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AEROSPACE STANDARD

SAE AS15531

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Digital Time Division Command/Response Multiplex Data Bus

RATIONALE

This document has been reaffirmed to comply with the SAE 5-year Review policy.

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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 equivalent to MIL-STD-1553B with Notice 2. 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.

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 system or subsystem development. The contractor is responsible for invoking all the applicable requirements of this document on any and all subcontractors he/she may employ.

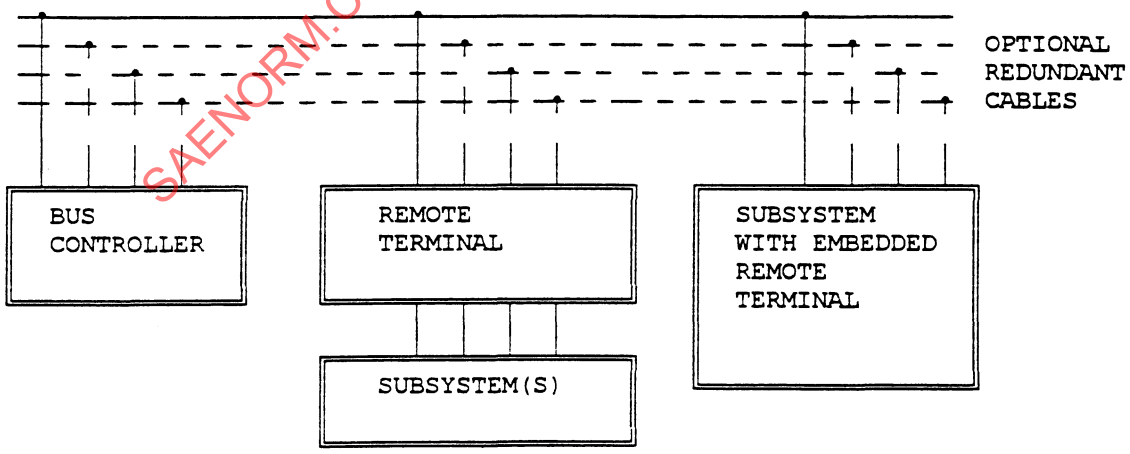


FIGURE 1 - Sample Multiplex Data Bus Architecture

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this specification 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 specification and references cited herein, the text of this specification takes precedence. Nothing in this specification, 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.

AIR4295	Handbook for the Digital Time Division Command/Response Multiplex Data Bus Test Plans
ARP4242	Electromagnetic Compatibility Control Requirements, System
AS4111	Validation Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Remote Terminals
AS4112	Production Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Remote Terminals
AS4113	Validation Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Bus Controllers
AS4114	Production Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Bus Controller
AS4115	Test Plan for the Digital Time Division Command/Response Multiplex Data Bus System
AS4116	Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Bus Monitors
AS4117	Test Plan for the Digital Time Division Command/Response Multiplex Data Bus Couplers, Terminators, and Data Bus Cables

2.1.2 U.S. Government Publications: Available from DODSSP, Subscription Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-STD-1553B Digital Time Division Command/Response Multiplex Data Bus

2.2 Definitions:

ASYNCHRONOUS OPERATION: 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: 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 of states of anything used to store or convey information.

Bit RATE: The number of bits transmitted per second.

2.2 (Continued):

BROADCAST: Operation of a data bus system such that information transmitted by the bus controller or a remote terminal (RT) is addressed to more than one of the RTs 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 receiving bus traffic and extracting selected information to be used at a later time.

CLEAR STATUS (CS): The status word may have the busy and/or service request bit set. All other status code bits in the status word must be zero and the associated message must have the proper word count.

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

DATA BUS: All the hardware (including twisted shielded pair cables, isolation resistors, transformers, etc.) required to provide a single data path between the BC and all the associated RTs.

DYNAMIC BUS CONTROL: The operation of a data bus system in which designated terminals are offered control of the data bus.

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

MESSAGE: A single message is the transmission of a command word, status word, and data words if they are specified. For the case of a remote terminal to remote terminal (RT to RT) transmission, the message shall include the two command words, the two status words, and data words.

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

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.

REDUNDANT DATA BUS: The use of more than one data bus to provide more than one data path between the subsystems, i.e., dual redundant data bus, tri-redundant data bus, etc.

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

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

2.2 (Continued):

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.

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: A sequence of 16 bits plus sync and parity. There are three types of words: command, status, and data. There are three types of command words: transmit command words, receive command words, and mode command words.

3. ACRONYMS:

µs	Microseconds
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

3. (Continued):

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 to RT	Remote terminal to remote terminal 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

4. GENERAL REQUIREMENTS:

4.1 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.

4.2 Data Bus Operation:

The multiplex data bus system in its most elemental configuration shall be as shown on Figure 1. 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 BC, which shall initiate all transmissions. The information flow on the data bus shall be comprised of messages which are, in turn, formed by three types of words (command, data, and status) as defined in 4.3.3.5.

4.3 Characteristics:

4.3.1 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 document. Any unused bit positions in a word shall be transmitted as logic zeroes.

4.3.2 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 MSBs 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.

4.3.3 Transmission Method:

4.3.3.1 Modulation: The signal shall be transferred over the data bus in serial digital PCM form.

4.3.3.2 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 2).

4.3.3.3 Transmission Bit Rate: The transmission bit rate on the bus shall be 1.0 megabit per second with a combined accuracy and long-term stability of ±0.1% (i.e., ±1000 Hz). The short-term stability (i.e., stability over 1.0 second interval) shall be at least ±0.01% (i.e., ±100 Hz).

4.3.3.4 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 3.

4.3.3.5 Word Formats: The word formats shall be as shown on Figure 3 for the command, data, and status words.

4.3.3.5.1 Command Word: A command word shall be comprised of a sync waveform, RT address field, transmit/receive (T/R) bit, subaddress/mode field, word count/mode code field, and a parity (P) bit (see Figure 3).

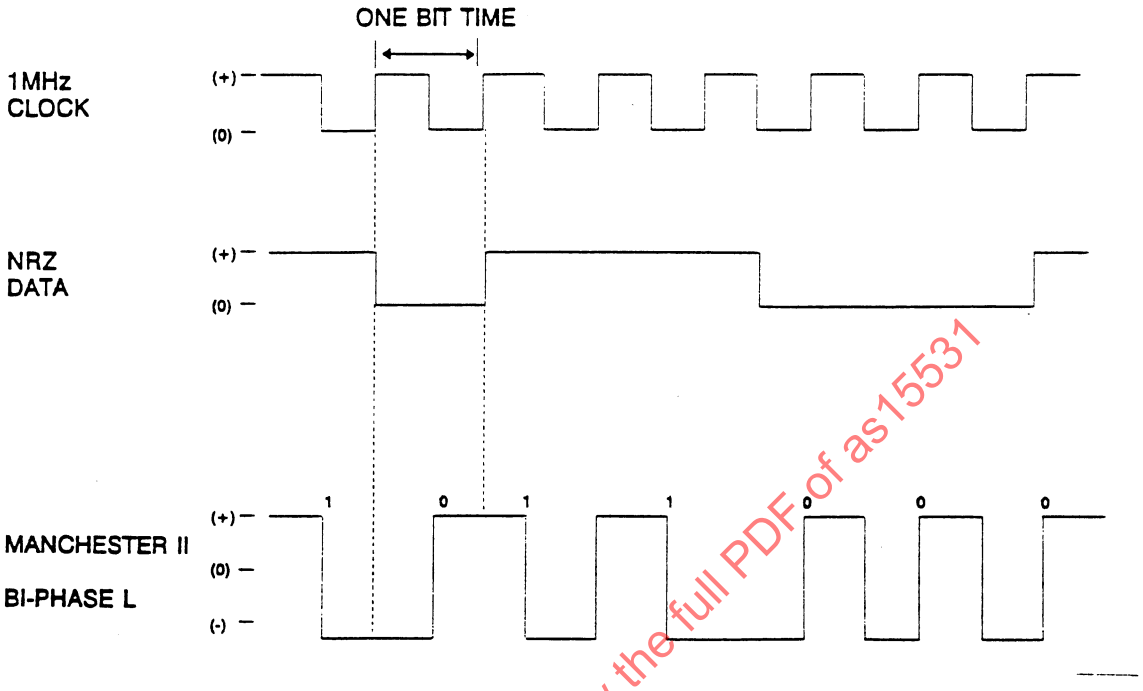
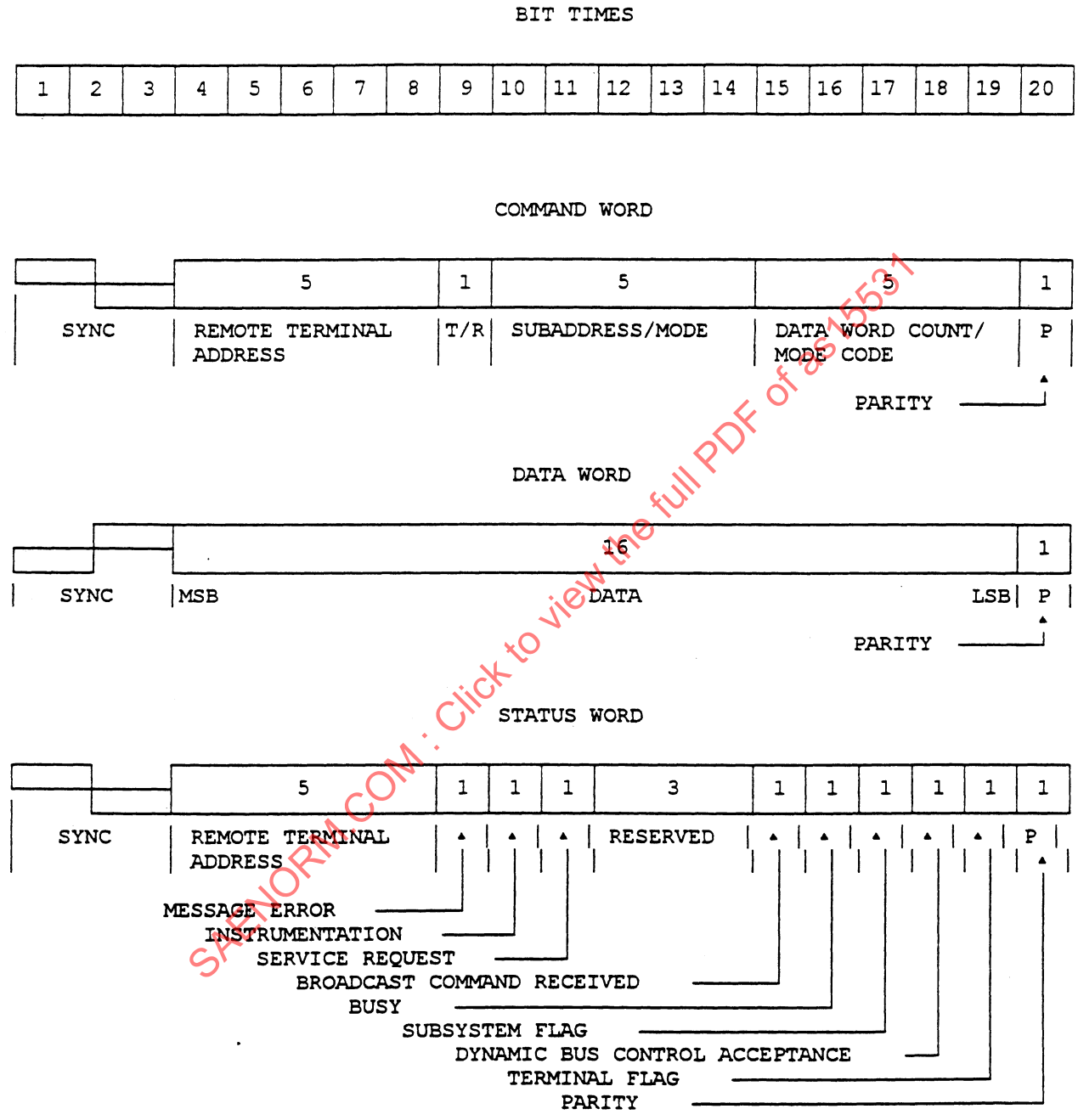


