MIL-STD-1553 Today and Into the Future
Presented to the IEEE Long Island Section, Instrumentation & Measurement Society on November 13th, 2008
MIL-STD-1553 also known as:
Digital Time Division
Command/Response Multiplex Data Bus

Spec First Released in 1973
1553A Released in 1975
1553B Released in 1978
1553B Noticed 2 Issued 1986
Discrete Wire versus a Bus
General Features

- **Characteristics**
  - 1 Mb/s Bus
  - Reliable
    - Fault Tolerant
    - High Availability
    - Deterministic
    - Dual Redundancy per 1553 channel

- **What Is It Used For?**
  - Typical Military Aircraft has over 100 computers, each performing a dedicated function
  - Computers need to share data with each other
  - Typically command and status (small amounts of data sent periodically)
Where is 1553 Used?

- Fighter Jets
- Cargo Planes
- Military Helicopters
- Tanks
- Ships
- Targeting Pods
- Launcher Interface (Ground and Aircraft)
- Missile Interface
- Smart Bombs
- Radar Interface
- Enhanced Vision System Interface
- Space: Military and Commercial Satellites, International Space Station, Deep Space Missions
1553 in New Applications

- 1553 is the preferred bus for the military
- It has been proven reliable and robust over many years
- For the first time on a civil aircraft it has been adopted digital signaling for the flight controls
- Switching from analogue to 1553
- Flight Global Article discusses details:
# 1553 Cable

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Twisted-shielded pair</td>
</tr>
<tr>
<td>Characteristic impedance ($Z_0$)</td>
<td>70 to 85 ohms at 1.0 MHz</td>
</tr>
<tr>
<td>Attenuation</td>
<td>1.5 dB/100 ft at 1.0 MHz, maximum</td>
</tr>
<tr>
<td>Shielding Coverage</td>
<td>75% minimum</td>
</tr>
<tr>
<td>Length of main bus</td>
<td>Not specified</td>
</tr>
<tr>
<td>Capacitance (wire to wire)</td>
<td>30 pF/ft, maximum</td>
</tr>
<tr>
<td>Twist Four per foot</td>
<td>0.33/in, minimum</td>
</tr>
</tbody>
</table>
MIL-STD-1553B Bus Coupling

Direct Coupling

 Transformer Coupling

1 ft. max

0.75Z_0

1.4 : 1.0

20 ft. max

* Isolation Transformer

Transceivers

Logic

BC, RT, or Monitor Terminal

2.5 : 1.0

55Ω

55Ω

1.79 : 1.0

*
Terminal and Bus Voltages

Transmitting

Direct-Coupled Terminal

Transformer-Coupled Terminal

18 to 27 $V_{PP}$

Receiving

Receiver Threshold 0.28 to 1.2 $V_{PP}$

Direct-Coupled Terminal

Transformer-Coupled Terminal

1.0 to 14.0 $V_{PP}$

Receiving

Receiver Threshold 0.2 to 0.86 $V_{PP}$

Voltagess Provided by Bus

$Z_0$
A logic one & logic zero is transmitted as a bipolar coded signal. A transition through zero occurs at the midpoint of each bit time.
The bus controller is responsible for initiating messages on the MIL-STD-1553 data bus.

Several terminals may be capable of performing as the bus controller but *only one* bus controller may be active at any one time.

The bus controller is the only terminal allowed to issue commands onto the data bus. The commands may be for the transfer of data or the control and management of the bus (mode commands).
Remote Terminals (RT)

- Remote terminals are defined within the standard as "All terminals not operating as the bus controller or as a bus monitor". Thus if it is not a controller, monitor, or the main bus or stub, it must be a remote terminal.
- The remote terminal comprises the electronics necessary to transfer data between the data bus and a subsystem.
- For 1553 applications, the subsystem is the sender or user of the data being transferred.
Bus Monitor (MT)

- Bus monitor is a terminal that listens to the exchange of information on the MIL-STD-1553 data bus.

- The standard defines how bus monitors may be used, stating that the information obtained by a bus monitor be 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."

