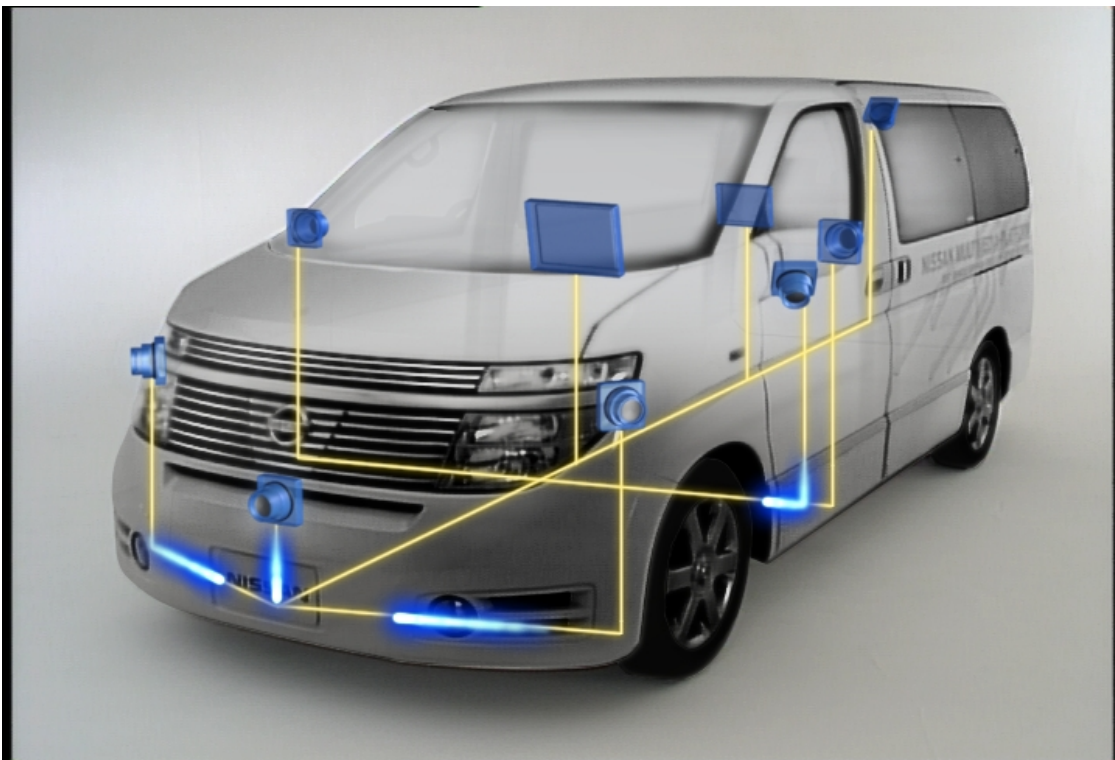


1394 Automotive Camera Systems Are on the Move: Simple Designs with High Bandwidth, Low Latency and Scalability

By Richard Mourn, Astek Corporation

Automotive camera systems are progressing from a single backup camera and simple sensors to detect objects to smart driver assist systems such as collision avoidance and sign recognition. These systems require high bandwidth, low latency, multi-camera synchronization, and scalability; and they must meet general automotive considerations like low cost, low maintenance and reduced weight, achievable using a flexible wire harness.



Picture courtesy of Nissan Motors

These system requirements are interrelated. For example, there are many high bandwidth solutions, but not can meet the low latency, multi-camera synchronization requirements while maintaining low costs.

Typical System

The typical driver assist system consists of a camera controller designed to interface to multiple image sensors (cameras). The controller communicates with the cameras to provide configuration information, and the cameras communicate with the controller to provide status and image stream data. The image stream data from each camera is received by the controller and processed to determine items like distance from objects,

relative speed and lane information. To compute multiple interrelated streams in real-time places special requirements on the network, requirements the 1394 Automotive Camera System was designed to meet.

