Aging Aircraft Sustainment with Non-Standard Engineering

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Evolution of Avionics Systems

FROM…

- Single-Function, stand-alone characterized by multiple subsystems
- Connected multiple analog signals using point-to-point wiring, to provide a single function

TO…

- Digital technology for information transfer
- Allowed network sharing of the physical interface
- Reduced number of interconnections within the airframe

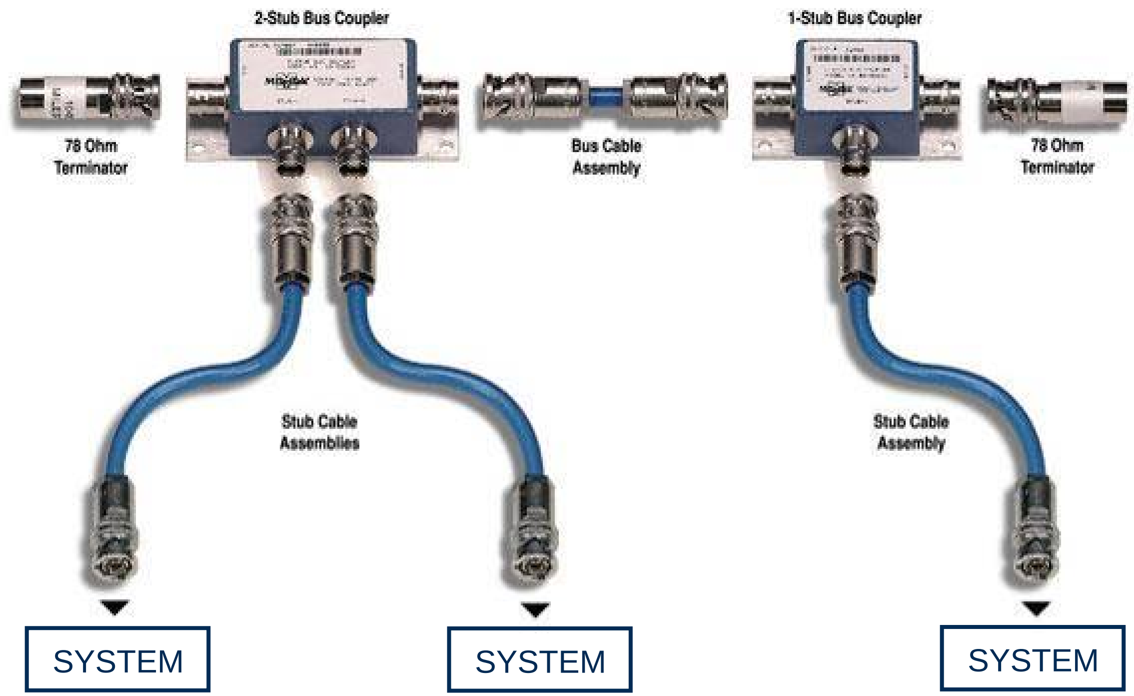
MIL-STD-1553

- Result of a cooperative effort between the military and industry
- Defines the electrical and protocol characteristics for a digital, serial communication standard among systems
- From its initial release in 1973, the standard has been revised and updated to reflect lessons learned from implementation.
- Currently standard version is revision B, Notice 6

MIL-STD-1553B Notice 6

- Defines the data bus network as a a main bus cable to which stubs are attached and terminals are connected to the stubs
- Voltage waveforms arrive at different terminals with the least amount of distortion
- Major parameters affecting waveform quality are bus length, number of stubs, and locations and lengths of stubs

A Design-to-Standard Bus



http://www.n-digital.co.jp/Milestek/diagramandtechinf/Mil1553bComp.intro.files/SVS.JPG

Non-Standard A/C 1553 Wiring Analysis

LEGACY ISSUES…

- While strides are being made to integrate avionics systems, the physical infrastructures on the target platforms may not be up to the bus standard.
- Installing wiring that conforms to the standard on any legacy system can be costly

POSSIBLE SOLUTION…

- Using non-compliant wiring installed on an aircraft, can systems reliably exchange information over the bus?
- Beneficial to derive and implement an analysis process

Non-Standard A/C 1553 Wiring Analysis

To ensure…

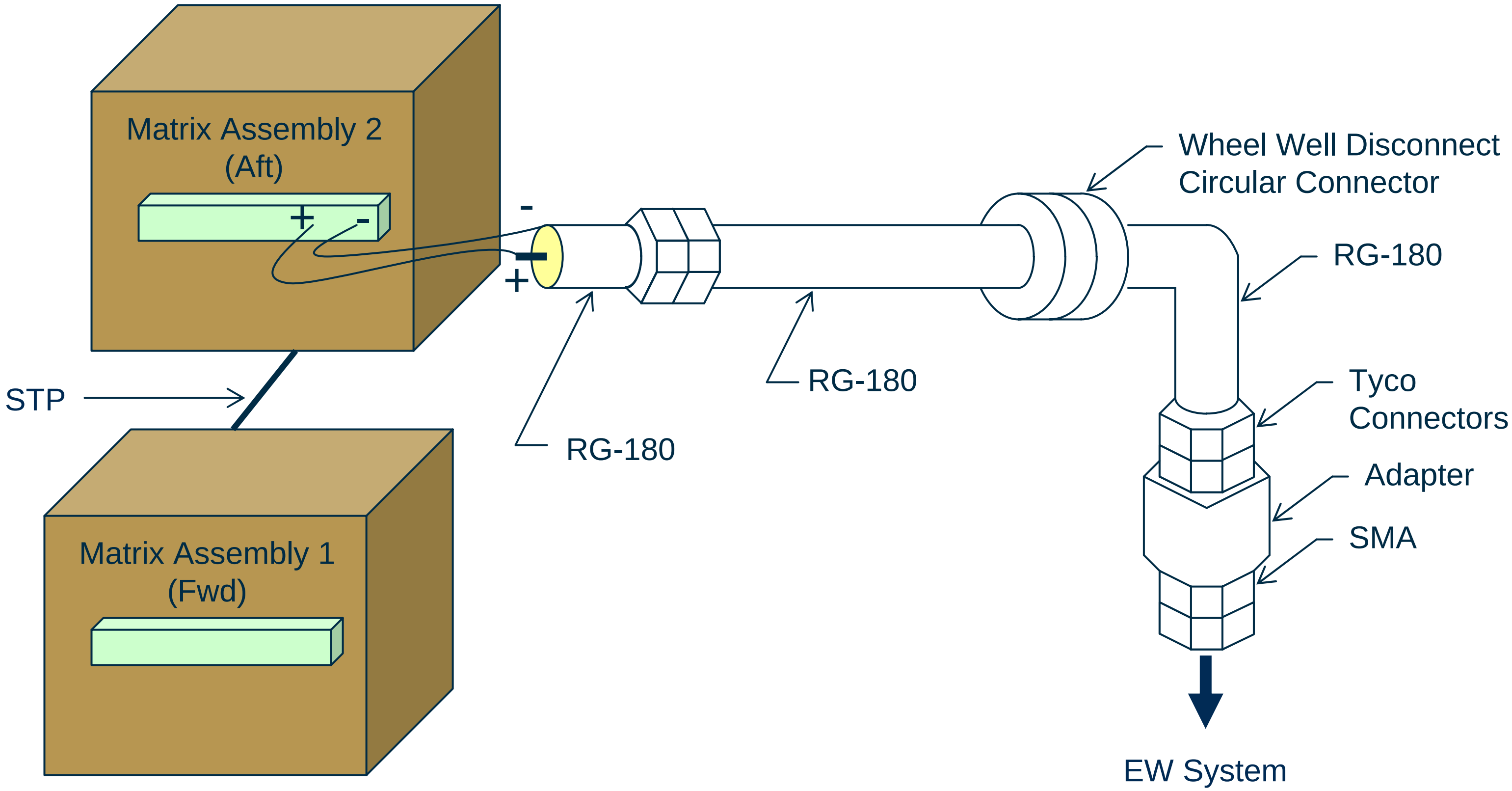
- Performance
- Maintenance
- Supportability

