MIL-STD-1553 Today and Into the Future

Presented to the IEEE Long Island Section, Instrumentation & Measurement Society on

November 13th, 2008

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History

- 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

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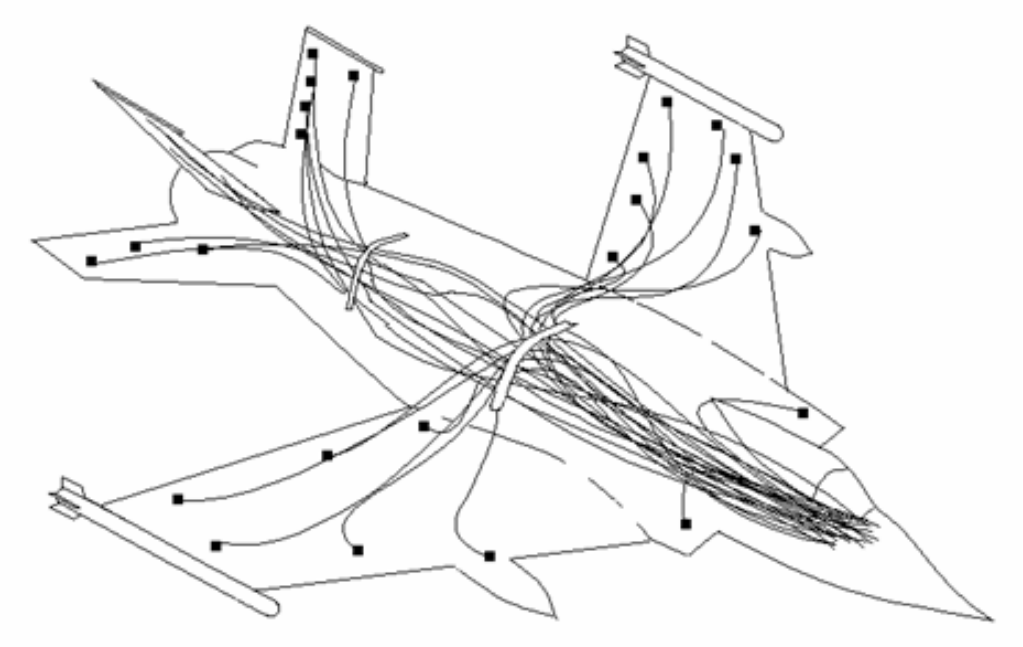
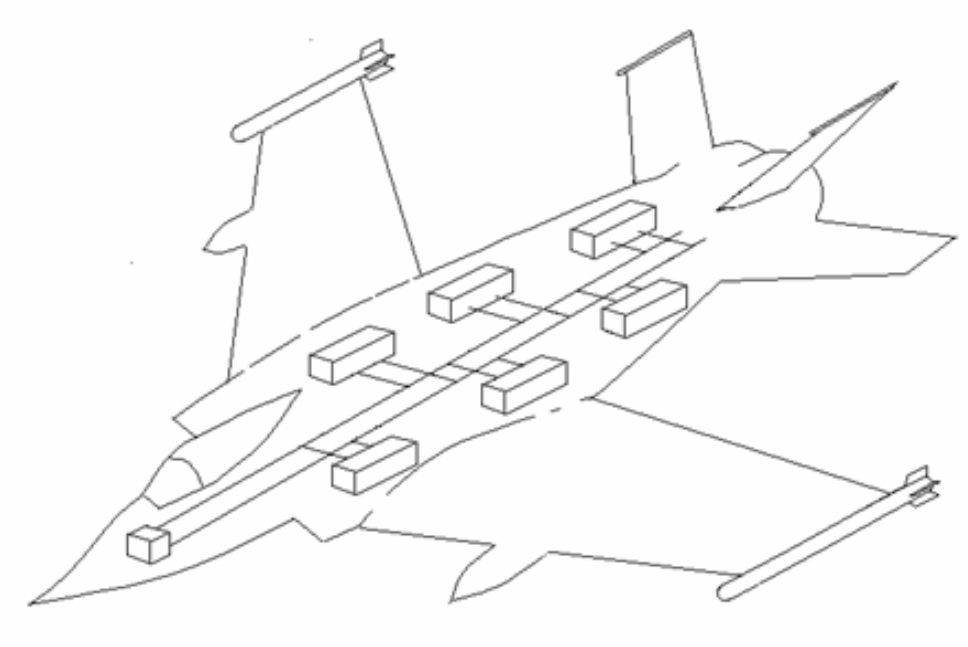
Discrete Wire versus a Bus





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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)

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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

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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:
  - http://www.flightglobal.com/articles/2008/07/08/225120/as-airbus-a350-takes-shape-can-it-avoid-the-a380s.html

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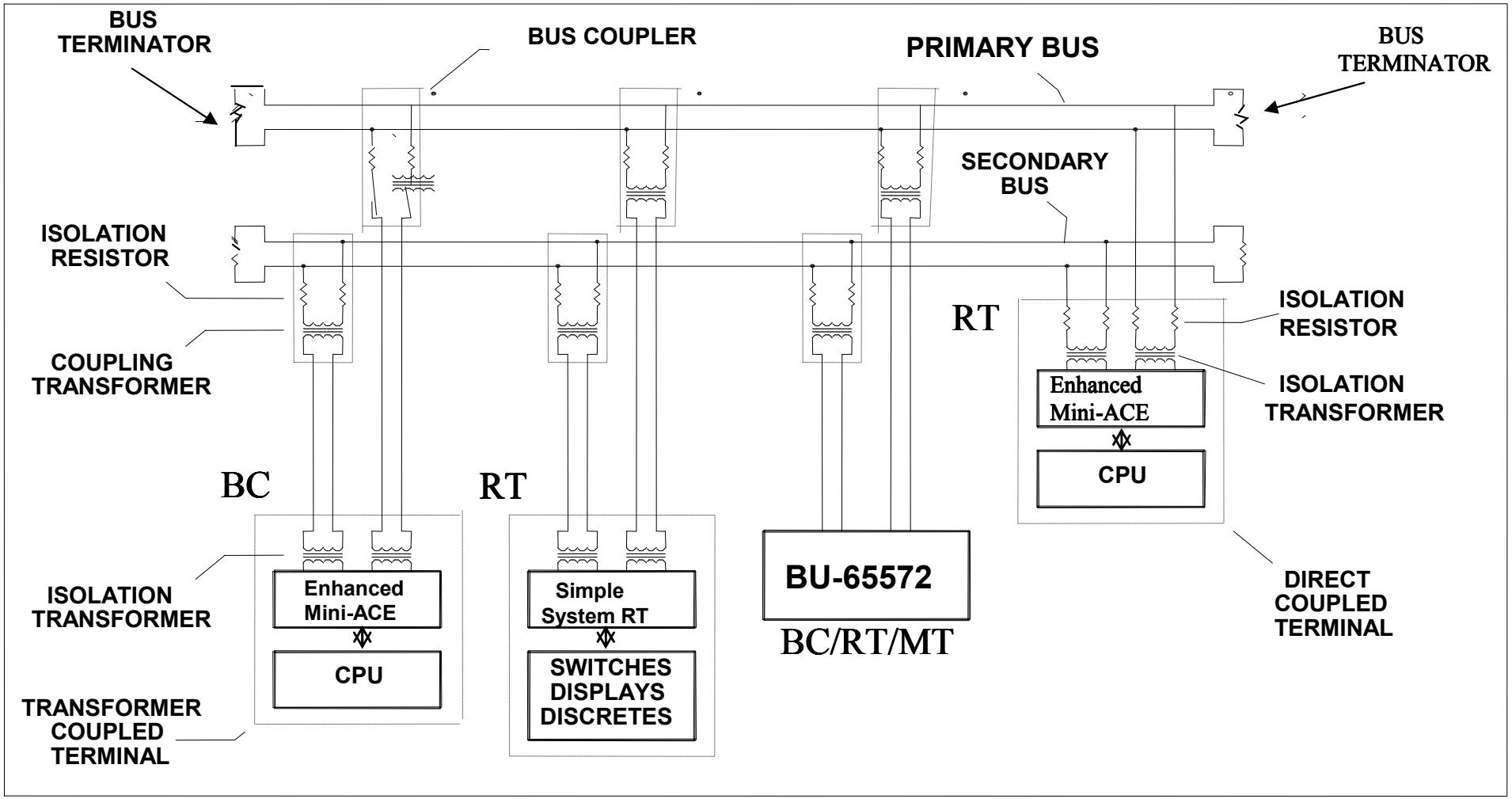
MIL-STD-1553B Architecture



