Design Considerations for Adapting Legacy System Architectures to Spacewire

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Legacy Architectures – MIL-STD-1553(1)

- Originally "Military Standard Aircraft Internal Time Division Command/Response Multiplex Data Bus"
  - Developed by United States Air Force for use on military aircraft and originally released in 1973 [2]
  - Later revised with MIL-STD-1553A and then MIL-STD-1553B [3]
    - 4 Notices were issued for MIL-STD-1553B
      - Notices 1 and 2 actually have some technical content
        - » Restricted the use of many options within the standard such as Broadcast
        - » Specifies that Dual Standby Redundant Busses should be used
      - Notice 3 opened up standard for other military branches
      - Notice 4 changed title to "Interface Standard for Internal Time Division Command/Response Multiplex Data Bus"
  - Also published as NATO STANAG 3838 AVS, SAE AS15531 and UK DEF STAN 00-18

Legacy Architectures – MIL-STD-1553(2)

- MIL-STD-1553B Characteristics:
  - Data Bus Architecture with shared communication medium
    - Failure in transmission medium may affect multiple devices
    - Supports transformer coupling for isolation
  - Command/Response Data Bus
    - Half-Duplex Operation
    - Well-defined timing, timeout used to detect communication problems
  - 1 MHz Clock Rate
    - Manchester II Bi-Phase Encoding (implicit clock)
    - Data rates of less than 600 Kb/s in practical systems
  - 20-bit words
    - Command, Response and Data Words
    - Includes parity
    - Data payload is 16 bits
- SpaceWire [1] characteristics:
  - Point-to-point links
    - Failures may be more localized
    - Does not currently support transformer coupling
  - Full-duplex Operation
    - Command/Response Operatation possibly through higher-level protocols
  - Variable clock rates
    - Data-strobe encoding (implicit clock)
    - Data rates of 2 Mb/s to ~400 Mb/s
  - 10-bit words
    - Includes parity
    - Data payload is 8 bits

Legacy Architectures – MIL-STD-1553(3)

- MIL-STD-1553B characteristics:
  - Centralized Control
    - Single Bus Controller (BC)
      - Can be the Bus Bottleneck
    - Up to 31 Remote Terminals (RTs)
    - 1 or more Bus Monitors (BMs)
  - Most modern systems use a Frame Controller (e.g. UTMC SμMMIT)
    - Process a message sequence in a repetitive fashion (i.e. bus schedule)
      - Highly deterministic timing
      - Automatic retries
  - Dual Redundant Standby Configuration
    - Automatic switchover on failures
  - Mode Codes
    - Provide for Control
    - Broadcast "Synchronize" Mode Code
      - Synchronize timing to within a few μs

- SpaceWire characteristics:
  - Centralized or decentralized control
    - Multiple initiators possible on network
    - Up to 224 unique logical addresses
      - Addressing can be extended by defining regions
  - No inherent bus schedule
  - Redundancy possible by adding links
  - Time Codes
    - Provide for Time Synchronization

Legacy Architectures – RS-422(1)

- Published as “Electrical Characteristics of Balanced Voltage Differential Interface Circuits”
  - Standardized by ANSI as TIA/EIA-422-B in 1994 [4]
  - Later adopted internationally as ITU-T Recommendation V1.11 [5]
  - Only specifies the electrical signaling characteristics
    - Connectors and protocols are not includes
  - Asynchronous Serial and Synchronous Serial Interfaces are commonly employed (e.g. transponder interfaces)
  - Analogous to SpaceWire Signal Level, Low-Voltage Differential Signaling (LVDS)
    - Standardized by ANSI as TIA/EIA-644A

Legacy Architectures – RS-422(2)

- RS-422 – Synchronous Serial characteristics:
  - Much variation in implementation
    - Necessitates modifications to interface electronics from mission to mission
    - Connectors often custom
  - 3-pair and 2-pair unidirectional are common
    - Clock, Data
    - Clock, Word, Data
      - Timeouts to indicate end-of-frame
    - Clock, Frame, Data
    - Clock rate typically fixed
  - Full-duplex achieved with two unidirectional interfaces
  - Framing can be accomplished through a higher level protocol
    - High-level Data Link Control (HDLC)
- SpaceWire characteristics
  - Physical Layer is part of standard
    - Standard 9-pin micro-miniature D-type connector
  - 4 differential pair plus Ground
  - Clock rate can be changed dynamically
  - Synchronization accomplished through the use of time codes
  - Boundaries of packets are determined by the use of control characters (i.e. NULL, EOP, and EEP)
  - Full-duplex

Legacy Architectures – RS-422(3)