FIGURE 2 - Data Encoding

4.3.3.5.1.1 Sync (Bit Times 1 - 3): The command word sync waveform shall be an invalid Manchester II waveform as shown on Figure 4. The width shall be three bit times, with the sync waveform being positive for the first one and one-half bit times, 1.5 microseconds (µs), 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 II encoding.

4.3.3.5.1.2 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). The address shall be established through an external connector, 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.



T/R = TRANSMIT/RECEIVE, P = PARITY

FIGURE 3 - Word Formats

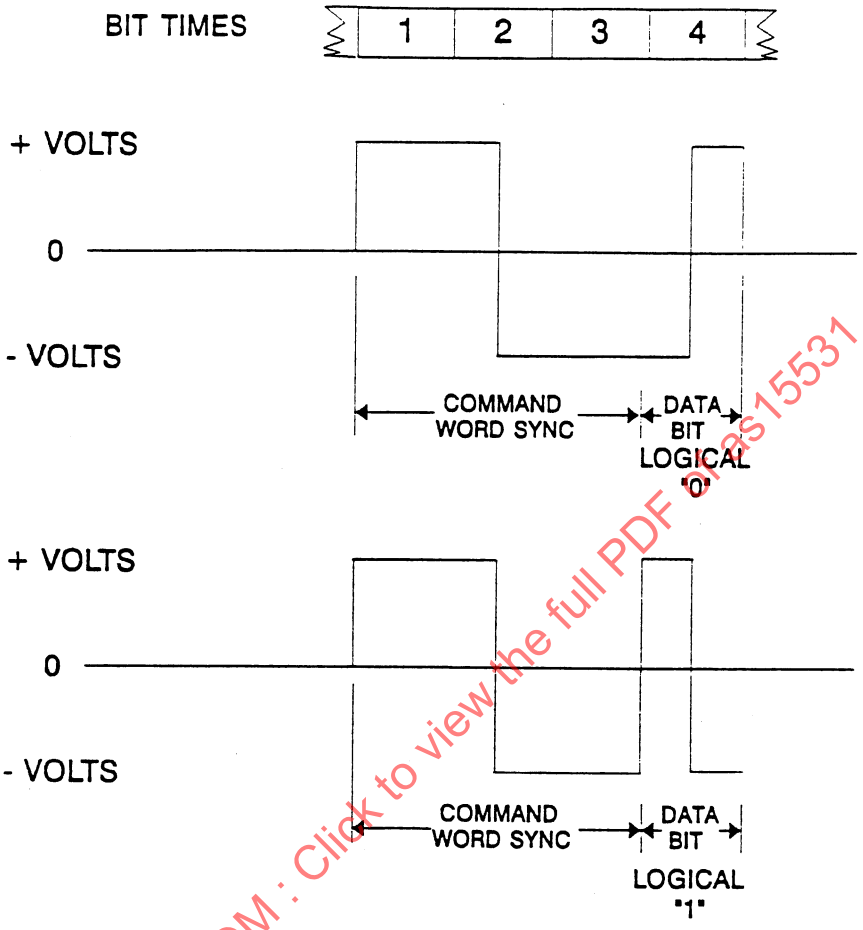


FIGURE 4 - Command Word and Status Word Sync

4.3.3.5.1.3 Transmit/Receive (Bit Time 9): The next bit following the RT 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.

4.3.3.5.1.4 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 4.3.3.5.1.7, 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.

4.3.3.5.1.4.1 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.

4.3.3.5.1.5 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 4.3.3.5.1.7. A maximum of 32 data words may be transmitted or received in any one message block. All 1's shall indicate a decimal count of 31, and all 0's shall indicate a decimal count of 32.

4.3.3.5.1.6 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.

4.3.3.5.1.7 Optional Mode Control: For RTs exercising this option a subaddress/mode code of 00000 or 11111 shall imply that the contents of the data word count/mode code field 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 4.3.3.5.1.3. No multiple data word transfer shall be implemented with any mode code. The mode codes are reserved for the specific functions as specified in Table 1 and shall not be used for any other purposes. If the designer chooses to implement any of these functions, the specific codes, T/R bit assignments, and use of a data word, shall be used as indicated. The use of the broadcast command option shall only be applied to particular mode codes as specified in Table 1.

4.3.3.5.1.7.1 Dynamic Bus Control (T/R = 1, MC = 00000): The controller shall issue a transmit command word to an RT capable of performing the bus control function. This RT shall respond with a status word as specified in 4.3.3.5.3. Control of the data bus passes from the offering BC to the accepting RT upon completion of the transmission of the status word by the RT. If the RT rejects control of the data bus, the offering BC retains control of the data bus.

4.3.3.5.1.7.2 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 4.3.3.5.3.

TABLE 1 - Assigned Mode Codes

T/R BIT	MODE CODE	FUNCTION	DATA WORD	BROADCAST ALLOWED
1	00000	Dynamic bus control	No	No
1	00001	Synchronize	No	Yes
1	00010	Transmit status word	No	No
1	00011	Initiate self-test	No	Yes
1	00100	Transmitter shutdown	No	Yes
1	00101	Override transmitter shutdown	No	Yes
1	00110	Inhibit terminal flag bit	No	Yes
1	00111	Override inhibit terminal flag bit	No	Yes
1	01000	Reset remote terminal	No	Yes
1	01001	Reserved	No	TBD
1	01010	Reserved	No	TBD
1	01011	Reserved	No	TBD
1	01100	Reserved	No	TBD
1	01101	Reserved	No	TBD
1	01110	Reserved	No	TBD
1	01111	Reserved	No	TBD
1	10000	Transmit vector word	Yes	No
1	10001	Reserved*	Yes	TBD
1	10010	Transmit last command word	Yes	No
1	10011	Transmit BIT word	Yes	No
1	10100	Reserved*	Yes	TBD
1	10101	Reserved*	Yes	TBD
1	10110	Reserved	Yes	TBD
1	10111	Reserved	Yes	TBD
1	11000	Reserved	Yes	TBD
1	11001	Reserved	Yes	TBD
1	11010	Reserved	Yes	TBD
1	11011	Reserved	Yes	TBD
1	11100	Reserved	Yes	TBD
1	11101	Reserved	Yes	TBD
1	11110	Reserved	Yes	TBD
1	11111	Reserved	Yes	TBD