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1553 Cable

Property	Value
Type	Twisted-shielded pair
Characteristic impedance (Z_0)	70 to 85 ohms at 1.0 MHz
Attenuation	1.5 dB/100 ft at 1.0 MHz, maximum
Shielding Coverage	75% minimum
Length of main bus	Not specified
Capacitance (wire to wire)	30 pF/ft, maximum
Twist Four per foot	0.33/in, minimum

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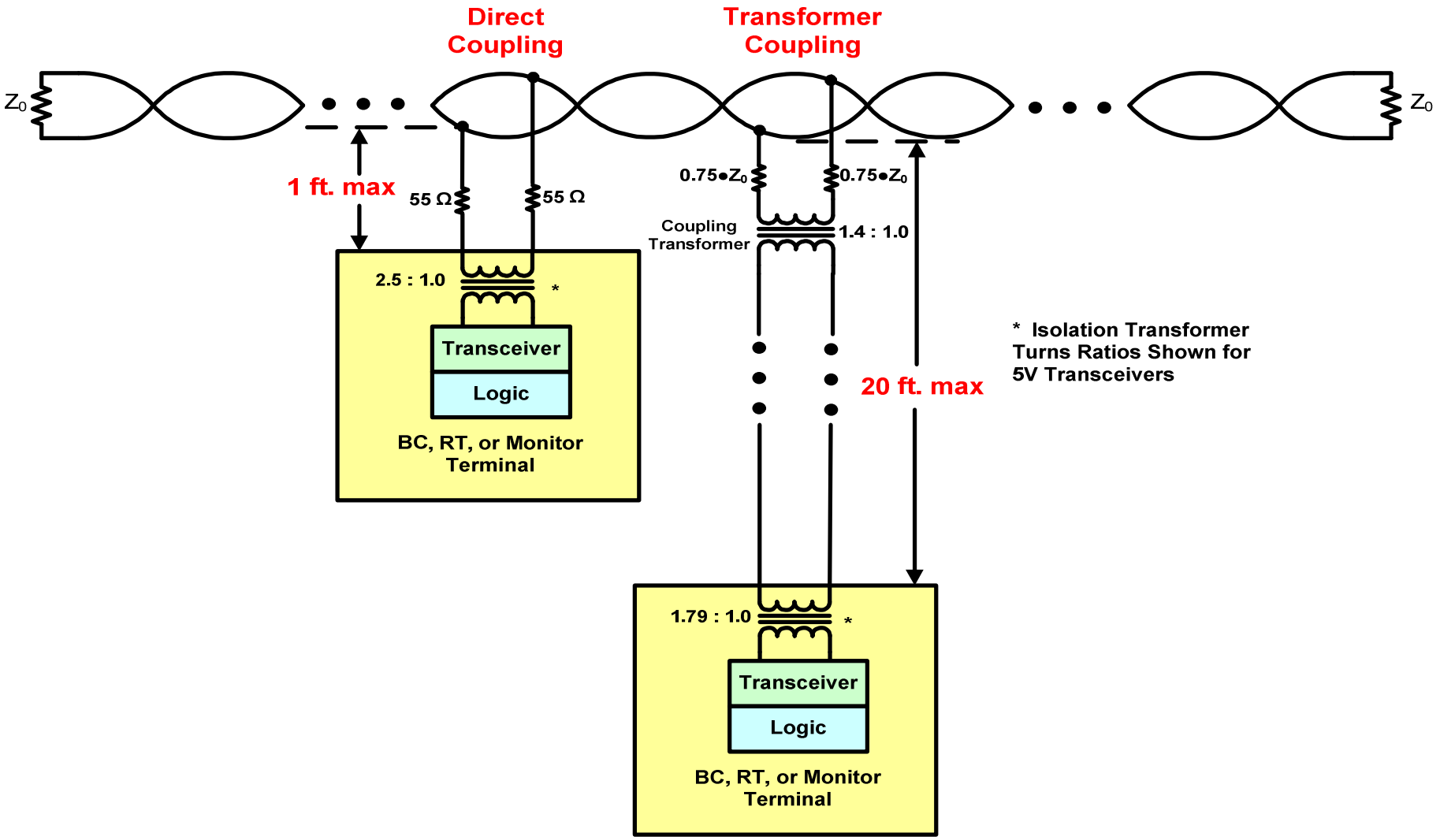
MIL-STD-1553B Bus Coupling



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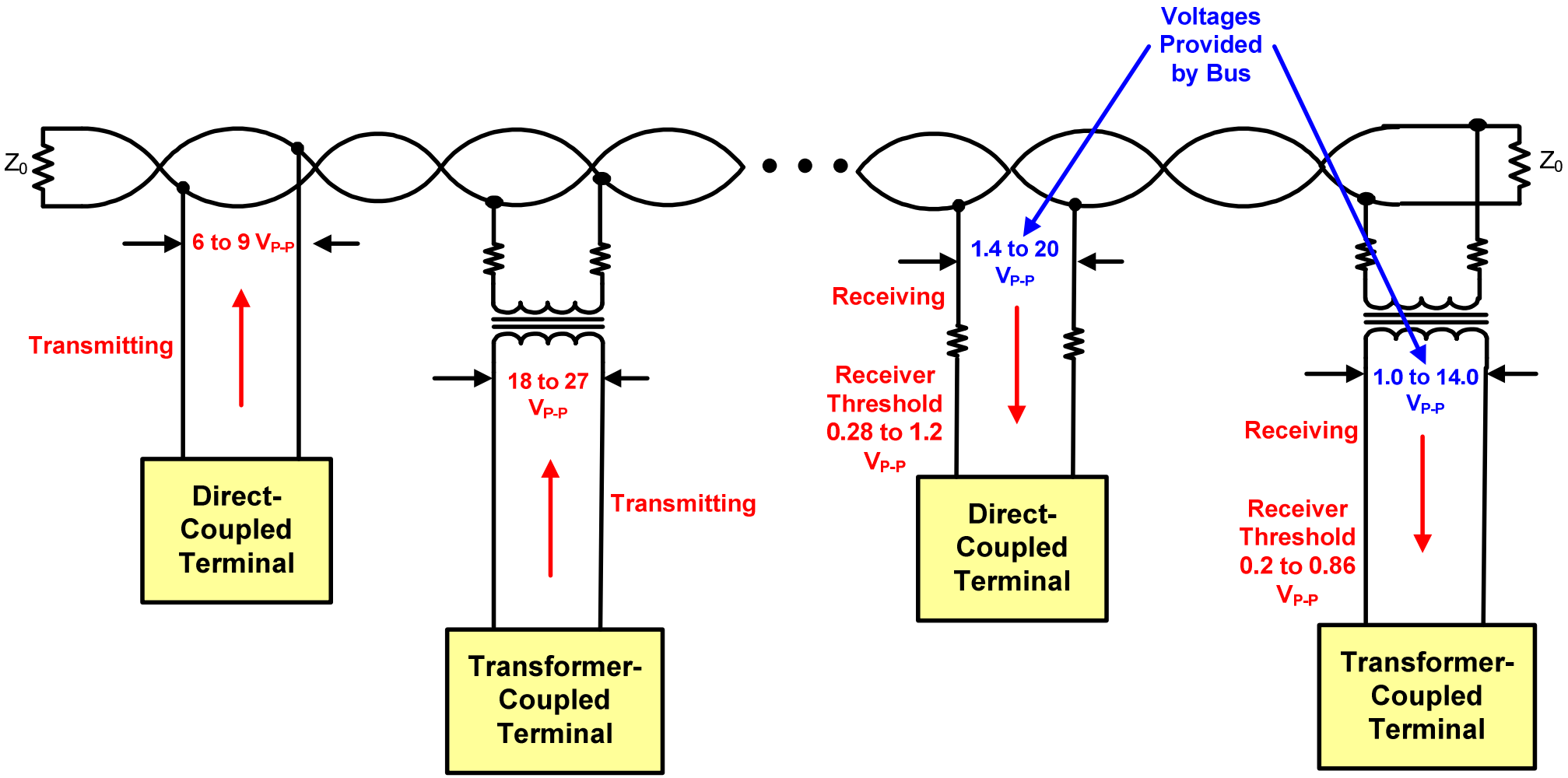
Terminal and Bus Voltages



