VPX Optical Interfaces: Standards, Protocols & Applications

Embedded Tech Trends
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Topics

- Embedded System Requirements
- Optical Gigabit Interface Technology
- Optical vs. Copper Links
- VITA Standards for Optical Links
- VITA 49 Radio Transport Protocol
- Application Strategies
Embedded System Technology Requirements

- **Wider Bandwidths: Video, Comms & Radar Signals**
  - Improved image resolution, target identification, signal detection & exploitation
  - More traffic within each expensive slice of the allocated radio frequency spectrum

- **Faster Sensors, Data Converters and DSPs**
  - Multi-gigahertz sampling rates required to digitize these wideband signals
  - DSP improves spectral efficiency, minimizes interference, and supports more users
  - Faster interfaces required on each device

- **Faster Links Between Embedded System Elements**
  - Higher data rates between boards within a chassis
  - Higher data rates between systems and racks
  - Digitizers and front end DSP operations are moving closer to the antenna
  - Longer data transmission paths to remotely located acquisition sub-systems
Optical Link “Nuts and Bolts”

- **Cable Type**
  - Multimode Fibre
  - Single Mode Fibre

- **Light Emitters**
  - LEDs: 780, 850, & 1300 nm
  - LASERs: 1310, 1550, & 1625 nm
  - VCSELs: 650 to 1300 nm

- **Light Detectors**
  - PIN Diode
  - Avalanche Photo Diode

- **Modulation Schemes**
  - AM - Simple, low performance
  - FM - Better, but limited bandwidth
  - Digital - Best speed and signal integrity
  - Costs are dropping rapidly

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AM</th>
<th>FM</th>
<th>Digital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal-to-Noise Ratio</td>
<td>Low-to-Moderate</td>
<td>Moderate-High</td>
<td>High</td>
</tr>
<tr>
<td>Performance vs. Attenuation</td>
<td>Sensitive</td>
<td>Tolerant</td>
<td>Invariant</td>
</tr>
<tr>
<td>Transmitter Cost</td>
<td>Moderate-High</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Receiver Cost</td>
<td>Moderate</td>
<td>Moderate-High</td>
<td>High</td>
</tr>
<tr>
<td>Receiver Gain Adjustment</td>
<td>Often Required</td>
<td>Not Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>Installation</td>
<td>Adjustments Requires</td>
<td>No Adjustments Required</td>
<td>No Adjustments Required</td>
</tr>
<tr>
<td>Multichannel Capabilities</td>
<td>Require High</td>
<td>Fewer Channels</td>
<td>Good</td>
</tr>
<tr>
<td>Performance Over Time</td>
<td>Moderate</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Environmental Factors</td>
<td>Moderate</td>
<td>Excellent</td>
<td>Excellent</td>
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</tbody>
</table>
Optical Cables: Multimode vs. Single Mode

- **Multimode**
  - Lowest cost transceivers and cable
  - Thicker optical core allows multiple paths (modes) for light to travel
  - Core diameters of 50 or 62.5 microns + cladding diameter of 125 microns
  - Compatible with less expensive lasers at 850 or 1300 nm
  - Supports 2.5 GHz data rates across 300 meters
  - Terminations (connectors) are easier to install

- **Single Mode**
  - More expensive transceivers and cable
  - Thin optical core allows a single path (mode) for light to travel
  - Core diameter typically 9 microns + cladding diameter of 125 microns
  - Compatible with more expensive lasers at 1310 or 1550 nm
  - Supports 2.5 GHz data rates greater than 10 km
  - Terminations require a skilled technician
## Copper vs. Optical Interfaces

<table>
<thead>
<tr>
<th>Property</th>
<th>Copper</th>
<th>Optical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface Transceiver Cost</td>
<td>Low</td>
<td>High but dropping</td>
</tr>
<tr>
<td>PC Network Interface Cards</td>
<td>Integrated in PC or laptop</td>
<td>Usually optional at $100-$200</td>
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<tr>
<td>Power over Ethernet</td>
<td>Supported at low cost</td>
<td>Not possible</td>
</tr>
<tr>
<td>Data Rate</td>
<td>1 GHz</td>
<td>&gt;10 GHz</td>
</tr>
<tr>
<td>Cable Loss - 100 meters</td>
<td>94%</td>
<td>3%</td>
</tr>
<tr>
<td>Max Transmission Distance</td>
<td>100 m (cat 6)</td>
<td>300 m (multi-mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10 km (single mode)</td>
</tr>
<tr>
<td>EMI Susceptibility Risk</td>
<td>Moderate</td>
<td>Zero</td>
</tr>
<tr>
<td>EMI Radiation Risk</td>
<td>Moderate</td>
<td>Zero</td>
</tr>
<tr>
<td>Security / Eavesdropping Risk</td>
<td>High</td>
<td>Extremely Low</td>
</tr>
<tr>
<td>Termination Costs</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Cable Cost per Length</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Cable Weight per 1000 m</td>
<td>60 to 600 kg</td>
<td>6 kg</td>
</tr>
<tr>
<td>Fire Hazard</td>
<td>Supports current flow if shorted</td>
<td>Zero</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>25 pounds</td>
<td>100-250 pounds</td>
</tr>
</tbody>
</table>
VITA 17.1 - Serial Front Panel Data Port (sFPDP)