- A monitor may collect all the data from the bus or may only collect selected data.
1553 Word Formats

<table>
<thead>
<tr>
<th>BIT TIMES</th>
<th>COMMAND WORD</th>
<th>DATA WORD</th>
<th>STATUS WORD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20</td>
<td>5 1 5 5 1</td>
<td>16</td>
<td>5 1 1 1 1 3 1 1 1 1 1 1</td>
</tr>
<tr>
<td>SYNC</td>
<td>REMOTE TERMINAL ADDRESS</td>
<td>T R</td>
<td>SUBADDRESS MODE</td>
</tr>
<tr>
<td>DATA</td>
<td>DATA</td>
<td>DATA</td>
<td>DATA</td>
</tr>
</tbody>
</table>

T/R transmit/receive

P  parity
Information Transfer Formats

- **Controller-to-RT Transfer**
  - RECEIVE COMMAND
  - DATA WORD
  - DATA WORD
  - DATA WORD
  - DATA WORD
  - STATUS WORD
  - NEXT COMMAND WORD

- **RT-to-Controller Transfer**
  - TRANSMIT COMMAND
  - STATUS WORD
  - DATA WORD
  - DATA WORD
  - DATA WORD
  - DATA WORD
  - NEXT COMMAND WORD

- **RT-to-RT Transfers**
  - RECEIVE COMMAND
  - TRANSMIT COMMAND
  - STATUS WORD
  - DATA WORD
  - DATA WORD
  - DATA WORD
  - DATA WORD
  - STATUS WORD
  - NEXT COMMAND WORD

# Intermesage gap
★ ★ Response time

*Data Device Corporation*
Broadcast Formats

CONTROLLER-TO-RT (S) TRANSFER

RT-TO-RT (S) TRANSFERS

MODE COMMAND WITHOUT DATA WORD

MODE COMMAND WITH DATA WORD

# Intermessage gap
★ ★ Response time
Mode Code Message Formats

MODE COMMAND WITHOUT DATA WORD

MODE COMMAND ★ ★ STATUS WORD # NEXT
COMMAND WORD

MODE COMMAND WITH DATA WORD (TRANSMIT)

MODE COMMAND ★ ★ STATUS WORD DATA WORD # NEXT
COMMAND WORD

MODE COMMAND WITH DATA WORD (RECEIVE)

MODE COMMAND ★ ★ DATA WORD ★ ★ STATUS WORD # NEXT
COMMAND WORD

# IntermESSAGE gap
★ ★ Response time
## Assigned 1553B Mode Codes

<table>
<thead>
<tr>
<th>T/R</th>
<th>MC</th>
<th>Function</th>
<th>Data Word</th>
<th>Broadcast</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>00000</td>
<td>Dynamic bus control</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>1</td>
<td>00001</td>
<td>Synchronize</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>00010</td>
<td>Transmit status word</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>1</td>
<td>00011</td>
<td>Initiate self-test</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>00100</td>
<td>Transmitter shutdown</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>00101</td>
<td>Override transmitter shutdown</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>00110</td>
<td>Inhibit terminal flag bit</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>00111</td>
<td>Override inhibit terminal flag bit</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>01000</td>
<td>Reset remote terminal</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>01001</td>
<td>Reserved</td>
<td>No</td>
<td>TBD</td>
</tr>
<tr>
<td>1</td>
<td>01111</td>
<td>Reserved</td>
<td>No</td>
<td>TBD</td>
</tr>
<tr>
<td>1</td>
<td>10000</td>
<td>Transmit vector word</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>0</td>
<td>10001</td>
<td>Synchronize</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>1</td>
<td>10010</td>
<td>Transmit last command</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>1</td>
<td>10011</td>
<td>Transmit bit word</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>0</td>
<td>10100</td>
<td>Selected transmitter shutdown</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>0</td>
<td>10101</td>
<td>Override selected transmitter shutdown</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>X</td>
<td>10110</td>
<td>Reserved</td>
<td>Yes</td>
<td>TBD</td>
</tr>
<tr>
<td>X</td>
<td>11111</td>
<td>Reserved</td>
<td>Yes</td>
<td>TBD</td>
</tr>
</tbody>
</table>
1553 Bus Troubleshooting Tips