TABLE 1 (CONTINUED)

T/R BIT	MODE CODE	FUNCTION	DATA WORD	BROADCAST ALLOWED
0	00000	Reserved*	No	TBD
0	00001	Reserved*	No	TBD
0	00010	Reserved*	No	TBD
0	00011	Reserved*	No	TBD
0	00100	Reserved*	No	TBD
0	00101	Reserved*	No	TBD
0	00110	Reserved*	No	TBD
0	00111	Reserved*	No	TBD
0	01000	Reserved*	No	TBD
0	01001	Reserved*	No	TBD
0	01010	Reserved*	No	TBD
0	01011	Reserved*	No	TBD
0	01100	Reserved*	No	TBD
0	01101	Reserved*	No	TBD
0	01110	Reserved*	No	TBD
0	01111	Reserved*	No	TBD
0	10000	Reserved*	Yes	TBD
0	10001	Synchronize	Yes	Yes
0	10010	Reserved*	Yes	TBD
0	10011	Reserved*	Yes	TBD
0	10100	Selected Transmitter Shutdown	Yes	Yes
0	10101	Override Selected Transmitter Shutdown	Yes	Yes
0	10110	Reserved	Yes	TBD
0	10111	Reserved	Yes	TBD
0	11000	Reserved	Yes	TBD
0	11001	Reserved	Yes	TBD
0	11010	Reserved	Yes	TBD
0	11011	Reserved	Yes	TBD
0	11100	Reserved	Yes	TBD
0	11101	Reserved	Yes	TBD
0	11110	Reserved	Yes	TBD
0	11111	Reserved	Yes	TBD

NOTE: * - Undefined in MIL-STD-1553B; To be determined (TBD)

4.3.3.5.1.7.3 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.

4.3.3.5.1.7.4 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 4.3.3.5.3. 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 milliseconds (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 Figures 5 and 6.

4.3.3.5.1.7.5 Transmitter Shutdown (T/R = 1, MC = 00100): This command (to only be used with dual redundant bus systems) shall cause the RT to disable the transmitter associated with the redundant bus. In all cases, the RT shall respond with a status word as specified in 4.3.3.5.3 after this command word.

4.3.3.5.1.7.6 Override Transmitter Shutdown (T/R = 1, MC = 00101): This command (to only be used with dual redundant bus systems) shall cause the RT to enable the transmitter, associated with the redundant bus, which was previously disabled. In all cases, the RT shall respond with a status word as specified in 4.3.3.5.3 after this command word.

4.3.3.5.1.7.7 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 4.3.3.5.3 to logic zero until otherwise commanded. The RT shall transmit the status word as specified in 4.3.3.5.3.

4.3.3.5.1.7.8 Override Inhibit TF Bit (T/R = 1, MC = 00111): This command shall cause the RT to override the inhibit TF bit specified in 4.3.3.5.1.7.7. The RT shall transmit the status word as specified in 4.3.3.5.3.

4.3.3.5.1.7.9 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 5.0 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 Figures 5 and 6.

