Aging Aircraft Sustainment with Non-Standard Engineering

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Kendal Hinton
404-407-6042
kendal.hinton@gtri.gatech.edu

Chris Fowler
404-407-7094
chris.fowler@gtri.gatech.edu
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 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

Matrix Assembly 2 (Aft)
Matrix Assembly 1 (Fwd)
STP
Wheel Well Disconnect Circular Connector
RG-180
RG-180
RG-180
Tyco Connectors
Adapter
SMA
EW System

GTRI_B-8
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

- Coupler
- PC with PASS As BC
- Scope
- 10' Twinax
- 40' Twinax
- 39' Coax
- 184 Circuit
- Scope

PC with PASS As RT
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

- BC commands one word transmit from RT (0xC21 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

- Measured Voltage
  - Twinax: 5.4 v
  - Coax: 3.12 v
- Requirement: 0.86 – 14.0 v
Input Waveform Zero-Crossing at RT

- 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 Tailloff 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 (0x0C211-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

- Measured Voltage
  - Twinax: 5.28 v
  - Coax: 2.82 v
- Requirement: 0.86 – 14.0 v
Input Waveform Zero-Crossing at BC

- 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