- Check the bus terminations first – usually 78 Ohms – since these are easy to get to.
- Use the rule of halves by cutting down the bus in two until you find the faulty components.
- Wrong cable, bus too long, attenuation too high.
- Too many terminals on a bus. A lot of long stubs can be problematic.
- Wrong signal polarity
- Noisy PC board layout
- Bus coupler placement
- Dynamic offset. This can be caused by board layout problems, or transformer leakage inductance.
- Wrong transformer turns ratio.
- Incorrect RT Address or parity.
- Wrong oscillator frequency.
MIL-STD-1553, 400ft Cable Test

RT

BU-65553

Bus Coupler

Term

400ft

Bus Coupler

Term

BC

BU-65549

O’Scope

Fault On/Off

Scope

Fault

On/Off

RT

BC
This indicates cable attenuation of almost 3 dB/100 ft (1553 max = 1.5 dB/100 ft).
Expanded RT data word. Amplitude of 1.8V at the "Smaller dominant amplitude" (3 boxes).
Expanded RT data word with Short Circuit Fault @ 400 ft35

Expanded RT data word with Short Circuit Fault Amplitude of 1.44V at the "Smaller dominant amplitude" (3.6 boxes).
The reason some of our parts seemed OK and some didn't is that the 1553 spec allows rise and fall times of between 100 and 300ns (wide variation). Slow parts passed OK in customers test setup, because of less reflection of harmonics; fast ones don't. But they are all within spec.
Enhanced Bit Rate 1553 (EBR-1553)

- 10 Mb/s
- MIL-STD-1553 Command/Response Protocol
  - “Link Mode” – RT Address = 00000
  - No RT-to-RT Transfers
- RS-485 Transceivers
- BC Hub Topology
- Used in MMSI, Miniature Munitions Stores Interface
New High Speed 1553

Market Problem:
- Need for Higher Speed on Existing Aircraft
- Re-Wiring Aircraft to add a new bus is very costly
- Time on Ground to re-wire aircraft is Prohibitive

Proposed Solution
- New higher speed 1553 that works with existing wiring
- Concept is the same as high speed DSL over old phone lines
DDC’s High Speed 1553

- New 1553 Notice 6 came out for high speed
- DDC worked in parallel with the specification
- DDC teamed with Boeing and Honeywell Aerospace to successfully complete a flight demonstration of new technology
  - Transferred data at 40 megabits per second over an existing 1553 data bus on an F-15
  - Concurrent with MIL-STD-1553 data being transmitted at 1 megabit per second.
  - The team also transferred data at 80 and 120 megabits per second on a second 1553 bus dedicated to the higher speed data
FC-AE-1553 -- Overview

- 1553-Like Protocol Over Fibre Channel Network
- Fibre Channel High-Speed Networking Standard
  - Used in Commercial Data Storage: SAN, Raid, etc.
  - Used in Several Military Programs: F-16, F-18, E-2D, JSF, B-2, others
  - Used in New Weapons Interface Standards
    - “High-Speed 1760”, etc.
- Fibre Channel Standard – Basic Characteristics
  - Copper or Optical Media
  - Point-to-Point, Loop, and Switched Fabric Topologies
  - 1.0625 Gb, 2.125 Gb, and Higher Data Rates
  - Physical and Encoding Layers
  - Framing and Addressing
  - Segmentation and Reassembly
  - Flow Control
Based on MIL-STD-1553B Constructs:
- **NC** = Network Controller
- **NT** = Network Terminal
- Each Node Can be an **NC** and/or an **NT**
- 24-bit **NT Address** (Fibre Channel S_ID/D_ID)
- 32-bit **Subaddress**
- 32-bit **Byte Count**

Provides Command/Response Protocol, Supports all 1553 Message Formats and Mode Codes
- Option for Non-Acknowledged Traffic (HS-1760 uses Status Acknowledgement)
- Broadcast and Multicast, with Optional Acknowledgement
- Rigorous Error Checking
- File Transfer Capability
  - Supports up to $2^{32}$ Bytes ≈ 4.3 GB
- **RDMA** – Remote DMA
  - Access to Remote Nodes’ Address Space
- Enables Bridging to 1 Mb/s 1553 Buses
FC-AE-1553: NC and NTs
When choosing a 1553 vendor you must first decide if you need a standard card form factor or are dealing with a custom design.

