation signal is sampled, quantized, and coded so that each element of information consists of different types or numbers of pulses and spaces.

REMOTE TERMINAL (RT): All terminals not operating as the bus controller or as a bus monitor.

RT LINK SHUTDOWN: The shutdown function contained within the BC/Logical Hub for inhibiting all transmissions to an RT link.

SUBSYSTEM: The device or functional unit receiving data transfer service from the data bus.

TERMINAL: The electronic module necessary to interface the data bus with the subsystem and the subsystem with the data bus. Terminals may exist as separate line replaceable units (LRUs) or be contained within the elements of the subsystem.

TERMINAL MONITOR (TM): The terminal assigned the task of listening to RT line traffic with ability to extract selected information, to be used at a later time. Terminal Monitor may be stand alone or incorporated into another terminal.

TIME DIVISION MULTIPLEXING (TDM): The transmission of information from several signal sources through one communication system with different signal samples staggered in time to form a composite pulse train.

WORD: In this document a word is a sequence of 16 bits plus sync and parity. There are three types of words: command, status and data.

2.3 Acronymns and Abbreviations:

AIR	Aerospace Information Report
ARP	Aerospace Recommended Practice
BC to RT	Bus controller to remote terminal transfer
BC	Bus controller
BIT	Built-in-test
BM	Bus monitor
CS	Clear Status
dB	Decibels
DC	Direct current
EMC	Electromagnetic compatibility
ft	Feet
kHz	Kilohertz
LRU	Line replaceable unit
LSB	Least significant bit
MC	Mode code
MHz	Megahertz
MIL-STD	Military Standard

MSB	Most significant bit
ms	Milliseconds
mV	Millivolts
ns	Nanoseconds
PCM	Pulse code modulation
P	Parity
RMS	Root-mean-square
RT to BC	Remote terminal to bus controller transfer
RT	Remote terminal
T/R	Transmit/receive
TBD	To be determined
TDM	Time division multiplexing
TF	Terminal flag
V	Volt
Z_o	Nominal characteristic impedance

3. GENERAL REQUIREMENTS:

3.1 Test and Operating Requirements:

All requirements as specified herein shall be valid over the environmental conditions, which the multiplex data bus system shall be required to operate.

3.2 Data Bus Operation:

The multiplex data bus system in its most elemental configuration shall be as shown on Figure 1, consisting of a Bus Controller with 1 - 31 individual lines, having one line to each respective Remote Terminal. An example of the data bus including subsystems and bus monitors can be seen in Figure 3. The multiplex data bus system shall function asynchronously in a command/response mode, and transmission shall occur in a half-duplex manner. Sole control of information transmission on the bus shall reside with the Bus Controller, which shall initiate all transmissions. The information flow on the data bus shall be comprised of messages, formed, by three types of words (command, data, and status) as defined in 3.3.3.5

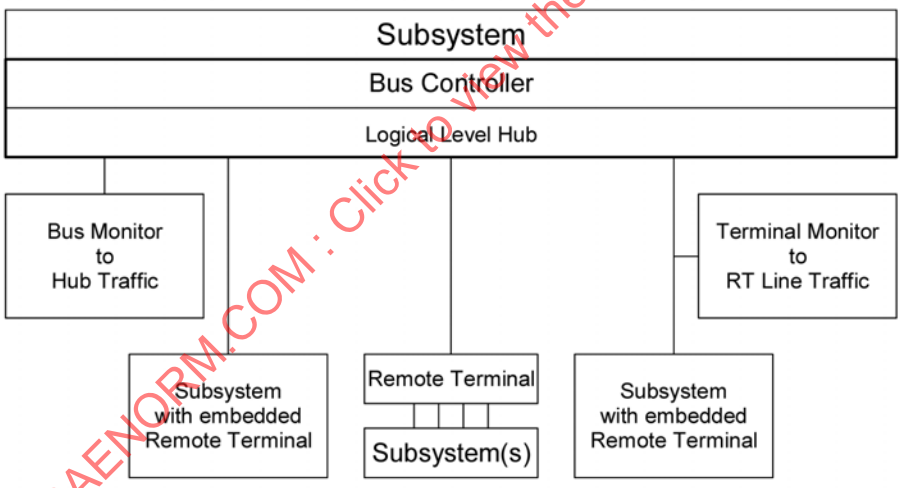


FIGURE 2 - Data Bus with Subsystems and Monitors

3.3 Characteristics:

3.3.1 Data Form: Digital data may be transmitted in any desired form, provided that the chosen form shall be compatible with the message and word formats defined in this standard. Any unused bit positions in a word shall be transmitted as logic zeros.

3.3.2 Bit Priority: The most significant bit (MSB) shall be transmitted first with the less significant bits following in descending order of value in the data word. The number of bits required to define a quantity shall be consistent with the resolution or accuracy required. In the event that multiple precision quantities (information accuracy or resolution requiring more than 16 bits) are transmitted, the most significant bits shall be transmitted first, followed by the word(s) containing the lesser significant bits in numerical descending order. Bit packing of multiple quantities in a single data word is permitted.

3.3.3 Transmission Method:

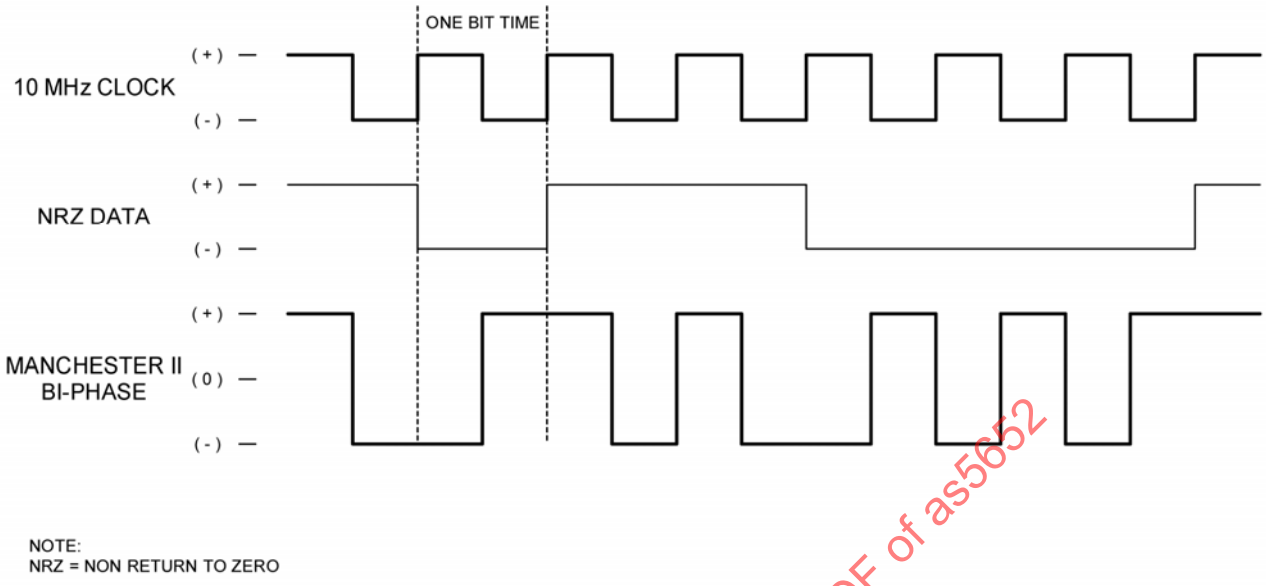
3.3.3.1 Modulation: The signal shall be transferred over the data bus in serial digital pulse code modulation (PCM) form.