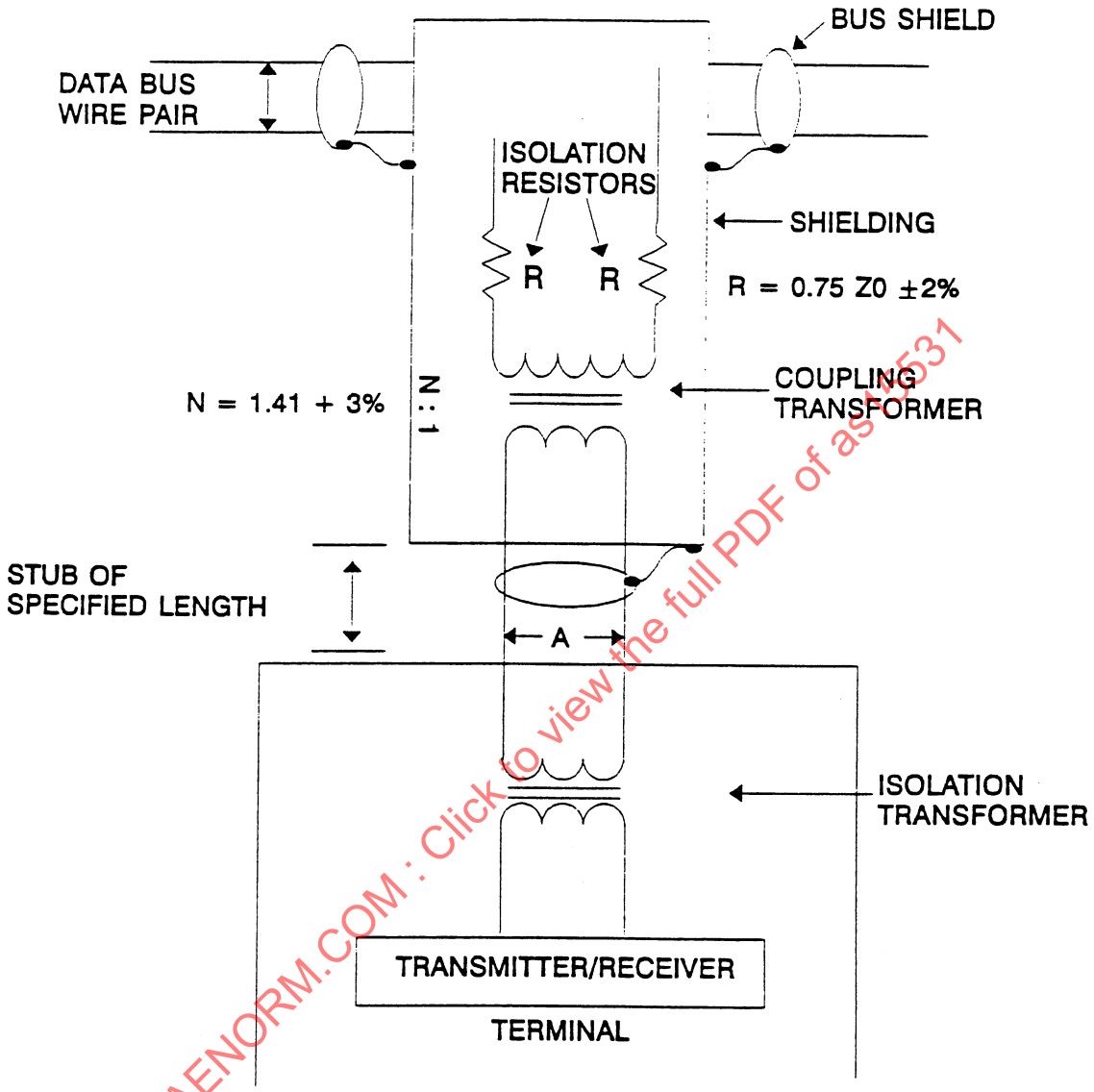


FIGURE 5 - Data Bus interface Using Transformer Coupling

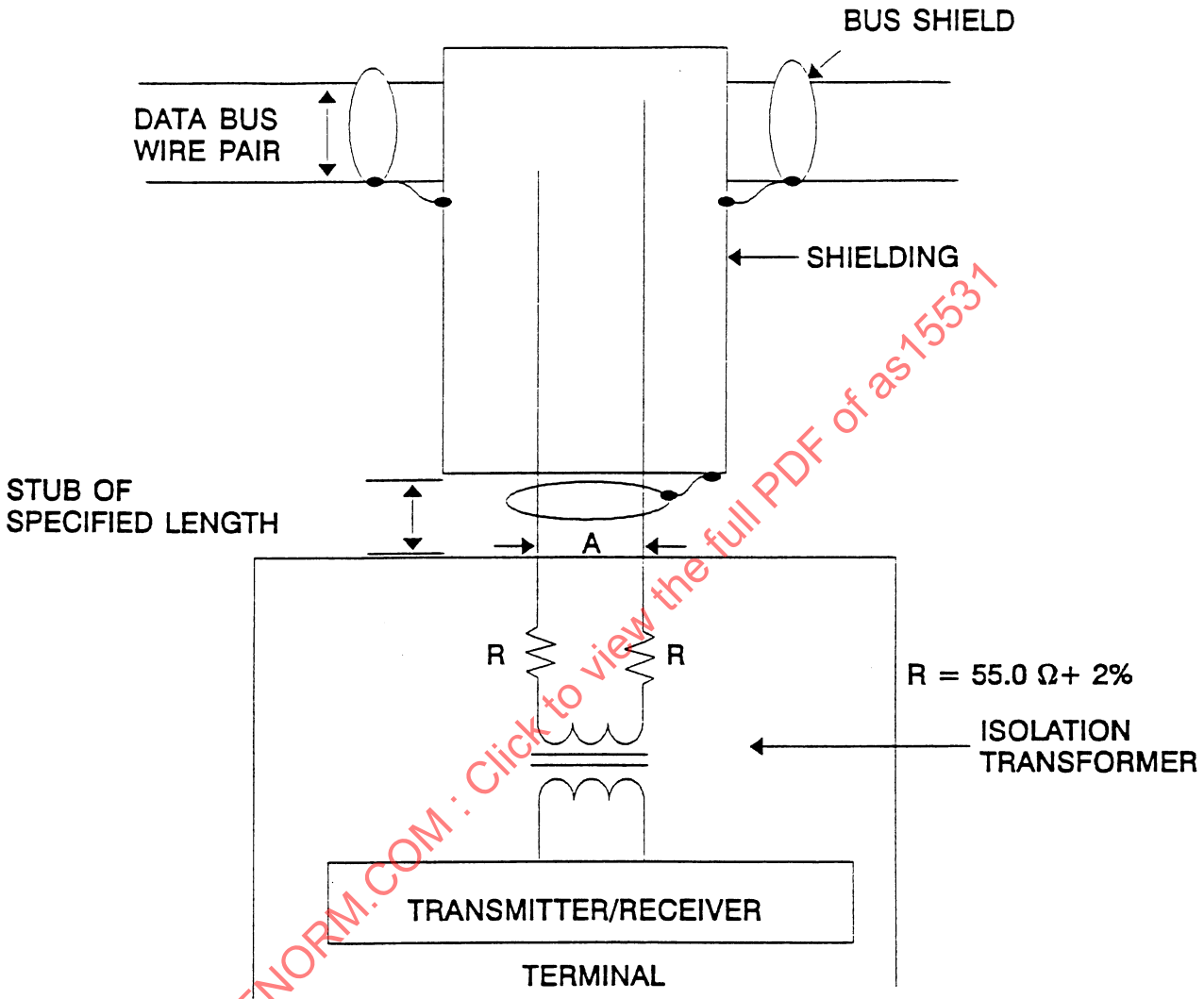


FIGURE 6 - Data Bus Interface Using Direct Coupling

4.3.3.5.1.7.10 Reserved Mode Codes (T/R = 1, MC = 01001 to 01111, 10001, 10100 to 11111): These mode codes are reserved and shall not be used.

4.3.3.5.1.7.11 Transmit Vector Word (T/R = 1, MC = 10000): This command shall cause the RT to transmit a status word as specified in 4.3.3.5.3 and a data word containing service request information.

4.3.3.5.1.7.12 Synchronize (with Data Word) (T/R = 0, MC = 10001): The RT shall receive a command word followed by a data word as specified in 4.3.3.5.2. The data word shall contain synchronization information for the RT. After receiving the command word and data word, the RT shall transmit the status word as specified in 4.3.3.5.3.

4.3.3.5.1.7.13 Transmit Last Command Word (T/R = 1, MC = 10010: This command shall cause the RT to transmit the status word associated with the last valid command word preceding this command, followed by a single data word which contains bit times 4 - 19 of the last valid 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.

4.3.3.5.1.7.14 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 4.3.3.5.3 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 word or a transmit status word mode code. This function shall not be used to convey BIT data from the associated subsystem(s).

4.3.3.5.1.7.15 Selected Transmitter Shutdown (T/R = 0, MC = 10100): This command shall cause the RT to disable the transmitter associated with a specified redundant data bus. The command is designed for use with systems employing more than two redundant buses. The transmitter that is to be disabled shall be identified in the data word following the command word in the format as specified in 4.3.3.5.2. The RT shall not comply with a command to shut down a transmitter on the bus from which this command is received. In all cases, the RT shall respond with a status word as specified in 4.3.3.5.3.

4.3.3.5.1.7.16 Override Selected Transmitter Shutdown (T/R = 0, MC = 10101): This command shall cause the RT to enable a transmitter which was previously disabled. The command is designed for use with systems employing more than two redundant buses. The transmitter that is to be enabled shall be identified in the data word following the command word in the format as specified in 4.3.3.5.2. The RT shall not comply with a command to enable a transmitter on the bus from which this command is received. In all cases, the RT shall respond with a status word as specified in 4.3.3.5.3.

4.3.3.5.1.7.17 Reserved Mode Codes (T/R = 0, MC = 00000 to 10011, 10110 to 11111): These mode codes are reserved and shall not be used.

4.3.3.5.2 Data Word: A data word shall be comprised of a sync waveform, data bits, and a parity bit (see Figure 3).

4.3.3.5.2.1 Sync (Bit Times 1 - 3): The data sync waveform shall be an invalid Manchester waveform as shown on Figure 7. The width shall be three bit times, with the waveform being negative for the first one and one-half bit times, 1.5 µs, 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.

4.3.3.5.2.2 Data (Bit Times 4 - 19): The sixteen bits following the sync shall be utilized for data transmission as specified in 4.3.2.

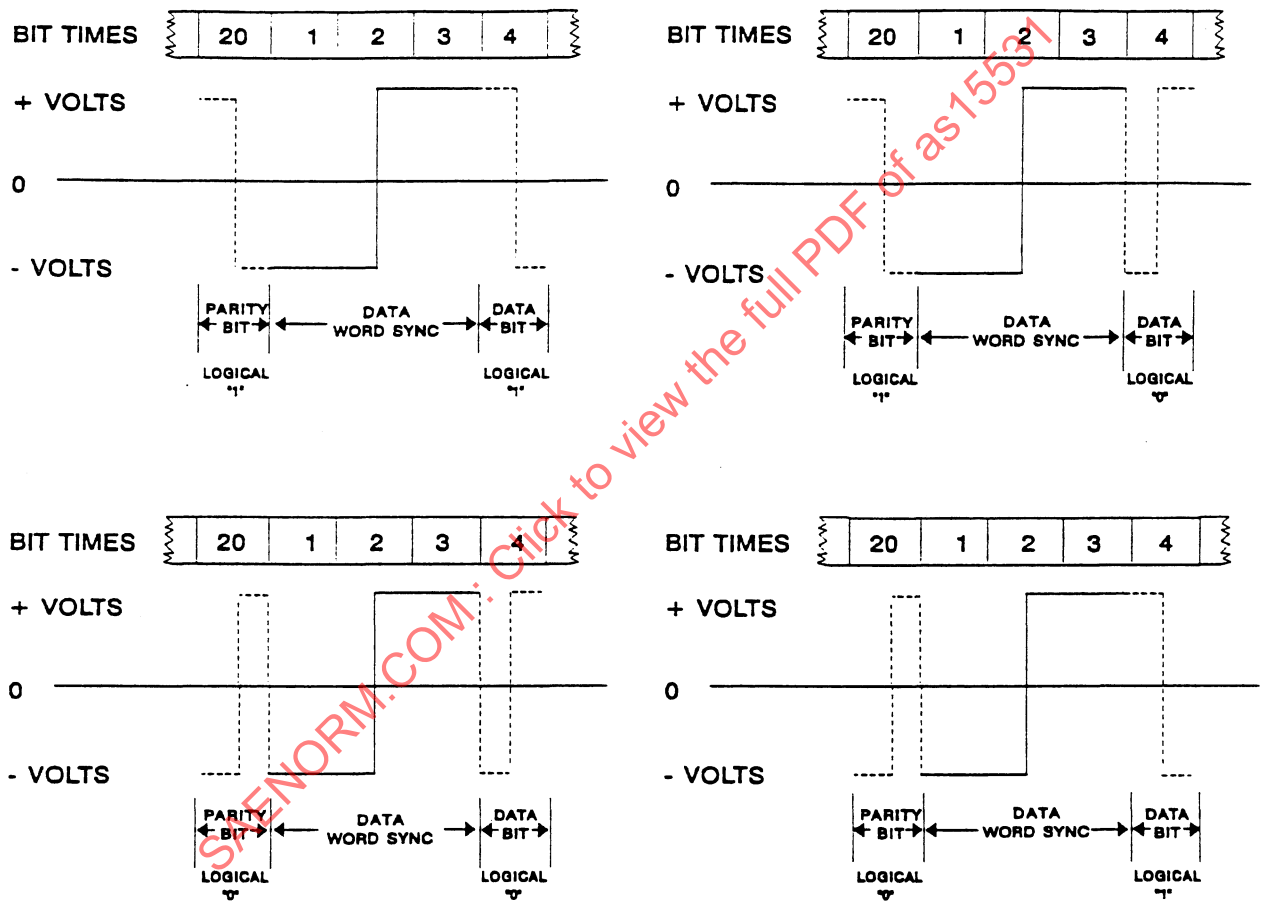


FIGURE 7 - Data Word Sync

4.3.3.5.2.3 Parity (Bit Time 20): The last bit shall be utilized for parity as specified in 4.3.3.5.1.6.

4.3.3.5.3 Status Word: A status word shall be comprised of a sync waveform, RT address, message error bit, instrumentation bit, service request bit, three reserved bits, broadcast command received bit, busy bit, subsystem flag bit, dynamic bus control acceptance bit, terminal flag bit, and a parity bit. 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 4.3.3.6.7.

4.3.3.5.3.1 Sync (Bit Times 1 - 3): The status sync waveform shall be as specified in 4.3.3.5.1.1.

4.3.3.5.3.2 RT Address (Bit Times 4 - 8): The next five bits following the sync shall contain the address of the RT which is transmitting the status word as defined in 4.3.3.5.1.2.