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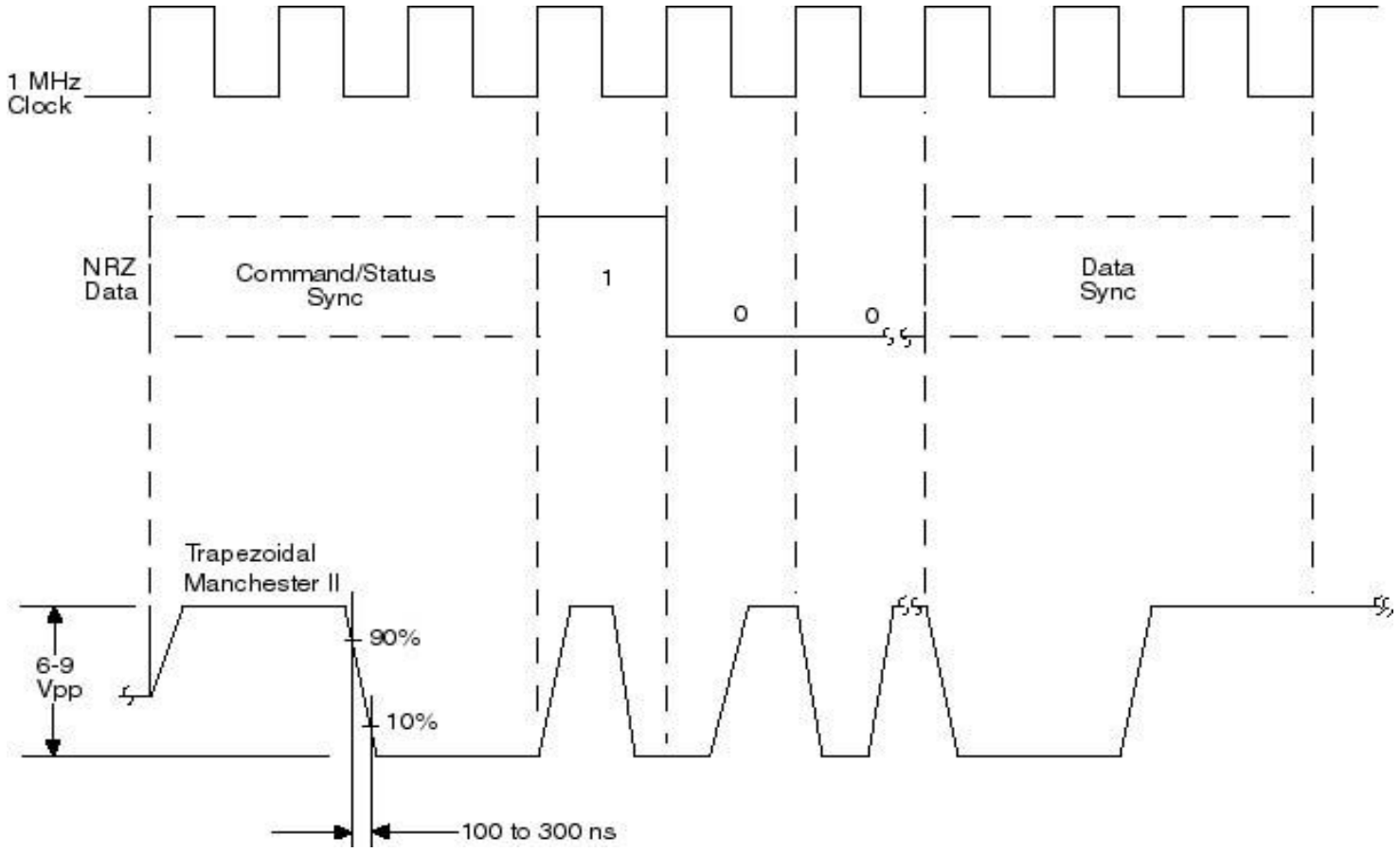
Manchester II Bi-Phase Encoding



A logic one & logic zero is transmitted as a bipolar coded signal. A transition through zero occurs at the midpoint of each bit time.

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Bus Controller (BC)

- 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.

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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.

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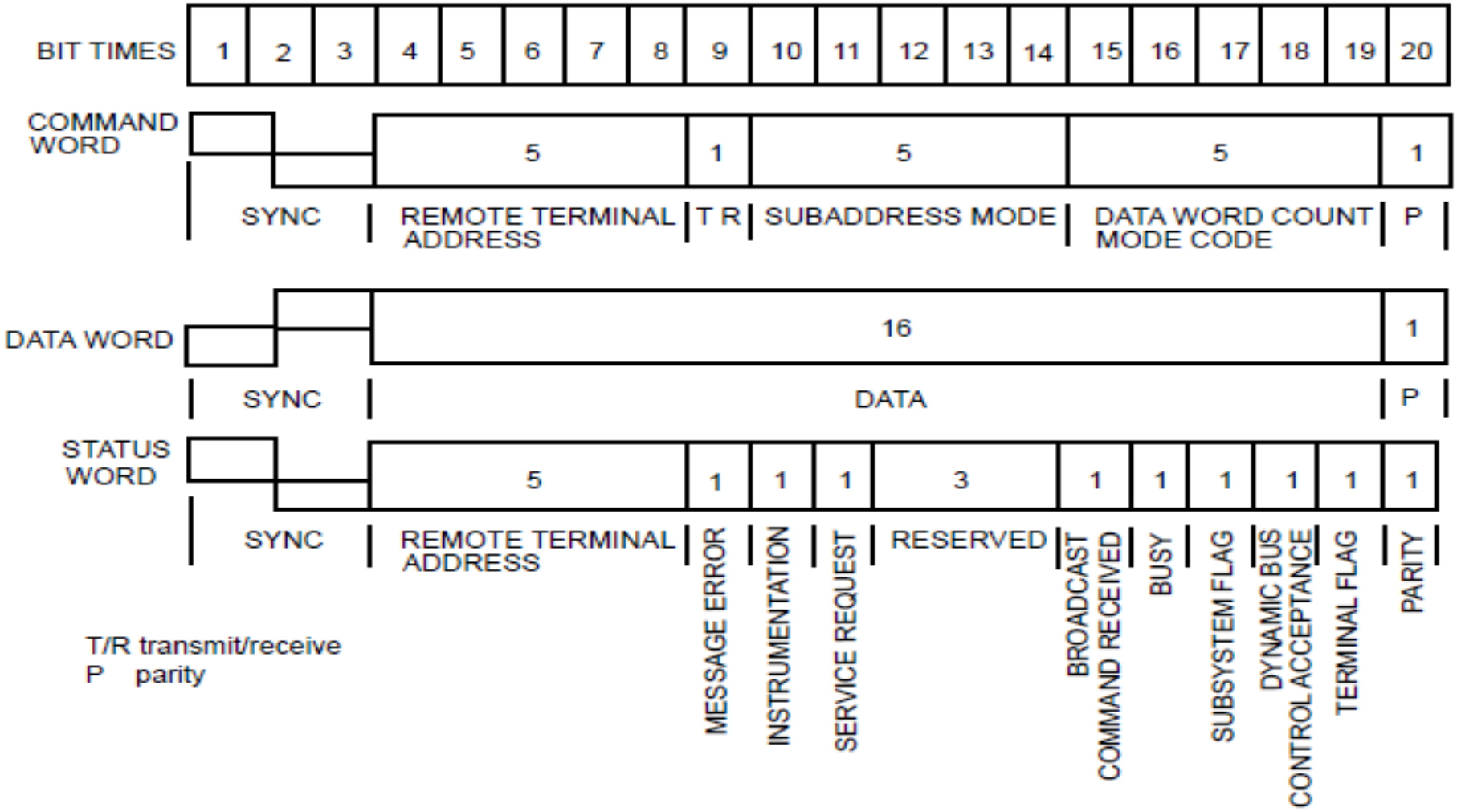
1553 Word Formats



