Comparing Ethernet and SerDes in ADAS Applications

Single-pair Ethernet is currently being deployed in automobiles over unshielded twisted pair (UTP) cable. Ethernet shows great promise as an in-vehicle networking technology for the “connected car” due to its ubiquity, tools, modularity, and IP support. Although some infotainment display and camera-based Advanced Driver Assistance Systems (ADAS) applications have introduced Ethernet to prove the technology, serializer/deserializer (SerDes) architectures (sometimes incorrectly called “LVDS”) are typically simpler, offer higher video quality, and are less expensive in these systems. Let’s compare these two technologies in detail using a 4-camera surround view application as an example.

Cable Assemblies

A main argument for Ethernet is lower cabling costs. UTP cable is typically compared to higher cost quad star shielded twisted pair (STP) cable. This is a misleading comparison, however, since many SerDes chipsets also drive less expensive coaxial (coax) cables whose costs are comparable to the controlled-twist-rate UTP cable assemblies used in cars. Therefore, it is more accurate to compare UTP and coax cables (figure 1).

Figure 1. Cable comparison.

Electromagnetic compliance (EMC) is very important for vehicle safety. Cable assemblies must pass stringent EMC tests. Twisted pair cable consists of carefully twisted wires to ensure coupled and radiated electromagnetic fields cancel.

Figure 2. Potential UTP EMC concerns.
Under ideal conditions, controlled-twist-rate UTP has excellent EMC characteristics. Factors such as cable flexing and the influence of nearby ground planes, however, can unbalance the wire pair, increasing the likelihood of electromagnetic issues (figure 2). These factors can result in strict procedures for ensuring cable twist rate and UTP placement in the harness (as well as automobile) are optimized to meet EMC requirements. In addition, some “special case” applications may also require jacket and/or shield over the twisted pair, significantly increasing cable costs. For short cable lengths, low-pass filters (LPF) may also be required to mitigate radiated Electromagnetic Interference (EMI), forcing the system design to be pre-configured for specific cable lengths. Other issues can occur at the connector where the cable “end twist” is not ideal and the connectors are not balanced or shielded.

Controlling pair twist rates and attaching connectors to the UTP cable can also be difficult to automate, due to wire-to-terminal alignment issues. Coax cable, in contrast, has a proven track record in automobiles over many years; its manufacture is highly automated. Therefore, despite their different construction, the costs of coax and UTP cable assemblies are very similar.

**System Complexity & Camera Module Size**

*Figure 3. Ethernet vs SerDes camera system block comparison. One camera link shown for each technology for clarity.*

Currently, single-pair automotive Ethernet supports speeds up to 100 megabits per second (Mbps). The limited 100 Mbps bandwidth requires high-resolution video to be compressed at the camera and then decompressed at the other end of the link (figure 3). This video compression, typically Motion JPEG (M-JPEG), requires a relatively powerful microcontroller in the camera modules as well as processing resources in the electronic control unit (ECU), increasing the power, component count, and cost of the system. In addition, compression creates noise artifacts in the video, potentially diminishing object recognition algorithm effectiveness. The additional components in the camera module can require multiple printed circuit boards (PCBs) with associated connectors and possibly flex circuit, driving up assembly cost and module size. In contrast, the FPD-Link serializer/deserializer (SerDes) system transmits uncompressed video directly from the camera sensor and is therefore far simpler, requiring fewer components.

Many systems also incorporate an image sensor co-processor (figure 3) for video pre-processing.
such as color and gamma correction, auto-exposure, white balance, and other functions. These co-processors often must communicate to the image sensor via a low deterministic latency control interface. In Ethernet camera systems, the co-processor must be located in the camera module due to latency. The very low latency I2C control channel in SerDes allows the co-processor to be located in the ECU away from the camera, minimizing camera module power consumption, size, and thermal noise.

Figure 4 illustrates a typical surround view system implemented using a SerDes chipset. The low component count and small footprint helps minimize camera module size, which is important, since camera modules are typically required to be as small as possible to fit in remote, space-constrained locations such as side view mirrors and bumpers. Video data and bidirectional control to each camera are transmitted a single coax cable without the need for a microcontroller in the camera module, saving cost and space. Since all the components can be placed on a single PCB, additional manufacturing costs are saved. Power can also be transmitted over the coax cable to the remote cameras further shrinking their size by eliminating the need for additional power and ground connectors. The single coax connector contains video, control signals, power, and ground, facilitating easier camera placement in the car as well as reducing cabling and installation costs. SerDes power-over-coax is achieved using a standard DC/DC power supply with a simple power switch to turn
power on/off and provide fault protection. A specialized power-over-Ethernet (PoE) style controller is not required to deliver power.