Plan to…

- Develop Spice Models
- Execute Lab Tests
- Perform SPICE Analysis of Actual A/C Wiring
- Perform Lab Analysis of Actual A/C Wiring

Existing A/C 1553 Wiring

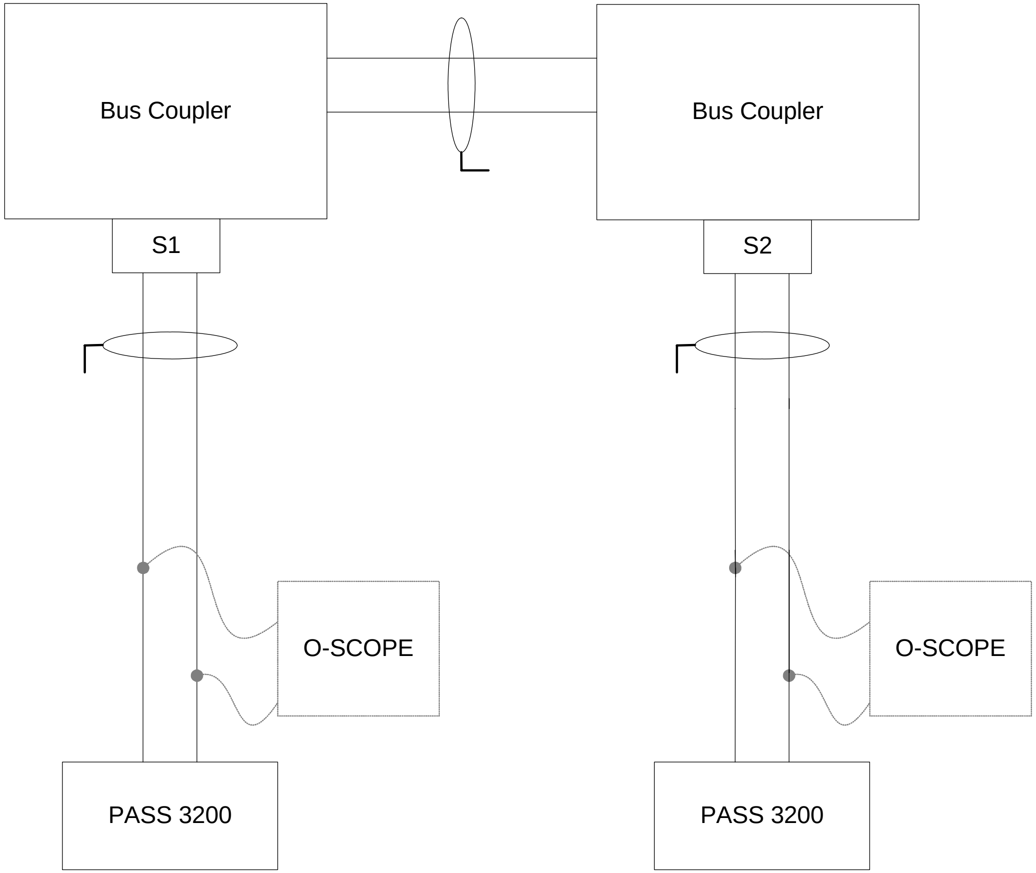
F-16C+ Block Diagram



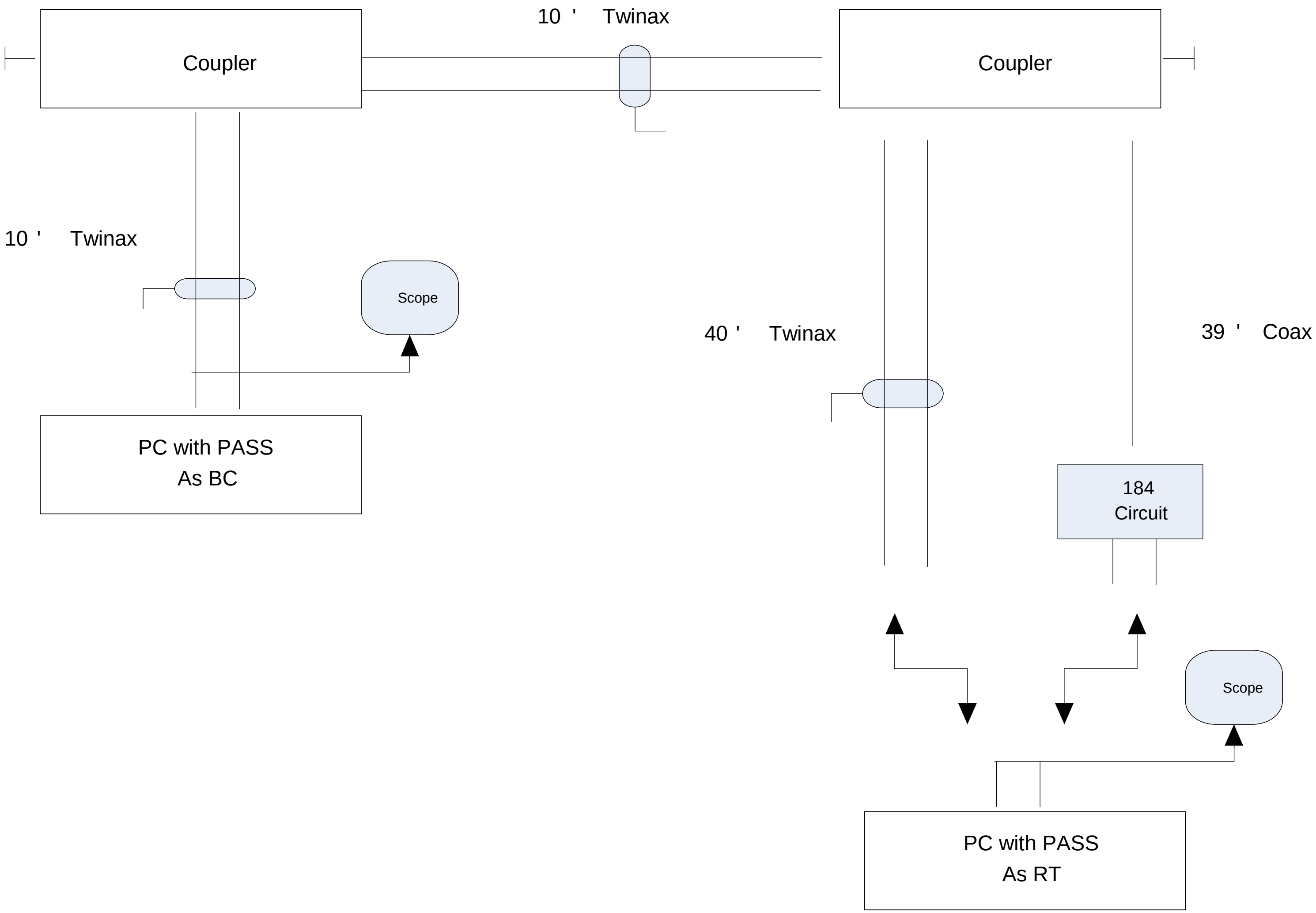
Examining Signal Quality on the Bus Network

- GOAL – To transfer voltage waveforms with minimum distortion
- To determine whether or not a network will perform reliably, its characteristics are measured and compared to the requirements of the standard.
- The quality of the waveform is determined by examining it in the following respects:
  - Amplitude
  - Zero-crossing distortion
  - Waveform tailoff