T/R transmit/receive
P parity

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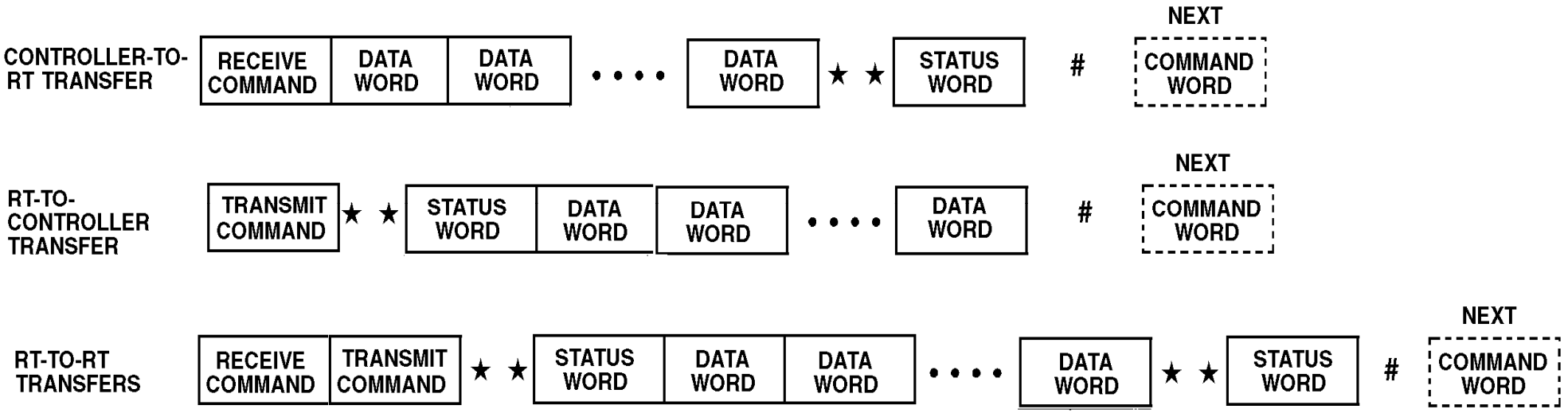
Information Transfer Formats



\# Intermessage gap

★ ★ Response time

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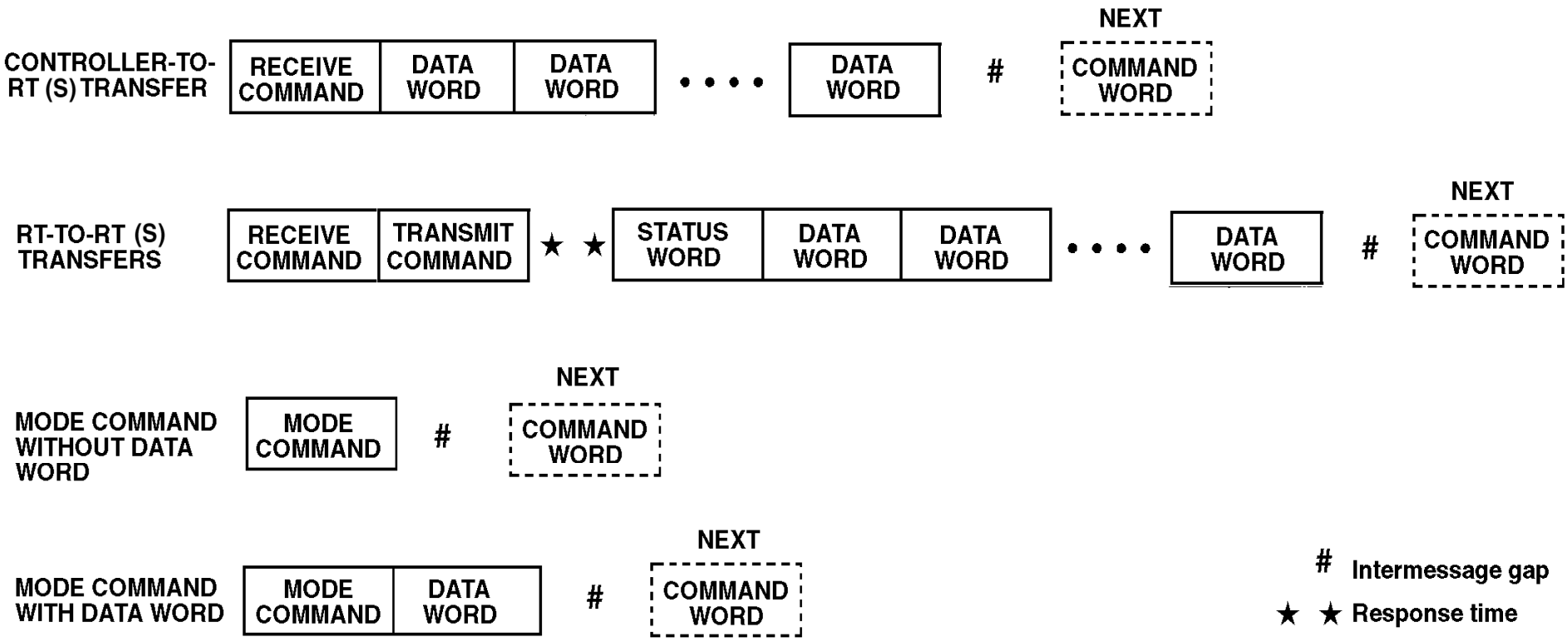
Broadcast Formats



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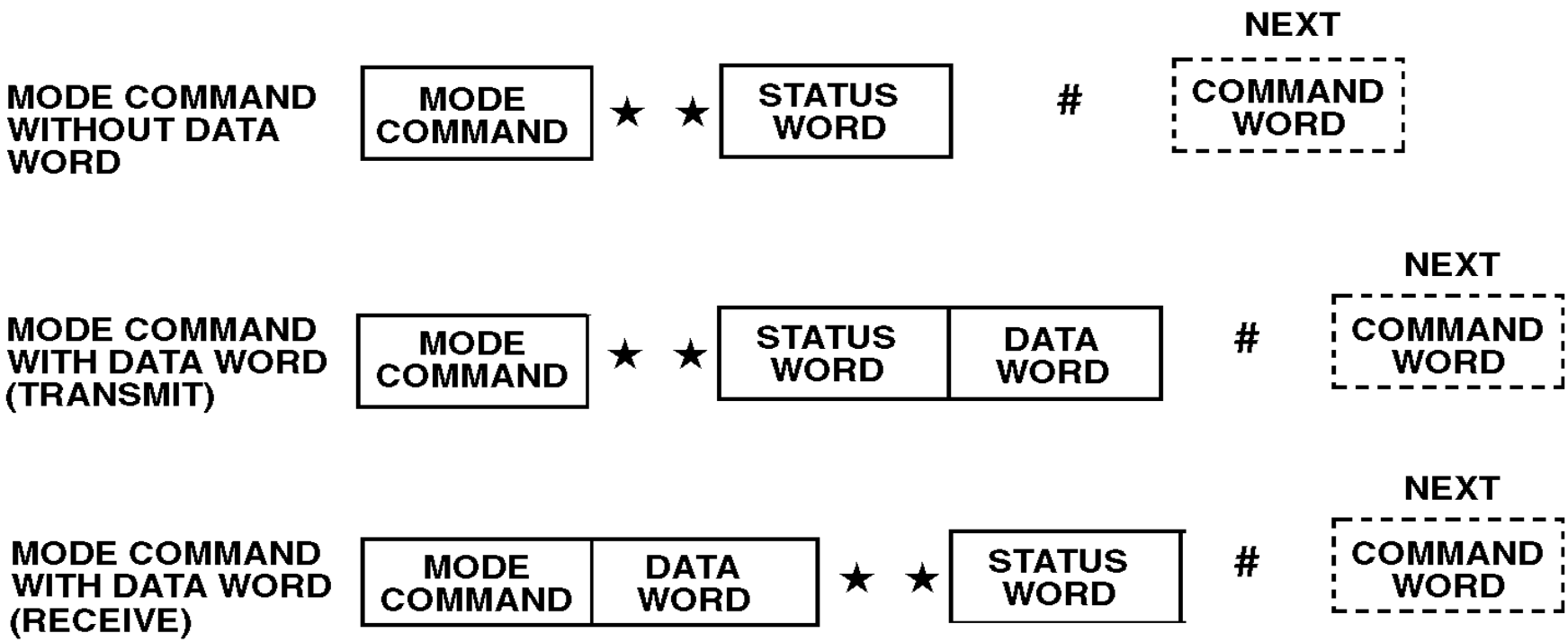
Mode Code Message Formats



\# Intermessage gap

★ ★ Response time

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Assigned 1553B Mode Codes

T/R	MC	Function	Data Word	Broadcast
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	01111	Reserved	No	TBD
1	10000	Transmit vector word	Yes	No
0	10001	Synchronize	Yes	Yes
1	10010	Transmit last command	Yes	No
1	10011	Transmit bit word	Yes	No
0	10100	Selected transmitter shutdown	Yes	Yes
0	10101	Override selected transmitter shutdown	Yes	Yes
X	10110	Reserved	Yes	TBD
X	11111	Reserved	Yes	TBD

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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.