- RS-422 – Asynchronous Serial characteristics:
  - Convenient for low-speed applications
  - Bit-order is not standardized
    - LSb first is often used because this is the convention originally chosen for the IBM PC
  - Baud rate is not standardized
    - Bauds of 9600, 19200, 38400, 57600, and 115200 are speeds commonly used
    - Baud rate typically fixed
  - Framing must be accomplished through a higher level protocol
    - Timeout between frames
    - Frame with sync pattern
    - High-level Data Link Control (HDLC)
    - Point-to-Point Protocol (PPP)
- SpaceWire characteristics
  - Physical Layer is part of standard
    - Standard 9-pin micro-miniature D-type connector
  - Clock rate can be changed dynamically
  - Boundaries of packets are determined by the use of control characters (i.e. NULL, EOP, and EEP)

Basic Design Process

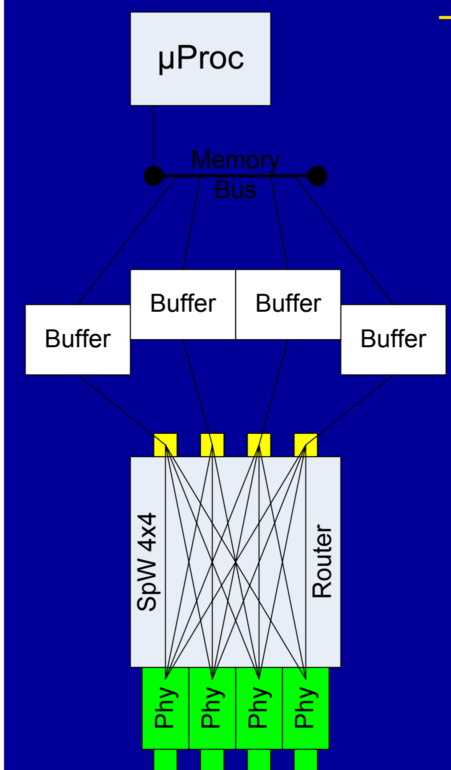
- Basic Design Process
  - Identify top-level requirements
    - Space systems are usually requirements driven
    - Flight heritage for electronics is desirable
      - Missions are collaborative
        - » Legacy interfaces from different missions are often not compatible
  - Conduct analysis and determine link rates
    - Some data rates are easy to determine and others are not
      - Science data can be bursty
        - » We must accommodate the worst case
        - » Difficult if phenomenon is not well understood – hence the reason for the mission in the first place
  - Design and size each link
    - Add margin (i.e. expect the unexpected)

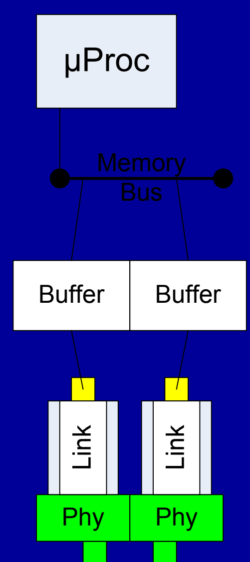
SpaceWire Architectures

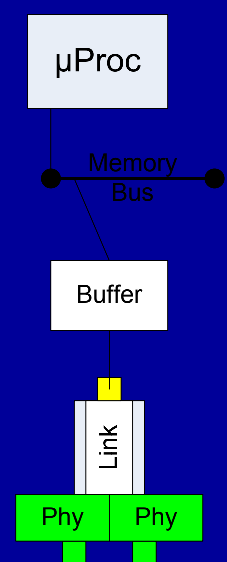
- Synchronized (Scheduled)
  - Well suited for control loop applications
    - Guidance, Navigation and Control
    - Thermal Control
    - Power Systems Control
  - SpaceWire provides support for Time Division Multiplexing (TDM)
    - Time Codes
      - Provides for establishing synchronized time frames
      - Extended by NASA GSFC to support 4 unique codes [6]
      - Researchers at St. Petersburg University developed "Distributed Interrupts" which support 32 unique codes [7]
  - Simplifies timing analysis for shared links
- Unsynchronized
  - Well suited for bursty data
    - Timing analysis can be more complicated
    - Dedicated links can help to avoid extensive buffering at producers
    - Group Adaptive Routing can help to avoid path conflicts
  - Well suited for infrequent data

SpaceWire Architectures

- Improving Reliability
  - Redundancy Options:
    - Include Router
      - Balanced input/output ports make an excellent building block