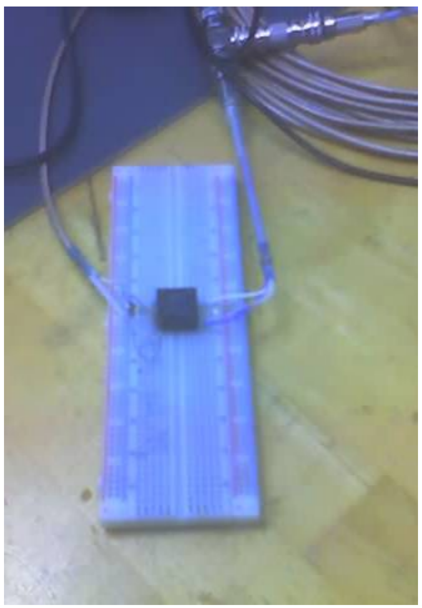
Test Waveform

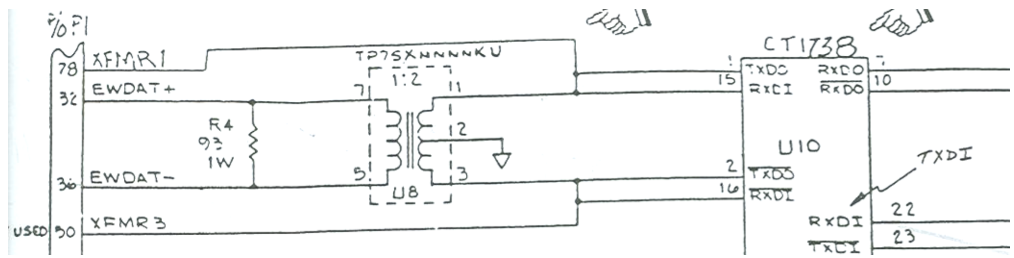


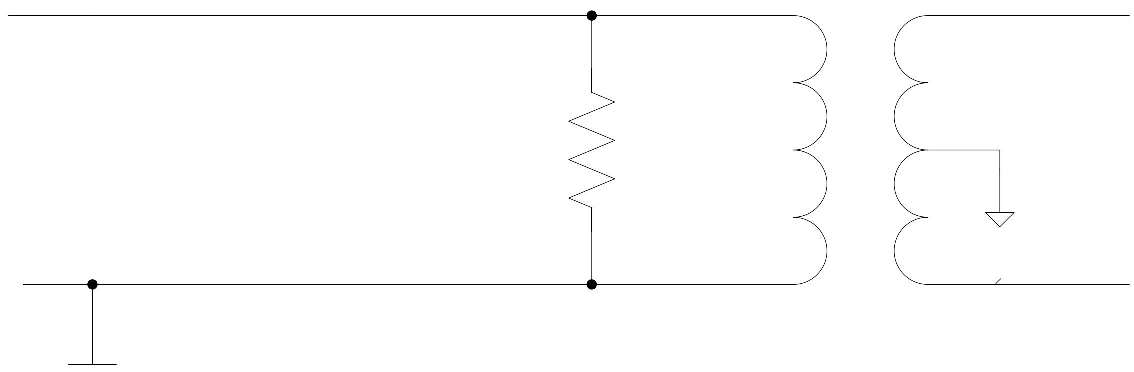
Laboratory Mockup



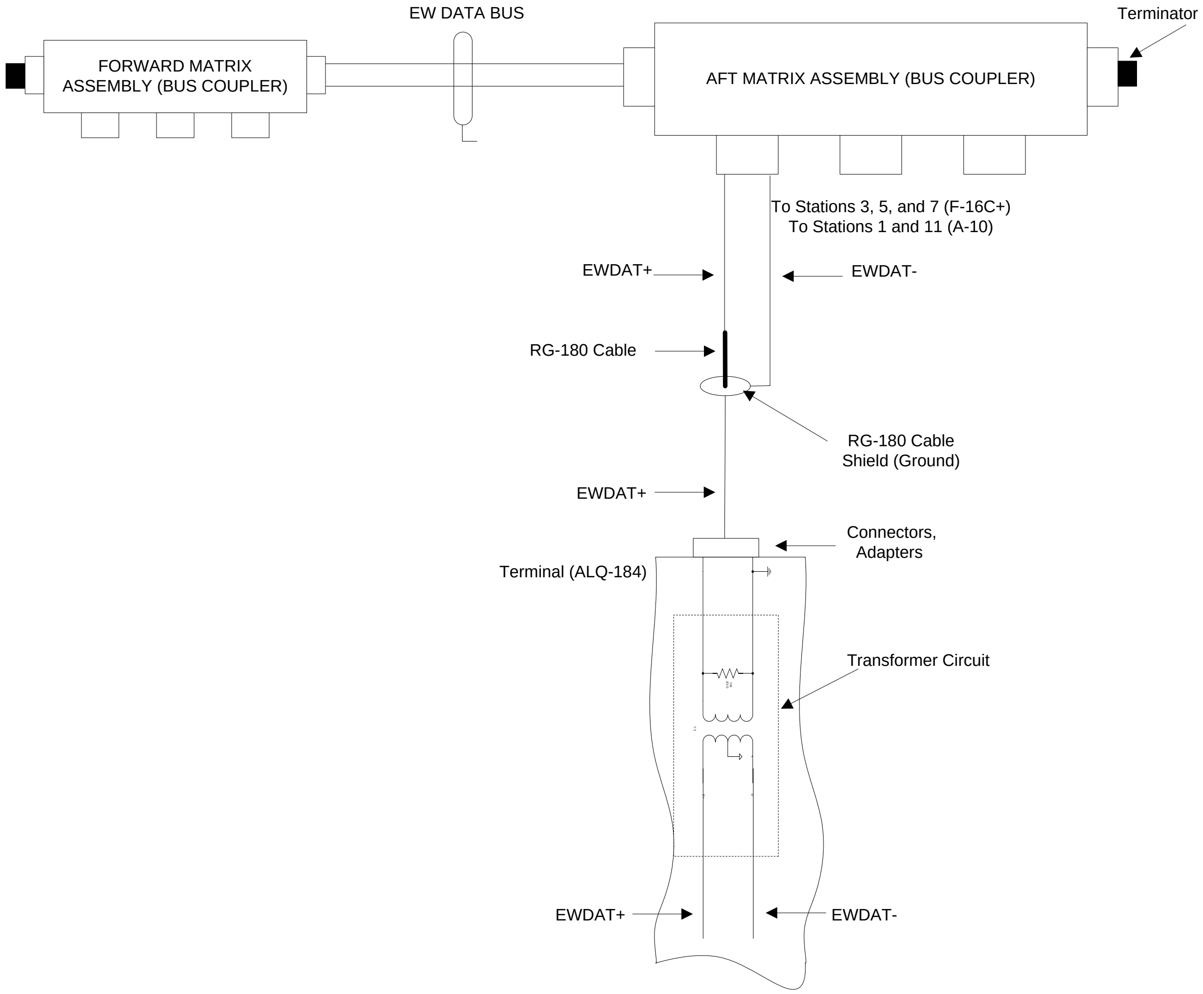
Transformer Circuit Solution







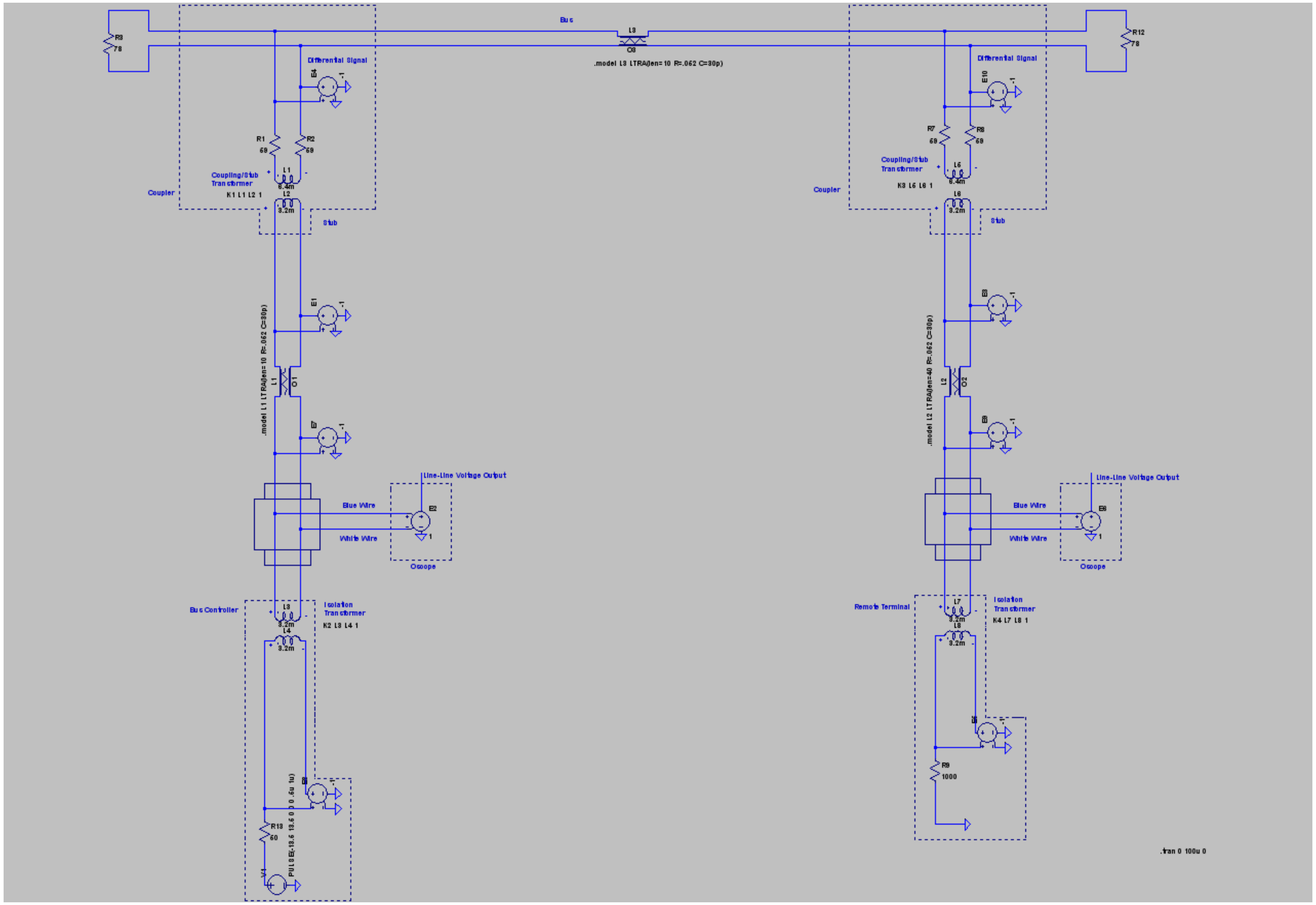
Existing A/C 1553 Wiring



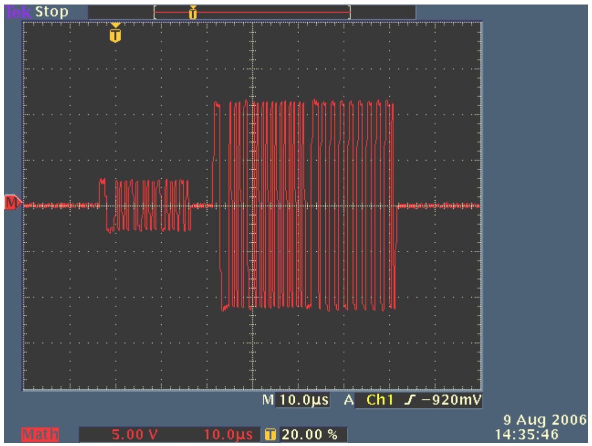
Computer Simulation

- Computer Simulation provides an approximation of the quality of the signal that can be achieved with a hardware mockup
