High Speed 1760 and FC-AE-1553

High Speed Weapons Systems Network
Supports MIL-STD-1553/1760 Messaging,
Accelerated File Transfers, and Video

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Introduction

Network interfaces for future "smart" weapons will need to support applications such as transfers of terrain maps, target templates, program files, and digitized images and video for lock-on before launch. These applications will require the use of a high-speed data interface.

For over 20 years, MIL-STD-1760, Aircraft/Store Electrical Interconnection System, has defined the interface between aircraft stores management computers, carriage stores (racks and launchers) and mission stores (bombs and missiles). This standard defines the connector, signal set definitions, topologies, types of interfaces, signal path requirements, and power; along with special requirements for MIL-STD-1553 bus interfaces. This includes a command set with detailed message formats, along with a defined protocol for mass data transfer.

In 2008, the SAE AS-1A2 task group released AS5653, the High Speed Network for MIL-STD-1760, aka High-Speed 1760. This standard defines a gigabit-speed communication option for MIL-STD-1760. AS5653 specifies a network based on Fibre Channel, operating at 1.0625 Gb/s over a pair of 75 ohm coaxial cables. The choice of 75 ohm coaxial cable was based on environmental ruggedness (relative to fiber optics) and the availability of positions for coax cable inserts in the MIL-STD-1760 connector.

Fibre Channel

The base standard for High-Speed 1760 is Fibre Channel. Fibre Channel is a high-performance networking standard that is deployed on a number of military/aerospace platforms and programs, including F/A-18E/F, F-16, F-35, B-2, E-2D, the MMH helicopter, and AESA Radar. Applications include mission computers, processor and DSP clusters; data storage; video processing and displays; sensors such as radar, FLIR, video, and IFF; and serial backplanes.

While Fibre Channel can also operate over point-to-point and loop topologies, AS5653 specifies the use of a switched fabric. The fabric topology provides advantages in terms of the number of nodes supported and aggregate data throughput. Fibre Channel provides a highly robust low level protocol providing strong throughput and latency performance, along with provisions for flow control, segmentation and reassembly, error checking, and broadcast. Fibre Channel's credit-based flow control ensures that data transfers between endpoints and switches do not result in overflow conditions, while segmentation and reassembly enable reliable in-order delivery for large data transfers such as program files and video.

Fibre Channel data is transmitted as frames, in which a 24-byte Fibre Channel frame header is followed by up to 2112 bytes of payload data. Fibre Channel Sequences

consist of series of one or more frames transmitted by the same sender to one or more receiving nodes. Fibre Channel Exchanges consist of series of Sequences transmitted by either the same end node and/or alternating between a pair of end nodes. Upper layer protocol (ULP) mappings define the series of Sequences that constitute individual Exchanges. Some ULPs used in avionics include ASM (Anonymous Subscriber Messaging), TCP/IP, and SCSI. AS5653 specifies the use of two upper layer protocols: FC-AE-1553 and FC-AV (Fibre Channel audio-video).

FC-AE-1553

The FC-AE-1553 Fibre Channel upper layer protocol is based primarily on the familiar word structures, command/response protocol, and message formats of MIL-STD-1553. In addition, FC-AE-1553 defines a number of extensions and additional capabilities. FC-AE-1553 supports all familiar MIL-STD-1553 constructs, including command and status, subaddresses, mode codes, RT-to-RT transfers, broadcast, and extensive error checking.

Since a portion of the FC-AE-1553 protocol maps directly to MIL-STD-1553 messages, FC-AE-1553 enables the reuse of software written for MIL-STD-1553 and MIL-STD-1760 applications. As a result, this allows software written for stores management systems, launchers, and weapons that involve the use of MIL-STD-1760 messages to be ported for use over AS5653 networks. In addition to providing an accelerated means for conveying MIL-STD-1553 messages, FC-AE-1553 includes extensions for supporting file transfers of up to 2^{32} bytes (≈ 4.3 GB).

Messaging software for future weapons will be based on UAI (Universal Armaments Interface), an emerging high level interface that's an extension of the MIL-STD-1760s message set. The intent for UAI is to enable software reuse of common software for weapons' OFPs (operational flight programs), with the goal of reducing the validation and integration times for new weapons. In addition to weapons, future applications for UAI may also extend to training pods and sensors.

FC-AE-1553 defines two types of nodes, NCs (Network Controllers) and NTs (Network Terminals). An FC-AE-1553 NC performs the function of network master, akin to a MIL-STD-1553 bus controller (BC), while an NT performs the function of network slave, akin to a MIL-STD-1553 remote terminal (RT). Since FC-AE-1553 can operate over a fabric network, rather than a multi-drop bus like MIL-STD-1553, it is possible to have multiple active NCs operating over the same network simultaneously.