If you are not dealing with a standard like VME or cPCI then you must select a 1553 component.

If you are working with a standard then you can select a card.
Design Criteria for Cards

- Form Factor
- Channel Count
- Power
- Temperature Range
- Reliability
- In Service History
- Ability to offload host processor
- Single Function BC/RT/MT vs. Multi-Function BC/RT/MT
- Safety critical MT mode only
- Playback, Error Injection, Voltage Variation
- Software
Design Criteria for components

- Size
- Weight
- Power
- Thermal Dissipation
- Ruggedization
- Control over Protocol, Transceivers and Transformers to ensure compatibility
- DO-254 Requirements
- Reliability
- In Service History
- Ability to offload host processor
• DDC has supported the ACE family for over 23 years.

• Legacy software & I/O compatibility
Component Product Mix

- **Mini-ACE® Mark 3**
  - Premier Military Solution
- **Micro-ACE® and Micro-ACE® TE**
  - Low-Cost Industrial Solution
- **ACE Flex-Core IP**
  - Sold with Transceivers, Transformers, and an IP Module (License Chip)
- **Transceivers (Single 3.3 and 5V)**
  - Sold with IP
- **SP’ACE II and Space RT II**
  - Rad Hard for Satellites
Board Form Factor Support

**MIL-STD-1553**
- PCI
- PCI-Express
- PCMCIA
- ExpressCard
- USB
- AMC
- PXI & cPCI
- PMC
- PC/104
- PC/104 Plus
- PCI-104
- VME

**ARINC 429**
- PCI
- PCMCIA
- USB
- PMC
- PC/104 Plus
- PCI-104
- AMC

**MIL-STD-1553 and ARINC 429 on same board**
- PCI
- USB
- PMC
- PC/104 Plus
- PCI-104
- AMC
USB Avionics Interface

- **Multi I/O USB**
  - 1 or 2 1553 Ch.
  - 4 Receive 429 Ch.
  - 2 Transmit 429 Ch.
  - IRIG-B Time Sync Input
  - 6 Discrete Digital I/O

- **Windows 2000/XP Support**

- **C Software Development Kit**

- **Windows GUI**

- **High Level LabVIEW Software Interface**
Multiple Configurations with up to:

- 4 Dual Redundant MIL-STD-1553 Channels
- 16 Receive ARINC 429 Channels
- 6 Transmit ARINC 429 Channels
- 6 User Programmable Digital Discrete I/O
- 2 RS-232 Serial I/O Channels
- 2 RS-422/485 Serial I/O Channels
- IRIG-B Time Code Input
BU-65590C Multi-IO PC/104 Plus Card

- Multiple Configurations with up to:
  - 2 Dual Redundant MIL-STD-1553 Channels
  - 16 Receive ARINC-429 Channels
  - 8 Transmit ARINC-429 Channels
  - 9 Digital Discrete I/O
  - 8 Avionics (+35V) Discrete I/O
BU-65590A Multi-IO AMC Card

- AMC.1 Four Lane PCI-Express
- Single Width, Mid-Height AMC
- Multi-I/O
  - 4 Dual Redundant MIL-STD-1553 Channels
  - 8 Receive, 4 Transmit ARINC 429 Channels
  - 6 User Programmable Digital Discrete I/O
  - 2 RS-232, 2 RS-422/485 Serial I/O Channels
  - IRIG-B Time Code Input
- Front Panel I/O (100 pin Micro-D Connector)
- Air Cooled (+65°C inlet air temperature)
- Software drivers for Windows 2000/XP
Contact Information

- George Los, 800-332-1773 or 631-567-5600, ext. 7669; los@ddc-web.com

- Mike Glass, 800-332-1773 or 631-567-5600, ext. 7409; glass@ddc-web.com