IJMEIT// Vol. 2 Issue 3//March 2014 //Page No: 153-165//e-ISSN: 2348-196x 2014

IJMEIT IGM Publication
International Journal Of Mechanical Engineering And Information Technology
An Official Publication Of IGM Publication

MIL-STD-1553 BUS CONTROLLER TERMINAL

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Abstract—

MIL-STD-1553 has evolved into the predominant, internationally accepted networking standard for the integration of military platforms. Today, the standard has expanded beyond its traditional domain of US Air Force and Navy aircraft to encompass applications for combat vehicles, ships, satellites, missiles, and the International Space Station Program, as well as advanced commercial avionic applications. Once considered primarily a military data bus standard, MIL-STD-1553 has caught the attention of commercial aircraft manufacturers who seek to capitalize upon the standard's inherent reliability, robustness, maturity, and superior EMI performance. Despite the recent advent of newer and higher-speed technologies, it is clearly evident that 1553 will continue to be used extensively in evolving upgrade programs as well as for new applications and integration platforms for years to come.MIL-STD-1553 is a military standard that defines the electrical and protocol characteristics for a data bus. A data bus is used to provide a medium for the exchange of data and information between various systems. It is similar to what the personal computer and office automation industry has dubbed a Local Area Network (LAN).In this project introduction to the MIL-STD-1553 data bus, its history, working, applications and use is studied. Project describes the physical elements that make up the bus, the protocol, including the message formats, word types, and command and status words of MIL-STD-1553 Data bus and implementation of MIL-STD-1553 Bus Controller terminal and its information transfer (message) formats is coded using Modelsim.

I. INTRODUCTION

MIL-STD:

A United States defense standard, often called a military standard, "MIL-STD", "MIL-SPEC", or (informally) "MilSpecs", is used to help achieve standardization objectives by the U.S Department of Defense. Standardization is beneficial in achieving interoperability, ensuring products meet certain requirements, commonality, reliability, total cost of ownership and compatibility with logistics systems. Defense standards are also used by other non-defense government organizations, technical organizations and industry.

Defense standards evolved from the need to ensure proper performance, maintainability and reparability and logistical usefulness of military equipment. In the late 18th century and throughout the 19th, the American and French militaries were early adopters and long time developmental sponsors and advocates of interchangeability and standardization. By World War II (1939-1945), virtually all national militaries and trans-national alliances of the same (Allied Forces, Axis powers) were busy standardizing and cataloguing. The U.S. AN-cataloguing system (Army-Navy) and the British Defence Standards (DEF-STAN) provide examples..

MIL-STD-1553 Data Bus:

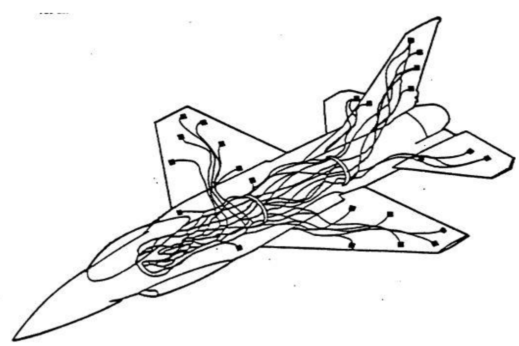
In the 1950s and 1960s, aviation electronics, referred to as avionics, were simple stand-alone systems. The navigation, communications, flight controls, and displays consisted of analog systems. Often these systems were composed of multiple boxes, or subsystems, connected to form a single system.

By the late 1960s and early 1970s, it became necessary to share information between the various systems to reduce the number of black boxes required by each system. As the system used point-to-point wiring, the system that was the source of the signal typically had to be modified to provide the additional hardware to output to the newly added subsystem. As such, inter-system connections had to be kept to the bare minimum.

The Advent of the Data Bus

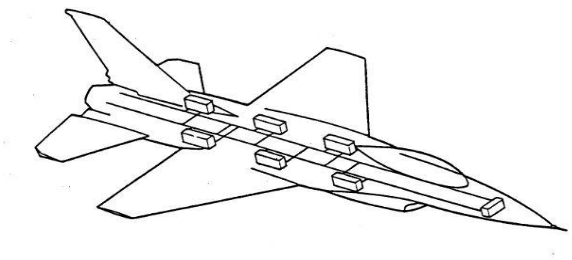
A data transmission medium, which would allow all systems and subsystems to share a single and common set of wires, was needed. By sharing the use of this interconnects, the various subsystems could send data between themselves and to other systems and subsystems, one at a time, and in a defined sequence, hence a data bus.