Latency Performance

Video frames must be synchronized in multi-camera systems. Ethernet-based applications typically employ Audio Video Bridging (AVB) software to synchronize cameras. The overhead from AVB plus compression encoding/decoding and packetization can lead to Ethernet camera latency (link delay) of up to 10 milliseconds or more. In some ADAS systems like forward vision, cameras need to remain on, but even in park assist systems, the cameras may need to operate at speeds up to 40 – 50 km/h. At these velocities, the vehicle travels more than a centimeter for every millisecond of latency (figure 5). Distances of 5 – 10 cm can create significant ADAS design challenges, potentially affecting system performance margins and vehicle integrity. SerDes such as the DS90UB913A/914A, however, achieve a maximum latency of 15 microseconds, or just 0.2 mm at 50 km/h.

![Figure 5. Distance traveled versus vehicle speed for 15 µs, 1 ms, 5 ms, and 10 ms latencies.](image)

Video Quality

Low-light and poor weather conditions are especially challenging for camera-based ADAS applications even when using high dynamic range (HDR) image sensors. Heat generated in the camera module further diminishes low-light image quality by increasing thermal noise and other artifacts, making it more difficult for machine vision algorithms (as well as the driver) to distinguish foreground objects from the background. With cameras powered on at speeds of 40-50 km/h or more,
heat can build up inside the camera modules. It can be difficult to remove this heat in space-constrained applications, especially when using cost-effective plastics for the module housing and/or support bracket. Since video compression can significantly increase camera module power consumption, internal Ethernet camera module temperatures can reach 60°C or more.

**Figure 6.** HDR camera image sensor noise under low light for different ambient temperatures.

Figure 6 shows an HDR camera under consistent low-light conditions at different temperatures. As the temperature rises, random thermal noise “speckle” increases and higher dark current can even overwhelm image control algorithms that compensate white/black levels and color channel balance. As can be seen in the camera images, these thermal noise effects make it tougher to differentiate the various color shades and grey scale areas. In addition, adding M-JPEG encoding on top of thermal noise speckle can further enhance noise, potentially leaving low-light images unusable by ADAS algorithms. In contrast, SerDes run cooler without needing to compress the video stream, delivering the best possible image quality in normal as well as challenging low light and inclement weather conditions.

**Table 1. Four-Camera Surround View Example Comparison**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ethernet</th>
<th>SerDes (DS90UB913A/4A)</th>
<th>FPD-Link Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera Module Electrical Components</td>
<td>Image sensor</td>
<td>Image sensor</td>
<td>20+% smaller camera module</td>
</tr>
<tr>
<td></td>
<td>MCU with compression engine &amp; MAC</td>
<td>Serializer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PHY</td>
<td>AC-coupling capacitors</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Common-mode choke</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EMI low-pass filter (optional)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AC-coupling capacitors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOM Cost component costs</td>
<td>Medium</td>
<td>Low</td>
<td>Up to 45% lower system BOM cost</td>
</tr>
<tr>
<td>number of PCBs</td>
<td>2 – 3 (plus connectors/flex)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>cable assembly cost</td>
<td>Low (controlled-twist UTP)</td>
<td>Low (coax)</td>
<td></td>
</tr>
<tr>
<td>Camera Power Consumption</td>
<td>1.5W</td>
<td>0.8W</td>
<td>46% lower power, no heat sink</td>
</tr>
<tr>
<td>Latency</td>
<td>1 – 10 milliseconds</td>
<td>15 µs max</td>
<td>100x lower latency</td>
</tr>
</tbody>
</table>
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### Camera Sync

<table>
<thead>
<tr>
<th>Camera Sync</th>
<th>AVB</th>
<th>Frame sync pin</th>
<th>Easier synchronization</th>
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<tbody>
<tr>
<td>Video Quality</td>
<td>Compressed</td>
<td>Uncompressed HDR</td>
<td>High quality raw video</td>
</tr>
<tr>
<td>Data Rate</td>
<td>100 Mbps</td>
<td>1.5 Gbps</td>
<td>15x higher bandwidth</td>
</tr>
<tr>
<td>PC Connection for Prototyping</td>
<td>Ethernet</td>
<td>Frame grabber</td>
<td></td>
</tr>
</tbody>
</table>

### Video Quality

- Compressed
- Uncompressed HDR
- High quality raw video

### Data Rate

- 100 Mbps
- 1.5 Gbps
- 15x higher bandwidth

### PC Connection for Prototyping

- Ethernet
- Frame grabber

### Conclusion

Ethernet is a very promising technology for in-vehicle networks. For high-resolution infotainment display and camera-based ADAS applications, however, SerDes such as the DS90UB913A/914A deliver higher performance at lower system cost, smaller footprint, and reduced power consumption.

### Author Biography

Dave Lewis is Automotive Analog Marketing Manager at Texas Instruments for infotainment and driver assistance systems. He is the author of several high-speed serializer/deserializer design guides and the editor of the original LVDS Owner’s Manual.

Keywords: LVDS, automotive Ethernet, BroadR-Reach, infotainment, driver assist, ADAS, surround view, top view, bird view, rear view camera, lane departure warning system (LDWS), traffic sign recognition (TSR), blind spot monitoring, mirror replacement camera (MRC), driver monitoring, high beam control (HBC), automotive vision, power-over-coax, MOST bus, APIX, GMSL, broadreach, central information display (CID), rear seat entertainment (RSE), instrument cluster