- A SPICE program was used to model a transmission line defined by the characteristics of the standard and non-standard wiring
- The transmission line was linked to other components, i.e. resistors and transformers, to form the standard 1553 bus design

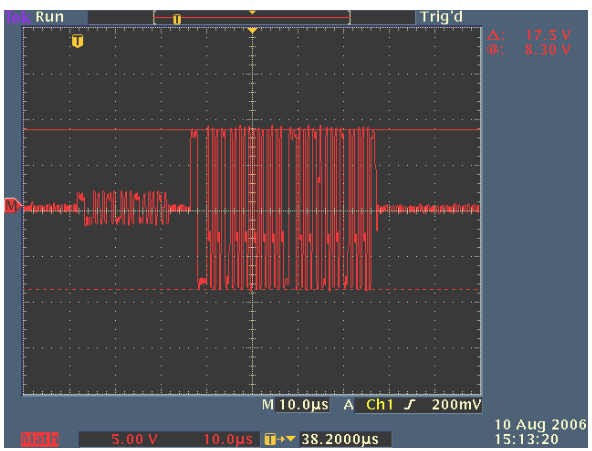
SPICE Bus Configuration



Impact of Non-Standard Wiring



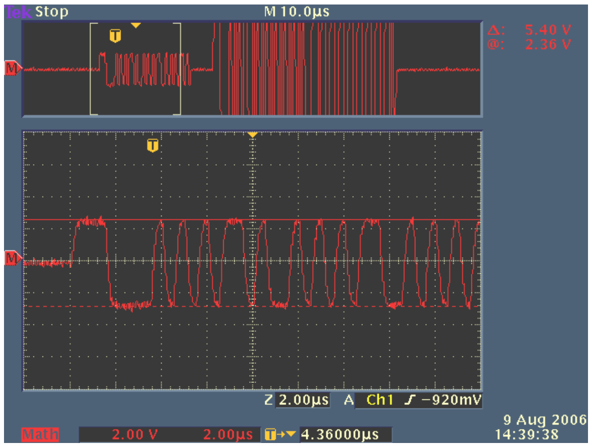
40’ Twinax



39’ Coax

- BC commands one word transmit from RT (0x0C21 1-T-1-1)
