SAE Aerospace
An SAE International Group

AEROSPACE STANDARD

SAE AS1773

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Fiber Optics Mechanization of a Digital Time Division Command/Response Multiplex Data Bus

FOREWORD

This SAE Aerospace Standard (AS) contains requirements for fiber optic mechanization of a digital time division command/response multiplex data bus for use in systems integration. The parent document for data bus protocol, bit assignment and related bus traffic management is MIL-STD-1553B. AS1773 provides for the use of fiber optics as the transmission medium in a manner which is similar to MIL-STD-1553B with the added the option of increased performance by using an alternate data rate of 20 Mbps.

This document is structured to follow the organization of MIL-STD-1553B as closely as possible with additions and omissions to MIL-STD-1553B only where necessary to allow fiber optics.

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1. SCOPE

1.1 Scope:

This document defines requirements for digital, command/ response time division multiplexing (data bus) techniques for fiber optic implementation. The concept of operation and information flow on the multiplex data bus and the functional formats to be employed are also defined.

1.2 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 of the applicable requirements of this aerospace standard on any and all subcontractors he may employ.

1.3 Purpose:

The purpose of this document is twofold:

a. It seeks to preserve the multiplex bus techniques which have been standardized in MIL-STD-1553B.

b. It provides guidelines for the application of fiber optic transmission techniques to the MIL-STD-1553B interconnect.

Use of this document with the Interoperability Requirements for AS1773 document (AIR4957) and the appropriate slash sheet is intended to provide interoperability between different suppliers of equipment.

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.

AIR4508 MIL-STD-1773 User's Handbook
AIR4957 Interoperability Requirements for AS1773

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	Aircraft Internal Time Division Command/Response Multiplex Data Bus
MIL-STD-1773	Fiber Optics Mechanization of a Digital Time Division Command/Response Multiplex Data Bus
MIL-S-1773	General Specification for MIL-STD-1773

3. DEFINITIONS:

3.1 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.

3.2 BIT RATE:

The number of bits transmitted per second.

3.3 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.

3.4 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.

3.5 HALF DUPLEX:

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

3.6 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.

3.7 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.

3.8 SUBSYSTEM:

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

3.9 DATA BUS:

Whenever a data bus or bus is referred to in this document, it shall imply all the hardware in the signal distribution network, including the harness assembly of fiber optic cables, coupler(s), connectors, etc., required to provide a path between all terminals.

3.10 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.

3.11 BUS CONTROLLER (BC):

The terminal assigned the task of initiating information transfers on the data bus.

3.12 BUS MONITOR (BM):

The terminal assigned the task of receiving bus traffic and extracting selected information to be used at a later time.

3.13 REMOTE TERMINAL (RT):

All terminals not operating as the bus controller or as a bus monitor.

3.14 ASYNCHRONOUS OPERATION:

For the purpose of this document, 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.

3.15 DYNAMIC BUS CONTROL:

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

3.16 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.

3.17 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.

3.18 BROADCAST:

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

3.19 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.

3.20 COUPLER:

A coupler is an optical device which distributes optical power among two or more ports. Star couplers and tee couplers are examples of couplers.

3.21 OPTICAL SIGNAL RANGE (OSR):

Optical Signal Range is the ratio of the maximum optical signal power to the minimum optical signal power expressed in dBs. As a system specification is applied to an optical bus network, it describes the maximum range of signals that can be seen by any terminal over the operating conditions specified. Although OSR is expressed as a ratio, it is important that maximum and minimum optical signal power levels be specified as well

3.22 MID-BIT TRANSITION:

The position in the optical waveform where the optical pulse goes from a high state to a completely off or low state or from a low state to a high state.

3.23 UNIPOLAR DATA:

Data signal transmission which includes only 2 possible states (i.e., 1 or 0). This type of transmission is typical of fiber optic signaling where optical power is typically modulated between the state of 1 (high light level) to off (low light level) in contrast to Bipolar data which includes two active states (i.e., positive or negative potential) and an inactive state (no potential). Bipolar transmission is typical of two wire bus networks such as 1553.

4. GENERAL REQUIREMENTS:

4.1 Test and Operating Requirements:

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

4.2 Data Bus Operation:

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 which are, in turn, formed by three types of words (command, data and status) as defined in 4.3.3.5. The multiplex data bus system architecture is illustrated in Figure 1.

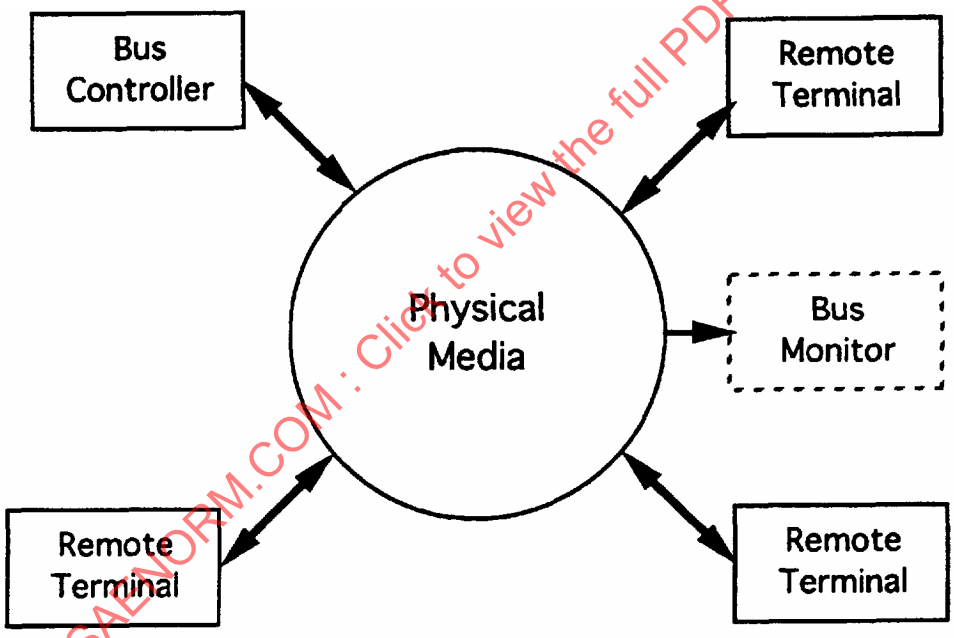

FIGURE 1 - Multiplex Data Bus Architecture

4.2.1 1 Mbps Operation: This is bus operation with all messages at 1 Mbps data rate. This is equivalent to MIL-STD-1553 and MIL-STD-1773 original release bus operation.