4.3.3.5.3.3 Message Error Bit (Bit Time 9): The status word bit at bit time nine (see Figure 3) shall be utilized to indicate that one or more of the data words associated with the preceding receive command word from the BC has failed to pass the RT's validity tests as specified in 4.4.1.1. This bit shall also be set under the conditions specified in 4.4.1.2, 4.4.3.4, and 4.4.3.6. 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.

4.3.3.5.3.4 Instrumentation Bit (Bit Time 10): The status word at bit time ten (see Figure 3) 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 to distinguish between a command and status word is optional.

4.3.3.5.3.5 Service Request Bit (Bit Time 11): The status word bit at bit time eleven (see Figure 3) 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 BC 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.

4.3.3.5.3.6 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.

4.3.3.5.3.7 Broadcast Command Received Bit (Bit Time 15): The status word bit 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.

4.3.3.5.3.8 Busy Bit (Bit Time 16): The status word bit at bit time sixteen (see Figure 3) 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.

4.3.3.5.3.9 Subsystem Flag Bit (Bit Time 17): The status word bit at bit time seventeen (see Figure 3) shall be reserved for the subsystem flag bit. If an associated subsystem has the capability for self-test, the use of this bit shall be required. This bit, when used, shall flag a subsystem fault condition, and alert the BC 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 logic zero its absence. If not used, this bit shall be set to logic zero.

4.3.3.5.3.10 Dynamic Bus Control Acceptance Bit (Bit Time 18): The status word bit at bit time eighteen (see Figure 3) shall be reserved for the acceptance of dynamic bus control. If the RT implements the dynamic bus control function, the use of this bit shall be required. This bit, when used, shall indicate acceptance or rejection of a dynamic bus control offer as specified in 4.3.3.5.1.7.1. A logic one shall indicate acceptance of control, and a logic zero shall indicate rejection of control. If this function is not used, this bit shall be set to logic zero.

4.3.3.5.3.11 Terminal Flag Bit (Bit Time 19): The status word bit at bit time nineteen (see Figure 3) shall be reserved for the terminal flag function. If an RT has the capability for self-test, the use of this bit shall be required. This bit, when used, shall flag an 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 logic zero.

4.3.3.5.3.12 Parity Bit (Bit Time 20): The least significant bit (LSB) in the status word shall be utilized for parity as specified in 4.3.3.5.1.6.

4.3.3.5.4 Status Word Reset: The status word bits, with the exception of the address, shall be set to logic zero after a valid command word is received by the RT with the exceptions as specified in 4.3.3.5.1.7. 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.

4.3.3.6 Message Formats: The messages transmitted on the data bus shall be in accordance with the formats on Figure 8 and Figure 9. The maximum and minimum response times shall be as stated in 4.3.3.7 and 4.3.3.8. No message formats, other than those defined herein, shall be used on the bus. RTs shall, as a minimum, implement the following nonbroadcast message formats: (1) RT to BC transfers, (2) BC to RT transfers, (3) RT to RT transfers (receive and transmit), and (4) mode command without data word transfers. For nonbroadcast messages, the RT shall not distinguish between data received during a BC to RT transfer or data received during an RT to RT transfer (receive) to the same subaddress. The RT shall not distinguish between data to be transmitted during an RT to BC transfer or data to be transmitted during an RT to RT transfer (transmit) from the same subaddress. BCs shall have the capability to issue all message formats.

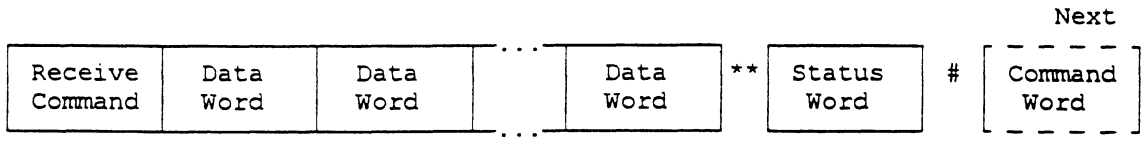
4.3.3.6.1 Bus Controller to Remote Terminal Transfers: The BC shall issue a receive command word followed by the specified number of data words. The RT shall, after message validation, transmit a status word back to the controller. The command word and data words shall be transmitted in a contiguous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

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

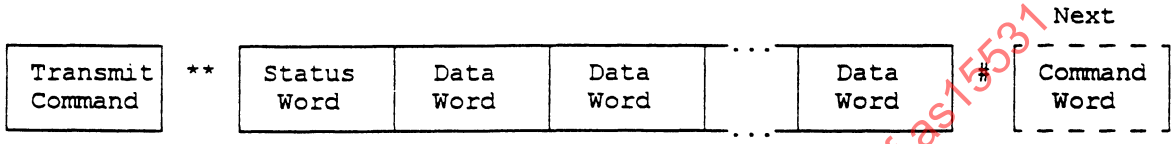
4.3.3.6.3 Remote Terminal to Remote Terminal Transfers: The BC shall issue a receive command word to RT A followed contiguously by a transmit command word to RT B. RT B shall, after command word validation, transmit a status word followed by the specified number of data words. The status and data words shall be transmitted in a contiguous fashion with no gap. At the conclusion of the data transmission by RT B, RT A shall transmit a status word within the specified time period.

4.3.3.6.4 Mode Command without Data Word: The BC shall issue a transmit command word to the RT using a mode code specified in Table 1. The RT shall, after command word validation, transmit a status word.

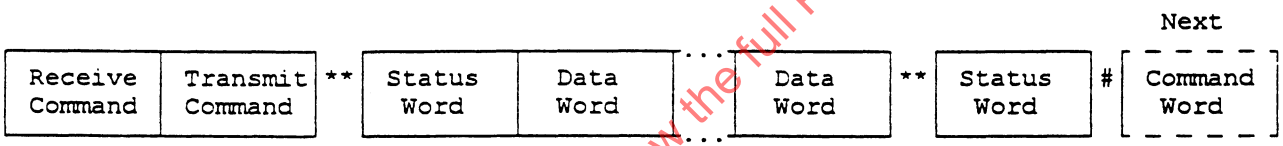
BUS CONTROLLER TO REMOTE TERMINAL TRANSFER



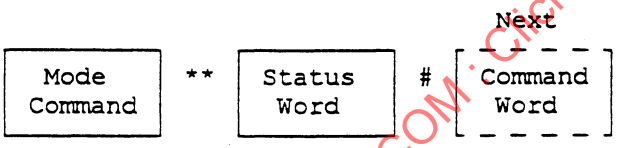
REMOTE TERMINAL TO BUS CONTROLLER TRANSFER



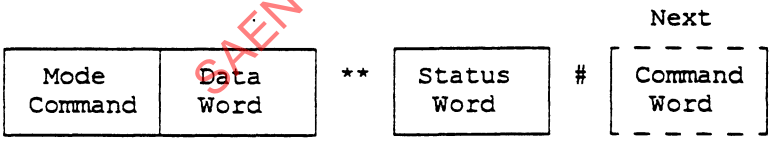
REMOTE TERMINAL TO REMOTE TERMINAL TRANSFER



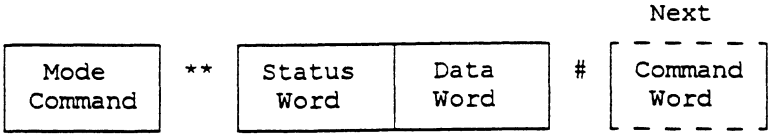
MODE COMMAND WITHOUT DATA WORD TRANSFER



MODE COMMAND WITH DATA WORD (RECEIVE) TRANSFER



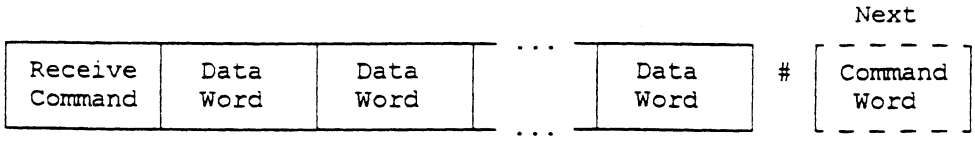
MODE COMMAND WITH DATA WORD (TRANSMIT) TRANSFER



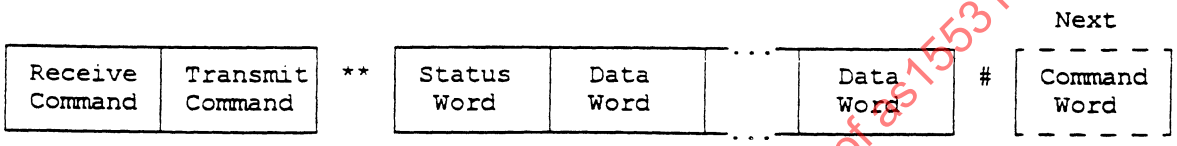
** - Response Time, # - Intermessage Gap

FIGURE 8 - Information Transfer Formats

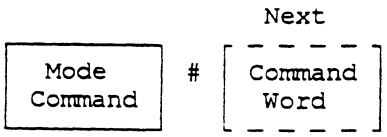
BUS CONTROLLER TO REMOTE TERMINAL(S) (BROADCAST) TRANSFER



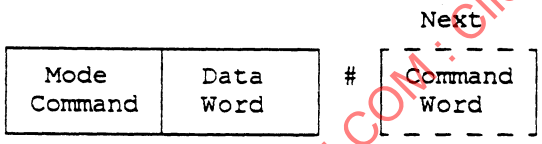
REMOTE TERMINAL TO REMOTE TERMINAL(S) (BROADCAST) TRANSFER



MODE COMMAND WITHOUT DATA WORD (BROADCAST) TRANSFER



MODE COMMAND WITH DATA WORD (BROADCAST) TRANSFER



** - Response Time, # - Intermessage Gap

FIGURE 9 - Broadcast Information Transfer Formats

4.3.3.6.5 Mode Command with Data Word (Transmit): The BC shall issue a transmit command word 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.