- RT answers with status word followed by 1 data word
- Examine waveform quality (MIL-HDBK-1553, § 40.9)
  - Amplitude
  - Zero-crossing distortion
  - Tailoff

Input Waveform Amplitude at RT



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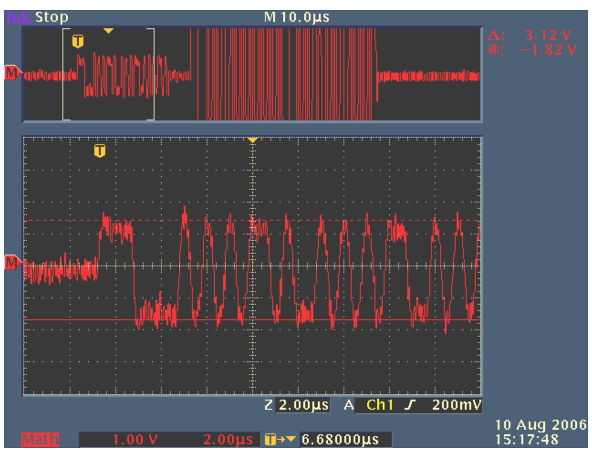
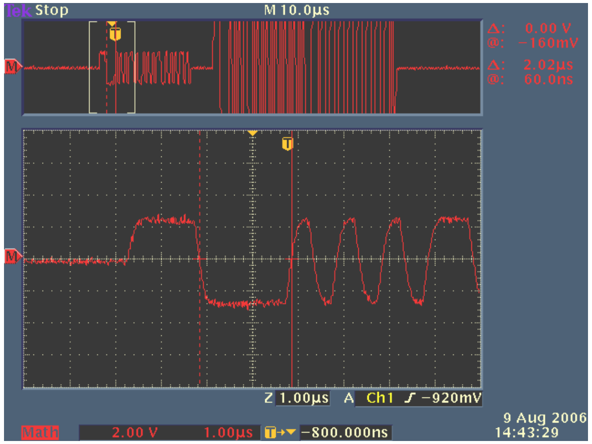


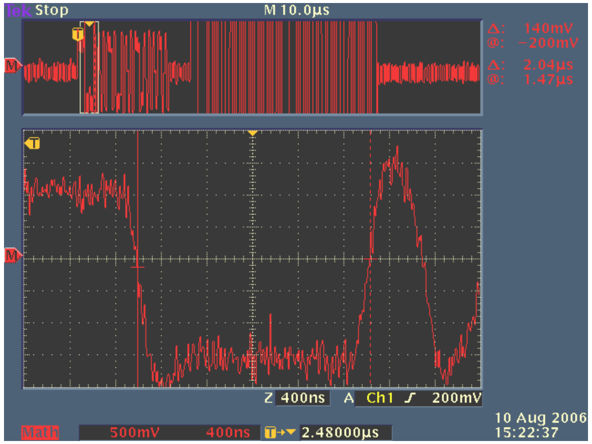
39' Coax

- **Measured Voltage**
  - **Twinax: 5.4 v**
  - **Coax: 3.12 v**
- **Requirement: 0.86 – 14.0 v**