3.3.3.2 Data Code: The data code shall be Manchester II bi-phase level. A logic one shall be transmitted as a bipolar coded signal 1 /0 (i.e., a positive pulse followed by a negative pulse). A logic zero shall be a bipolar coded signal 0/1 (i.e., a negative pulse followed by a positive pulse). A transition through zero occurs at the midpoint of each bit time (see Figure 4).

3.3.3.3 Transmission Bit Rate: The transmission bit rate on the bus shall be 10 megabit per second with a combined accuracy and long-term stability of ±0.1% (i.e., ±10,000 Hz). The short-term stability (i.e., stability over 1 second interval) shall be at least ±0.01% (i.e., ±1000 Hz).

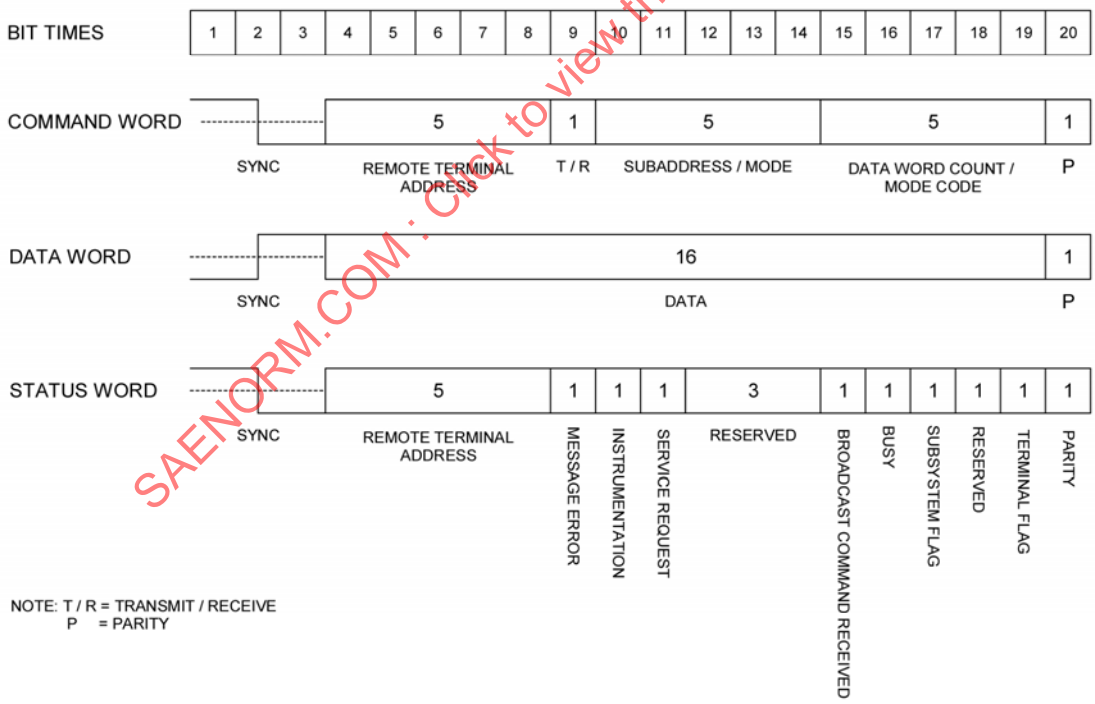
3.3.3.4 Word Size: The word size shall be 16 bits plus the sync waveform and the parity bit for a total of 20 bits times as shown on Figure 5.

3.3.3.5 Word Formats: The word format shall be as shown on Figure 5 for the command, data, and status words.



NOTE:
NRZ = NON RETURN TO ZERO

FIGURE 3 - Data Encoding



NOTE: T / R = TRANSMIT / RECEIVE
P = PARITY

FIGURE 4 - Word Formats

3.3.3.5.1 Command Word: A command word shall be comprised of a sync waveform, remote terminal (RT) address field, transmit/receive (T/R) bit, subaddress/mode field, word count/mode code field, and a parity (P) bit (see Figure 5).

3.3.3.5.1.1 Svnc (Bit Times 1-3): The command sync waveform shall be an invalid Manchester waveform as shown on Figure 6A. The width shall be three bit times, with the sync waveform being positive for the first one and one-half bit times (150 ns), and then negative for the following one and one-half bit times. If the next bit following the sync waveform is a logic zero, then the last half of the sync waveform will have an apparent width of two clock periods due to the Manchester encoding.

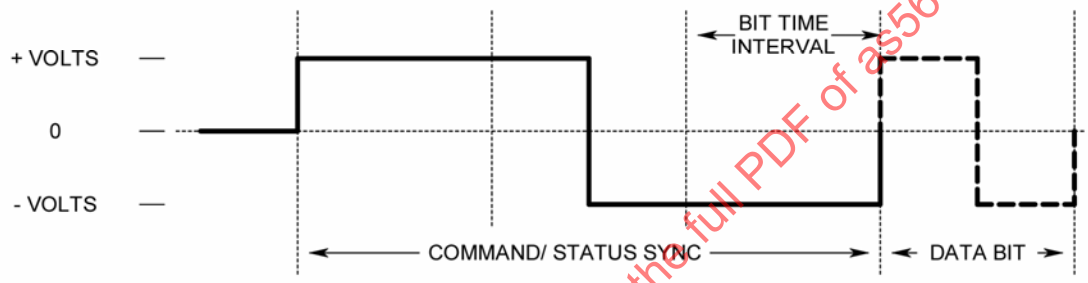


FIGURE 6A - Command and Status Sync Waveform

3.3.3.5.1.2 Remote Terminal Address (Bit Times 4-8): The next five bits following the sync shall be the RT address. Each RT shall be assigned a unique address. Decimal address 31 (11111) shall not be assigned as a unique address. In addition to its unique address, an RT shall be assigned decimal address 31 (11111) as the common address, if the broadcast option is used. All RTs shall be capable of being assigned any unique address from decimal address 0 (00000) through decimal address 30 (11110). RT address shall be established by some external mechanism, such as software registers, hardwired through an external connector or a separate interface which is part of the system wiring and connects to the RT. Changing the unique address of an RT shall not require the physical modification or manipulation of any part of the RT. The RT shall, as a minimum, determine and validate its address during power-up conditions. No single point failure shall cause a terminal to validate a false address. The RT shall not respond to any messages if it has determined its unique address is not valid.