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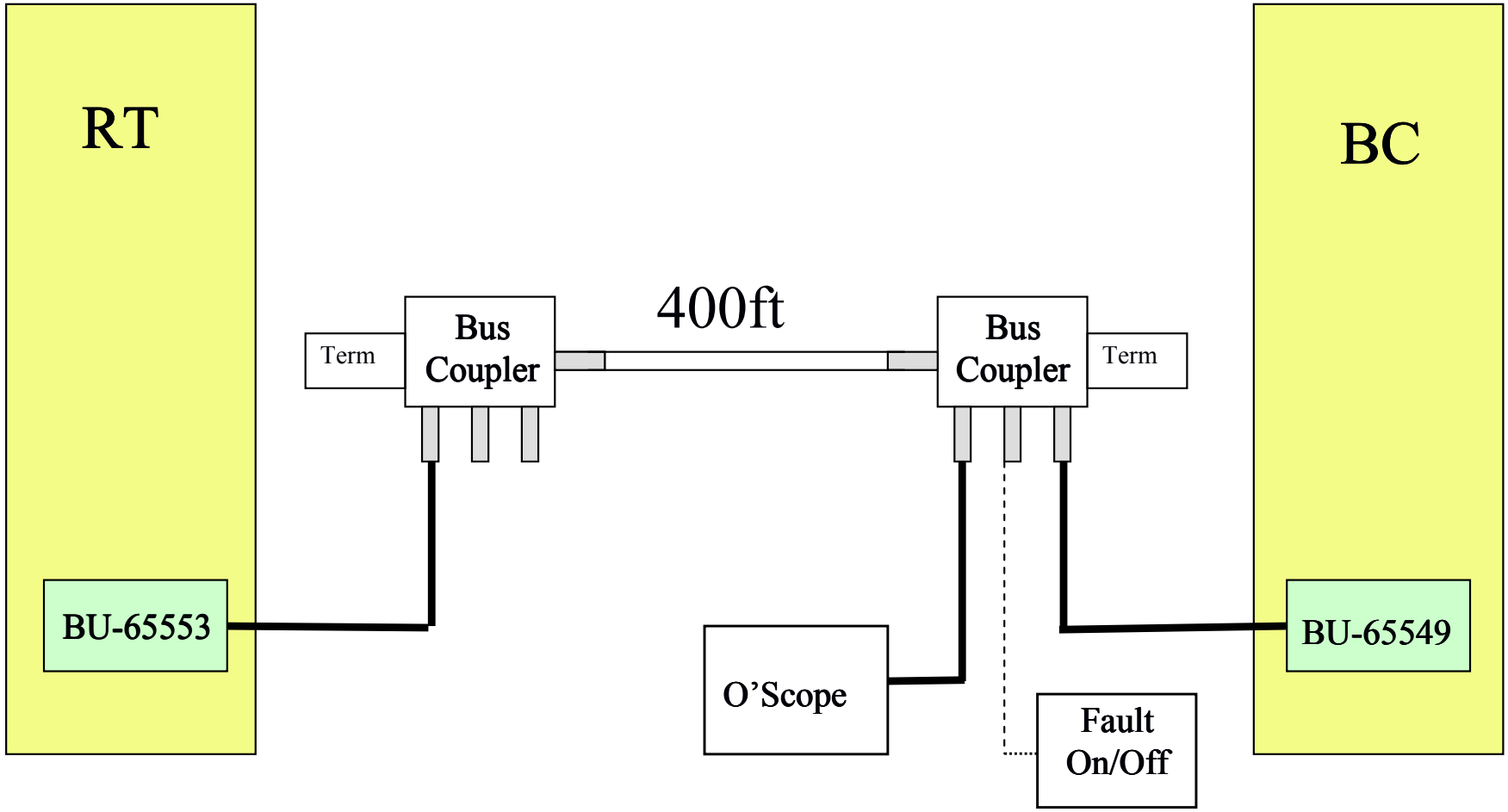
MIL-STD-1553, 400ft Cable Test



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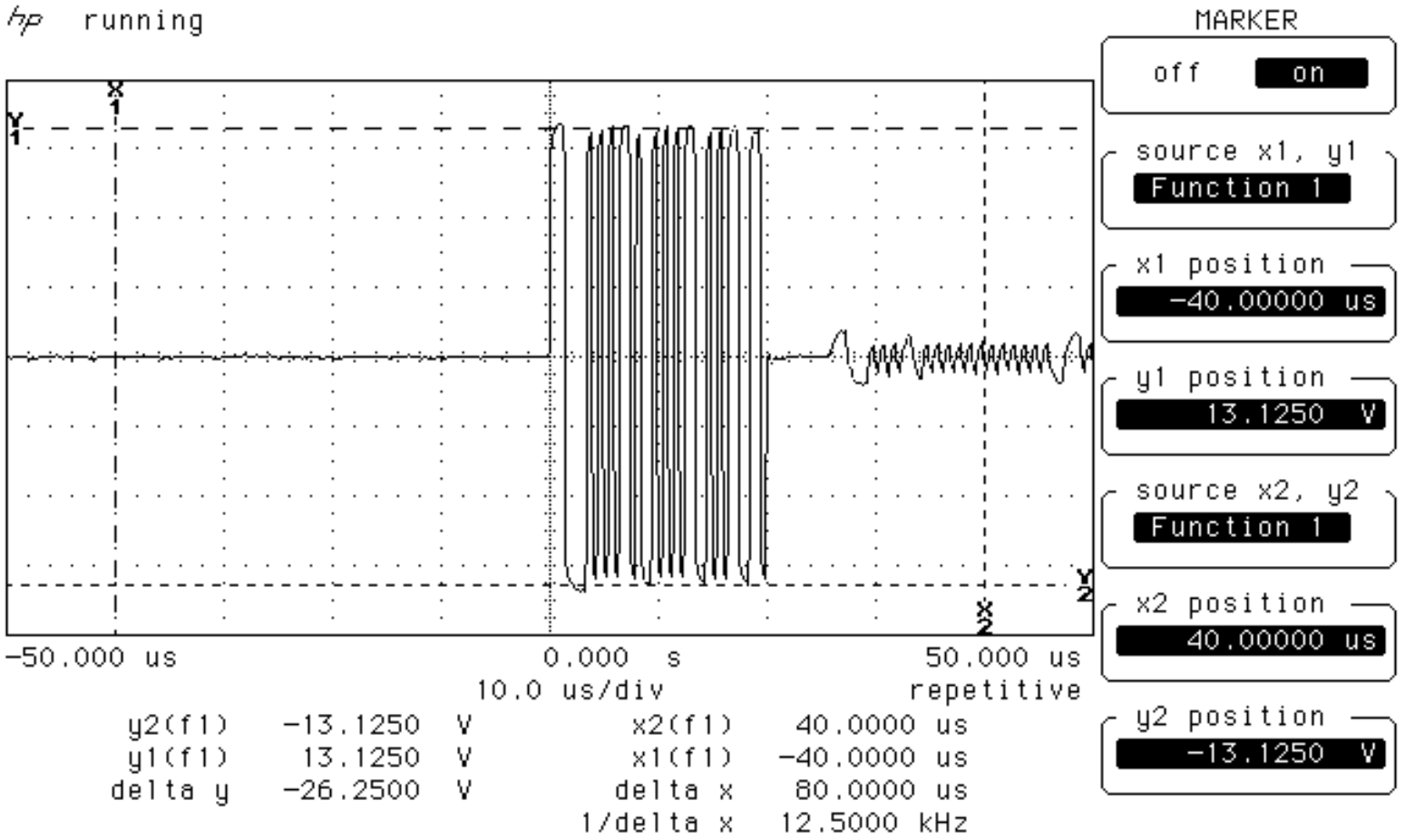
BC Command Word @ 0 ft, RT Status Word @ 400 ft



BC Command word amplitude = 26.25V p-p. RT Status word at 400ft. Amplitude = 1.75V p-p. This indicates cable attenuation of almost 3 dB/100 ft (1553 max = 1.5 dB/100 ft).