Input Waveform Zero-Crossing at RT



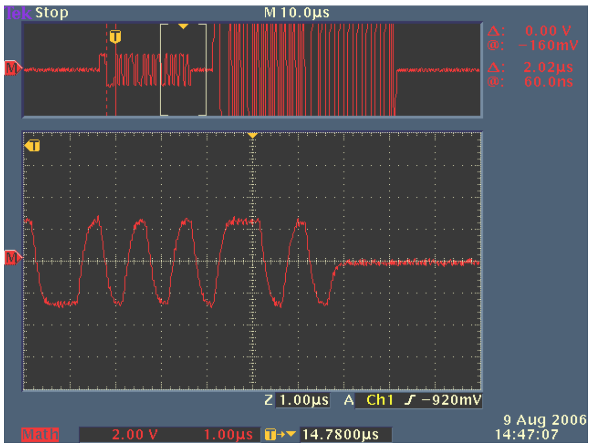
40’ Twinax

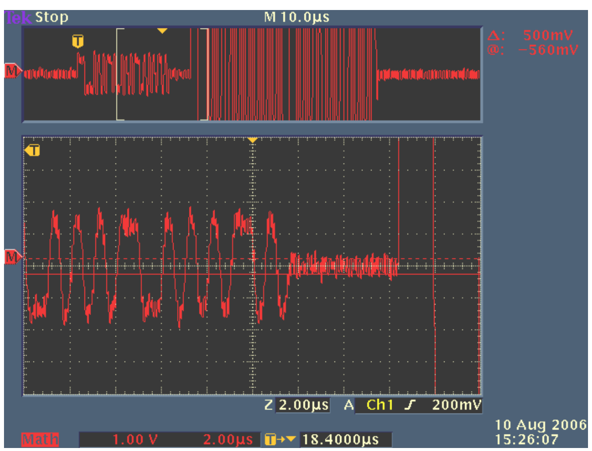


39’ Coax

- Measurement shown is zero-crossing for first bit of command word to the first bit of the data word
- Measured Time
  - Twinax: 2.02 µs
  - Coax: 2.04 µs
- Requirement: 2 µs ±150 ns

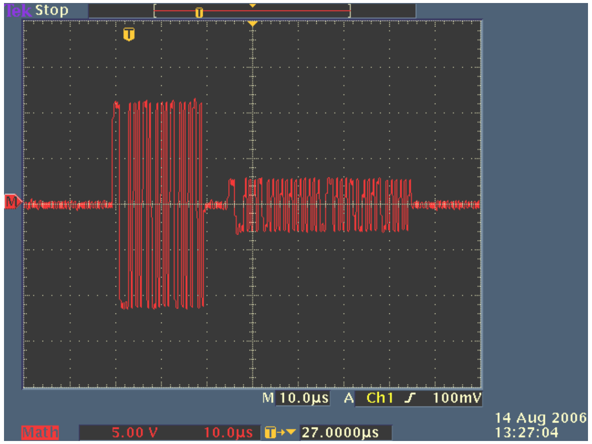
Input Waveform Tailoff at RT

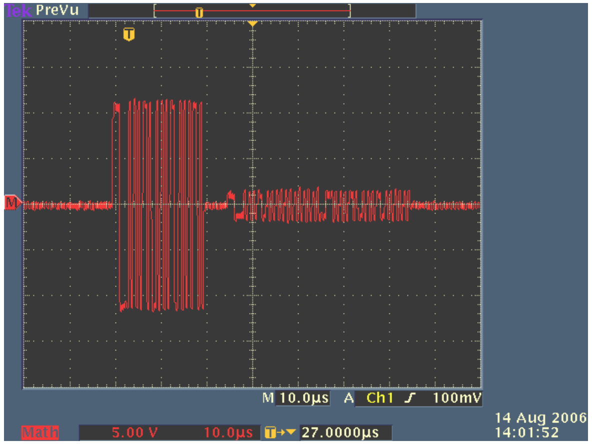




- Voltage must be less than ±250 mV for the period beginning 2.5 µs following the last mid-bit zero-crossing.
- Both waveforms exhibit clear end to data waveform.

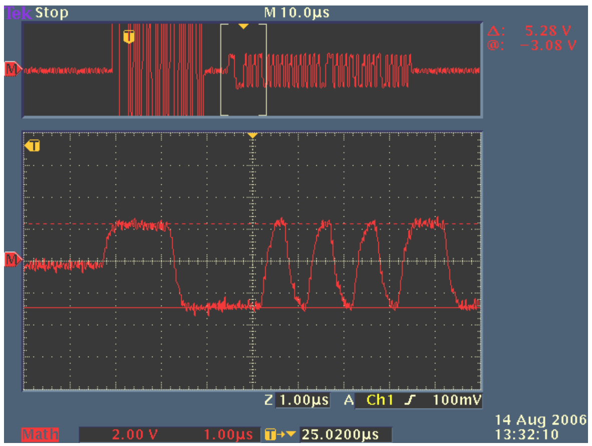
Impact of Non-Standard Wiring – BC



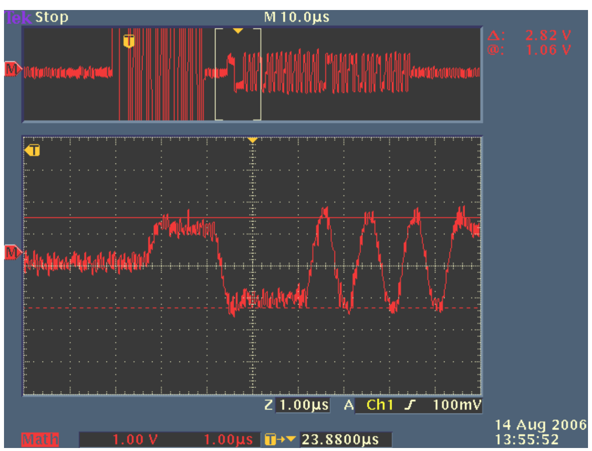


- BC commands 1-word transmit from RT 1 (0x0C21 1-T-1-1)
- RT 1 answers with status word followed by 1 data word
- Examine waveform quality (MIL-HDBK-1553, § 40.9)
  - Amplitude
  - Zero-crossing distortion
  - Tailoff