For example, this could enable one weapon attached to an AS5653 network to transmit a video stream to a stores management computer, while the computer in a launcher transmits commands to other attached weapons. Alternatively, FC-AE-1553 networks can operate with a single network controller. In addition, individual nodes may operate as NCs and NTs simultaneously.

The FC-AE-1553 address field is expanded from MIL-STD-1553's 5 bits to Fibre Channel's 24-bit address space. Similarly, the 1553 subaddress field is expanded from 5 to 32 bits, while the 1553 5-bit word count field is expanded to a 32-bit byte count field. FC-AE-1553 defines all of the standard MIL-STD-1553B Status bits (Message Error, Service request, etc.) and mode codes, such as Transmit status, Transmit last command, Synchronize, etc.

Exchange Formats

Within SAE AS5653, FC-AE-1553 supports three different types of operations: (1) periodic (deterministic) or asynchronous "MIL-STD-1553-like" command and control messages; (2) file transfers; and (3) transfers of large data structures such as images.

FC-AE-1553's command and control Exchange formats directly mirror MIL-STD-1553 message formats. As a result, these include NC-to-NT, NT-to-NC, and NT-to-NT transfers; mode codes; along with broadcast support. Figure 1 illustrates an FC-AE-1553 NC-to-NT transfer Exchange, which is directly akin to a MIL-STD-1553 BC-to-RT transfer message.
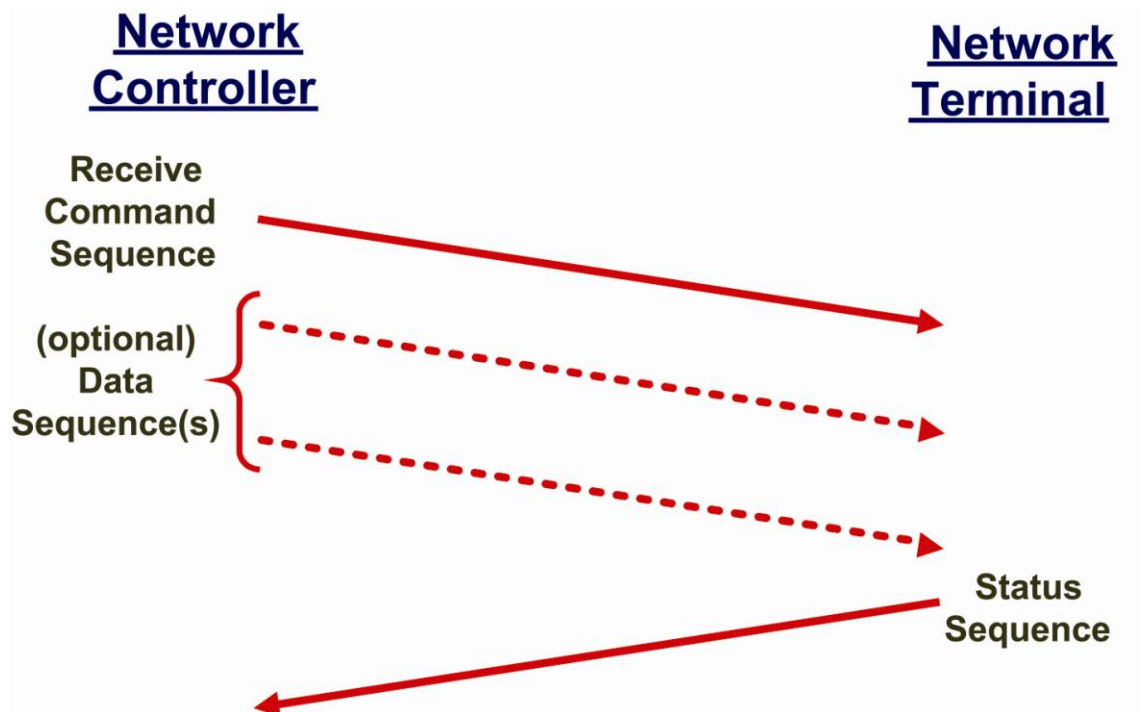

Figure 1. FC-AE-1553 NC-to-NT Transfer Exchange

As shown, the NC initiates an NC-to-NT Exchange by transmitting a receive Command Sequence. This Sequence, which consists of one or more Fibre Channel Frames, includes a 24-byte FC-AE-1553 Command Header in its first frame, and may contain the first portion of payload data bytes for the Exchange. For example, for High-Speed 1760, Subaddresses '00 00 00 01'h through '00 00 00 1E'h are used for command and

control Exchanges to mimic MIL-STD-1553B messages. As a result, the data payloads for these Exchanges will be limited to a maximum size of 64 bytes.