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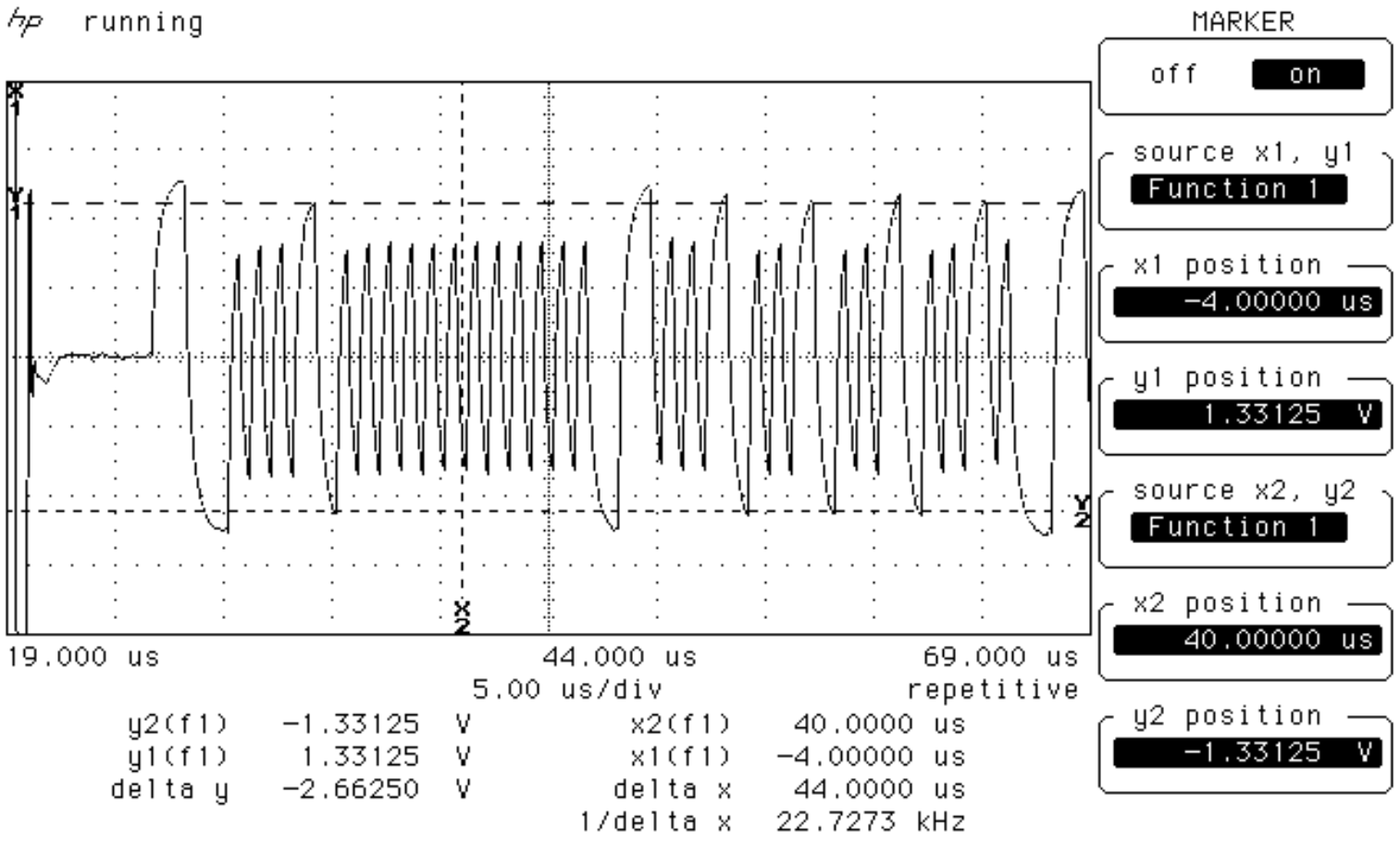
Expanded RT Status Word @ 400 ft



Expanded RT data word. Amplitude of 1.8V at the "Smaller dominant amplitude" (3 boxes).

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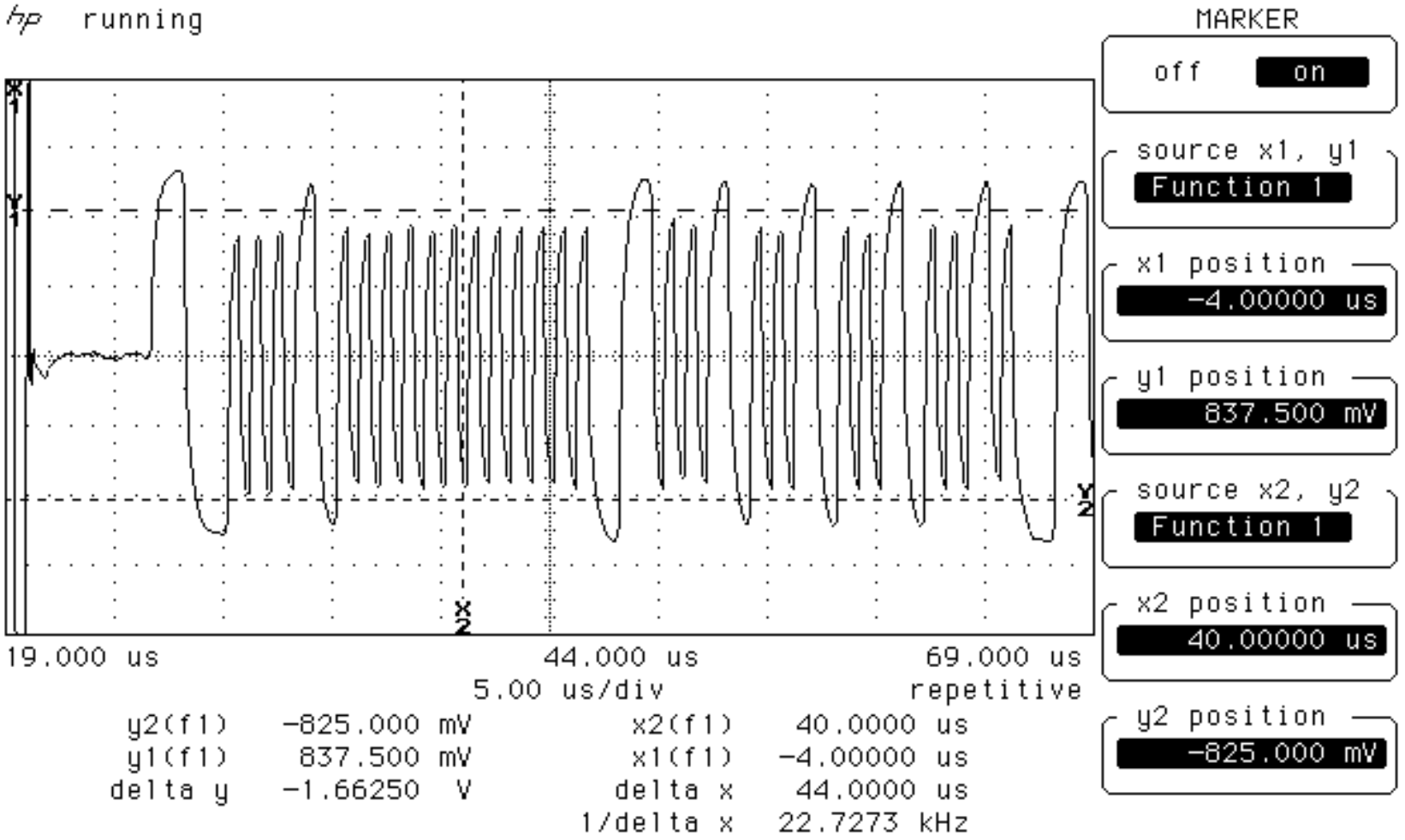
Expanded RT Status Word with Short Circuit Fault @ 400 ft35



Expanded RT data word with Short Circuit Fault Amplitude of 1.44V at the "Smaller dominant amplitude" (3.6 boxes).