4.2.2 20 Mbps Operation: This is bus operation with all messages transmitted at 20 Mbps. The message format, with the exception listed in preamble 4.3.3.3.1, is identical to 1 Mbps operation.

4.2.3 Combined Data Rates Operation: This is bus operation which allows one bus controller to control 1 Mbps and 20 Mbps RTs on the same physical media.

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 standard. Any unused bit positions in a word shall be transmitted as logic zeros.

4.3.2 Bit Priority: The most significant bit 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.

4.3.3 Transmission Method:

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

4.3.3.2 Data Code Modulation Format: The data code shall be Manchester II bi-phase level. A logic one shall be transmitted as a coded signal 1/0 (i.e., an optical high level pulse followed by a low level). A logic zero shall be coded 0/1 (i.e., an optical high level pulse preceded by a low level). A transition 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 Mbps or 20 Mbps with a combined accuracy and long-term stability of ±0.1%. The short-term stability (i.e., stability over 1.0 second interval) shall be at least 0.01% (i.e., ±100 bits per second for 1 Mbps operation, ±2000 bits per second for 20 Mbps operation).

4.3.3.3.1 Preamble: For any 20 Mbps message transmission a 16 bit preamble consisting of all Manchester 1's shall immediately and contiguously precede the Command Word and Status Word. For 1 Mbps operation no preamble is allowed.

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 bit 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.