3.3.3.5.1.3 Transmit/Receive (Bit Time 9): The next bit following the remote terminal address shall be the T/R bit, which shall indicate the action required of the RT. A logic zero shall indicate the RT is to receive, and a logic one shall indicate the RT is to transmit.

3.3.3.5.1.4 Subaddress/Mode (Bit Times 10 - 14): The next five bits following the T/R bit shall be utilized to indicate an RT subaddress or use of mode control, as is dictated by the individual terminal requirements. The subaddress/mode values of 00000 and 11111 are reserved for special purposes, as specified in 3.3.3.5.1.7, and shall not be utilized for any other function. An RT shall have the capability to respond to mode codes with both subaddress/mode of 00000 and 11111. BCs shall have the capability to issue mode commands with both subaddress/mode of 00000 and 11111. The subaddress/mode of 00000 and 11111 shall not convey different information.

3.3.3.5.1.4.1 Data Wrap-Around: RTs shall provide a receive subaddress to which one to N data words of any bit pattern can be received. RTs shall provide a transmit subaddress from which a minimum of N data words can be transmitted. N is equal to the maximum word count from the set of all messages defined for the RT. A valid receive message to the data wrap-around receive subaddress followed by a valid transmit command to the data wrap-around transmit subaddress, with the same word count and without any intervening valid commands to that RT, shall cause the RT to respond with each data word having the same bit pattern as the corresponding received data word. A data wrap-around receive and transmit subaddress of decimal 30 (11110) is desired.

3.3.3.5.1.5 Data Word Count/Mode Code (Bit Times 15-19): The next five bits following the subaddress/mode field shall be the quantity of data words to be either sent out or received by the RT or the optional mode code as specified in subsection 3.3.3.5.1.7. A maximum of 32 data words may be transmitted or received in any one message block. All 1s shall indicate a decimal count of 31, and all 0s shall indicate a decimal count of 32.

3.3.3.5.1.6 Parity (Bit Time 20): The last bit in the word shall be used for parity over the preceding 16 bits. Odd parity shall be utilized.

3.3.3.5.1.7 Mode Control: Mode Control shall be designated by a subaddress/mode code of 00000 or 11111 in bit fields 10 through 14 and shall imply that the contents of the data word count/mode code (bit fields 15 thru 19) are to be decoded as a five-bit mode command. The mode code shall only be used to communicate with the multiplex bus related hardware, and to assist in the management of information flow, and not to extract data from or feed data to a functional subsystem. Codes 00000 through 01111 shall only be used for mode codes, which do not require transfer of a data word. For these codes, the T/R bit shall be set to 1. Codes 10000 through 11111 shall only be used for mode codes, which require transfer of a single data word. For these mode codes, the T/R bit shall indicate the direction of data word flow as specified in 3.3.3.5.1.3. No multiple data word transfer shall be implemented with any mode code. Mode codes are reserved for the specific functions and shall not be used for any other purpose. The specific codes, T/R bit assignments, use of a data word, and allowance of broad cast option shall be used as indicated in Table 1. The use of the broadcast command option shall only be applied to particular mode codes as specified in Table 1. Required mode codes are specified in 3.4.3.7.

3.3.3.5.1.7.1 Reserved (T/R = 1, MC = 00000): This mode code is reserved, shall not be used, and shall be set to a logic zero (0).

3.3.3.5.1.7.2 Synchronize (without Data Word) (T/R = 1, MC = 00001): This command shall cause the RT to synchronize (e.g., to reset the internal timer, to start a sequence, etc.). The RT shall transmit the status word as specified in 3.3.3.5.3.

3.3.3.5.1.7.3 Transmit Status Word (T/R = 1, MC = 00010): This command shall cause the RT to transmit the status word associated with the last valid command word preceding this command. This mode command shall not alter the state of the status word.

3.3.3.5.1.7.4 Initiate Self-test (T/R = 1, MC = 00011): This command shall be used to initiate self-test within the RT. The RT shall transmit the status word as specified in 3.3.3.5.3. If the initiate self-test mode command is implemented in the RT, then the RT receiving the initiate self-test mode code shall respond with a status word and then initiate the RT self-test function. Subsequent valid commands may terminate the self-test function. While the RT self-test is in progress, the RT shall respond to a valid command with any of the following: (1) no response on either data bus, (2) status word transmitted with the busy bit set, or (3) normal response. If any data is transmitted from the RT while it is in self-test, the information content of the data shall be valid. An RT receiving this mode code shall complete the self-test function and have the results of the self-test available within 100 ms following transmission of the status word. The time shall be measured from the mid-bit zero crossing of the parity bit of the status word to the mid-sync zero crossing of the command word at point A on Figure 13.

3.3.3.5.1.7.5 Inhibit Terminal Flag (TF) bit (T/R = 1, MC = 00110): This command shall cause the RT to set the TF bit in the status word specified in 3.3.3.5.3.10 to logic zero until otherwise commanded. The RT shall transmit the status word as specified in 3.3.3.5.3.

3.3.3.5.1.7.6 Override Inhibit TF bit (T/R = 1, MC = 00111): This command shall cause the RT to override the inhibit TF bit specified in 3.3.3.5.3.10. The RT shall transmit the status word as specified in 3.3.3.5.3.

3.3.3.5.1.7.7 Reset Remote Terminal (T/R = 1, MC = 01000): This command shall be used to reset the RT to a power up initialized state. An RT receiving the reset RT mode code shall respond with a status word and then reset. While the RT is being reset, the RT shall respond to a valid command with any of the following: (1) no response on either data bus, (2) status word transmitted with the busy bit set, or (3) normal response. If any data is transmitted from the RT while it is being reset, the information content of the data shall be valid. An RT receiving this mode code shall complete the reset function within 5 ms following transmission of the status word.

Therefore, after the Bus Controller issues the command, it should suspend transmissions to the terminal for 5 ms. The time shall be measured from the mid-bit zero crossing of the parity bit of the status word to the mid-sync zero crossing of the command word at point A on Figure 13.

3.3.3.5.1.7.8 Reserved Mode Codes: These mode codes are reserved for future use and shall not be used; see Table 1 for complete list of reserved mode codes.

3.3.3.5.1.7.9 Transmit Vector Word T/R = 1, MC = 10000): This command shall cause, the RT to transmit a status word as specified in 3.3.3.5.3 and a data word containing service request information.

3.3.3.5.1.7.10 Synchronize With Data Word (T/R = 0, MC = 10001): The RT shall receive a command word followed by a data word as specified in 3.3.3.5.2. The data word shall contain synchronization information for the RT. After receiving the command and data word, the RT shall transmit the status word as specified in 3.3.3.5.3.