High Bandwidth

There are several factors that drive the need for high bandwidth; items like uncompressed or lightly compressed video, video resolution, color depth, and frame rate. For driver assist applications the video is typically uncompressed or lightly compressed video. This is required for two primary reasons: the delay from image sensor frame capture to start of frame processing must be small and predictable; few, if any, compression artifacts can be tolerated.

Depending on the system, the video resolution may range from 640 x 480 to 2048 x 1536 and color depth may range from 8 to 24-bit and the frame rate may range from 15 fps to 60 fps. 1394 Automotive is based on IEEE-1394-2008 which supports 98.304 Mb/s to 3.932 Gb/s (S3200) with 983.04Mb/s (S800) chips shipping in high volume now. Gaining higher speeds is easy, since 8B10B based technologies are common now and S1600 and S3200 devices have been demonstrated successfully.

At S800 data rates, six uncompressed 640 x 480 at 30 fps and 8-bit monochrome cameras plus one uncompressed 640 x 480, 30 fps, 16-bit color camera for driver viewing is possible with nearly 200 Mb/s bandwidth remaining for the back channel or other network devices.

At S3200 data rates, four uncompressed 2048 x 1536 at 30 fps and 8-bit monochrome cameras is possible for a dedicated camera network with 125 Mb/s bandwidth left for the back channel or other network devices.

Low Latency

Adequate bandwidth brings the opportunity for low latency -- however adequate bandwidth does not always guarantee low latency. 1394 provides enough bandwidth to send uncompressed video from multiple cameras. which significantly reduces latency. Also, 1394's isochronous capability allows each camera's image data to reach the camera controller predictably, with a guaranteed maximum latency of 250 microseconds.

If light compression is required, it must meet the latency requirements of driver assist systems. Safety critical applications can tolerate very little latency from sensor frame capture to start of frame processing (from encode to decode). For safety critical applications, which are the most stringent, a maximum of 5ms can be tolerated. 1394 Automotive Camera Systems, with 250 microseconds, coupled with Fujitsu's SmartCodec,TM provides 4x compression with 5ms of encode-to-decode latency.

This means at S3200 1394 can support two maximum resolution, frame rate and color depth cameras (2048 x 1526 at 60 fps and 24-bit color) with enough bandwidth to support six compressed 1024 x 768 at 30 fps and 16-bit color cameras while maintaining a maximum latency of 5ms for all cameras.

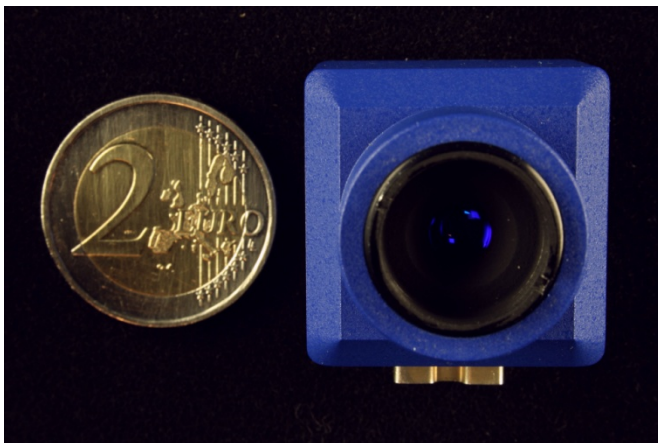
Multi-Camera Synchronization

Images from the cameras are streamed real-time 8,000 times a second. Before each 125-microsecond interval a 40-nanosecond resolution timestamp packet is broadcast to all devices, which resynchronizes all of them. This timestamp is generated by hardware and isn't affected by non-1394 system loading which allows for highly accurate triangulation calculations. The 40 nsec resolution timestamp coupled with the VersaPHY™¹ Remote Sensor Profile enables highly accurate 'look ahead' camera triggers for pixel and line accurate synchronization with latency far below the 10 microseconds typically required.