Input Waveform Amplitude at BC



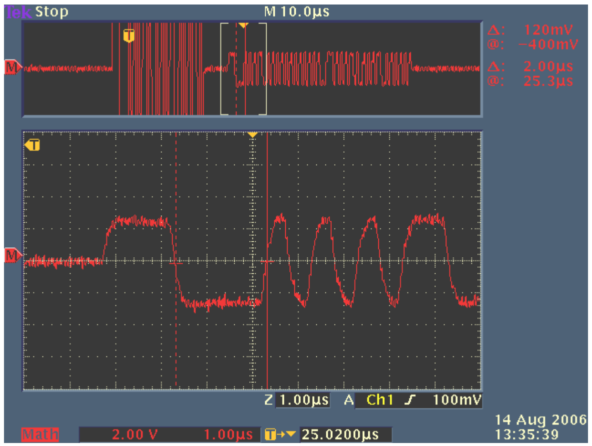
40’ Twinax



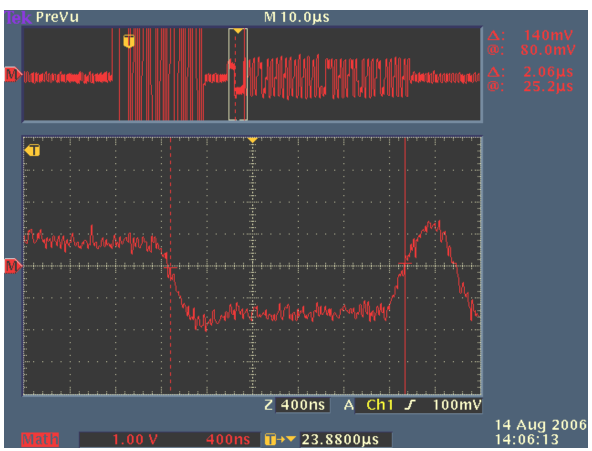
39’ Coax

- **Measured Voltage**
  - **Twinax: 5.28 v**
  - **Coax: 2.82 v**
- **Requirement: 0.86 – 14.0 v**

Input Waveform Zero-Crossing at BC



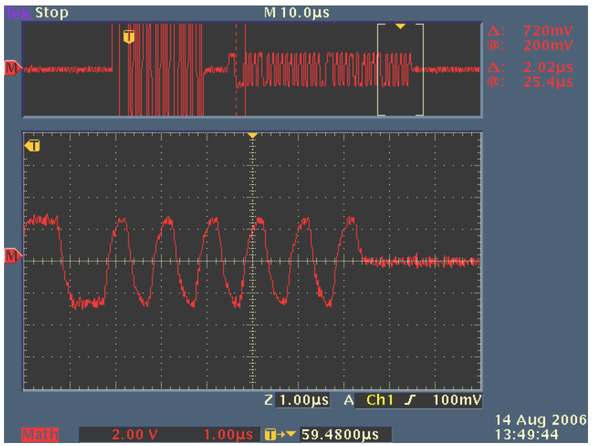
40' Twinax

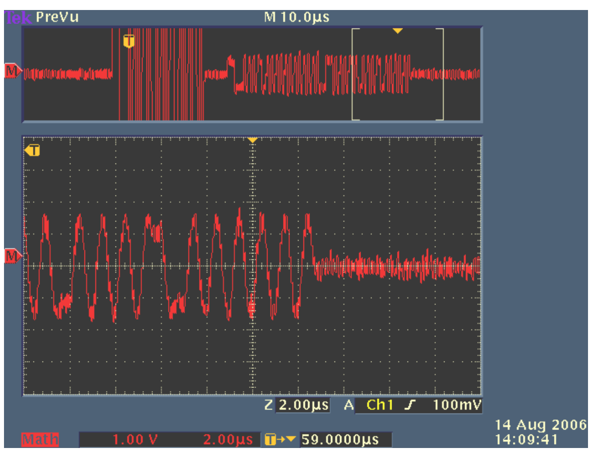


39' Coax

- Measurement shown is zero-crossing for first bit of command word to the first bit of the data word
- Measured Time
  - Twinax: 2.0 µs
  - Coax: 2.06 µs
- Requirement: 2 µs ±150 ns

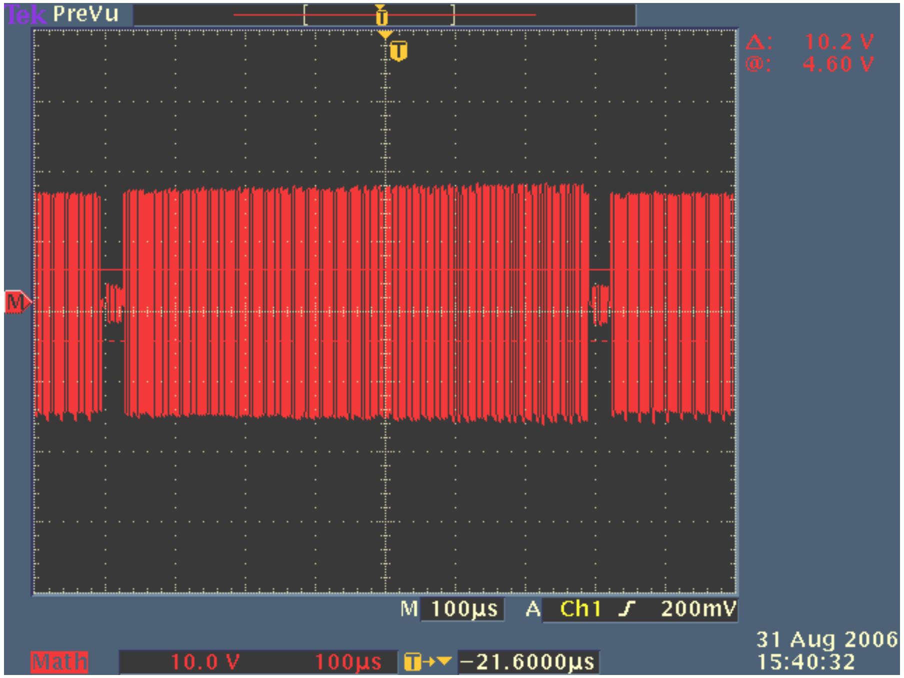
Input Waveform Tailoff at BC





- Voltage must be less than ±250 mV for the period beginning 2.5 µs following the last mid-bit zero-crossing.
- Both waveforms exhibit clear end to data waveform.