3.3.3.5.1.7.11 Transmit Last Command Word (T/R = 1, MC = 10010): This command shall cause the RT to transmit its status word as specified in 3.3.3.5.3 followed by a single data word which contains the bit information from bit times 4 - 19 of the last command word, excluding a transmit last command word mode code received by the RT. This mode command shall not alter the state of the RT's status word.

TABLE 1 - Assigned Mode Codes

T/R Bit	Mode Code	Function	Associated Data Words	Broadcast Command Allowed	Required Mode Code
		Mode Code Without Data Words			
1	00000	Reserved – Not to be Used	No	TBD	No
1	00001	Synchronize	No	Yes	Yes
1	00010	Transmit Status Word	No	No	Yes
1	00011	Initiate Self Test	No	Yes	No
I	00100	Reserved – Not to be Used	No	TBD	No
1	00101	Reserved – Not to be Used	No	TBD	No
I	00110	Inhibit Terminal Flag Bit	No	Yes	No
1	00111	Override Inhibit Terminal Flag Bit	No	Yes	No
1	01000	Reset Remote Terminal	No	Yes	Yes
1	01001	Reserved – Not to be Used	No	TBD	No
	To				
1	01111	Reserved – Not to be Used	No	TBD	No
		Mode Codes With Data Words			
1	10000	Transmit Vector Word	Yes	No	No
0	10001	Synchronize	Yes	Yes	Yes
1	10010	Transmit Last Command	Yes	No	No
1	10011	Transmit Built In Test Word	Yes	No	No
0	10100	Reserved – Not to be Used	Yes	TBD	No
0	10101	Reserved – Not to be Used	Yes	TBD	No
1 or 0	10110	Reserved – Not to be Used	Yes	TBD	No
	To				
1 or 0	11111	Reserved – Not to be Used	Yes	TBD	No

NOTE: Required Mode Codes refer to 3.4.3.7; TBD = to be determined

3.3.3.5.1.7.12 Transmit Built-in-Test (BIT) Word (T/R = 1, MC = 10011): This command shall cause the RT to transmit its status word as specified in 3.3.3.5.3 followed by a single data word containing the RT BIT data. This function is intended to supplement the available bits in the status word when the RT hardware is sufficiently complex to warrant its use. The data word, containing the RT BIT data, shall not be altered by the reception of a Transmit Last Command or a Transmit Status Word mode code. This function shall not be used to convey BIT data from the associated subsystems.

3.3.3.5.2 Data Word: A data word shall be comprised of a sync waveform, data bits, and a parity bit (see Figure 5).

3.3.3.5.2.1 Sync (Bit Times 1-3): The data sync waveform shall be an invalid Manchester waveform as shown on Figure 6B. The width shall be three bit times, with the waveform being negative for the first one and one-half bit times, and then positive for the following one and one-half bit times. Note that if the bits preceding and following the sync are logic ones, then the apparent width of the sync waveform will be increased to four bit times.

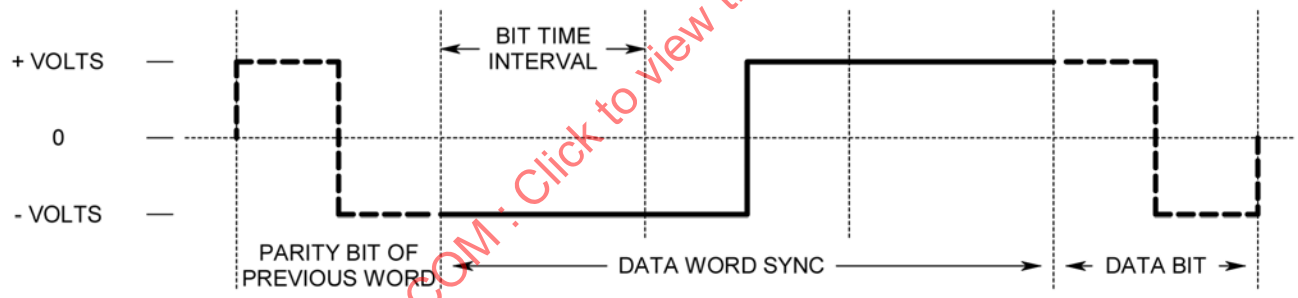


FIGURE 5B - Data Word Sync

3.3.3.5.2.2 Data (Bit Times 4 - 19): The sixteen bits following the sync shall be utilized for data transmission as specified in 3.3.2 and as seen in Figure 5.

3.3.3.5.2.3 Parity (Bit Time 20): The last bit shall be utilized for parity as specified in 3.3.3.5.1.6.

3.3.3.5.3 Status Word: A status word shall be comprised of a sync waveform, RT address, message error bit, instrumentation bit, service request bit, four reserved bits, broadcast command received bit, busy bit, subsystem flag bit, terminal flag bit, and a parity bit, see Figure 5. The status word transmitted by an RT shall contain valid information at all times, e.g., following: (1) RT power up, (2) during initialization, and (3) during normal operation. For optional broadcast operation, transmission of the status word shall be suppressed as specified in 3.3.3.6.6.

3.3.3.5.3.1 Sync (Bit Times 1 - 3): The status sync waveform shall be the same format as the Command Word as specified in 3.3.3.5.1.1 and as depicted in Figure 6A.

3.3.3.5.3.2 RT Address (Bit Times 4 - 8): The next five bits following the sync shall contain the address of the RT transmitting the status word, using the same format as the Command Word, as defined in 3.3.3.5.1.2.

3.3.3.5.3.3 Message Error Bit (Bit Time 9): The status word bit at bit time nine shall be utilized to indicate that one or more of the data words associated with the preceding receive command word from the bus controller has failed to pass the RT's validity tests as specified in 3.4.1.1. This bit shall also be set under the conditions specified in 3.4.1.2, 3.4.3.4 and 3.4.3.6. A logic one shall indicate the presence of a message error, and a logic zero shall show its absence. All RTs shall implement the message error bit.

3.3.3.5.3.4 Instrumentation Bit (Bit Time 10): The status word at bit time ten shall be reserved for the instrumentation bit and shall always be a logic zero. This bit is intended to be used in conjunction with a logic one in bit time ten of the command word to distinguish between a command word and a status word. The use of the instrumentation bit is optional.

3.3.3.5.3.5 Service Request Bit (Bit Time 11): The status word bit at bit time eleven shall be reserved for the service request bit. The use of this bit is optional. This bit when used shall indicate the need for the bus controller to take specific predefined actions relative to either the RT or associated subsystem. Multiple subsystems, interfaced to a single RT, which individually require a service request signal shall logically OR their individual signals into the single status word bit. In the event this logical OR is performed, then the designer must make provisions in a separate data word to identify the specific requesting subsystem. The service request bit is intended to be used only to trigger data transfer operations, which take place on an exception rather than periodic basis. A logic one shall indicate the presence of a service request, and a logic zero its absence. If this function is not implemented, the bit shall be set to zero.