4.3.3.6.6 Mode Command with Data Word (Receive): The BC shall issue a receive command word 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 word and data word validation, transmit a status word back to the controller.

4.3.3.6.7 Optional Broadcast Command: The broadcast option may be implemented in RTs. If an RT implements the broadcast option, it shall be capable of distinguishing between a broadcast and a nonbroadcast message to the same subaddress for nonmode command messages. The RT address of 11111 is reserved for broadcast and shall not be used for any other purpose. See 5.6 for additional information on the use of the broadcast command.

4.3.3.6.7.1 Bus Controller to Remote Terminal(s) Transfer (Broadcast): The BC 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. The RT(s) with the broadcast option shall after message validation, set the broadcast command received bit in the status word as specified in 4.3.3.5.3.7 and shall not transmit the status word.

4.3.3.6.7.2 Remote Terminal to Remote Terminal(s) Transfers (Broadcast): The BC shall issue a receive command word with 11111 in the RT address field followed by a transmit command word to RT A using the RT's address. RT A shall, after command word validation, transmit a status word followed by the specified number of data words. The status and data words shall be transmitted in a contiguous fashion with no gap. The RT(s) with the broadcast option, excluding RT A, shall after message validation, set the broadcast received bit in the status word as specified in 4.3.3.5.3.7 and shall not transmit the status word.

4.3.3.6.7.3 Mode Command without Data Word (Broadcast): The BC shall issue a transmit command word with 11111 in the RT address field, and a mode code specified in Table 1. The RT(s) with the broadcast option shall, after command word validation, set the broadcast received bit in the status word as specified in 4.3.3.5.3.7 and shall not transmit the status word.

4.3.3.6.7.4 Mode Command with Data Word (Broadcast): The BC 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. The RT(s) with the broadcast option shall, after message validation, set the broadcast received bit in the status word as specified in 4.3.3.5.3.7 and shall not transmit the status word.

4.3.3.7 Intermessage Gap: The BC shall provide a minimum gap time of 4.0 µs between messages as shown on Figure 8 and Figure 9. This time period, shown as T on Figure 10, is measured at point A of the BC as shown on Figure 5 or Figure 6. 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.

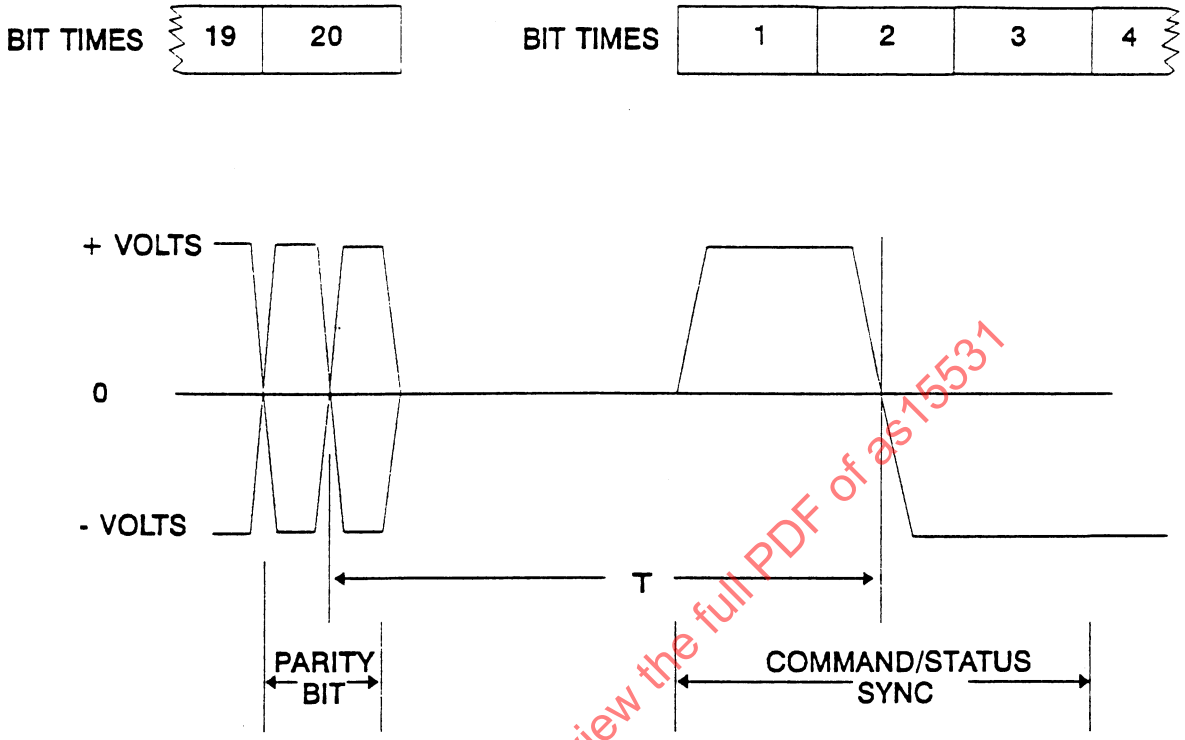


FIGURE 10 - Intermessage Gap and Response Time

4.3.3.8 Response Time: The RT shall respond, in accordance with 4.3.3.6, to a valid command word within the time period of 4.0 to 12.0 µs. This time period, shown as T on Figure 10, is measured at point A of the RT as shown on Figure 5 or Figure 6. The time is measured from the mid bit zero crossing of the last word as specified in 4.3.3.6 and as shown on Figure 8 and Figure 9 to the mid-zero crossing of the status word sync.

4.3.3.9 Minimum No-response Time-out: The minimum time that a terminal shall wait before considering that a response as specified in 4.3.3.8 has not occurred shall be 14.0 µs. 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 5 or Figure 6.

4.4 Terminal Operation:

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

4.4.1.1 Word Validation: The terminal shall insure that each word conforms to the following criteria:

a. The word begins with a valid sync field.
b. The bits are in a valid Manchester II code.
c. The information field has 16 bits plus parity.
d. The word parity is odd.

When a word fails to conform to the preceding criteria, the word shall be considered invalid.

4.4.1.2 Transmission Continuity: The terminal shall verify that the message is contiguous as defined in 4.3.3.6. Improperly timed data syncs shall be considered a message error.

4.4.1.3 Terminal Fail-Safe: The terminal shall contain a hardware implemented time-out to preclude a signal transmission of greater than 800.0 µs. 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.

4.4.2 Bus Controller Operation: A terminal operating as a BC shall be responsible for sending data bus commands, participating in data transfers, receiving status responses, and monitoring system status as defined in this document. The BC 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.

4.4.2.1 Bus Controller Required Mode Codes: The BC shall have the capability to implement all of the mode codes as defined in 4.3.3.5.1.7.

4.4.3 Remote Terminal:

4.4.3.1 Operation: An RT shall operate in response to valid commands received from the BC. The RT shall accept a command word as valid when the command word meets the criteria of 4.4.1.1, 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. No combination of RT address bits, T/R bit, subaddress/mode bits, and data word count/mode code bits of a command word shall result in invalid transmissions by the RT. Subsequent valid commands shall be properly responded to by the RT.

4.4.3.2 Superseding Valid Commands: The RT shall be capable of receiving a command word on the data bus after the minimum intermessage gap time as specified in 4.3.3.7 has been exceeded, when the RT is not in the time period T as specified in 4.3.3.8 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 word. The RT shall respond to the second valid command as specified in 4.3.3.8.

4.4.3.3 Invalid Command Word: An RT shall not respond to a command word which fails to meet the criteria specified in 4.4.3.1.

4.4.3.4 Illegal Command Word: An illegal command word is a valid command word as specified in 4.4.3.1, 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 BC to assure that no illegal command words are sent out. The RT designer has the option of monitoring for illegal command words. If an RT that is designed with this option detects an illegal command word 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.

4.4.3.5 Valid Data Reception: The RT 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 4.4.1.1.

4.4.3.6 Invalid Data Reception: Any data word(s) associated with a valid receive command that does not meet the criteria specified in 4.4.1.1 and 4.4.1.2 or an error in the data word count shall cause the RT 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.

4.4.3.7 Remote Terminal Required Mode Codes: An RT shall implement the following mode codes as a minimum transmit status word (T/R = 1, MC = 00010), transmitter shutdown (T/R = 1, MC = 00100), override transmitter shutdown (T/R = 1, MC = 00101), reset RT (T/R = 1, MC = 01000).