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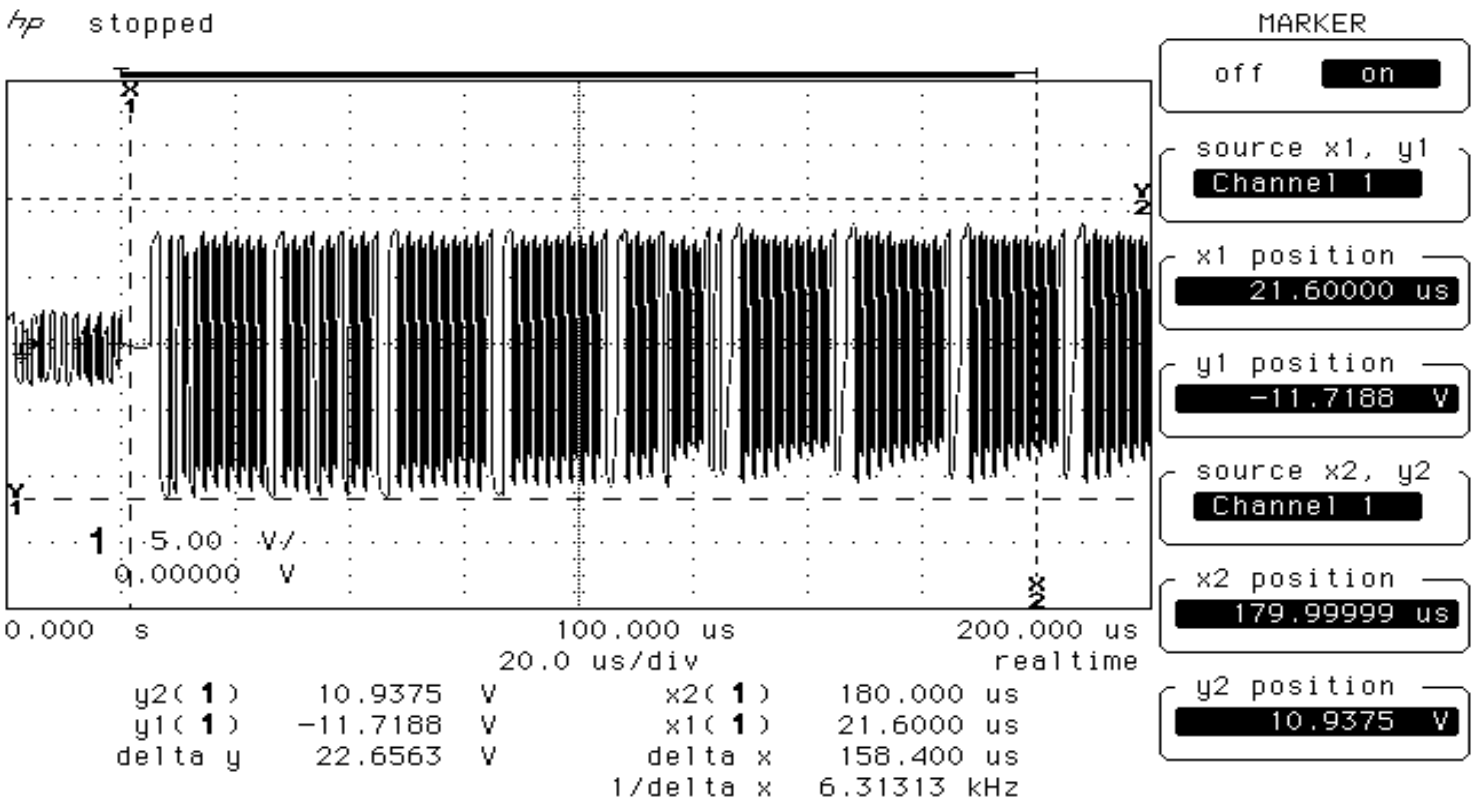
Overshoot and/or Dynamic Offset Problems



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.

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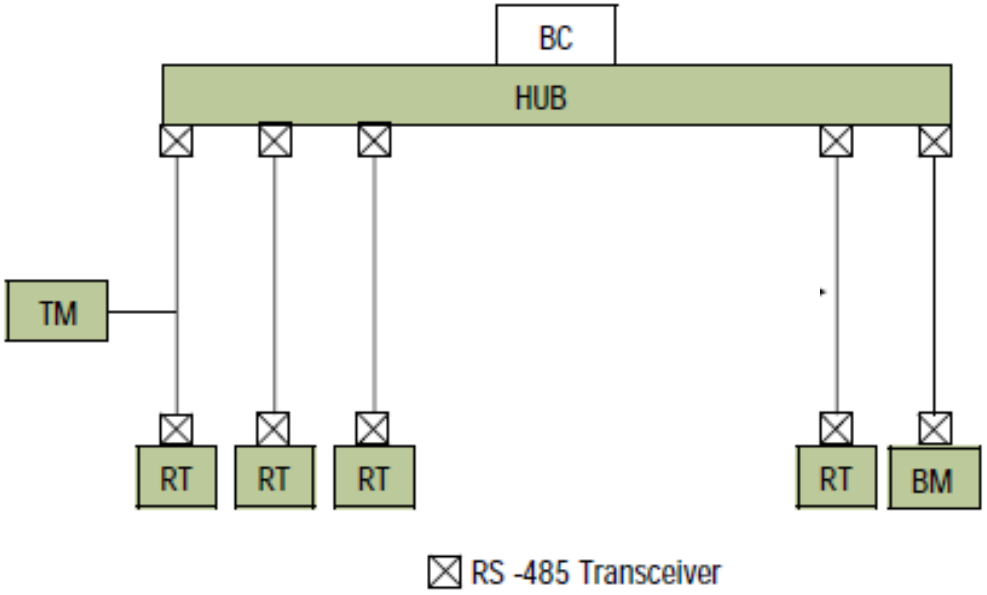
Enhanced Bit Rate 1553 (EBR-1553)

- 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



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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

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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

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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

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FC-AE-1553 -- Overview

- 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

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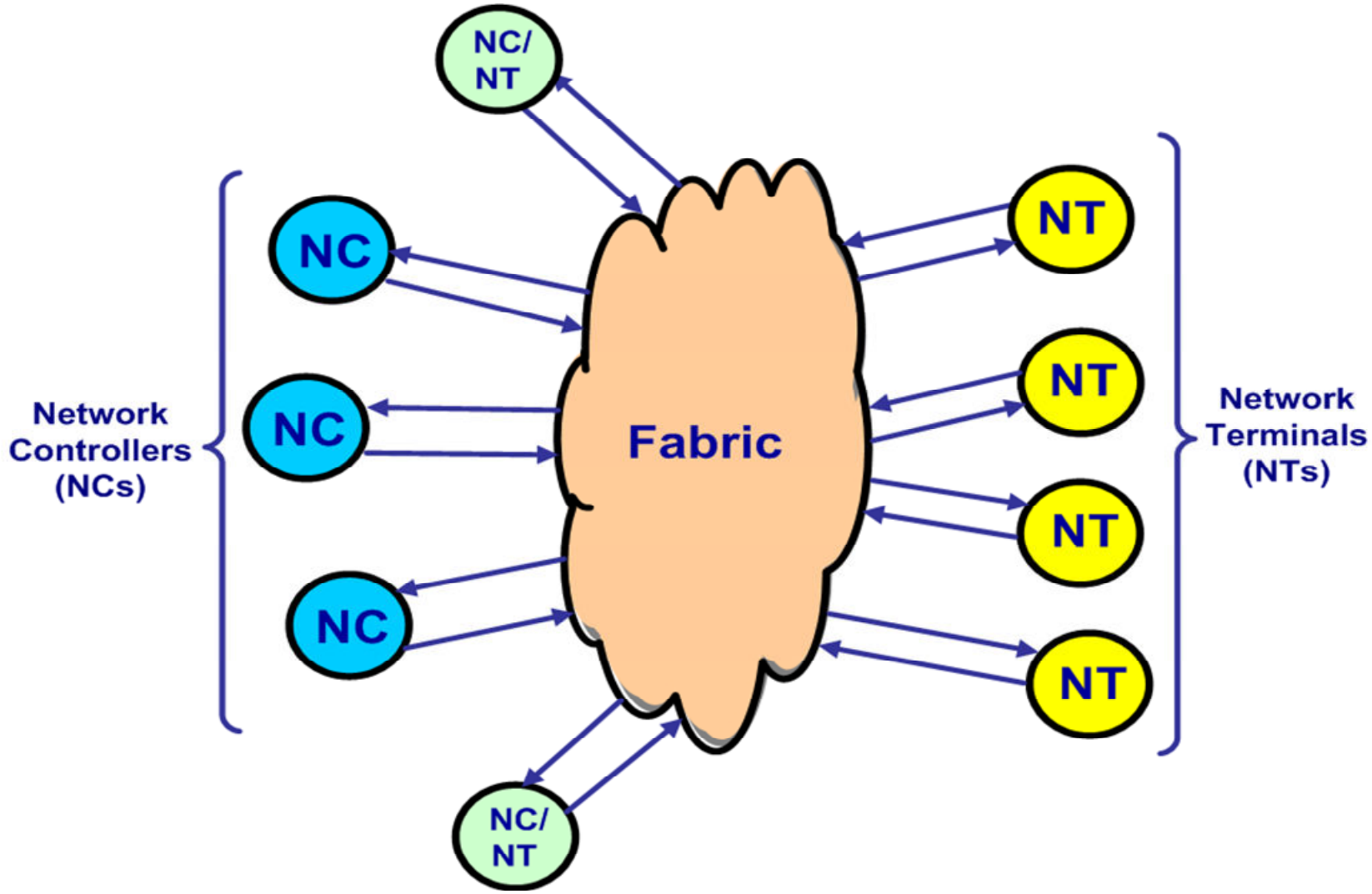
FC-AE-1553: NC and NTs