3.3.3.5.3.6 Reserved Status Bits (Bit Times 12 - 14): The status word bits at bit times twelve through fourteen are reserved for future use and shall not be used. These bits shall be set to a logic zero.

3.3.3.5.3.7 Broadcast Command Received Bit (Bit Time 15): The status word at bit time fifteen shall be set to a logic one to indicate that the preceding valid command word was a broadcast command and a logic zero shall show it was not a broadcast command. If the RT implements the broadcast option, then the use of this bit shall be required. If the broadcast command option is not used, this bit shall be set to a logic zero.

3.3.3.5.3.8 Busy Bit (Bit Time 16): The status word bit at bit time sixteen shall be reserved for the busy bit. The use of this bit is optional. This bit, when used, shall indicate that the RT or subsystem is unable to move data to or from the subsystem in compliance with the BC's command. A logic one shall indicate the presence of a busy condition, and a logic zero its absence. In the event the busy bit is set in response to a transmit command, then the RT shall transmit its status word only. If this function is not implemented, the bit shall be set to logic zero. The existence of busy conditions is discouraged. However, any busy condition, in the RT or the subsystem interface that would affect communication over the bus shall be conveyed via the busy bit. Busy conditions, and thus the setting of the busy bit, shall occur only as a result of particular command words/messages sent to an RT. Thus for a non-failed RT, the BC can, with prior knowledge of the RT characteristics, determine when the RT can become busy and when it will not be busy. However, the RT may also set the busy bit (in addition to setting the terminal flag bit or subsystem flag bit) as a result of failure/fault conditions within the RT/subsystem.

3.3.3.5.3.9 Subsystem Flag Bit (Bit Time 17): The status word bit at bit time seventeen shall be reserved for the subsystem flag bit. The use of this bit is optional. This bit, when used, shall flag a subsystem fault condition, and alert the bus controller to potentially invalid data. Multiple subsystems, interfaced to a single RT, which individually require a subsystem flag bit signal shall logically OR their individual signals into the single status word bit. In the event this logical OR is performed, then the designer must make provisions in a separate data word to identify the specific reporting subsystem. A logic one shall indicate the presence of the flag, and a logical zero its absence. If not used, this bit shall be set to a logical zero.

3.3.3.5.3.10 Reserved (Bit Time 18): This bit shall be set to logical zero.

3.3.3.5.3.11 Terminal Flag Bit (Bit Time 19): The status word bit at bit time nineteen shall be reserved for the terminal flag function. The use of this bit in optional. This bit, when used, shall flag a RT fault condition. A logic one shall indicate the presence of the flag, and a logic zero, its absence. If not used, this bit shall be set to a logical zero.

3.3.3.5.3.12 Parity Bit (Bit Time 20): The least significant bit (LSB) in the status word shall be utilized for parity as specified in 3.3.3.5.1.6.

3.3.3.5.4 Status Word Reset: The status word bit, with the exception of the address, shall be set to logic zero after a valid command word is received by the RT with the exception as specified in 3.3.3.5.1.7. If the conditions which caused bits in the status word to be set (e.g., terminal flag) continue after the bits are reset to logic zero, then the affected status word bit shall be again set, and then transmitted on the bus as required.

3.3.3.6 Message Formats: The messages transmitted on the data bus shall be in accordance with the formats on Figure 7 and Figure 8. The maximum and minimum response times shall be as stated in 3.3.3.7 and 3.3.3.8. No message formats, other than those defined herein, shall be used on the bus. RTs shall, as a minimum, implement the following non-broadcast message formats: (1) RT to BC transfers, (2) BC to RT transfers, and (3) mode command without data word transfers. A BC shall have the capability to issue all message formats.

3.3.3.6.1 Bus Controller to Remote Terminal Transfers: The bus controller shall issue a receive command followed by the specified number of data words. The RT shall, after message validation, transmit a status word back to the controller. The command and data words shall be transmitted in a contiguous fashion with no inter-word gaps.

3.3.3.6.2 Remote Terminal to Bus Controller Transfers: The bus controller shall issue a transmit command to the RT. The RT shall, after command word validation, transmit a status word back to the bus controller, followed by the specified number of data words. The status and data words shall be transmitted in a contiguous fashion with no inter-word gaps.

3.3.3.6.3 Mode Command Without Data Word: The bus controller shall issue a transmit command to the RT using a mode code specified in Table 1. The RT shall, after command word validation, transmit a status word.

3.3.3.6.4 Mode Command With Data Word (Transmit): The bus controller shall issue a transmit command to the RT using a mode code specified in Table 1. The RT shall, after command word validation, transmit a status word followed by one data word. The status word and data word shall be transmitted in a contiguous fashion with no gap.

3.3.3.6.5 Mode Command With Data Word (Receive): The bus controller shall issue a receive command to the RT using a mode code specified in Table 1, followed by one data word. The command word and data word shall be transmitted in a contiguous fashion with no gap. The RT shall, after command and data word validation, transmit a status word back to the controller.

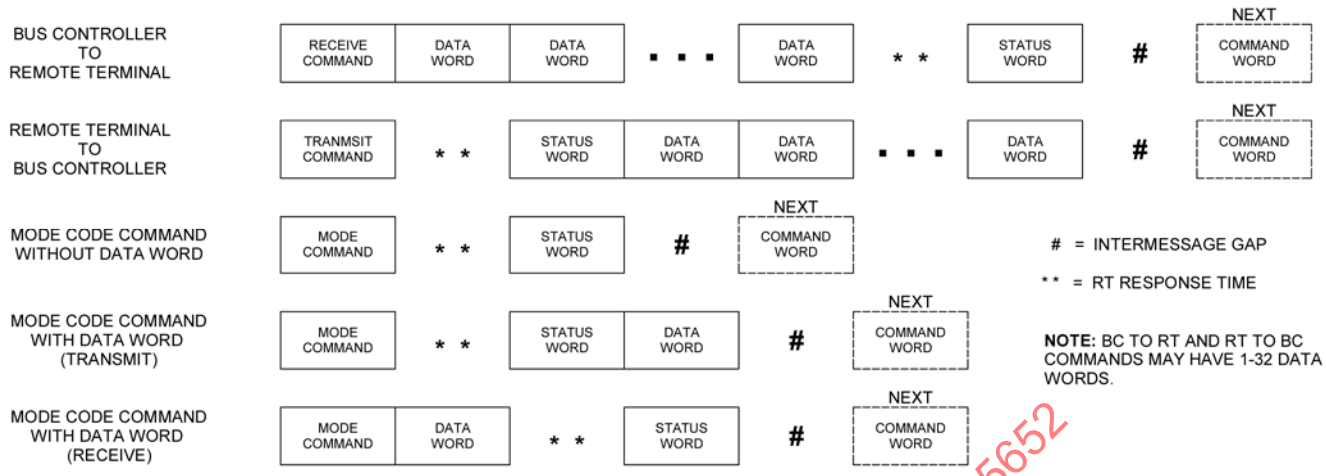


FIGURE 6 - Information Transfer Formats

3.3.3.6.6 Optional Broadcast Command: The use of a broadcast message (with RT address 11111 in 3.3.3.5.1.2 and as defined below), represents a significant departure from the basic philosophy of a Command/Response bus; it does not provide a positive closed-loop control of bus traffic because the RT does not respond with a status word. If the broadcast command is implemented, consideration should be given to the potential effects of a missed broadcast message, and the subsequent implications for fault or error recovery design in the remote terminals and bus controllers. If the RT implements the broadcast option and after passing message validation, the RT shall set the broadcast command received bit in the status word as specified in 3.3.3.5.3.7 and shall not transmit the status. This process shall apply for every broadcast command.