- Replaces older VITA 17 FPDP 32-bit parallel flat ribbon cable specification
  - Limited to 160 MB/sec
  - Limited to a few meters in length
  - Simple raw data interface with flow control, single & multi-drop

- VITA 17.1 Features and Benefits
  - Gigabit serial data stream implementation of FPDP
  - Optical and copper implementations supported
  - Nominal data rates of 247 MB/sec
  - Data rates limited only by cable/transceiver technologies
  - Distance limited by cable/transceiver technologies
  - Full duplex operation with CRC, loop, flow control, etc.
  - Copy mode allows boards to be daisy-chained
  - Much smaller and lighter cables and connectors
VITA 17.1 sFPDP Deployments

- Sonar upgrades for US Navy Guided Missile Destroyers
  - SQQ-89 program USS McCampbell

- US Navy NSSN Sonar Transmit System
  - USS Texas

- US Navy Airborne Laser Mine Detection System (ALMDS)
  - Northrop Grumman ALMDS
  - USS North Carolina

- US Navy NSSN Simulation/Stimulation System
VITA 17.1 sFPDP Products for VPX

- **Front panel sFPDP Connectors**
  - Flexible SFP+ (small form-factor pluggable) modular interfaces
  - Copper (TwinAX) or Optical (LC), single or multi-mode
  - Low-cost industry standard with many vendors

- **FPGA Functions**
  - SFP+ gigabit serial interfaces
  - sFPDP protocol engine supports all VITA 17.1 modes and specs
  - PCIe Gen2 x8 interface – 4 GB/sec
  - Eight DMA engines for PCIe
  - 2 GB SDRAM memory buffers
  - CRC Support
  - Metadata packet headers
  - Simplifies system integration
MT Optical Interconnects

- **MT Ferrule**
  - An extremely popular connection for x4 to x24 optical lanes
  - Operates at rates up to 20 Gbits/sec per lane
  - Supports single and multi-mode links
  - Typically protected in a shell, collar or ferrule
    - Like the VITA 66.4 housing
  - Availability of 48, 72 and 96 lane MT ferrules

- **MTP**
  - MT Pluggable
    - MT ferrule inside a keyed collar with a locking tab
  - Wide variety of cables, lengths available

- **Circular Bulkhead MTP**
  - Full spec sealed connectors for military applications
Ruggedized Optical MT Backplane Interconnect System
- Replaces half of VPX P2
- Self-aligning, blind mate connector housings
- Floating, MT ferrule inside housings
- Eliminates front panel optical I/O
- Supports any optical protocol
  - Including sFPDP, Xilinx Aurora, 10GbE, SRIO, VITA Radio Transport, etc
- Backplane connections between modules
- Backplane connections to chassis bulkhead connectors
- Specification is being updated for final balloting and approval
Samtec FireFly™ Micro Flyover System

- Complete Electrical-Optical Transceiver Assembly
- Uses 24-lane male MT connector
- Spring-loaded, fits inside VITA 66.4 housing
- One 12-lane optical receiver
- One 12-lane optical transmitter
- Provides 12 full-duplex optical links
- Data rates to 14 Gbits/sec per optical lane

13 cm or 5.1 in
VITA 66.4 Optical Backplane Products for VPX

- 3U VPX FMC Carrier with Virtex-7 FPGA
- High Pin Count FMC Site
- x8 PCIe Gen 3 delivers 8 GB/sec
- Flexible PCIe DMA Controllers
- 4 GB 1600 MHz DDR3 SDRAM

- 16-pairs LVDS User I/O on P2
- VITA-46, VITA-48, VITA-65, VITA-57.1
- Shipping now, delivering 12 GBytes/sec optical I/O
- Air-cooled and conduction cooled versions
- Industry’s First Product for VITA-66.4