Fig 1. point to point wiring scheme



A tri-service version, MIL-STD-1553A was released in 1975, modified to MIL-STD-1553B in 1978 and utilized in the Air Force F-16 and the United States (US) Army AH-64A Apache Attack Helicopter.MIL-STD-1553B has become the internationally accepted networking standard for integrating military platforms.

Fig 2. data bus architecture



MIL-STD-1553 is a military standard published by the United States Department of Defense that defines the mechanical, electrical, and functional characteristics of a serial data bus. MIL-STD-1553B defines the term Time Division Multiplexing (TDM) as “the transmission of information from several signal sources through one communications system with different signal samples staggered in time to form a composite pulse train.

II. LITERATURE SURVEY

Overview

MIL-STD-1553 is a military standard that defines the electrical and protocol characteristics for a data bus. A data bus is used to provide a medium for the exchange of data and information between various systems. It is similar to what the personal computer and office automation industry has dubbed a Local Area Network (LAN).

This thesis provides an introduction to the MIL-STD-1553 data bus, its history, applications, and use. It also describes:

1. The hardware elements that make up the bus.
2. The protocol, including the message formats, word types, command and status words. Status word bits and mode commands and their definitions and use from the bus controller perspective.
3. Comparisons with other data buses and future enhancements over it.

History and Applications

In 1968 the Society of Automotive Engineers (SAE), a technical body of military and industrial members, established a subcommittee to define a serial data bus to meet the needs of the military avionics community. Known as the A2-K, this subcommittee developed the first draft of the document in 1970. Three years of military and government reviews and changes led to the release of MIL-STD-1553 (USAF) in August of 1973.The primary user of the initial standard was the F-16. Further changes and improvements were made and a tri-service version, MIL-STD-1553A was released in 1975. The first users of the “A” version of the standard was the Air Force's F-16 and the Army's new attack helicopter, the AH-64A Apache.

MIL-STD-1553 Applications

Since its inception, MIL-STD-1553 has found numerous applications. The following is a summary of its uses.

While the standard has been applied to satellites as well as payloads within the space shuttle (it is even being used on the International Space Station), its military applications are the most numerous and far ranging. It has been employed on large transports, aerial refuelers, and bombers, tactical fighters, and helicopters. It is even contained within missiles and serves, in some instances, as the primary interface between the aircraft and a missile. The Navy has applied the data bus to both surface and subsurface ships. The Army, in addition to its helicopters, has put 1553 into tanks and howitzers.

Summary of MIL-STD-1553 Characteristics

Data Rate	**1MHz**
Word Length	**20 bits**
Data Bits/Word	**16 bits**
Message Length	**Maximum of 32 data words**
Transmission Technique	**Half-Duplex**
Operation	**Asynchronous**
Encoding	**Manchester II bi-phase**
Protocol	**Command/Response**
Bus Control	**Single or Multiple**
Fault Tolerance	**Dual redundant**
Message Formats	**Controller to terminal** **Terminal to controller** **Terminal to terminal** **Broadcast** **System control**
Number of Remote Terminals	**Maximum of 31**
Terminal Types	**Remote terminal** **Bus Controller** **Bus Monitor**
Transmission Media	**Twisted shielded pair**
Coupling	**Transformer and direct**

Table1.Summary of MIL-STD-1553 Characteristics

III. HARDWARE ELEMENTS

MIL-STD-1553 defines certain aspects regarding the design of the data bus system. The standard defines four hardware elements. These are:

1. The transmission media.
2. Remote terminals.
3. Bus controllers.
4. Bus monitors.

Main Hardware Elements:

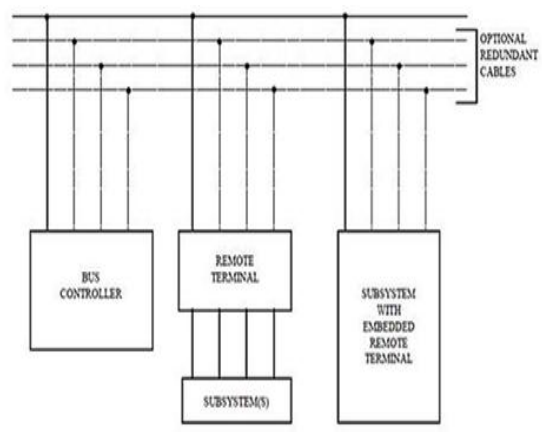


Fig 3. Hardware Elements

Transmission Media

The transmission media, or data bus, is defined as a twisted shielded pair transmission line consisting of the main bus and a number of stubs. There is one stub for each terminal connected to the bus. The main data bus is terminated at each end with a resistance equal to the cable's characteristic impedance (plus or minus two percent). This termination makes the data bus behave electrically like an infinite transmission line. Stubs, which are added to the main bus to connect the terminals, provide "local" loads and produce impedance mismatch where added. This mismatch, if not properly controlled, produces electrical reflections and degrades the performance of the main bus.

Bus Controller

The main function of the bus controller (BC) is to provide data flow control for all transmissions on the bus. In addition to initiating all data transfers, the BC must transmit, receive and coordinate the transfer of information on the data bus. All information is communicated in command/response mode - the BC sends a command to the RTs, which reply with a response.

The bus controller, according to MIL-STD-1553B, is the "key part of the data bus system" and "the sole control of information transmission on the bus shall reside with the bus controller, which shall initiate all transmission". The bus can support multiple BCs, but only one can be active at a time. Normal BC data flow control includes transmitting commands to RTs at predetermined time intervals. The commands may include data or requests for data (including status) from RTs.

Remote Terminal

The remote terminal (RT) is a device designed to interface various subsystems with the 1553 data bus. The interface device may be embedded within the subsystem itself, or be an external interface to tie a non-1553 compatible device to the bus. As a function of the interface requirement, the RT receives and decodes commands from the BC, detects any errors and reacts to those errors. The RT must be able to properly handle both protocol errors (missing data, extra words etc.) and electrical errors (waveform distortion, rise time violations etc.). RTs are the largest segment of bus components. RT characteristics include:

a. Up to 31 remote terminals can be connected to the data bus

b. Each remote terminal can have 31 sub addresses

c. No remote terminal shall speak unless spoken to first by the bus controller and specifically commanded to transmit.

Bus Monitor

The bus monitor (BM) listens to all messages on the bus and records selected activities. The BM is a passive device that collects data for real-time or post capture analysis. The BM can store all or portions of traffic on the bus, including electrical and protocol errors. BMs are primarily used for instrumentation and data bus testing.

IV. PROTOCOL

The rules under which the transfers occur are referred to as "protocol". The control, data flow, status reporting, and management of the bus are provided by three word types. **Word Types**

Three distinct word types are defined by the standard. These are:

1. Command words.
2. Data words.
3. Status words.

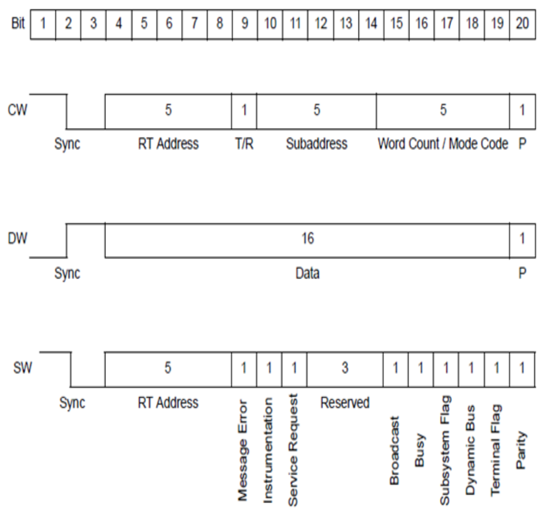


Fig 4.Word Formats

Each word type has a unique format, yet all three maintain a common structure. Each word is twenty bits in length. The first three bits are used as a synchronization field, thereby allowing the decode clock to re-sync at the beginning of each new word. The next sixteen bits are the information field and are different between the three word types. The last bit is the parity bit. Parity is based on odd parity for the single word.