3.3.3.6.7 Bus Controller to Remote Terminals Transfer (Broadcast): The bus controller shall issue a receive command word with 11111 in the RT address field followed by the specified number of data words. The command word and data words shall be transmitted in a contiguous fashion with no gap.

3.3.3.6.8 Mode Command Without Data Word (Broadcast): The bus controller shall issue a transmit command word with 11111 in the RT address field, and a mode code specified in Table 1.

3.3.3.6.9 Mode Command With Data Word (Broadcasts): The bus controller shall issue a receive command word with 11111 in the RT address field and a mode code specified in Table 1, followed by one data word. The command word and data word shall be transmitted in a contiguous fashion with no gap.

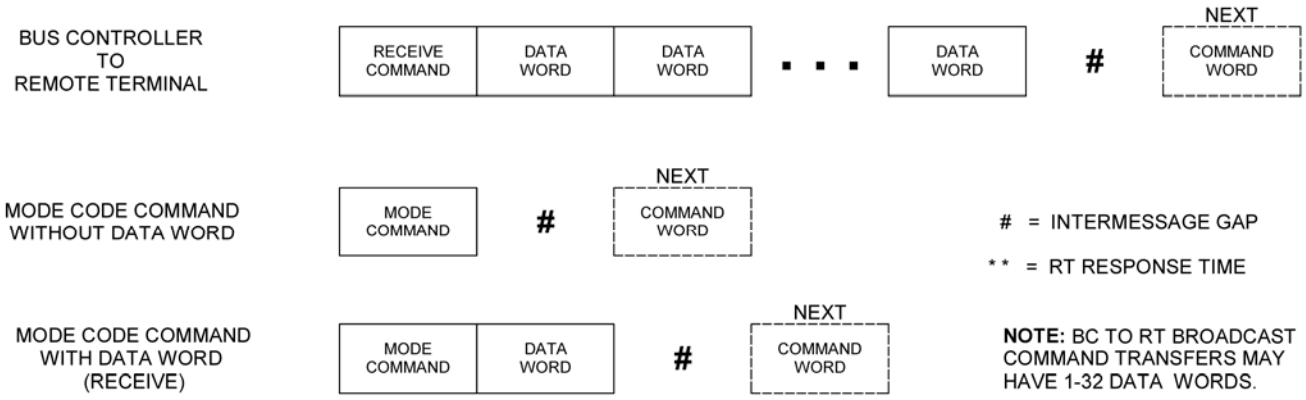


FIGURE 7 - Broadcast Information Transfer Formats

3.3.3.7 Intermessage Gap: The bus controller shall provide a minimum gap time of 1 microsecond between messages as shown on Figure 7 and Figure 8. This time period, shown as T on Figure 9, is measured at point A of the bus controller as shown on Figure 13. The time is measured from the mid-bit zero crossing of the last bit of the preceding message to mid-zero crossing of the next command word sync.

3.3.3.8 Response Time: The RT shall respond, in accordance with 3.3.3.6, to a valid command word within the time period of 0.4 microseconds to 4 microseconds. This time period, shown as T on Figure 9, is measured at point A of the RT as shown on Figure 11 or Figure 13. The time is measured from the mid bit zero crossing of the last word to the mid-zero crossing of the status word sync, as specified in 3.3.3.6 and as shown on Figure 7, Figure 8, and Figure 9.

3.3.3.9 Minimum No-Response Time-Out: The minimum time that a terminal shall wait before considering that a response as specified in 3.3.3.8 has not occurred shall be 8 microseconds. The time is measured from the mid-bit zero crossing of the last bit of the last word to the mid-zero crossing of the expected status word sync at point A of the terminal as shown on Figure 11 or Figure 13.

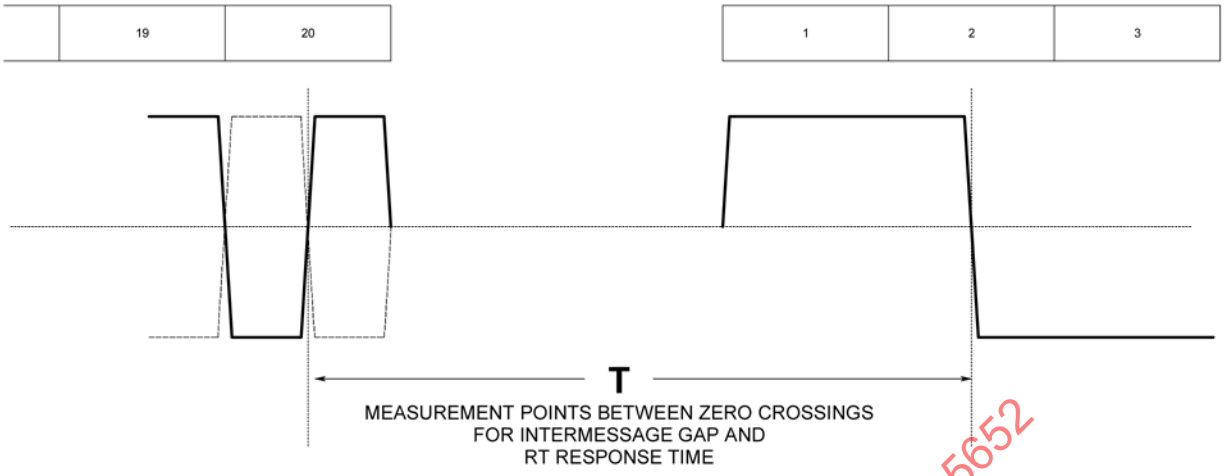


FIGURE 8 - Intermessage Gap and RT Response Time

3.4 Terminal Operation:

3.4.1 Common Operation: Terminals shall have common operating capabilities as specified in the following paragraphs.

3.4.1.1 Word Validation: The terminal shall ensure that each word conforms to the following minimum criteria:

3.4.1.1.1 The word begins with a valid sync field.

3.4.1.1.2 The bits are in a valid Manchester II code.

3.4.1.1.3 The information field has 16 bits plus parity. The word parity is odd.When a word fails to conform to the preceding criteria, the word shall be considered invalid.

3.4.1.2 Transmission Continuity: The terminal shall verify that the message is contiguous as defined in 3.3.3.6. Improperly timed data syncs shall be considered a message error.