4.4.3.8 Remote Terminal to Remote Terminal Validation: For RT to RT transfers, in addition to the validation criteria specified in 4.4.3.6, if a valid receive command is received by the RT and the first data word is received after 57.0 µs ± 3.0 µs, the RT shall consider the message invalid and respond as specified in 4.4.3.6. The time shall be measured from the mid-bit zero crossing of the parity bit of the receive command word to the mid-sync zero crossing of the first expected data word at point A as shown on Figures 5 and 6. It is recommended that the receiving RT of an RT to RT transfer verify the proper occurrence of the transmit command word and status word as specified in 4.3.3.6.3 and 4.3.3.6.7.2.

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

4.5 Hardware Characteristics:

4.5.1 Data Bus Characteristics: All cable to connector junctions, cable terminations, and bus-stub junctions shall have continuous 360 degree shielding which shall provide a minimum of 75.0% coverage.

4.5.1.1 Cable: The cable used for the main bus and all stubs shall be a two conductor, twisted, shielded, jacketed cable. The wire-to-wire distributed capacitance shall not exceed 30.0 picofarads per foot. The cables shall be formed with not less than four 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 90.0% coverage.

4.5.1.2 Characteristic Impedance: The characteristic impedance of the cable shall be within the range of 70.0 to 85.0 ohms at a sinusoidal frequency of 1.0 megahertz (MHz).

4.5.1.3 Cable Attenuation: At the frequency of 4.5.1.2, the cable power loss shall not exceed 1.5 decibels (dB)/100 feet (ft)).

4.5.1.4 Cable Termination: The two ends of the cable shall be terminated with a resistance, equal to the selected cable nominal characteristic impedance (Z_o) ±2.0%.

4.5.1.5 Cable Stub Requirements: The cable shall be coupled to the terminal as shown on Figure 5 or Figure 6. The use of long stubs is discouraged, and the length of a stub should be minimized. However, if installation requirements dictate, stub lengths exceeding those lengths specified in 4.5.1.5.1 and 4.5.1.5.2 are permissible. Each terminal shall have transformer coupled stub connections, but may also have direct coupled stub connections. Unused terminal connections shall have a minimum of 75% shielding coverage.

4.5.1.5.1 Transformer Coupled Stubs: The length of a transformer coupled stub should not exceed 20 ft. If a transformer coupled stub is used, then the following shall apply.

4.5.1.5.1.1 Coupling Transformer: A coupling transformer, as shown on Figure 5, shall be required. This transformer shall have a turns ratio of 1:1.41 ± 3.0%, with the higher turns on the isolation resistor side of the stub.

4.5.1.5.1.1.1 Transformer Input Impedance: The open circuit impedance as seen at point B on Figure 11 shall be greater than 3000 ohms over the frequency range of 75.0 kilohertz (kHz) to 1.0 MHz, when measured with a 1.0 V root-mean-square (RMS) sine wave.

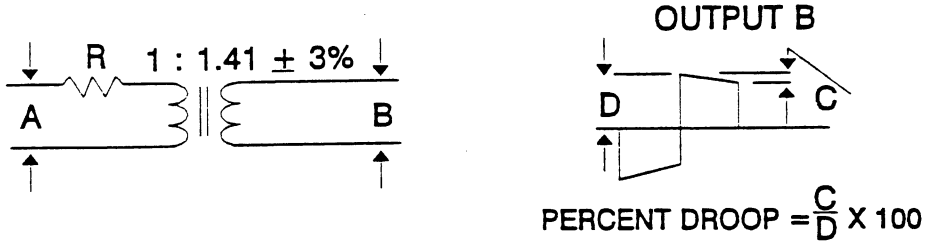


FIGURE 11 - Coupling Transformer

4.5.1.5.1.1.2 Transformer Waveform Integrity: The droop of the transformer using the test configuration shown on Figure 11 at point B, shall not exceed 20.0%. Overshoot and ringing as measured at point B shall be less that ±1.0 volt (V) peak. For this test, R shall equal 360.0 ohms ± 5.0% and the input A of Figure 11 shall be a 250.0 kHz square wave, 27.0 V peak-to-peak, with a rise and fall time no greater than 100 nanoseconds (ns).

4.5.1.5.1.1.3 Transformer Common Mode Rejection: The coupling transformer shall have a common mode rejection ratio greater than 45.0 dB at 1.0 MHz.

4.5.1.5.1.2 Fault Isolation: An isolation resistor shall be placed in series with each connection to the data bus cable. This resistor shall have a value of 0.75 Z_o ohms ± 2.0%, where Z_o is the selected cable nominal characteristic impedance. The impedance placed across the data bus cable shall be no less than 1.5 Z_o ohms for any failure of the coupling transformer, cable stub, or terminal transmitter/receiver.

4.5.1.5.1.3 Cable Coupling: All coupling transformers and isolation resistors, as specified in 4.5.1.5.1.1 and 4.5.1.5.1.2, shall have continuous shielding which will provide a minimum of 75% coverage. The isolation resistors and coupling transformers shall be placed at minimum possible distance from the junction of the stub to the main bus.

4.5.1.5.1.4 Stub Voltage Requirements: Every data bus shall be designed such that all stubs at point A of Figure 5 shall have a peak-to-peak amplitude, line-to-line within the range of 1.0 V and 14.0 V for a transmission by any terminal on the data bus. This shall include the maximum reduction of data bus signal amplitude in the event that one of the terminals has a fault which causes it to reflect a fault impedance specified in 4.5.1.5.1.2 on the data bus. This shall also include the worse case output voltage of the terminals as specified in 4.5.2.1.1.1 and 4.5.2.2.1.1.

4.5.1.5.2 Direct Coupled Stubs: The length of a direct coupled stub should not exceed 1.0 ft. Refer to 5.5 for comments concerning direct coupled stubs. If a direct coupled stub is used, then the following shall apply:

4.5.1.5.2.1 Fault Isolation: An isolation resistor shall be placed in series with each connection to the data bus cable. This resistor shall have a value of 55.0 ohms ± 2.0%. The isolation resistors shall be placed within the RT as shown on Figure 6.

4.5.1.5.2.2 Cable Coupling: All bus-stub junctions shall have continuous shielding which will provide a minimum of 75% coverage.

4.5.1.5.2.3 Stub Voltage Requirements: Every data bus shall be designed such that all stubs at point A of Figure 6 shall have a peak-to-peak amplitude, line-to-line within the range of 1.4 V and 20.0 V for a transmission by any terminal on the data bus. This shall include the maximum reduction of data bus signal amplitude in the event that one of the terminals has a fault which causes it to reflect a fault impedance of 110 ohms on the data bus. This shall also include the worst case output voltage of the terminals as specified in 4.5.2.1.1.1 and 4.5.2.2.1.1.

4.5.1.5.3 Wiring and Cabling for EMC: For purposes of electromagnetic compatibility (EMC), the wiring and cabling provisions of ARP4242 shall apply.

4.5.1.6 Connector Polarity: For applications that use concentric connectors or inserts for each bus, the center pin of the connector or insert shall be used for the high (positive) Manchester bi-phase signal. The inner ring shall be used for the low (negative) Manchester bi-phase signal.

4.5.2 Terminal Characteristics:

4.5.2.1 Terminals with Transformer Coupled Stubs:

4.5.2.1.1 Terminal Output Characteristics: The following characteristics shall be measured with R_L, as shown on Figure 12, equal to 70.0 ohms ± 2.0%.

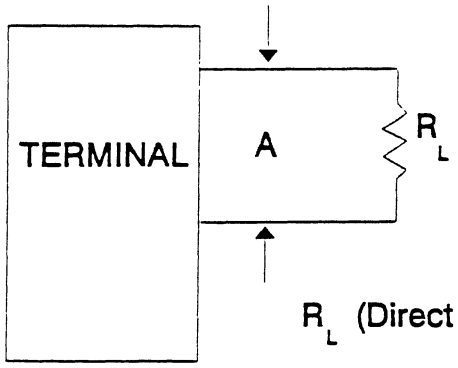
4.5.2.1.1.1 Output Levels: The terminal output voltage levels shall be measured using the test configuration shown on Figure 12. The terminal output voltage shall be within the range of 18.0 to 27.0 V, peak-to-peak, line-to-line, when measured at point A on Figure 12.

4.5.2.1.1.2 Output Waveform: The waveform, when measured at point A on Figure 12, shall have zero crossing deviations which are equal to, or less than, 25.0 ns from the ideal crossing point, measured with respect to the previous zero crossing (i.e., 0.5 ± 0.025 µs 1.0 ± 0.025 µs 1.5 ± 0.025 µs and 2.0 ± 0.025 µs). The zero crossings include the zero crossings between words.

The rise and fall time of this waveform shall be from 100.0 to 300.0 ns when measured from levels of 10 to 90% of full waveform peak-to-peak, line-to-line, voltage as shown on Figure 13. Any distortion of the waveform including overshoot and ringing shall not exceed ±900.0 millivolts (mV) peak, line-to-line, as measured at point A, Figure 12.

4.5.2.1.1.3 Output Noise: Any noise transmitted when the terminal is receiving or has power removed, shall not exceed a value of 14.0 mV, RMS, line-to-line, as measured at point A, Figure 12.