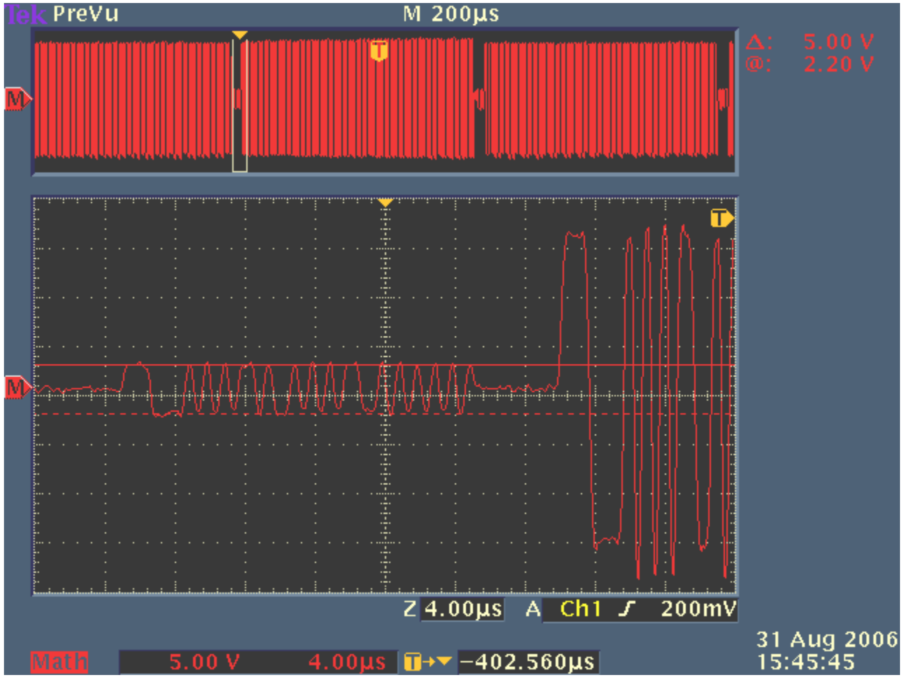
Impact of High Traffic Level



- Maximum bus loading was added to the analysis
- Message changed to a 32-word transfer at the minimum inter-message gap, resulting in a bus loading at just over 99%

Impact of High Traffic Level

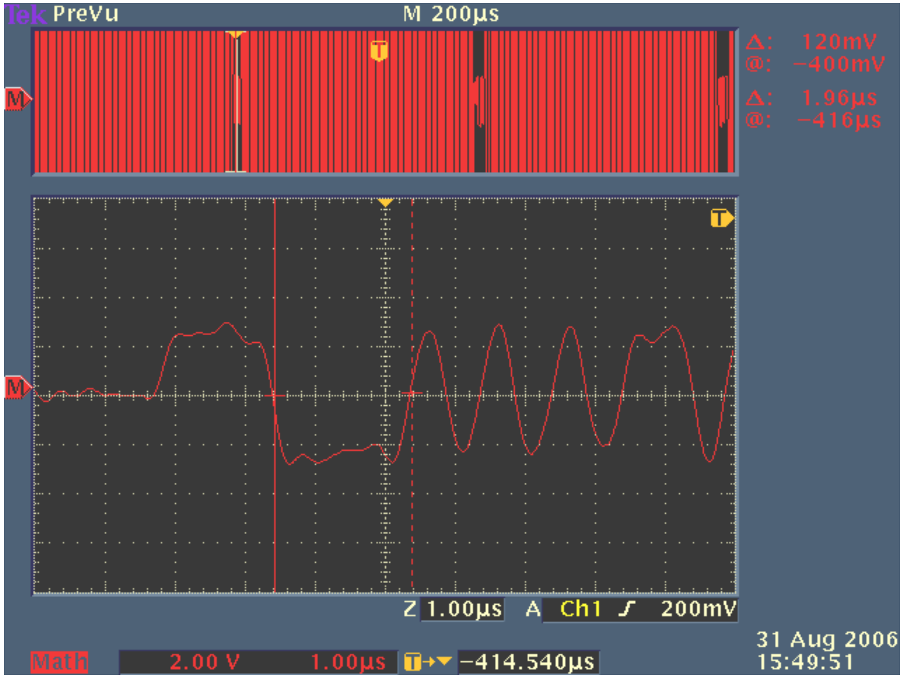
Input Waveform Amplitude



- **Measured Voltage**
  - **5.0 v**

Impact of High Traffic Level

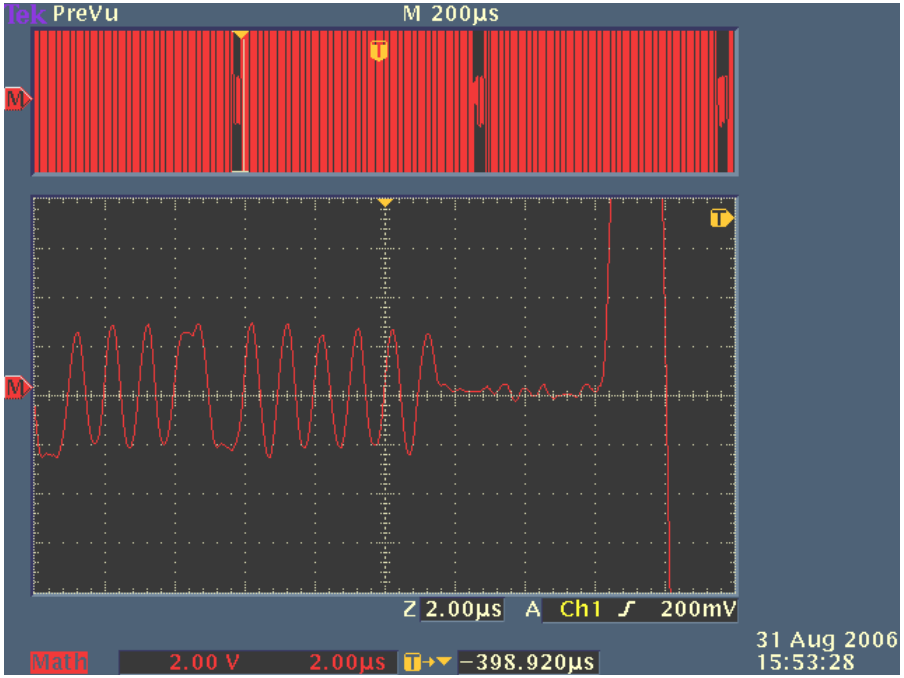
Zero-crossing Deviation



- **Measured Time**
  - **1.96 µs**

Impact of High Traffic Level

Input Waveform Tailoff



- The waveform exhibits a clear end to data waveform

Use of non-standard wiring OK?

- **Short answer: Yes.**
- **What gets "done-to" should be "un-done" at the terminal end.**

Non-Standard A/C 1553 Wiring Analysis

- Sufficient Performance
- Low Maintenance
- Easy Supportability
- Minimal Cost