Automotive Ethernet
Leading the transition to Ethernet in automotive

Design high-speed Automotive Ethernet communication links between advanced driver assistance systems (ADAS), infotainment, cameras, and other electronic control units (ECUs) by leveraging the Cadence® Ethernet media access controller (MAC) IP.

The Cadence Ethernet MAC IP supports three different operating speeds (10/100/1000M), the Audio-Video Bridging Transport Protocol standard (AVB), and Time Sensitive Networking (TSN), and is ISO 26262 ASIL-B ready.

Overview
The automotive industry is trending toward Ethernet for in-vehicle networking (IVN) based on open IEEE standards. Driven by the OPEN Alliance SIG, these standards aim to develop a simpler, but more powerful, automotive electrical/electronic architecture. Demand for deterministic, high-performance bandwidth features and low-cost cabling solutions are accelerating Ethernet-based networks. Ethernet for IVN (Figure 1) provides the lowest cost cabling solution with low-weight, single-pair, unshielded twisted-pair cable.

Automotive Ethernet MAC Design IP
In order to build highly integrated Ethernet-based systems on chip (SoCs), Cadence provides key design IP such as the Cadence Automotive Ethernet MAC.

AVB and TSN are the two key features to enable Ethernet for Automotive applications. AVB describes how to guarantee bandwidth and enable data synchronization over Ethernet to ensure a high quality of service (QoS). However, to meet the safety and low-latency requirements of mission-critical control systems like braking, steering, etc., a new set of open standards—collectively referred to as Time Sensitive Networking (TSN)—is being developed. TSN enables robust, low-latency, and deterministic synchronized packet transmission and is a super-set of the AVB standard.

Key Features
The Cadence Ethernet MAC IP is widely licensed for high-volume production, and supports:

- Three different operating speeds (10/100/1000Mbps)
- TSN/AVB protocol support including IEEE 802.1Qbv, 802.1AS, 802.1Qbu/802.3br, 802.1CB, 802.1Qci
- Enhanced active functional safety features
- ISO 26262 ASIL-B ready
- IEEE 802.3 compliant and UNH tested
- TCP/IP offloading capability and IEEE 1588 support
- High-performance scatter/gather DMA
- AXI4, AHB, and DMA support
- Support for MII, RMII, GMII, RGMII, and TBI interfaces
- Seamless interoperability with 100Mbps and 1Gbps Ethernet PHYs
- Comprehensive software stack, including Linux driver
Product Details

The Controller IP supports TSN/AVB protocols, integrated 1000BASE-X PCS, DMA, and functional safety features specifically for automotive applications.

GEM

Gigabit Ethernet MAC (GEM) is compliant with IEEE 802.1Qbb priority-based flow control (PFC) with support for up to 16 priority queues and pause frames on both TX and RX. GEM supports virtual LANs by IEEE 802.1Q VLAN tagging with recognition of incoming VLAN and priority tagged frames. It provides address checking logic for up to 32 specific Ethernet (MAC) addresses, four type IDs, hash matching of unicast and multi-cast destination addresses and wake-on-LAN. GEM performs padding and CRC generation for transmit frames.

Functional Safety Features and Documentation

GEM has additional functional safety features targeting automotive applications. This includes memory protection using ECC, datapath and address parity protection, fatal fault detection, reporting, and recovery mechanisms. The deliverables also include a FMEDA report, safety manual, and ISO 26262 ASIL readiness certificate.

IEEE 802.1 Specifications

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VIP for Ethernet up to 100G

Incorporating the latest protocol updates, the mature and comprehensive Cadence Verification IP (VIP) for the Ethernet up to 100G protocols provides a complete bus functional model (BFM) including error insertion, integrated automatic protocol checkers, and coverage model. Designed for easy integration in testbenches at IP, SoC, and system levels, the VIP for Ethernet up to 100G helps you reduce time to test, accelerate verification closure, and ensure end-product quality.

The VIP for Ethernet up to 100G runs on all major simulators, and supports SystemVerilog and e verification languages along with associated methodologies, including the Universal Verification Methodology (UVM) and Open Verification Methodology (OVM).