Bit encoding for all words is based on bi-phase Manchester II format. The Manchester II format provides a self-clocking waveform in which the bit sequence is independent. The positive and negative voltage levels of the Manchester waveform is DC-balanced (same amount of positive signal as there is negative signal) and, as such, is well suited for transformer coupling.

The Manchester waveform is shown in Figure. A transition of the signal occurs at the centre of the bit time. Logic "0" is a signal that transitions from a negative level to a positive level. Logic "1" is a signal that transitions from a positive level to a negative level.

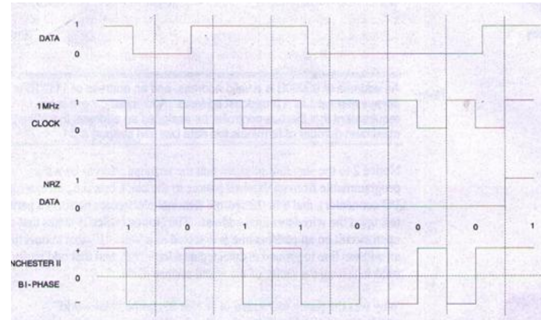


Fig 5.Data Encoding and Decoding

Command Words

The Command Word (CW) specifies the function that a remote terminal is to perform. Only the active bus controller transmits this word. The word begins with command sync in the first three bit times.The next bit (bit time 9) makes up the Transmit/Receive (T/R) bit. This defines the direction of information flow and is *always* from the point of view of the remote terminal. A transmit command (logic 1) indicates that the remote terminal is to transmit data, while a receive command (logic 0) indicates that the remote terminal is going to receive data. The only exceptions to this rule are associated with mode commands.

The next five bits (bit times 10-14) make up the Subaddress (SA)/Mode Command bits. Logic 00000B or 11111B within this field is decoded to indicate that the command is a Mode Code Command. All other logic combinations of this field are used to direct the data to different functions within the subsystem. An example might be that 00001B is position and rate data, 00010B is frequency data, 10010B is display information, and 10011B is self-test data.

The next five bit positions (bit times 15-19) define the Word Count (WC) or Mode Code to be performed. If the Subaddress/Mode Code field is 00000B or 11111B, then this field defines the mode code to be performed. If not a mode code, then this field defines the number of data words to be received or transmitted depending on the T/R bit. A word count field of 00000B is decoded as 32 data words.

The last bit (bit time 20) is the word parity bit. Only odd parity is used.

Data Word

The Data Word (DW) contains the actual information that is being transferred within a message. The first three-bit time contains data sync. This sync pattern is the opposite of that used for command and status words and therefore is unique to the word type. Data words can be transmitted by either a remote terminal (transit command) or a bus controller (receive command). Transmit and Receive, by convention, references the remote terminal. The next sixteen bits of information are left to the designer to define. The only standard requirement is that the most significant bit (MSB) of the data be transmitted first.

The last bit (bit time 20) is the word parity bit. Only odd parity is used. Data words contain the actual information and can be transmitted by a BC or an RT. Data words are transmitted by a BC, or by an RT in response to a BC request. Data words may also be sent between two RTs. MIL-STD-1553B allows a maximum of 32 data words to be sent in a packet with a command word. Data words contain the most information of the three words and are the least structured words in MIL-STD-1553B. The Data word sync is unique. The command and status word sync pattern is the same.

Status word

A remote terminal in response to a valid message transmits only the status word (SW). The status word is used to convey to the bus controller whether a message was properly received or to convey the state of the remote terminal (i.e., service request, busy, etc.). The status word is defined in Figure. Since the status word conveys information to the bus controller, there are two views as to the meaning of each bit:

1. What the setting of the bit means to a remote terminal.

2. What the setting of the bit means to a bus controller.

Status words are transmitted by a remote terminal in response to an error free, non-broadcast command. Status words relay conditional information about the RT, errors detected by the RT in the command or data sent from the BC, or an RT request for service. Status words are only transmitted by RTs after receiving a command from a BC. The purpose of transmitting the RT address in a status response allows the BC to verify the correct RT is responding and prevents any other RT from mistaking the status response as a command (the sync pattern for both is the same) due to different addresses. Resetting of the Status Word