Model 5973 3U VPX Carrier with cover plate removed exposing Samtec FireFly VITA 66.4 Interface cabling
VPX Optical Connections: System Strategies

- Optical links are faster than copper for critical high-bandwidth board-to-board interconnects within a chassis
  - MT-to-MT cables are easy to install as required
- Bulkhead connectors offer external optical links
- MTP-to-MTP cables connect between chassis
  - Benefits: High Speed and Long Distance
- Small Remote Sensor Acquisition Sub-Systems
  - Exploit optical MTP cable interconnections – speed, weight, distance
- Supports a judicious mix of copper and optical interconnects to meet requirements
VITA 49 – VITA Radio Transport Protocol

- Transport-layer protocol designed for radio equipment interoperability
  - For digitized signal sample streams for software radio systems
  - Originally, between radio receivers and signal processing equipment
  - Now, also between signal processing equipment and radio transmitters

- Target Applications
  - Spectral Monitoring and Scanning
  - SIGINT and Tactical Information
  - Communications and COMINT
  - Radar and EW Countermeasures

- Functional Objectives
  - Precision time stamping for beamforming, antenna array processing
  - Synchronization across channels and sites
  - Stream tagging for identification, content, format and operational parameters
  - Monitor status of receiver and transmitter equipment
  - Control operation of receiver and transmitter equipment
VITA 49.0 – VITA Radio Transport Protocol

- VRT IF Data Packets capture payload data, time stamp, channel and signal ID
  - Flexible data formats and support for extremely precise time stamping
- VRT Context Packets report all operational parameter values of the radio equipment
  - Standardized methodology for a wide range of standard and unique parameters
- VRT Information Stream contains IF Data Packets and Context Packets
  - VRT Receiver associates data and context streams appropriately for different applications
- Same radio hardware can be used for a wide range of applications
  - VITA 49.0 does not support control of hardware or radio transmit operations

![Diagram of VITA 49.0 - VITA Radio Transport Protocol](image-url)
VITA 49.2 – Transmit and Control Extension

- Maintains Receive IF Data and Receive Context Packets from VITA 49.0
- Adds new protocols for complete receive and transmit systems, plus control:
  - **Stimulus Packets** provide radio signals to be transmitted
  - **Capabilities Packets** announce configurable assets of each device and parameter ranges
  - **Control Packets** send operational control parameters to radio equipment with acknowledgement
  - **Transmitter Context Packets** deliver operational status and parameters of transmitters
  - **Spectrum Packets** deliver limited spectral data for monitoring and scanning

- VITA 49 working group participants are from industry, universities, and government
Remote Sensor Sub-Systems with Optical Links

- Digitize at the Antenna across Optical Links
  - Local FPGA preprocessing tasks
    - Digital downconverters, tuning & bandwidth selection
  - Choose from popular FPGA-based protocols
    - Aurora or sFPDP: lightweight, good for raw data
    - 1 or 10 GbE: vast infrastructure, more overhead
    - SerialRapidIO: flexible, routable, scalable
    - VITA 49 VRT: complete radio transceiver protocol
  - Avoids signal degradation through long copper coaxial cables
  - Eliminates EMI susceptibility and radiation
  - Improves eavesdropping security, tamper resistance
  - Cables are immune to shorts, moisture, corrosion, easier to install, lighter and smaller diameter
  - Ideal for large ships, aircraft, antenna farms, UAVs, and SIGINT facilities
VITA Optical Standards for VPX – Leading the Way

- Optical links are replacing copper in embedded systems
- VITA 17.1 Serial FPDP offers simple, efficient raw data link
- VITA 66.4 backplane optical I/O ready for deployment
- VITA 49 VRT protocol ideal for optically-connected radio systems
- Mature and diverse optical cable and connector technologies
- Cost for optical transceivers, cables and connectors are dropping
- Optical offers lower maintenance costs and improved reliability
- Light weight optical cables benefit unmanned vehicle systems
- FPGA protocols can be installed to match the application
- Remote optically-connected sensor sub-systems make sense
- More Information: www.pentek.com
Looking into the Future

- **VITA Architectures for Optical Study Group**
  - Study architectures to exploit optical interfaces for embedded systems
  - Processors, carrier cards, backplanes, connectors, etc.

- **Optical Interfaces on FPGA**
  - Built-in optical transceivers simplifying designs
  - Eliminates separate transceivers

- **Optical links embedded within backplanes**
  - Replace copper traces with optical links
  - Simplifies integration
  - Standardized optical switching