3.4.1.3 Terminal Fail-Safe: The terminal shall contain a hardware implemented time-out to preclude a signal transmission of greater than 80 microseconds. This hardware shall not preclude a correct transmission in response to a command. Reset of this time-out function shall be performed by the reception of a valid command on the bus on which the time-out has occurred.

3.4.2 Bus Controller Operation: A terminal operating as a bus controller shall be responsible for sending data bus commands, participating in data transfers, receiving status responses, and monitoring system status as defined in this standard. The bus controller function may be embodied as either a stand-alone terminal, whose sole function is to control the data bus(s), or contained within a subsystem. Only one terminal shall be in active control of a data bus at any one time.

3.4.3 Remote Terminal:

3.4.3.1 Operation: A remote terminal (RT) shall operate in response to valid commands received from the bus controller. The RT shall accept a command word as valid when the command word meets the criteria of 3.4.1.1, and the command word contains a terminal address which matches the RT address or an address of 11111, if the RT has the broadcast option.

3.4.3.2 Superseding Valid Commands: A RT shall be capable of receiving a command word on the data bus after the minimum intermessage gap time as specified in 3.3.3.7 has been exceeded, when the RT is not in the time period T as specified in 3.3.3.8 prior to the transmission of a status word, and when it is not transmitting on that data bus. A second valid command word sent to an RT shall take precedence over the previous command. The RT shall respond to the second valid command as specified in 3.3.3.8.

3.4.3.3 Invalid Commands: A remote terminal shall not respond to a command word which fails to meet the criteria specified in 3.4.3.1.

3.4.3.4 Illegal Command: An illegal command is a valid command as specified in 3.4.3.1, where the bits in the subaddress/mode field, data word count/mode code field, and the T/R bit indicate a mode command, subaddress, or word count that has not been implemented in the RT. It is the responsibility of the bus controller to assure that no illegal commands are sent out. The RT designer has the option of monitoring for illegal commands. If an RT that is designed with this option detects an illegal command and the proper number of contiguous valid data words as specified by the illegal command word, it shall respond with a status word only, setting the message error bit, and not use the information received.

3.4.3.5 Valid Data Reception: The remote terminal shall respond with a status word when a valid command word and the proper number of contiguous valid data words are received, or a single valid word associated with a mode code is received. Each data word shall meet the criteria specified in 3.4.1.1.

3.4.3.6 Invalid Data Reception: Any data word(s) associated with a valid receive command that does not meet the criteria specified in 3.4.1.1 and 3.4.1.2 or an error in the data word count shall cause the remote terminal to set the message error bit in the status word to a logic one and suppress the transmission of the status word. If a message error has occurred, then the entire message shall be considered invalid.

3.4.3.7 Required Mode Codes: A Remote Terminal shall operate in response to Synchronize without Data (00001), Synchronize with data (10001), Transmit Status Word (00010), and Terminal Reset (01000) modes codes as specified in 3.3.3.5.1.7 and as required in 3.4.3.5. The implementation of other mode codes as defined in Table 1 is optional.

3.4.4 Monitor Operation: A terminal operating as a monitor shall receive bus traffic and may extract selected information. While operating as a monitor, the terminal shall not respond to any message except one containing its own unique address if one is assigned (making it also a Remote Terminal). All information obtained while acting as a monitor shall be strictly used for off-line applications (e.g., flight test recording, maintenance recording or mission analysis) or to provide the back up bus controller sufficient information to take over as the bus controller.

3.4.4.1 Bus Monitor: A terminal operating as the Bus Monitor receives its information from the composite traffic line provided by the Bus Controller, as shown in Figure 2 and Figure 3.

3.4.4.2 Terminal Monitor: A terminal operating as a Terminal Monitor shall have at least one receive line and may have as many as 31 receive lines allowing the Terminal Monitor to acquire communications between a specific Remote Terminal(s) and the Bus Controller, as shown on Figure 3.

3.5 Hardware Characteristics:

3.5.1 Data Bus Characteristics:

3.5.1.1 Cable: The cable used for every RT is the Interface Line Cable and shall be a two conductor, twisted, shielded, jacketed cable. The cables shall be formed with not less than six twists per foot where a twist is defined as a 360-degree rotation of the wire pairs and the cable shield shall provide a minimum of 95% coverage.

3.5.1.2 Characteristic Impedance: The characteristic impedance of the cable (Z_0) shall be 120 ohms ± 10% at a sinusoidal frequency of 10 MHz nominal.

3.5.1.3 Cable Attenuation: At the frequency of 3.5.1.2, the cable power loss shall not exceed 4.75 dB/100 ft.

3.5.1.4 Cable Termination: The two ends of the cable shall be terminated with a resistance, using a Z_0 nominal value selected at 120 ohms ± 2%, as specified in 3.5.2.1, as seen in Figure 10 and Figure 13.

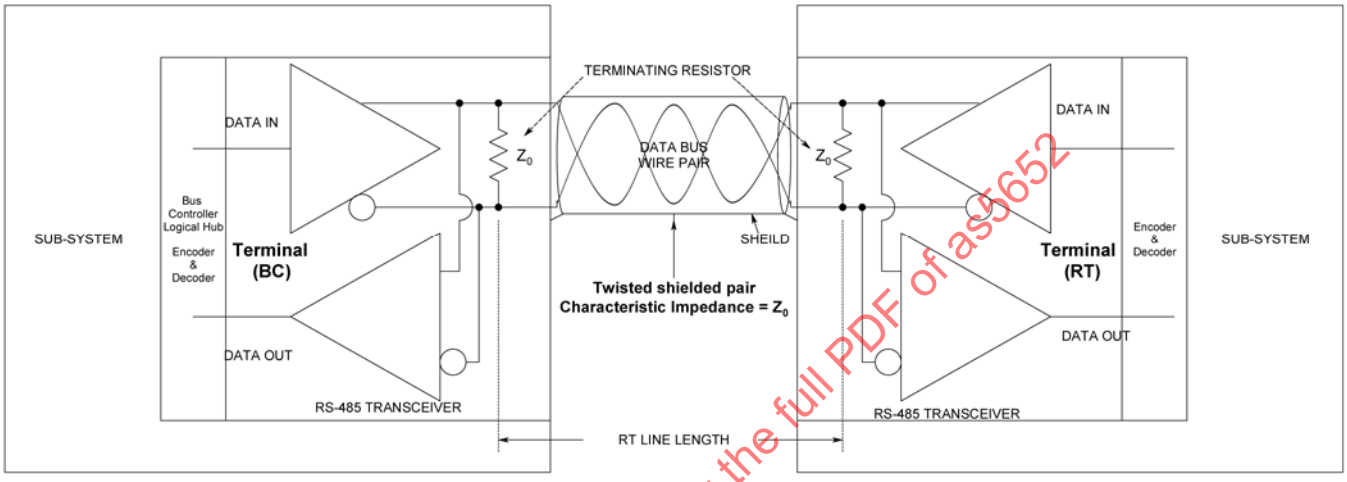


FIGURE 9 - Example Implementation of BC to RT Interface Line Cable

3.5.1.5 Interface Line Cable: The cable shall be coupled to the terminal as shown on Figure 10. The RT Interface Line Cable length is measured between the terminating resistor at the BC end and the terminating resistor at the RT end. Since maximum cable lengths can be transceiver and implementation dependent, a typical cable length is not expected to exceed 100 meters.