Scalability

Scalability means different things to different engineers. In the case of 1394 Automotive Camera Systems covers everything, from data rate to topology to cabling to protocol to system; it scales in almost every direction.

- Data rate: 98.304Mb/s (S100) to 3.932 Gb/s (S3200)
- Topology: point-to-point, daisy-chain, tree and looped (ring) topologies supported
- Cabling: the media layer of 1394 support copper, plastic fiber, hard clad plastic fiber, and glass fiber.
- Protocol: IEEE-1394 is a very capable transport supporting native camera, AV, mass storage, and VersaPHY profiles as well as Internet Protocol (IP). IEEE-1394 supports both memory mapped (very efficient for mass storage) and channel architectures (very efficient for audio/video streaming).
- System: 1394 Automotive Camera System cost effectively scales from a simple point-to-point camera and display to complex multi-camera driver assist implements with the same hardware implementations.



Picture courtesy of Hella Aglaia

Flexible Wire Harness

IEEE-1394 is a peer-to-peer network that allows point-to-point, daisy-chains, trees and looped (ring) topologies. In addition, 1394 Automotive supports multiple media types like shielded twisted pair, shielded twisted quad, coax and plastic fiber. 1394 Automotive is specified to work at least 8 meters with five inline connections. All this flexibility gives the camera system implementer unmatched tools to construct the most functional, low weight and cost effective driver assist network wire harness strategy.

Simple – No Software Required

Automotive implementations vary greatly, from simple camera to display applications through multiple cameras connected to a camera controller running sophisticated collision detect algorithms. 1394 Automotive Camera Systems utilize 1394's isochronous streaming capability, which allows point-to-point analog like simplicity on a networked bus architecture. This simplicity is enabled by 1394's isochronous streaming architecture, which can be implemented 100 percent in hardware. This means video from the sensor is placed on the bus and received from the bus and displayed or processed with no 1394 software. This greatly simplifies the camera because it can be put in place with no software or processor. Additionally, the new VersaPHY additions to 1394 allow the camera to be controlled with no software in the camera and minimal and very simple software in the controller. For some applications like a single camera to display absolutely no software is required in the camera or the display.

Reduced Cost

Cost is critical - the suitability of the 1394 Automotive Camera System in terms of cost is very high.

S800 1394 silicon is widely available. 1394 scales to S3200 using main stream SERDES technology that is used in many other high volume applications allowing 1394 Automotive Camera Systems to scale and provide more bandwidth simply and cost effectively.

As mentioned previously in this article, the worst case latency for uncompressed video is 250 μ sec which means the camera only needs to buffer a maximum of 250 μ sec worth of data. The limited buffer requirement reduces the silicon gate count making a single chip 1394 solution and two chip, sensor and 1394, camera implementation incredibly cost effective.

While other technologies often require separate trigger or clock signals to trigger and/or synchronize the devices on the network, synchronization of 1394 streaming devices is fundamental to the architecture and is implemented in hardware. This allows 1394 Automotive Camera Systems to achieve this functionality at no additional cost.

Because 1394 Automotive Camera Systems scale in so many ways automakers can choose 1394 for all models, increasing volume and reducing costs. From point-to-point topologies to large camera networks 1394 easily handles it all.

Wire harness strategy is critical when trying to reduce the implementation cost. 1394's support for multiple media types and topology arrangements is second to none. This unmatched flexibility allows the auto maker choose media the meets the system level cost goals while balance performance, scalability, and weight.

Because video streaming is a fundamental feature of 1394 the cost of doing so is minimal. From reduced silicon cost to very low management overhead 1394 costs are comparable with point-to-point solutions yet it provides all the benefits of a networked technology.

1394 Automotive Camera Systems provides all the features and functions required for automotive applications while maintaining the best price performance.

VersaPHY is a trademark of Astek d.b.a. Quantum Parametrics
SmartCodec is a trademark of Fujitsu Microelectronics