4.5.2.1.1.4 Output Symmetry: From the time beginning 2.5 ms after the mid-bit crossing of the parity bit of the last word transmitted by a terminal, the maximum voltage at point A of Figure 12 shall be no greater than ±250.0 mV peak, line-to-line. This shall be tested with the terminal transmitting the maximum number of words it is designed to transmit, up to 33. This test shall be run six times with each word in a contiguous block of words having the same bit pattern. The six word contents that shall be used are 8000_{16}, $7FFF_{16}$, 0000_{16}, $FFFF_{16}$, 5555_{16}, and $AAAA_{16}$. The output of the terminal shall be as specified in 4.5.2.1.1.1 and 4.5.2.1.1.2.



R_L (Direct Coupled) = 35 ohms ± 2%

R_L (Transformer Coupled) = 70 ohms ± 2%

FIGURE 12 - Terminal Output Characteristics for Transformer Coupled and Direct Coupled Stubs

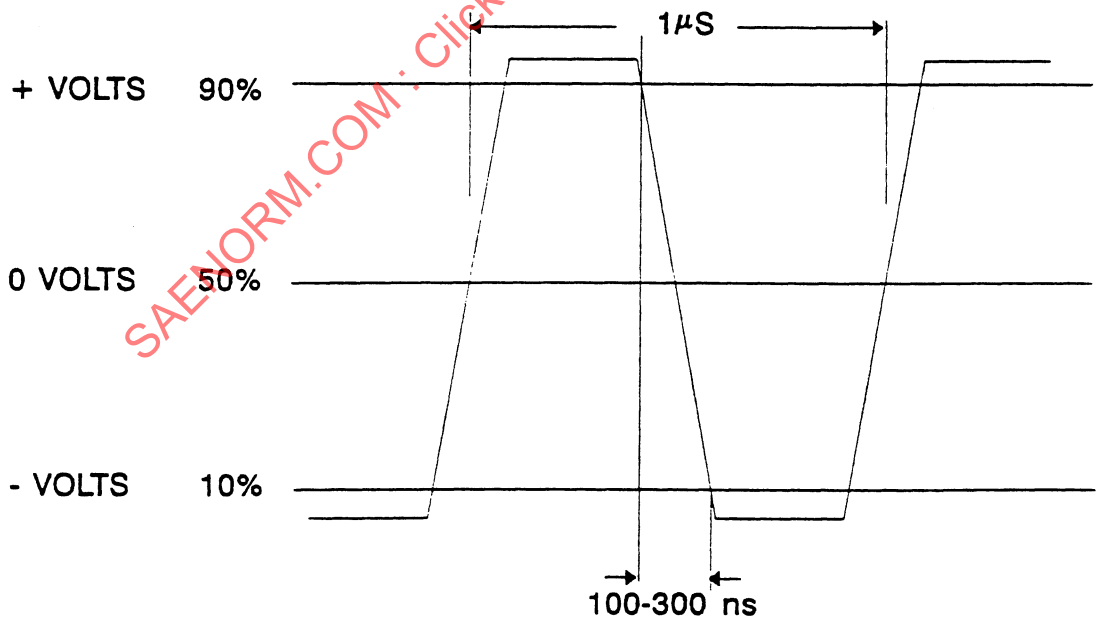


FIGURE 13 - Output Waveform

4.5.2.1.1.5 Power On/Off Noise: A terminal shall limit any spurious output during a power-up or power-down sequence. The maximum allowable output noise amplitude shall be ±250 mV peak, line-to-line, measured at point A of Figure 12.

4.5.2.1.2 Terminal Input Characteristics: The following characteristics shall be measured independently.

4.5.2.1.2.1 Input Waveform Compatibility: The terminal shall be capable of receiving and operating with the incoming signals specified herein, and shall accept waveform varying from a square wave to a sine wave with a maximum zero crossing deviation from the ideal with respect to the previous zero crossing of ±150 ns, (i.e., 2.0 ± 0.15 µs, 1.5 ± 0.15 µs, 1.0 ± 0.15 µs, 0.5 ± 0.15 µs). The terminal shall respond to an input signal whose peak-to-peak amplitude, line-to-line, is within the range of 0.86 to 14.0 V. The terminal shall not respond to an input signal whose peak-to-peak amplitude, line-to-line, is within the range of 0.0 to 0.20 V. The voltages are measured at point A on Figure 5.

4.5.2.1.2.2 Common Mode Rejection: Any signals from direct current (DC) to 2.0 MHz, with amplitudes equal to or less than ±10.0 V peak, line-to-ground, measured at point A on Figure 5, shall not degrade the performance of the receiver.

4.5.2.1.2.3 Input Impedance: The magnitude of the terminal input impedance, when the RT is not transmitting, or has power removed, shall be a minimum of 1000.0 ohms within the frequency range of 75.0 kHz to 1.0 MHz. This impedance is that measured line-to-line at point A on Figure 5. For LRUs, this impedance is that measured at the input to the LRU, line to line (point A on Figure 5).

4.5.2.1.2.4 Noise Rejection: The terminal shall exhibit a maximum word error rate of one part in 10^7, on all words received by the terminal, after validation checks as specified in 4.4, when operating in the presence of additive white Gaussian noise distributed over a bandwidth of 1.0 kHz to 4.0 MHz at an RMS amplitude of 140 mV. A word error shall include any fault which causes the message error bit to be set in the terminal's status word, or one which causes a terminal to not respond to a valid command word, or to respond with other than CS. The word error rate shall be measured with a 2.1 V peak-to-peak, line-to-line, input to the terminal as measured at point A on Figure 5. The noise tests shall be run continuously until, for a particular number of failures, the number of words received by the terminal, including both command and data words, exceeds the required number for acceptance of the terminal, or is less than the required number for rejection of the terminal, as specified in Table 2. All data words used in the tests shall contain random bit patterns. These bit patterns shall be unique for each data word in a message, and shall change randomly from message to message.

4.5.2.2 Terminals with Direct Coupled Stubs:

4.5.2.2.1 Terminal Output Characteristics: The following characteristics shall be measured with R_L, as shown on Figure 12, equal to 35.0 ohms ± 2.0%.

TABLE 2 - Criteria for Acceptance or Rejection of a Terminal for the Noise Rejection Test

No. of Errors	Total Words Received by the Terminal (in multiples of 10^7) Reject (Equal or Less)	Total Words Received by the Terminal (in multiples of 10^7) Accept (Equal or Less)
0	N/A	4.40
1	N/A	5.21
2	N/A	6.02
3	N/A	6.83
4	N/A	7.64
5	N/A	8.45
6	0.45	9.27
7	1.26	10.08
8	2.07	10.89
9	2.88	11.70
10	3.69	12.51
11	4.50	13.32
12	5.31	14.13
13	6.12	14.94
14	6.93	15.75
15	7.74	16.56
16	8.55	17.37
17	9.37	18.19
18	10.18	19.00
19	10.99	19.81
20	11.80	20.62
21	12.61	21.43
22	13.42	22.24
23	14.23	23.05
24	REJECT	REJECT

4.5.2.2.1.1 Output Levels: The terminal output voltage levels shall be measured using the test configuration shown on Figure 12. The terminal output voltage shall be within the range of 6.0 to 9.0 V, peak-to-peak, line-to-line, when measured at point A on Figure 12.

4.5.2.2.1.2 Output Waveform: The waveform, when measured at point A on Figure 12, shall have zero crossing deviations which are equal to, or less than, 25.0 ns from the ideal crossing point, measured with respect to the previous zero crossing (i.e., 0.5 ± 0.025 µs, 1.0 ± 0.025 µs, 1.5 ± 0.025 µs and 2.0 ± 0.025 µs). The zero crossings include the zero crossings between words.

The rise and fall time of this waveform shall be from 100.0 to 300.0 ns when measured from levels of 10 to 90% of full waveform peak-to-peak, line-to-line, voltage as shown on Figure 13. Any distortion of the waveform including overshoot and ringing shall not exceed ±300.0 mV peak, line-to-line, as measured at point A on Figure 12.

4.5.2.2.1.3 Output Noise: Any noise transmitted when the terminal is receiving or has power removed, shall not exceed a value of 5.0 mV, RMS, line-to-line, as measured at point A on Figure 12.

4.5.2.2.1.4 Output Symmetry: From the time beginning 2.5 µs after the mid-bit crossing of the parity bit of the last word transmitted by a terminal, the maximum voltage at point A on Figure 12 shall be no greater than ±90.0 mV peak, line-to-line. This shall be tested with the terminal transmitting the maximum number of words it is designed to transmit, up to 33. This test shall be run six times with each word in a contiguous block of words having the same bit pattern. The six word contents that shall be used are 8000_{16}, $7FFF_{16}$, 0000_{16}, $FFFF_{16}$, 5555_{16}, and $AAAA_{16}$. The output of the terminal shall be as specified in 4.5.2.2.1.1 and 4.5.2.2.1.2.

4.5.2.2.1.5 Power On/Off Noise: A terminal shall limit any spurious output during a power-up or power-down sequence. The maximum allowable output noise amplitude shall be ±90 mV peak, line-to-line, measured at point A of Figure 12.