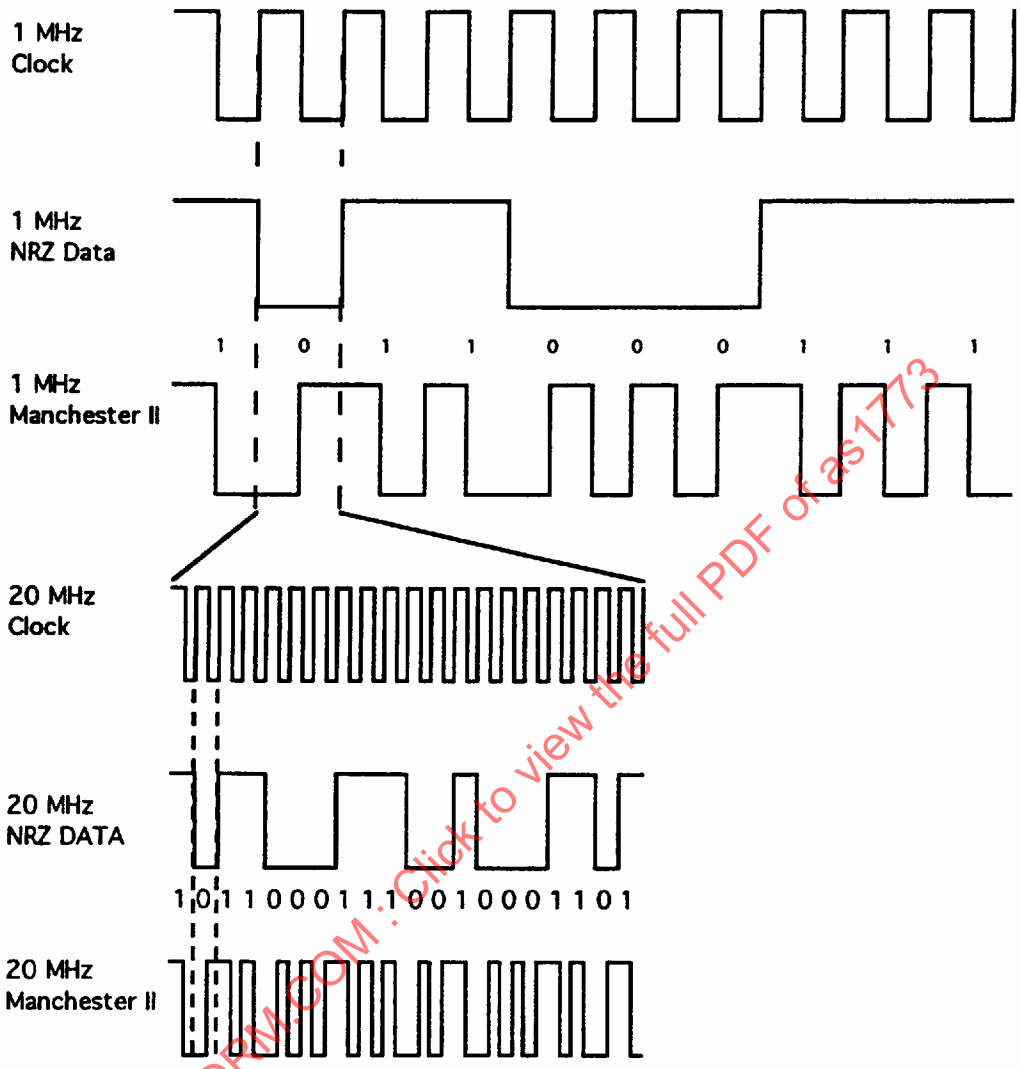

FIGURE 2 - Date Encoding

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

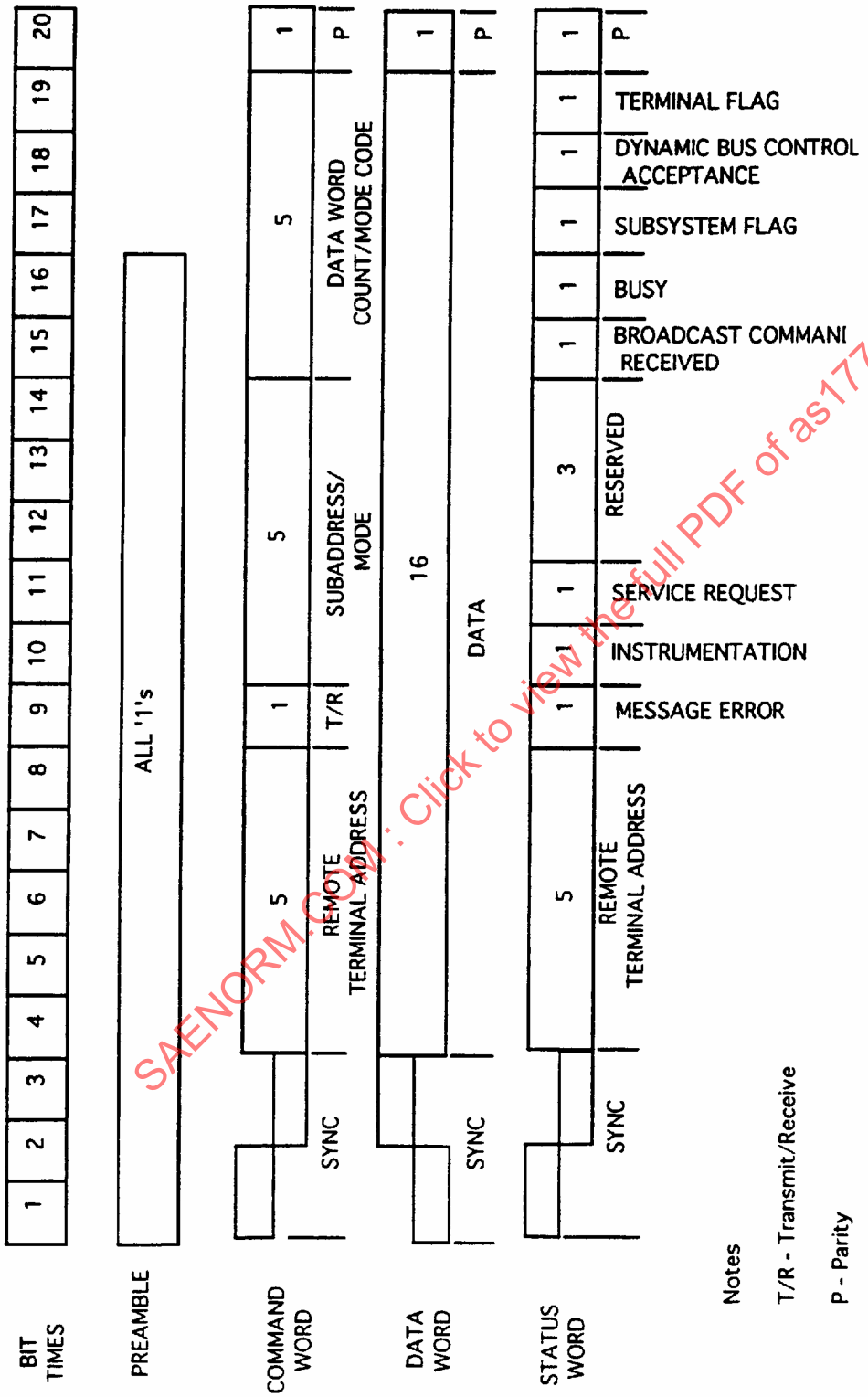

FIGURE 3 - Word Formats

4.3.3.5.1.1 Command Sync Format: The command sync waveform shall be an invalid Manchester waveform as shown in Figure 4. The width of the sync waveform shall be three bit times, with an optical high level pulse for the first one and one-half bit times and then a low level 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.