As a means of minimizing overhead, SAE AS5653 requires that Exchanges (such as command and control Exchanges) with payloads of less than or equal to 2048 bytes be transmitted as single-frame Sequences. As shown in Figure 1, Exchanges with larger payload sizes, such as images, may be sent either as a single Sequence, or as a Command Sequences followed by one or more Data Sequences.

File Transfers

AS5653 provides two different methods for performing file transfers:

1. Use of the MIL-STD-1760 Mass Data Transfer (MDT) protocol. This protocol can operate over FC-AE-1553, using NC-to-NT or NT-to-NC data transfers. While this method allows reuse of legacy MDT software written for MIL-STD-1553/1760, it is burdened with a high level of overhead, since individual MDT Exchanges are limited to 30 words (60 bytes).

2. Within AS5653, the far more efficient option for transferring files is by means of FC-AE-1553 file transfer Exchanges. These support file transfers from NCs to NTs, NTs to NCs, and between NTs. FC-AE-1553's 32-bit byte count field enables file transfer Exchanges of up to 4.3 GB.

For a "write" (NC-to-NT transfer) type of file transfer operation (Figure 2), an NT is able to "throttle" the NC's transmission of a large data Exchange by directing the transmitting NC to segment its transmission into smaller Sequences. For example, this mechanism may allow an NT to force an NC to segment a 1 GB file into one hundred 10 MB segments.

For a file transfer Exchange, the NC's Command Sequence will indicate the overall byte count for the Exchange (1GB). Following reception of this command, the NT will include an indication of the maximum size segment that it can receive in its initial Status Sequence response (e.g., 100 MB). After the NC transmits its first Data Sequence, this process repeats until all data has been transmitted. The "throttling" mechanism provides the receiving NT with sufficient time to transfer received data from high-speed memory buffers to lower speed memory, such as flash.
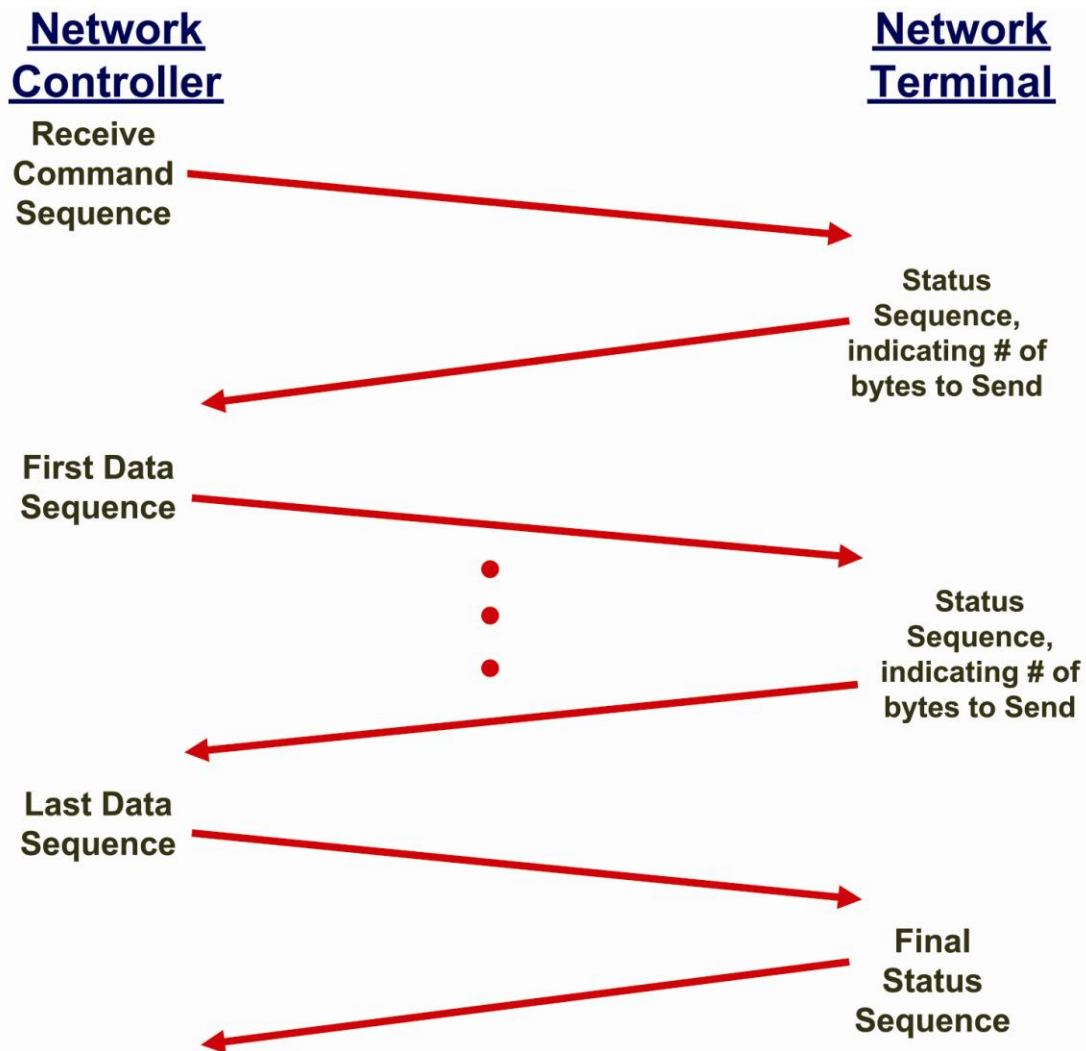
Figure 2. FC-AE-1553 NC-to-NT File Transfer