IV. MESSAGE FORMATS

The primary purpose of the data bus is to provide a common media for the exchange of data between systems. The exchange of data is based on message transmissions. The standard defines ten types of message transmission formats. All of these formats are based on the three word

types just defined. The message formats have been divided into two groups. These are referred to within the standard as the "information transfer formats" and the "broadcast information transfer formats". The information transfer formats are based on the command/response philosophy in that all error free transmissions received by a remote terminal are followed by the transmission of a status word from the terminal to the bus controller. This handshaking principle validates the receipt of the message by the remote terminal. Broadcast messages are transmitted to multiple remote terminals at the same time. The terminals suppress the transmission of their status words (not doing so would have multiple boxes trying to talk at the same time and thereby "jam" the bus). In order for the bus controller to determine if a terminal received the message, a polling sequence to each terminal must be initiated to collect the status words.

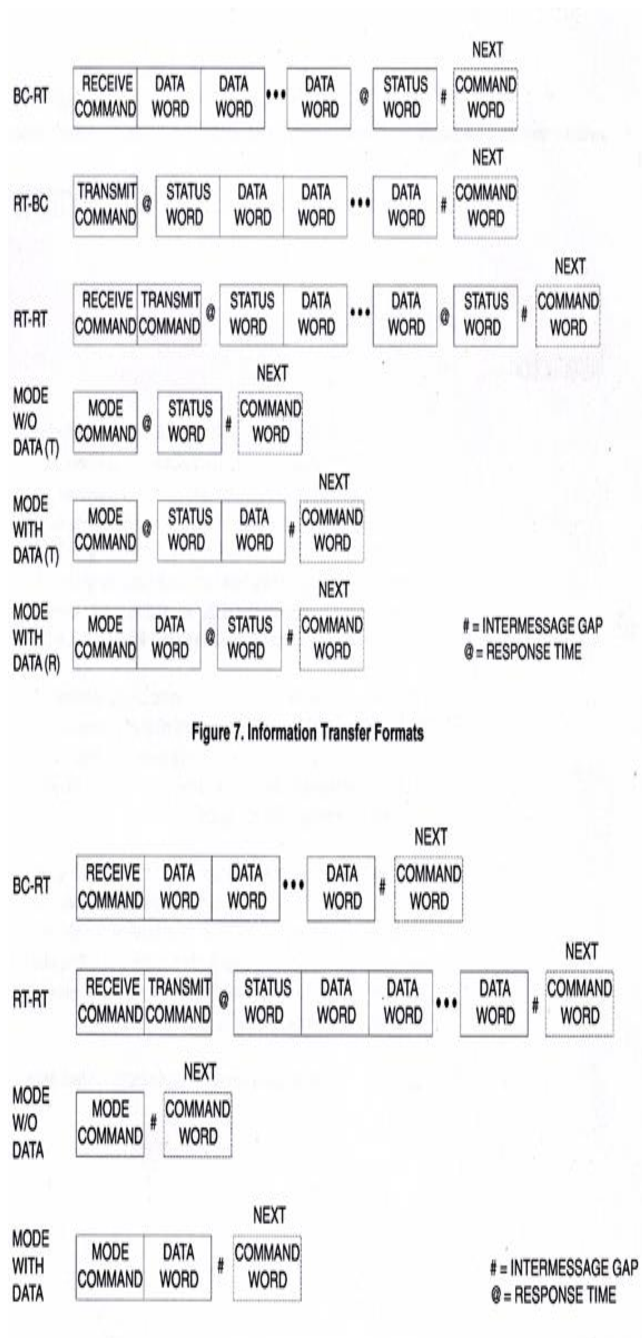


Fig 6. Information Transfer Formats

Bus Controller to Remote Terminal

The bus controller to remote terminal (BC-RT) message is referred to as the *receive* command since the remote terminal is going to receive data.

Remote Terminal to Bus Controller

The remote terminal to bus controller (RT-BC) message is referred to as a *transmit* command. The bus controller issues only a transmit command word to the remote terminal.

Remote Terminal to Remote Terminal

The remote terminal to remote terminal (RT-RT) command allows a terminal (the data source) to transfer data directly to another terminal (the data sink) without going through the bus controller.

Mode Command Formats

Three mode command formats are provided. This allows for mode commands with no data words and for the mode commands with one data word (either transmitted or received). The status/data sequencing is the same as the BC-RT or RT-BC messages except that the data word count is either one or zero.