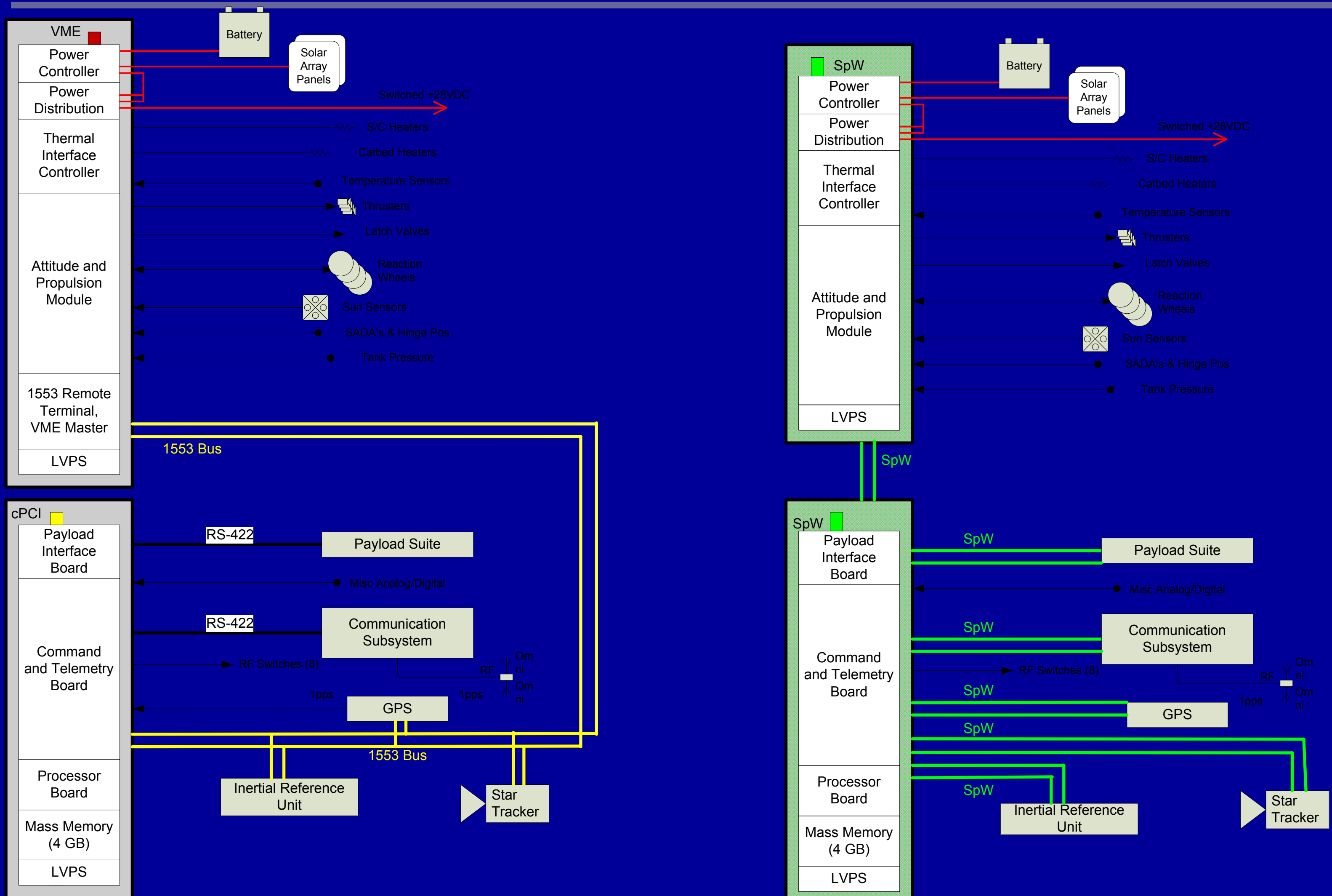






  - Redundancy Options:
    - Include multiple links
    - Include multiple PHY [6]
- Reliable Data Transfers
  - Remote Memory Access Protocol (RMAP) [8]
    - Standard read/reply
      - Helpful for telemetry
      - By adding timeout, can emulate retry operation of the MIL-STD-1553 in a dual redundant standby configuration
    - Acknowledged and verified writes
      - Help for commands
    - Read-modify-write supports arbitration handshaking
  - SpaceWire-RT

SpaceWire Architectures



Conclusions

- SpaceWire has a rich feature set that provides much versatility
  - When employed appropriately, it can be used to provide many of the same benefits as MIL-STD-1553B and RS-422
    - Using SpaceWire in place of legacy technologies promises to help reduce the costs of mission development by reducing the up-front engineering effort required for interface definition (and redefinition)
      - Continued standardization efforts by ECSS for SpaceWire will help to substantiate this even more.
        - » Standard backplanes based on SpaceWire
        - » Support for electrical isolation

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