3.5.1.6 Cable Coupling: All junctions shall provide a minimum of 75% shielded coverage.

3.5.1.7 Wiring and Cabling for EMC: For purposes of electromagnetic capability (EMC), the wiring and cabling provisions of MIL-STD-464 shall apply.

3.5.2 Terminal Characteristics:

3.5.2.1 Terminating Resistor: The terminating resistor for each end of the Interface Line Cable will be located as close as possible to the terminal's transceiver and is considered part of the terminal and transceiver circuitry, see Figure 10. Terminating resistor shall not be present on a Terminal Monitor, providing a high impedance interface (suggested at least 10 times higher then the terminating resistor) in order to prevent loading on the terminal line.

3.5.2.2 Bus/Line Biasing (optional):

3.5.2.2.1 BC shall not be biased. BC shall function with an RT that is designed without a bias network.

3.5.2.2.2 RT Biasing: If biasing is implemented, the bias network shall take into account the BC and RT side terminating resistors. Standard RS-485 commercial practices shall be observed, resulting in a 0.3 to 0.5 V bias.

3.5.2.3 Terminal Output Characteristics: The following characteristics shall be measured with R_L, as shown on Figure 11, equal to 100 ohms ± 1% and C_L, equal to 50 pF ± 20%.

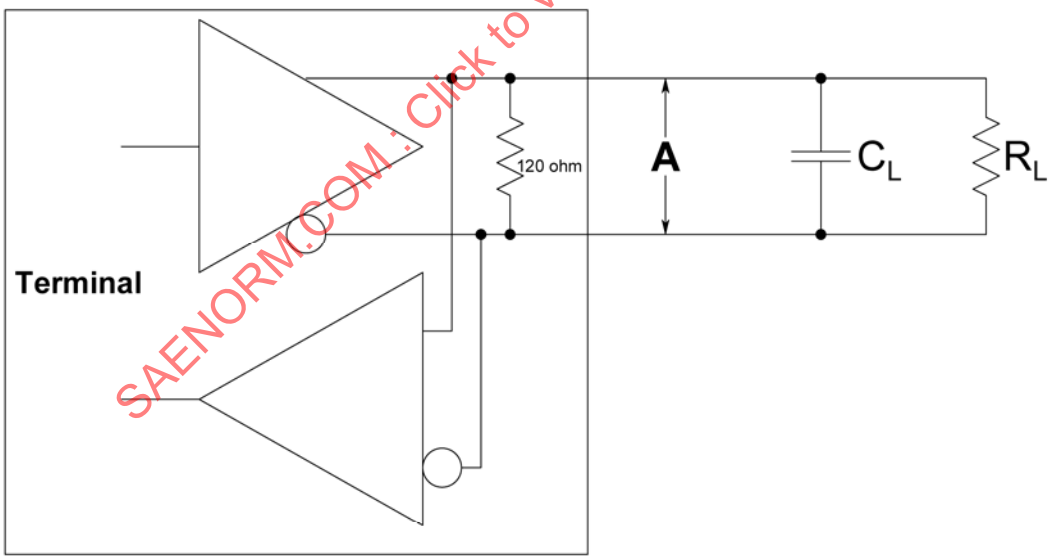


FIGURE 10 - Terminal I/O Characteristics

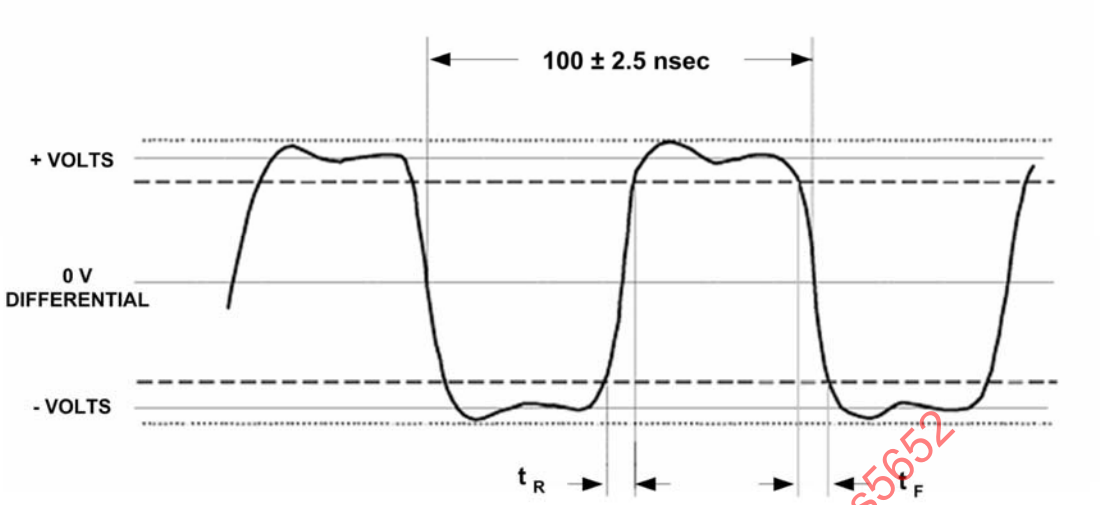


FIGURE 12 - Output Waveform

3.5.2.3.1 Output Levels: The terminal output voltage levels shall be measured as shown in Figure 12, using the test configuration shown on Figure 11. The terminal output voltage shall be within the range of 1.5 to 10 V, peak-to-peak, line-to-line, when measured at point A on Figure 11.

3.5.2.3.2 Output Waveform: The waveform shall be measured at point A on Figure 11 and as depicted in Figure 12. The waveform shall have zero crossing deviations which are equal to, or less than, 2.5 ns when measured at zero crossing point intervals from one zero crossing point with respect to the next zero crossing point, i.e., at 50 ns ± 2.5 ns, 100 ns ± 2.5 ns, 150 ns ± 2.5 ns, and 200 ns ± 2.5 ns. The rise time (t_R) and fall time (t_F) of this waveform shall be less than 30 ns when measured from levels of 10 to 90% of full waveform peak-to-peak, line-to-line. Any distortion of the waveform including overshoot and ringing shall not exceed ±300 mV peak, line-to-line.

3.5.2.3.3 Output Noise: Any noise transmitted when the terminal is receiving power (until ready to respond) or has power removed, shall not exceed a value of 5 mV, RMS, line-to-line, as measured at point A on Figure 11.