Broadcast Information Transfer Formats

The broadcast information transfer formats, as shown in figure , is identical to the non-broadcast formats described above with the following two exceptions.

1. The bus controller issues commands to terminal address 31 (11111B) that is reserved for this function.

2. The remote terminals receiving the messages (those that implement the broadcast option) suppress the transmission of their status word.

Terminal Response Time

The standard states that a remote terminal, upon validation of a transmit command word or a receive message (command word and all data words) shall transmit its status word to the bus controller. The response time is the amount of time the terminal has to transmit its status word

Inter-message Gap

The bus controller must provide for a minimum of 4.0 microseconds between messages. This time frame is measured from the mid-crossing of the parity bit of the last data word or the status word and the mid-crossing of the sync field of the next command word.

Superseding Commands

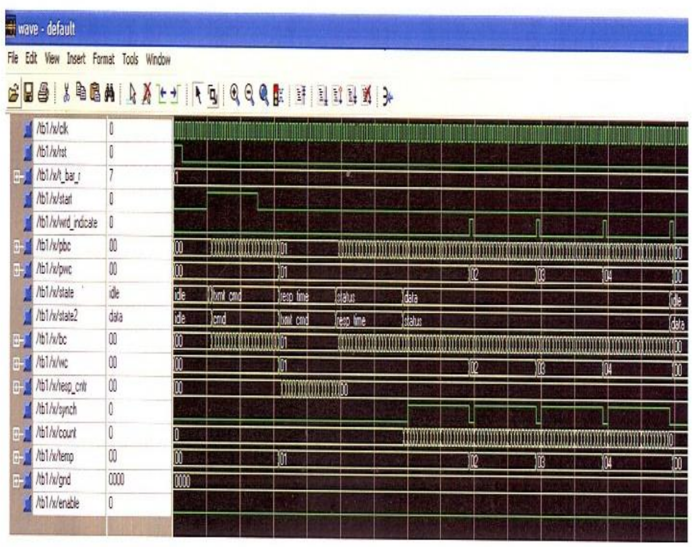
A remote terminal must always be capable of receiving a new command. This may occur when operating on a command on bus A, and after the minimum inter-message gap, a new command appears, or when operating on bus A, a new command appears on bus B. This is referred to as a Superseding command.

VI .SIMULATION RESULTS

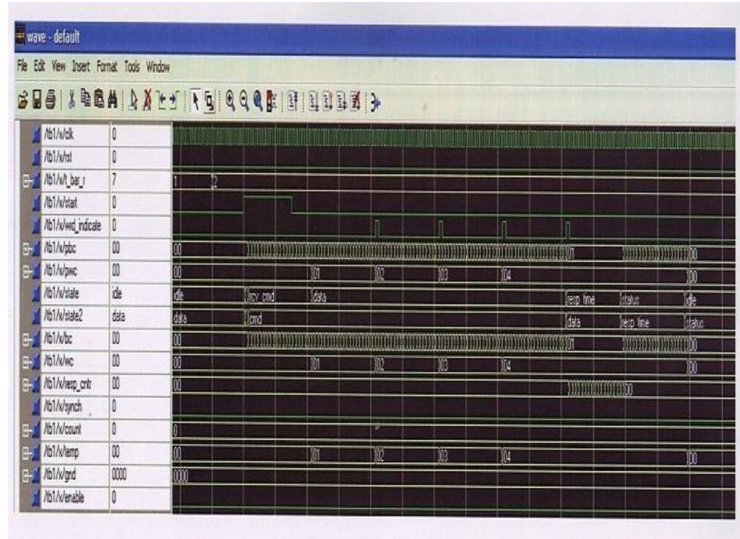
Tool used: **Modelsim 10.2b**

ModelSim is an easy-to-use yet versatile VHDL/(System)Verilog/SystemC simulator by Mentor Graphics. It supports behavioral, register transfer level, and gate-level modeling. ModelSim supports all platforms used here at the Institute of Digital and Computer Systems (i.e. Linux, Solaris and Windows) and many others too. ModelSim is an IDE for hardware design which provides behavioral simulation of a number of languages, i.e., Verilog, VHDL, and System C. HDL's are languages which are used to describe the functionality of a piece of hardware as opposed to the execution of sequential instructions like that in a regular software application.