FC-AE-1553 defines all MIL-STD-1553 mode codes, along with a few additional ones. FC-AE-1553 also calls for rigorous error checking, including correct delimiters and encoding, Fibre Channel and FC-AE-1553 header fields, Exchange byte count, and frame CRCs. In addition to the features required by AS5653, FC-AE-1553 also includes provisions for:

- Multicast transfers.

- Options for either acknowledged or unacknowledged transfers, including for broadcast and multicast. Similar to MIL-STD-553, AS5653 uses only acknowledged non-broadcast transfers and unacknowledged broadcast transfers.

- RDMA capability, which uses the FC-AE-1553 Subaddress field to enable direct access to remote nodes' memory address spaces.

- Methods for bridging to 1 Mb/s MIL-STD-1553 buses.

FC-AV

The FC-AV upper layer protocol, which is included in AS5653, supports containerization of multiple video and audio streams, and provides standardized methods for identifying pixel characteristics, lines, frames, frame rates, and color information. For weapons, target applications for FC-AV include the transmission of video, FLIR, radar, and image sensor data from weapons to an aircraft. As FC-AV provides a great deal of flexibility in terms of the video formats it can handle, it is able to support a wide range of sensors and displays.

FFI

Another protocol incorporated into High-Speed 1760 is FFI, or Fast Fabric Initialization. FFI provides modifications to the standard Fibre Channel protocol for assigning switch addresses over a multi-switch fabric. For a weapons network, this could entail multiple switches, on the aircraft, and/or installed in launchers, racks, or weapons. The benefits of FFI for a weapons network include deterministic switch addressing, along with reduced time for initialization and re-initialization following power outages.

Weapons Interface Standards

The protocols defined by the High Speed Network for MIL-STD-1760 have been incorporated into three weapons interface standards:

1. For MIL-STD-1760E, MIL-STD-1553 is a required interface, with the Class I option also providing SAE AS5653

2. For SAE AS5725, MMSI (Miniature Munitions Store Interface) Rev. D, EBR-1553 is a required interface, with the Class I option also providing AS5653

3. AS5653 is the only interface defined for SAE draft standard AS5726, the Interface for Micro Munitions, or IMM. This standard is expected to be published in 2009. IMM, which is intended for use on small weapons (under 50 pounds) and for UAVs, specifies the provision of 28V or 56V power over Fibre Channel (Figure 3), which enables the use of a small, 7-pin connector.

Physical Layer

The Fibre Channel physical layer for MIL-STD-1760E is defined by SAE AS5653. This specifies the use of 75 coax cable, and a transmitter voltage range of 2.0 to 3.0 volts peak-to-peak, through the "High Bandwidth" HB2 and HB4 locations in the MIL-STD-1760E connector. This voltage range is higher than the standard Fibre Channel range of 1.1 to 2.0 volts.

This was necessary to achieve the SAE working group's benchmark for operation over 100 feet of coax cable with 5 disconnects, with cable that is sufficiently small in diameter to fit in the MIL-STD-1760 connector's size 12 inserts.

The MMSI and IMM standards were not burdened with the need to accommodate legacy coax connector positions. As a result, the physical layer for these two standards calls for 150 ohm differential signaling, and the standard Fibre Channel transmitter voltage range of 1.1 to 2.0 volts peak-to-peak.