The VIP for Ethernet up to 100G enables verification of Ethernet interfaces in standalone, partial-stack, and full-stack mode for speeds from 10Mbps to 100Gbps:

- XMII level: Between MAC and PHY
- PHY sub-layers: Between PCS, FEC, PMA, and PMD
- Link partners: Between TX Station and RX Station

The VIP for Ethernet up to 100G complies with IEEE 802.3 Ethernet standards and draft specifications. It supports other widely popular Ethernet interfaces, which are proprietary and based on IEEE 802.3. Hence the VIP supports different configurations, as shown in Figure 3 and Figure 4.

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VIP for Ethernet up to 100G
The Cadence VIP for Time Sensitive Networks (TSN) provides a mature, highly capable compliance verification solution for the TSN protocol stack, incorporating BFM including error insertion, integrated automatic protocol checkers, and coverage model. The VIP for Ethernet TSN is designed for easy integration in testbenches at IP, SoC, and system levels, helping to reduce time to test, accelerate verification closure, and ensure end-product quality.

The following set of protocols are a part of the VIP for Ethernet TSN:

- IEEE 802.1AS PTP
- IEEE 802.1Qbu
- IEEE 802.3br
- IEEE 802.1Qav
- IEEE 802.1Qbv
- IEEE 802.1Qat
- IEEE 802.1AE
- IEEE 1722

The TSN protocols are usually designed to work over a framework of Ethernet MAC and PHY layers working at speed of 1Gbps or below.

**VIP for Standard Interface Compliance**

The increasing number and complexity of interfaces in automotive SoCs make it difficult to thoroughly verify designs. Cadence VIP boosts quality by providing VIP components that check compliance with standard interface specification such as CAN, LIN, Ethernet, DDR, Flash, USB, and dozens of others.

**Benefits:**

- Proven VIP provider, chosen by over 500 customers
- VIP available for over 100 interface and memory standards
- Verifies compliance to standard interface specifications for mission-critical designs

**Sigrity SystemSI Automotive Ethernet Channel Simulation**

Implement automotive Ethernet networks and analyze the ECU-to-ECU communication performance via the physical Ethernet channel with Cadence Sigrity™ SystemSI™ technology for automated chip-to-chip signal integrity analysis.

Simulate full physical channel to ensure Ethernet compliance:

- Test different PHY, connector, and cable combinations
- Supports cable segmentation (different cable length)
- With or without jacket, shielding
- Simulation-based EMI verification and optimization from ECU to ECU
- Analyze cable aging effects
- Run power integrity analysis on PCB
- Supports automotive Ethernet compliance checks for 100Base-T1 and 1000Base-T1 PHYs

**Automotive Ethernet Compliance Tests for 100Base-T1 PHY**

- IBIS AMI models of PHY working on any cable topology – TX and RX models
- Physical channel simulated in Sigrity SystemSI technology
- Supported compliance tests:
  - Transmitter output droop
  - Transmitter power spectral density
  - Transmitter jitter (master/slave)
  - Transmitter clock frequency (PAM3)
  - Transmitter distortion
  - Return loss measurement

**Figure 5: 100Base-T1 transmitter output droop**
Ethernet Rapid Prototyping

For fast FPGA-based prototyping, Cadence has developed a BroadR-Reach PHY interface card that can be plugged into the Cadence Protium™ FPGA-Based Prototyping Platform. By doing so, external hardware like Ethernet cameras, infotainment head units, and other devices can be directly connected via an unshielded twisted-pair cable with the FPGA system. In this way, a SoC that was initially implemented as a FPGA prototype can also run software to do early hardware/software validation of the system leveraging the Protium solution. This setup also helps to analyze the impact of using different cables, connectors, and other hardware configurations on the overall system performance.

A relevant application for Ethernet rapid prototyping is using cameras within parking-assist systems in a top-view or rear-view configuration. Leveraging a hardware/software co-design methodology allows engineers to develop and test drive their Automotive Ethernet application (hardware/software) before the hardware—including the SoC—is available.

The Cadence BroadR-Reach Interface card can connect any external Ethernet device with the ECU or other control unit via the Cadence Automotive Ethernet MAC.

Further Information

To learn more about Cadence’s IP options for automotive, visit www.cadence.com/automotive.

Figure 6: 100Base-T1 eye diagram

Figure 7: Key components of the physical Ethernet channel