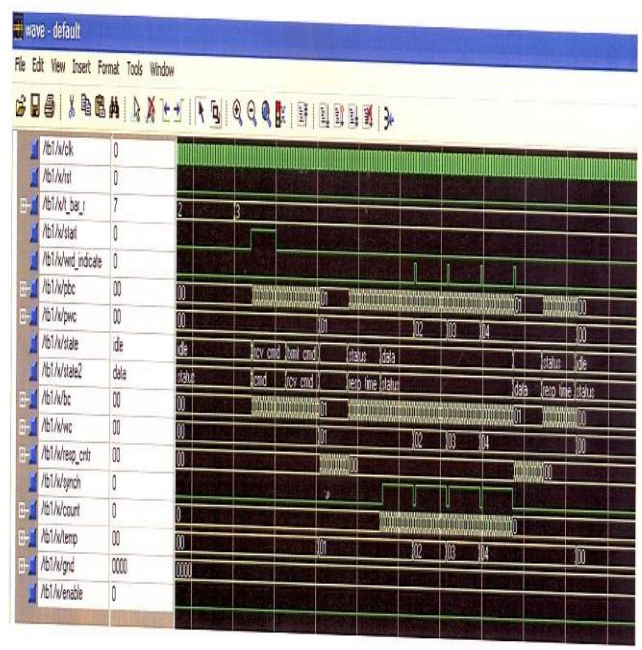
a. Simulation Result of message transmission format: RT- BC



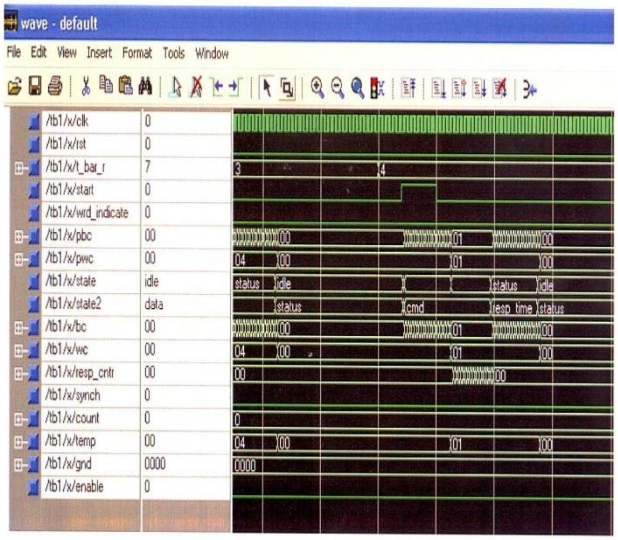
b. Simulation Result of message transmission format : BC-RT



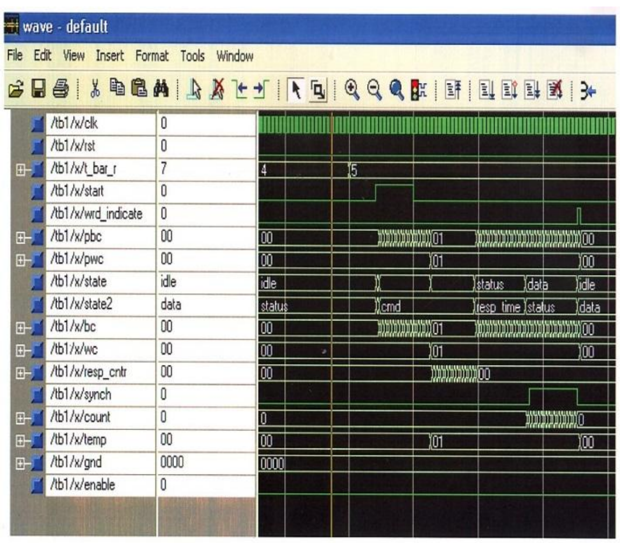
c. Simulation Result of message transmission format: RT-RT