Figure 3 illustrates power over Fibre Channel, as defined by the IMM standard. This interface also includes a pair of discrete signals not shown in Figure 3: MATED STATUS, to indicate a physical connection; and SAFETY ENABLE DISCRETE, a safety interlock signal. As shown, the Micro Munition operating power is transferred over the same two wires as the UFC (Up Fibre Channel, weapon to host) differential pair, while the Micro Munition safety enable power is transferred over the same two wires as the DFC (Down Fibre Channel, host to weapon) differential pair. The IMM standard defines the detailed requirements for isolating between the Fibre Channel signals and power.
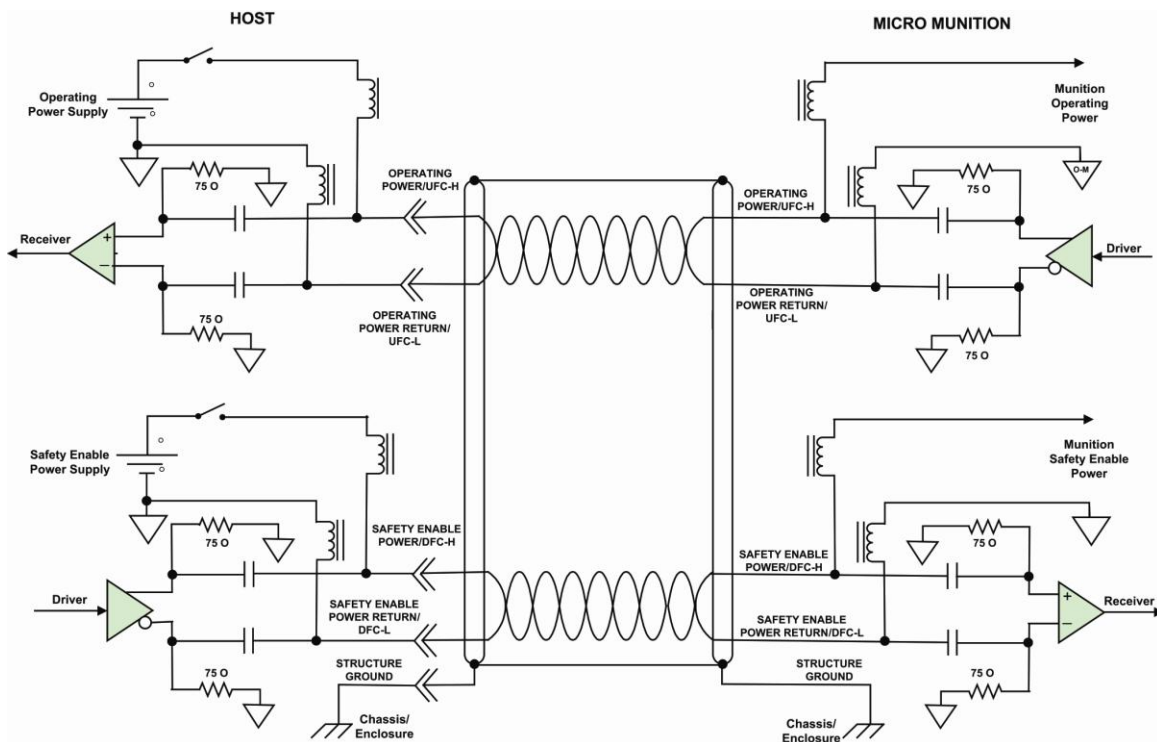

Figure 3. Interface for Micro Munitions Power Over Fibre Channel

Solution

DDC's FibreACCESS NAC (network access controller) card shown in Figure 4 is an example of a COTS Fibre Channel interface card. The FibreACCESS cards are ruggedized, dual-channel PMC cards designed for embedded applications, and operate at 1 or 2 Gb over copper or optical media. They include 64-Bit, 66 MHz PCI or 66/100 MHz PCI-X Initiator/Target interfaces, operate on all Fibre Channel topologies, and provide near "line rate" throughput with capability for end-to-end latencies on the order of 10 µS.

Figure 4. FibreACESS NAC Card

This card currently provides multiple upper layer protocols, including TCP/IP, SCSI Initiator, SCSI, and Raw Mode, with software drivers for VxWorks and Linux. DDC can modify FibreACCESS to provide support of AS5653 and FC-AE-1553, including both NC and NT operation.

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Data Device Corporation is recognized as an international leading supplier of high-reliability data interface products for military and commercial aerospace applications since 1964 and MIL-STD-1553 products for more than 25 years. DDC's design and manufacturing facility is located in Bohemia, N.Y.