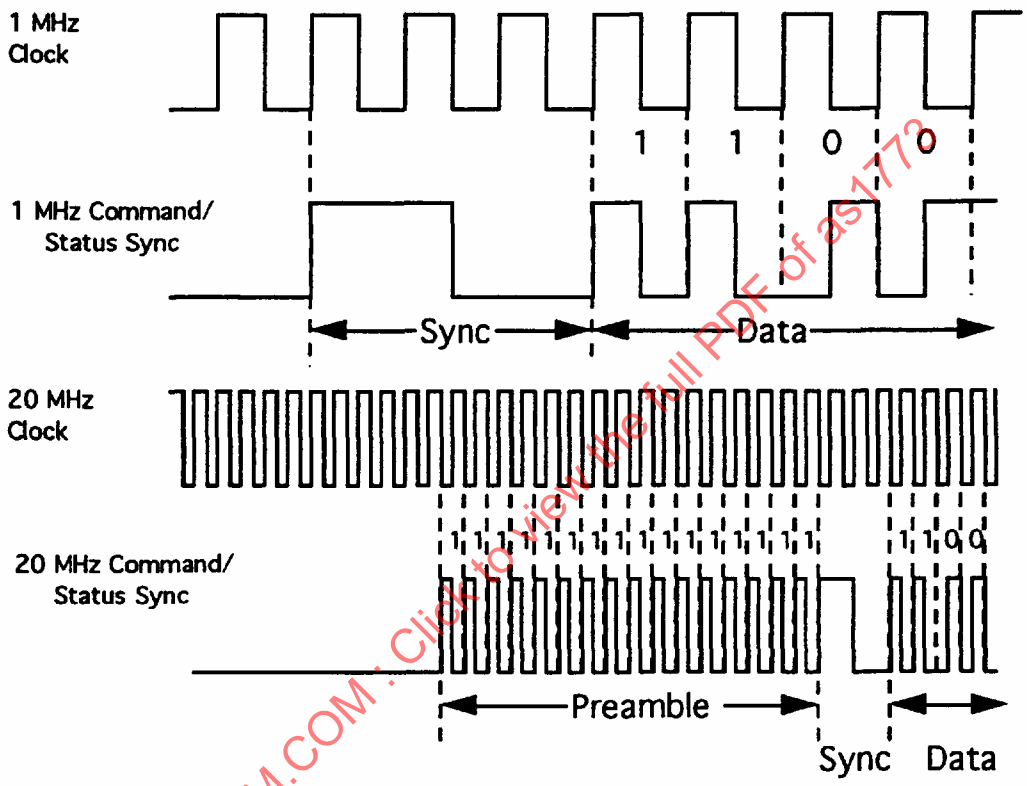

FIGURE 4 - Command and Status Word Sync

4.3.3.5.1.2 Remote Terminal Address: The next five bits following the sync shall be the RT address. Each RT for a particular data rate shall be assigned a unique address. Decimal address 31 (11111) shall not be assigned as a unique address. In addition to its unique address, a RT shall be assigned decimal address 31 (11111) as the common address, if the broadcast option is used.

4.3.3.5.1.3 Transmit/Receive: 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.

4.3.3.5.1.4 Subaddress/Mode: 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.

4.3.3.5.1.5 Data Word Count/Mode Code: 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 0s shall indicate a decimal count of 32.

4.3.3.5.1.6 Parity. 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 purpose. 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: The controller shall issue a transmit command 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 bus controller 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 bus controller retains control of the data bus.

4.3.3.5.1.7.2 Synchronize (without data word): 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.

4.3.3.5.1.7.3 Transmit Status Word: 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.

TABLE 1 - Assigned mode codes

T/R BIT	MODE CODE	ASSOCIATED FUNCTION	DATA WORDS	BROADCAST COMMAND ALLOWED
1	00000	Dynamic Bus Control	No	No
1	00001	Synchronize	No	Yes
1	00010	Transmit Status	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]
1	10010 to	Reserved	No	TBD[1]
1	01111	Reserved	No	TBD[1]
1	10000	Transmit Vector Word	Yes	No
0	10001	Synchronize	Yes	Yes
1	10010	Transmit Last Command	Yes	No
1	10011	Transmit Build In Test Word	Yes	No
0	10100	Selected Transmitter Shutdown	Yes	Yes
0	10101	Override Selected Transmitter Shutdown	Yes	Yes
1 or 0	10110	Reserved	Yes	TBD[1]
1 or 0	10111 to	Reserved	Yes	TBD[1]
1 or 0	11111	Reserved	Yes	TBD[1]

[1] Reserved for future use.

4.3.3.5.1.7.4 Initiate Self Test: 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.

4.3.3.5.1.7.5 Transmitter Shutdown: This command (to only be used with dual redundant bus systems) shall cause the RT to disable the transmitter associated with the redundant bus. 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 after this command.

4.3.3.5.1.7.6 Override Transmitter Shutdown: This command (to only be used with dual redundant bus systems) shall cause the RT to enable a transmitter which was previously disabled. 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 after this command.

4.3.3.5.1.7.7 Inhibit Terminal Flag (T/F) Bit: This command shall cause the RT to set the T/F 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 T/F Bit: This command shall cause the RT to override the inhibit T/F 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: This command shall be used to reset the RT to a power up initialized state. The RT shall first transmit its status word and then reset.

4.3.3.5.1.7.10 Reserved Mode Codes (01001 to 01111): These mode codes are reserved for future use and shall not be used.

4.3.3.5.1.7.11 Transmit Vector Word: 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): 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 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: 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 which contains bits 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.

4.3.3.5.1.7.14 Transmit Built-In-Test (BIT) Word 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 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: 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: 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 (10110 to 11111): These mode codes are reserved for future use 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 Data Sync Format: The data sync waveform shall be an invalid Manchester waveform as shown in Figure 5. The width of the sync waveform shall be three bit times, with an optical high level pulse for one and one-half bit times preceded by a low level for one and one-half bit times.

NOTE: If the bit preceding or following the sync waveform is a logic one, then the apparent width of the sync waveform will be increased.