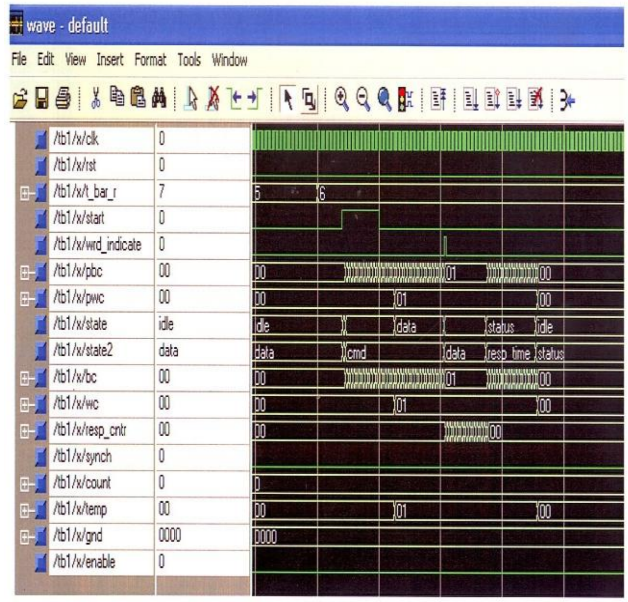
d. Simulation Result of message transmission format: Mode W/O Data(T)



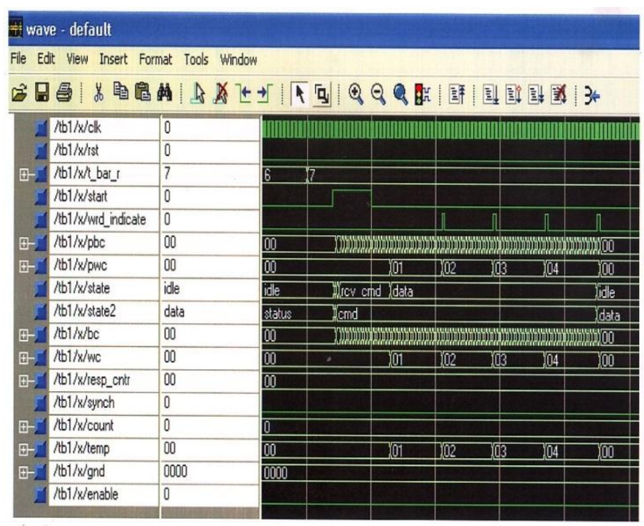
e. Simulation Result of message transmission format: Mode with Data(T)



f. Simulation Result of message transmission format: Mode with Data(R)

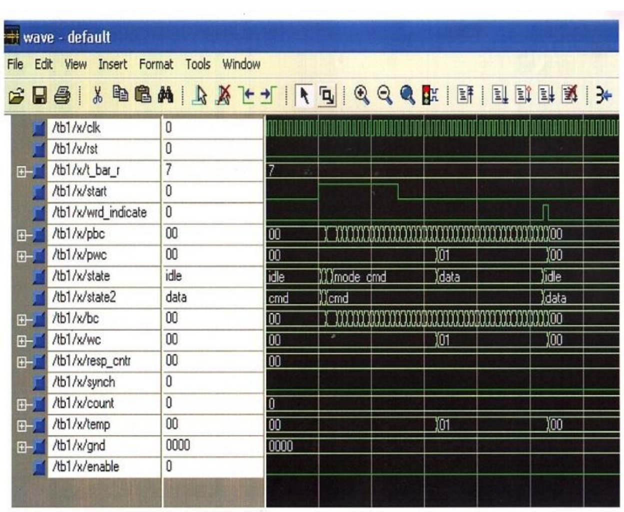


g. Simulation Result of message transmission format : BC-RT(Broadcast)



h. Simulation Result of message transmission format: RT-RT(Broadcast)

i. Simulation Result of message transmission format: Mode with Data(Broadcast)



CONCLUSION

MIL-STD-1553B is a very well established, well proven, serial data bus system for military real time system applications and has qualities well suited to command and control applications in severe environments. It compares well against a number of related commercial systems and given the availability of lower cost interface components could well provide an appropriate solution for many industrial applications.

In this project working and applications of MIL-STD-1553 Data bus is studied and implementation of MIL-STD-1553 Bus Controller and its information transfer(message) formats is coded using Modelsim .In short, A data transmission medium, which would allow all systems and subsystems to share a single and common set of wires, was needed. By MIL-STD-1553B defines the term Time Division Multiplexing (TDM)"the transmission of information from several signal sources through one communications system with different signal samples staggered in time to form a composite pulse train." Data can be transferred between multiple avionics units over a single transmission media, with the communications between the different avionics boxes taking place at different moments in time.

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