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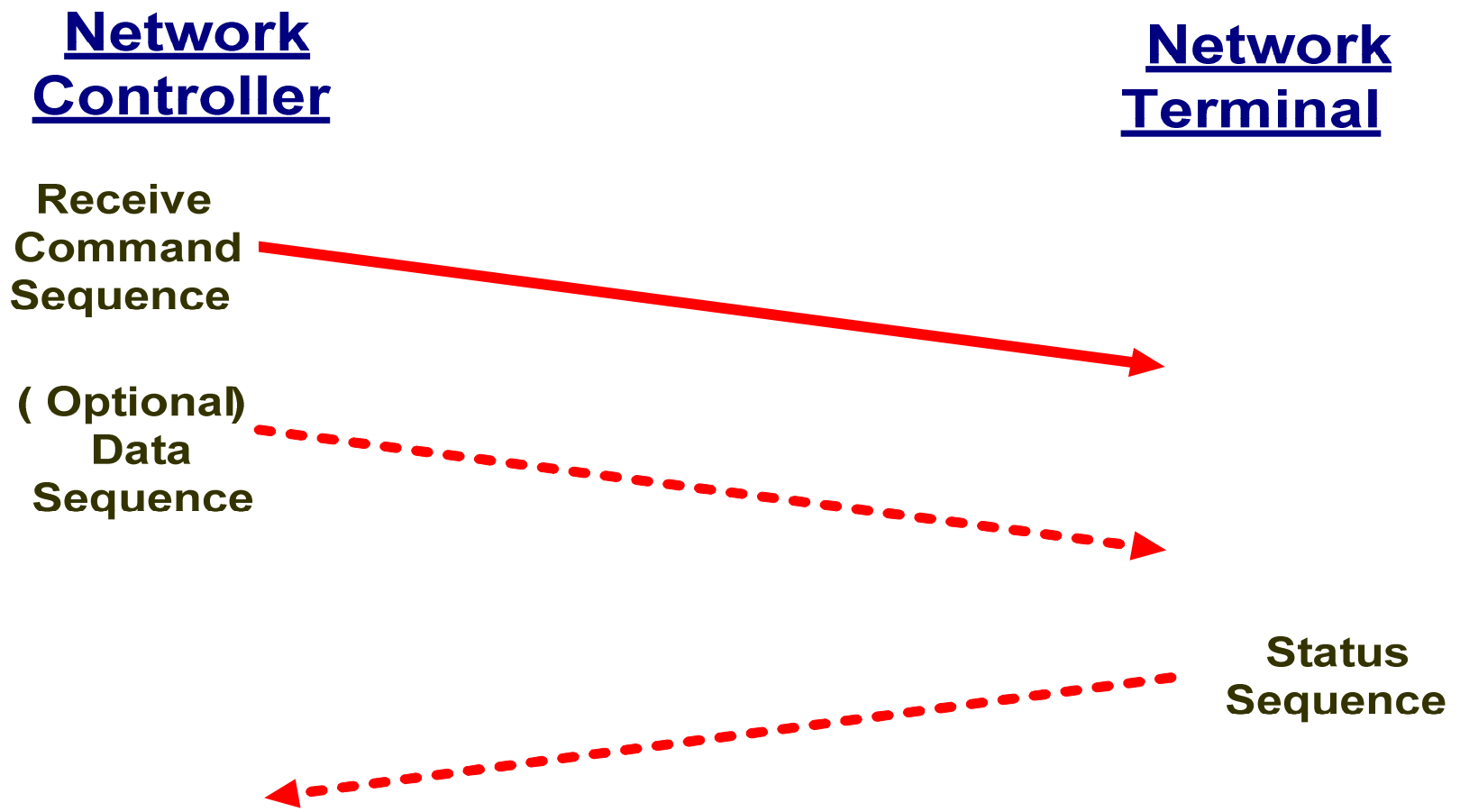
FC-AE-1553 NC-to-NT Transfer



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Design Criteria

- 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

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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

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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

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The ACE Legacy

- DDC has supported the ACE family for over 23 years.
- Legacy software & I/O compatibility

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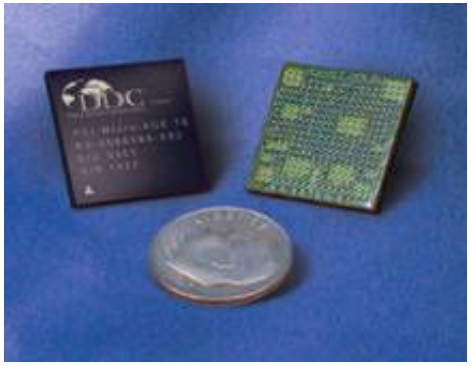
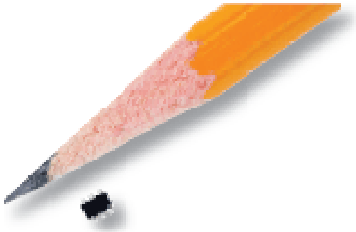
Component Product Mix

- 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





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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

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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

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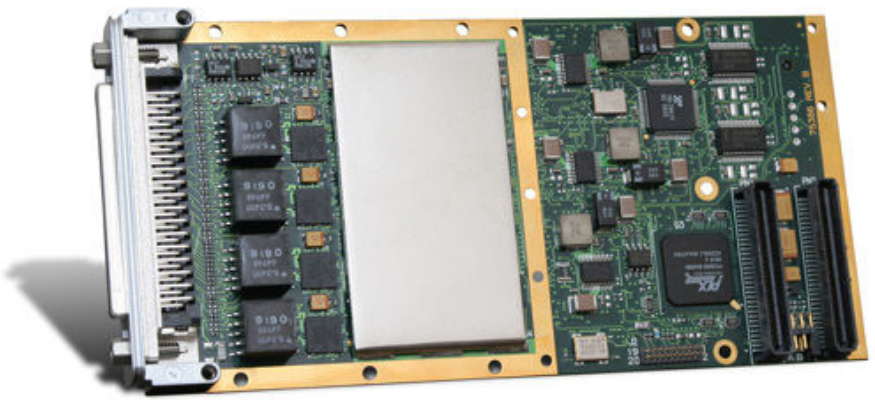
BU-65590F/M Multi-IO PMC Card

- 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



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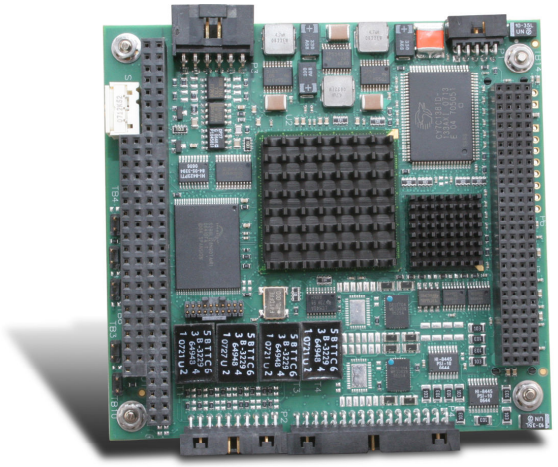
BU-65590C Multi-IO PC/104 Plus Card

- 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



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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 Channe
  - 8 Receive, 4 Transmit ARINC 429 Channe
  - 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

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Thank you!

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

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