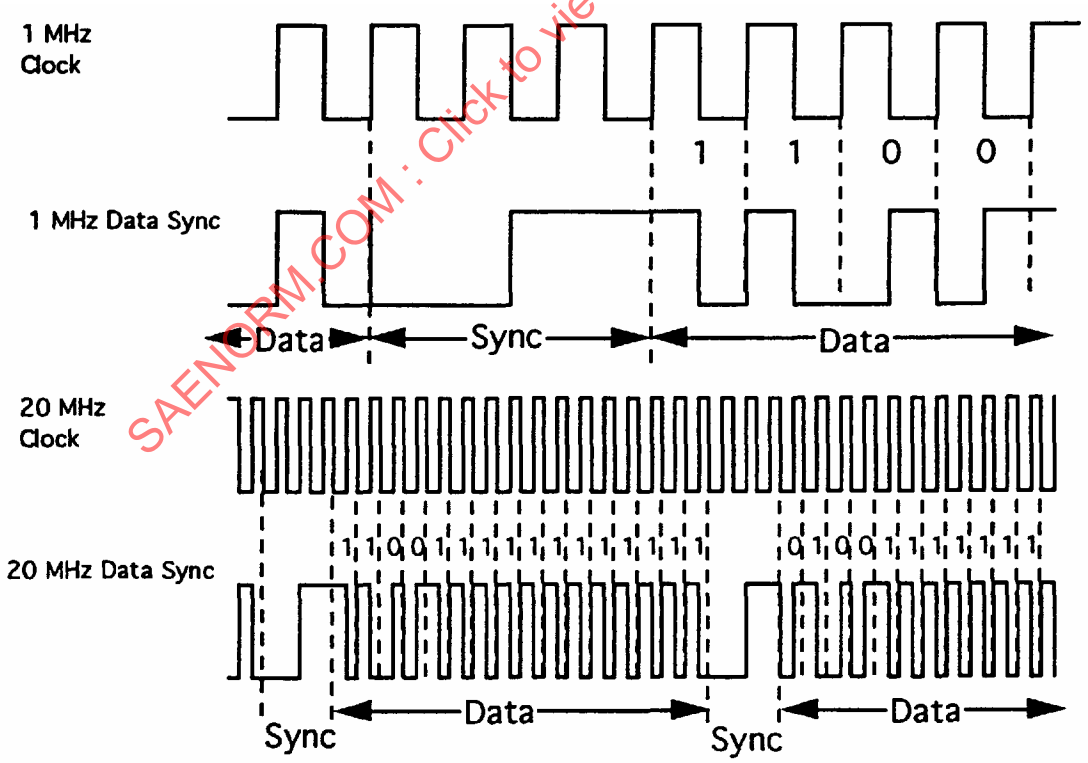

FIGURE 5 - Data Word Sync

4.3.3.5.2.2 Data: The sixteen bits following the sync shall be utilized for data transmission as specified in 4.3.2.

4.3.3.5.2.3 Parity: 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. 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 Status Sync Modulation Format: The status sync waveform shall be as specified in 4.3.3.5.1.1.

4.3.3.5.3.2 RT Address: 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: 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 bus controller 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: 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 is optional.

4.3.3.5.3.5 Service Request Bit: 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 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.

4.3.3.5.3.6 Reserved Status Bits: 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: 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 broadcast command option is not used, this bit shall be set to a logic zero.

4.3.3.5.3.8 Busy Bit: 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 bus controller'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.

4.3.3.5.3.9 Subsystem Flag Bit The status word bit at bit time seventeen (see Figure 3) 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 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: The status word bit at bit time eighteen (see Figure 3) shall be reserved for the acceptance of dynamic bus control. This bit shall be used if the RT implements the optional dynamic bus control function. 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: The status word bit at bit time nineteen (see Figure 3) shall be reserved for the terminal flag function. The use of this bit is 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 logic zero.

4.3.3.5.3.12 Parity Bit: The least significant bit 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 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 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 in Figure 6 and Figure 7. 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.

4.3.3.6.1 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 interword gaps.

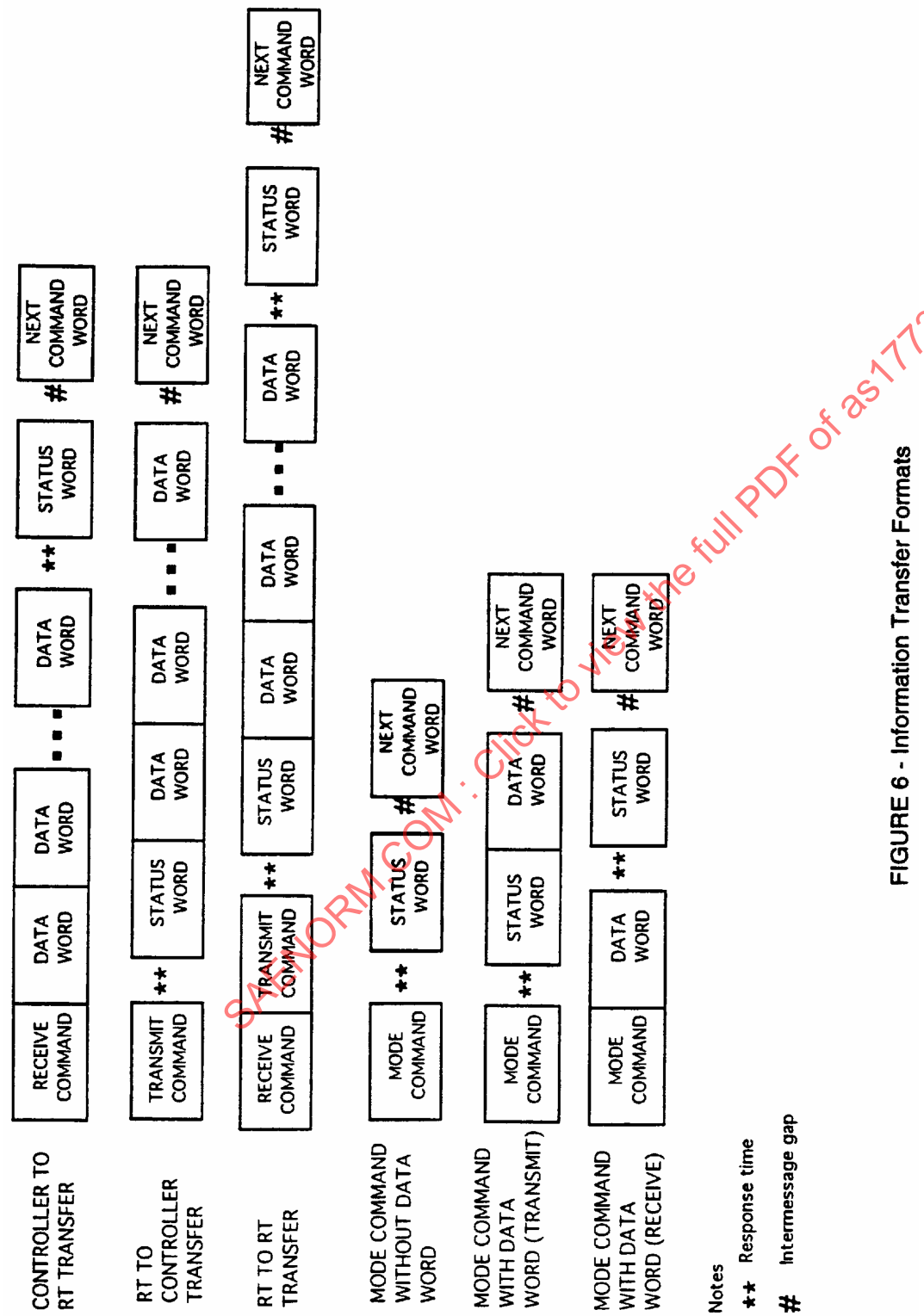

FIGURE 6 - Information Transfer Formats

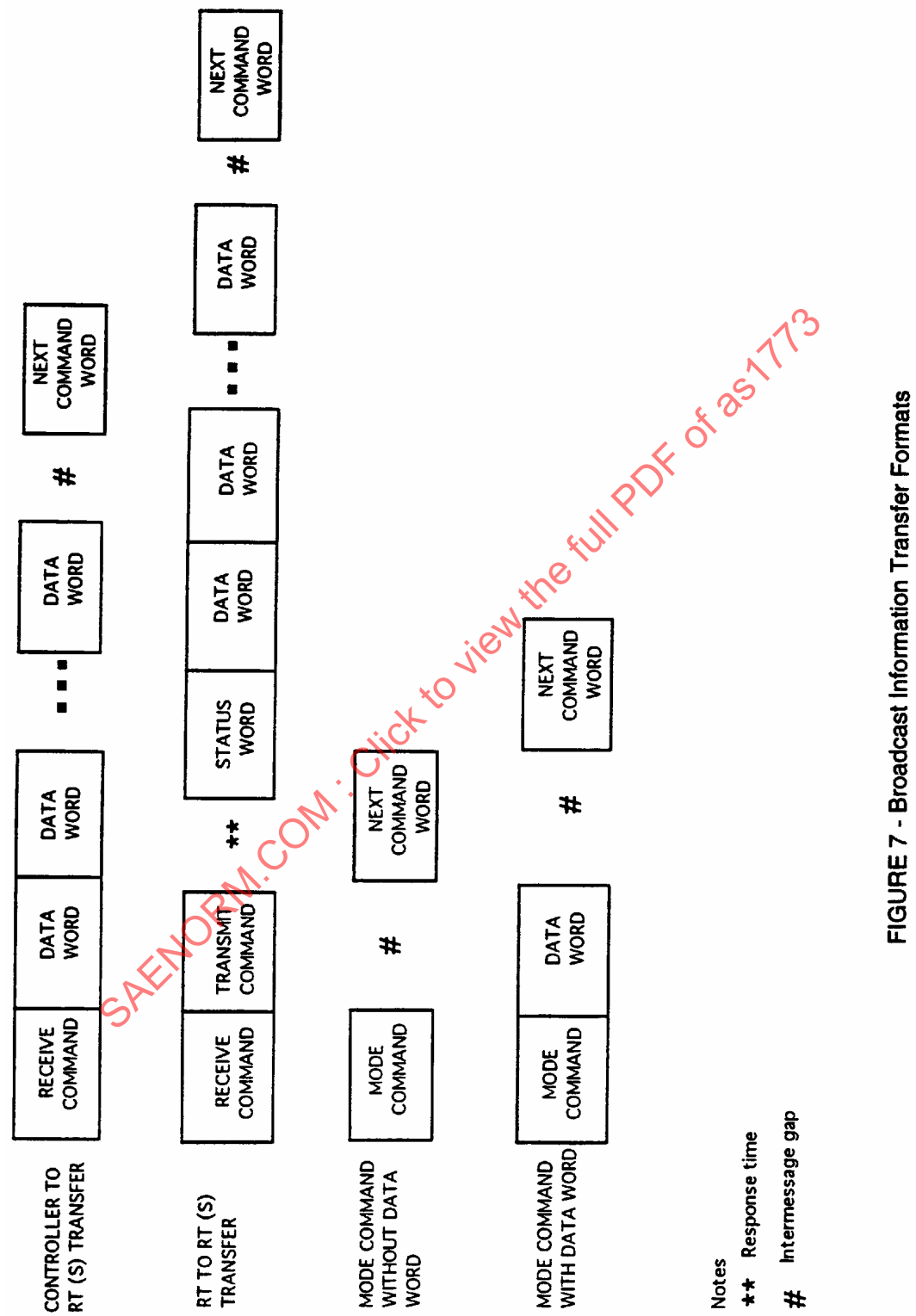

FIGURE 7 - Broadcast Information Transfer Formats

4.3.3.6.2 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 interword gaps.

4.3.3.6.3 Remote Terminal to Remote Terminal Transfers: The bus controller shall issue a receive command to RT A followed continuously by a transmit command to RT B. RT B shall, after command 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 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.

4.3.3.6.5 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.

4.3.3.6.6 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.

4.3.3.6.7 Optional Broadcast Command: See 10.5 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 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. 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 bus controller shall issue a receive command word with 11111 in the RT address field followed by a transmit command 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 bus controller 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 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. 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 bus controller shall provide a minimum gap time between messages per Table 2 and as shown in Figures 6 and 7. This time period, shown as T in Figure 8, is measured with respect to point A of the bus controller as shown in Figure 9 or 10. The time is measured from the mid-bit transition of the last bit of the preceding message to mid-sync transition of the next command word sync.

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 as shown in Table 2.. This time period, shown as T in Figure 8, is measured with respect to point A of the RT as shown in Figure 9 or 10. The time is measured from the mid-bit transition of the last word as specified in 4.3.3.6 and as shown on Figure 6 and Figure 7 to the mid-sync transition 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 as shown in Table 2. The time is measured from the mid-bit transition of the last bit of the last word to the mid-sync transition of the expected status word sync with respect point A of the terminal as shown in Figure 9 or 10. The no-response time-out may be increased for longer media delay at the expense of bus throughput efficiency.

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 minimum 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.

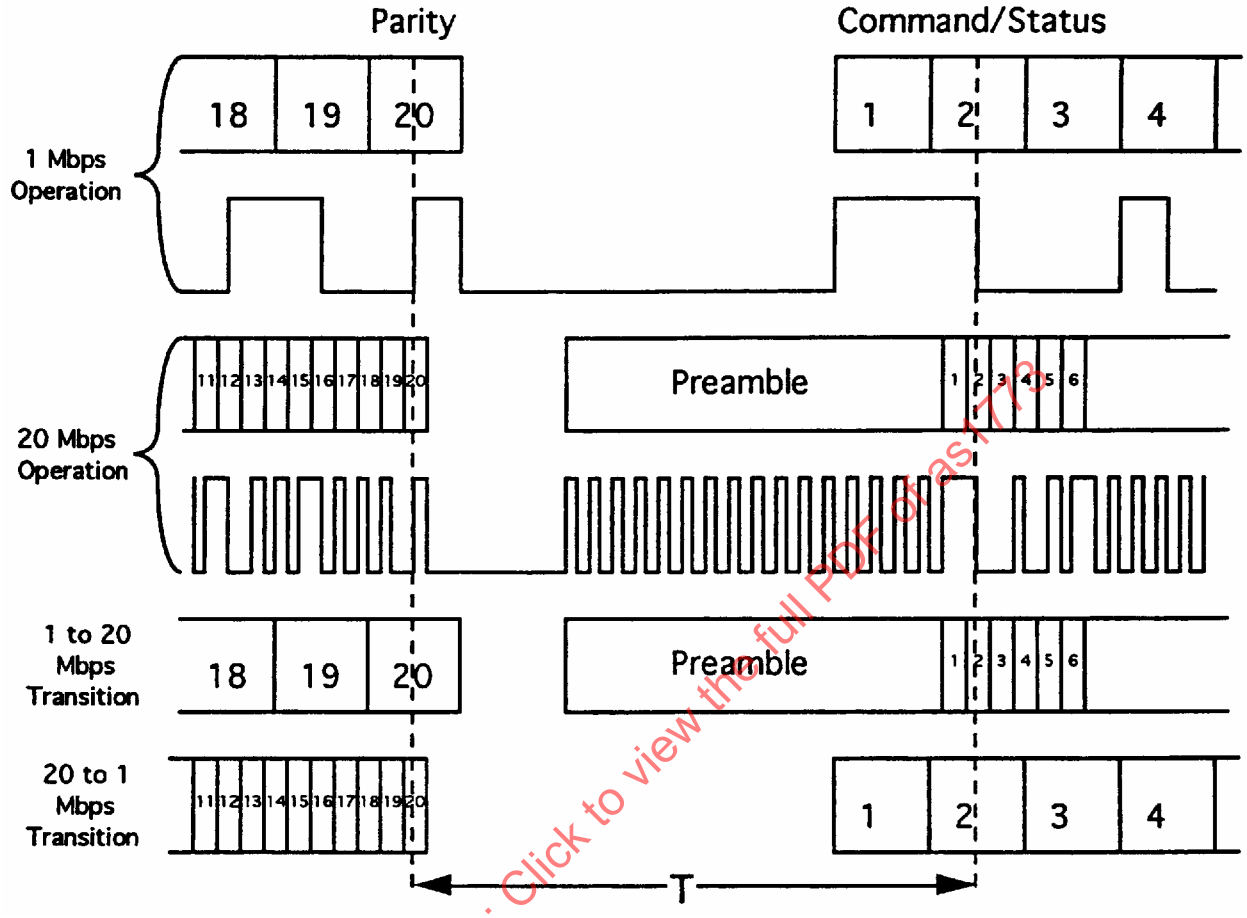

FIGURE 8 - Intermessage Gap and Response Time

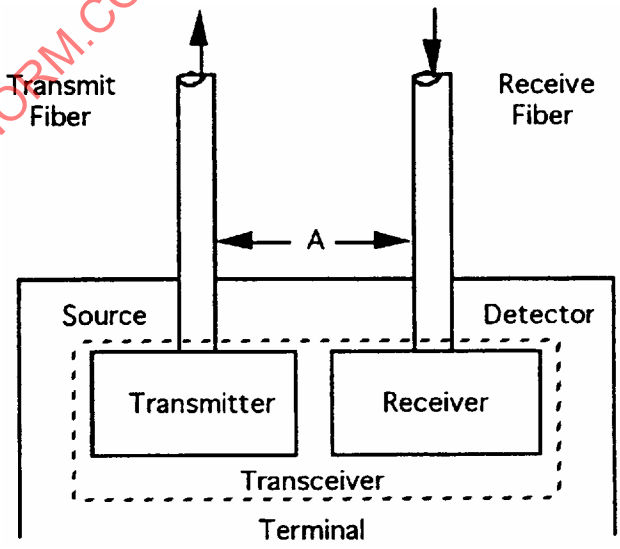

FIGURE 9 - Data Bus Interface with Pigtailed Fibers

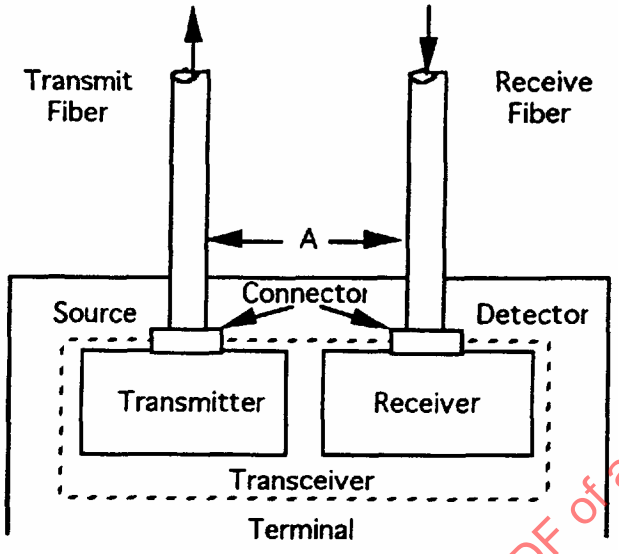

FIGURE 10 - Data Bus Interface with Connectorized Components

TABLE 2 - Parameters for Time Measurements Versus Data Rates

Data Rate	1 Mbps	20 Mbps	1-20 Mbps Transition	20-1 Mbps Transition
Minimum Intermessage Gap	4.0 µs	1.2 µs	4.0 µs	4.0 µs
Response Time	4.0 - 12.0 µs	1.2 - 4.0 µs	N/A	N/A
Minimum No-response Time-Out	14.0 µs	6.0 µs	N/A	N/A

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 operating at 1 Mbps shall contain a hardware implemented time-out to preclude a signal transmission of greater than 800.0 ms. 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. For a terminal operating at 20 Mbps this time shall be 40 ms.

4.4.2 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. A network with both 1 Mbps and 20 Mbps remote terminals shall have one bus controller operating to control data for both rates.

4.4.3 Remote Terminal:

4.4.3.1 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 following criteria:

a. The word meets requirements of 4.4.1.1
b. The data rate is correct for the RT
c. The terminal address matches the RT address, or an address of 11111 if the RT has the broadcast option

Remote terminals operating at different data rates may have the same terminal address but no two terminals operating at the same data rate shall have the same terminal address. The BC shall address terminals based upon the terminal address and data rate. 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 transmission 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. The RT shall respond to the second valid command as specified in 4.3.3.8.

4.4.3.3 Invalid Commands: A remote terminal 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: An illegal command is a valid command 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 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.

4.4.3.5 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 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 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.

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 back-up bus controller sufficient information to take over as the bus controller.

NOTE: A bus monitor may be set to 1 Mbps or to 20 Mbps or to both.

4.5 Hardware Characteristics:

For detailed hardware characteristics refer to the Interoperability Requirements for AS1773 document (AIR4957) with appropriate slash sheet and the user's system specification.

4.5.1 Error Rate: 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. 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. The terminal shall achieve this error rate when receiving two successive messages which differ in optical power by the maximum OSR in accordance with the system specification(s) for messages separated in time by the intermessage gap as specified in 4.3.3.7, irrespective of order. The error test 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 in accordance with Table 3. All data words used in the test 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. If the terminal under test is a bus controller with the capability of 1 and 20 Mbps operation the test shall be run with alternating messages at 1 and 20 Mbps. If the terminal under test is a remote terminal the data rate shall be fixed to the applicable terminal operation data rate.

4.6 Redundant Data Bus Requirements:

If redundant data buses are used, the requirements specified in Table 3 shall apply.

4.6.1 Electrical/Optical Isolation: Electrical and/or optical isolation between multiple-redundant data buses shall be as specified in the system specification(s).

4.6.2 Single Event Failures: All data buses shall be routed to minimize the possibility that a single event failure to a data bus shall cause the loss of more than that particular data bus.

4.6.3 Dual Standby Redundant Data Bus: If a dual redundant data bus is used, then it shall be a dual standby redundant data bus as specified in the following paragraphs.

4.6.3.1 Data Bus Activity: Only one data bus can be active at any given time except as specified in 4.6.3.2.

TABLE 3 - Criteria for Acceptance or Rejection of a Terminal for the Error Rate Test

Total Words Received by the Terminal (in multiples of 10^7) 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 More)
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
>24	REJECT	REJECT

4.6.3.2 Superseding Valid Command: If while operating on a command, a terminal receives another valid command, from the other data bus, it shall reset and respond to the new command on the data bus on which the new command is received. The terminal shall respond to the new command as specified in 4.3.3.8.

5. DETAILED REQUIREMENTS:

5.1 Specific Implementations:

Specific fiber optic bus implementation, based on this standard, shall be in accordance with the user's system specification .

6. NOTES:

6.1 Intended Use:

Multiplex data buses conforming to the requirements of this standard are intended for use in general military fiber optic applications.

6.2 Subject Term (Key Word) Listing:

Coupler, bit, bit rate, bus controller, bus monitor, cable connectors, data bus, detector, error rate, fiber optics, mode code, modulation, optical signal power, optical signal terminal, parity, remote terminal, source, terminal, time division multiplexing, word

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APPENDIX A

A.1 GENERAL:

The following paragraphs in this appendix are presented in order to discuss certain aspects of the standard in a general sense. They are intended to provide a user of the standard with more insight into the aspects discussed.

A.1.1 Redundancy:

It is intended that this standard be used to support rather than to supplant the system design process. However, it has been found, through application experience in various aircraft, that the use of a dual standby redundancy technique is very desirable for use in integrating mission avionics. For this reason, this redundancy scheme is defined in 4.6 of this standard. Nonetheless, the system designer should utilize this standard as the needs of a particular application dictate. The use of redundancy, the degree to which it is implemented, and the form which it takes must be determined on an individual application basis. Figures A1 and A2 illustrate some possible approaches to dual redundancy. These illustrations are not intended to be inclusive, but rather representative. It should be noted that analogous approaches exist for the triple and quad redundant cases.

A.1.2 Bus Controller:

The bus controller is a key part of the data bus system. The functions of the bus controller, in addition to the issuance of commands, must include the constant monitoring of data bus and the traffic on the bus. It is envisioned that most of the routine minute details of bus monitoring (e.g., parity checking, terminal non-response time-out, etc.) will be embodied in hardware, while the algorithms for bus control and decision making will reside in software. It is also envisioned that, in general, the bus controller will be the general purpose airborne computer with a special input/output (I/0) to interface with the data bus. It is of extreme importance in bus controller design that the bus controller be readily able to accommodate terminals of differing protocols and status word bits used. Equipment designed to MIL-STD-1553A will be in use for a considerable period of time; thus, bus controllers must be capable of adjusting to their differing needs. It is also important to remember that the bus controller will be the focal point for modification and growth within the multiplex system and thus the software must be written in such a manner as to permit modification with relative ease.

A.1.3 Multiplex Selection Criteria:

The design of multiplex bus and selection of candidate signals for that bus is a complex trade of performance parameters such as update rate, bandwidth, latency, reliability, weight, and power with program considerations such cost and schedule. For aid in analyzing candidate signals for multiplexing refer to the 1773 User's Handbook (AIR4508) .