# Learn More About TSN

## What Is a TSN Switch?

A Time-Sensitive Networking (TSN) switch is a network switch designed to support the IEEE® 802.1 TSN standards, which provide deterministic networking capabilities. These switches are used in environments where precise timing and low-latency communication are critical, such as industrial automation, automotive networks and professional audio/video systems.

## Features of a TSN Switch

Key features of TSN switches include:

- **Time synchronization:** Ensures all devices on the network have a common understanding of time, typically using the Precision Time Protocol (PTP), which follows the IEEE 1588v2 standard, or the Generalized Precision Time Protocol (gPTP), which follows the IEEE 802.1AS standard to synchronize clocks across the network with high precision.
- **Traffic scheduling and shaping:** Manages the transmission of data to meet strict timing requirements, often using the IEEE 802.1Qbv standard for time-aware scheduling and shaping to control the timing of packet transmissions, ensuring that high-priority traffic is delivered within strict time constraints.
- **Low latency, jitter and Quality of Service (QoS):** TSN switches implement QoS mechanisms to prioritize traffic based on importance and ensure that critical data is transmitted with minimal delay and jitter, which is crucial for real-time critical applications.
- **Redundancy, reliability and fault tolerance:** Provides mechanisms for redundant paths, frame replication, fault tolerance and high availability such as frame replication (IEEE 802.1CB—Frame Replication and Elimination for Reliability), ensuring reliable communication even in the presence of network failures.
- **Frame preemption:** IEEE 802.1Qbu and IEEE 802.3br standards allow for frame preemption, enabling high-priority frames to interrupt lower-priority frames, reducing latency for critical traffic.
- **Ingress policing:** TSN switches use ingress policing mechanisms to enforce traffic profiles and prevent network congestion by controlling the rate of incoming traffic.
- **Stream reservation:** IEEE 802.1Qat (Stream Reservation Protocol) allows devices to reserve network resources for specific data streams, ensuring that critical traffic receives the necessary bandwidth and priority.
- **Centralized network configuration:** TSN switches often support centralized network configuration protocols, such as IEEE 802.1Qcc, which allows for the centralized management and configuration of TSN features across the network.

By incorporating these features, TSN switches enable the reliable and predictable transmission of time-sensitive data across Ethernet networks, making them essential for applications that require synchronized and timely communication.

## Benefits of a TSN Switch

A TSN switch offers several benefits, particularly in environments where precise timing and low-latency communication are critical. Key advantages include:

- **Deterministic communication:** TSN switches provide deterministic network behavior, ensuring that data packets are delivered within a guaranteed time frame. This is crucial for applications requiring real-time data transmission, such as industrial automation and control systems.
- **High reliability:** TSN switches enhance network reliability by supporting redundancy protocols and fault-tolerant mechanisms. This ensures continuous operation even in the event of a network failure.
- **Scalability:** TSN switches can be integrated into existing Ethernet networks, allowing for scalable and flexible network architectures. This makes it easier to expand and upgrade networks without significant overhauls.
- **Interoperability:** TSN is based on IEEE standards, ensuring interoperability between devices from different manufacturers. This standardization facilitates the integration of diverse systems and components.

- **Bandwidth efficiency:** TSN switches optimize bandwidth usage by prioritizing critical traffic and managing network resources effectively. This leads to more efficient use of available bandwidth.
- **Enhanced security:** TSN includes features that enhance network security, such as traffic isolation and secure communication channels. This is particularly important in industrial and critical infrastructure applications.
- **Support for mixed-criticality traffic:** TSN switches can handle different types of traffic with varying levels of criticality on the same network. This allows for the coexistence of real-time control data and regular IT traffic without compromising performance.
- **Future-proofing:** As industries move towards more connected and automated systems, TSN provides a future-proof networking solution that can support emerging technologies and applications.

Overall, TSN switches are essential for modern networks that require precise timing, high reliability and efficient resource management, making them well suited for industrial, automotive and other time-sensitive applications.

## Convergence of Information and Operational Technologies

TSN can have a significant impact in converging Information Technology (IT) and Operational Technology (OT) because it addresses the need for reliable, low-latency data transmission in industrial environments. Converging IT and OT using TSN offers several significant benefits:

- **Improved efficiency and performance:** TSN provides deterministic networking capabilities, ensuring that data is transmitted with minimal latency and high reliability. This is crucial for OT systems that require precise timing and synchronization, such as industrial automation and control systems. By integrating IT and OT, organizations can achieve more efficient and optimized operations.
- **Enhanced data sharing and analytics:** Convergence allows for seamless data flow between IT and OT systems without critical data disruption. This integration enables better data collection, analysis and utilization, leading to more informed decision making and improved operational insights. For example, real-time data from OT systems close to the field devices can be analyzed using IT tools to optimize production processes.
- **Increased flexibility and scalability:** Converging IT and OT on a common TSN infrastructure allows for greater flexibility in network design and scalability. Organizations can more easily expand their networks and integrate new devices and applications without compromising performance or reliability.
- **Cost savings:** A unified network infrastructure reduces the need for separate IT and OT networks, leading to cost savings in terms of hardware, maintenance and management. Additionally, streamlined operations and improved efficiency can result in lower operational costs.
- **Enhanced security:** Integrating IT and OT systems can improve overall security by implementing consistent security policies and practices across the entire network. TSN's deterministic nature also helps in isolating and protecting critical OT traffic from potential IT network threats.
- **Simplified management:** Since there is only a single infrastructure to oversee, a converged network simplifies management and monitoring. Using standard Ethernet's tools and protocols leads to more effective network management, quicker troubleshooting and reduced downtime.
- **Support for Industry 4.0 and IIoT:** The convergence of IT and OT is a key enabler for Industry 4.0 and the Industrial Internet of Things (IIoT). TSN provides the necessary infrastructure to support the high-speed, low-latency communication required for advanced manufacturing technologies, smart factories and connected devices.

Overall, the convergence of IT and OT technologies using TSN creates a more robust, efficient and secure network environment that supports modern industrial and enterprise needs.

## Applications for TSN Switches

Key applications for TSN switches include:

- **Industrial automation:** TSN switches are used in factory automation systems to ensure real-time communication between sensors, controllers and actuators. This is crucial for processes that require precise timing and synchronization, such as robotic assembly lines and motion control systems.
- **Automotive networks:** In modern vehicles, TSN switches enable reliable and timely communication between various Electronic Control Units (ECUs), sensors and actuators. This is essential for Advanced Driver-Assistance Systems (ADAS), autonomous driving and in-vehicle infotainment systems.
- **Audio/video broadcasting:** TSN switches are used in professional audio and video production environments to ensure synchronized and low-latency transmission of high-quality audio and video streams. This is important for live broadcasting, studio production and large-scale events.
- **Power and energy:** In smart grid and power distribution networks, TSN switches facilitate real-time communication for monitoring and controlling power generation, distribution and consumption. This helps in maintaining grid stability and optimizing energy usage.
- **Aerospace and defense:** TSN switches are employed in avionics and defense systems to provide deterministic communication for mission-critical applications, such as flight control systems, radar and communication systems.

- **Healthcare:** In medical environments, TSN switches support real-time data transmission for critical applications where timing and reliability are paramount, such as telemedicine, remote surgery and patient monitoring systems.
- **Telecommunications:** TSN switches can be used in telecom networks to ensure low-latency and high-reliability communication for services where precise timing and synchronization are essential for network performance, such as 5G.
- **Smart cities:** TSN switches enable real-time data exchange in smart city applications where timely and reliable communication is necessary for efficient city operations, such as traffic management, public safety and environmental monitoring.

Overall, TSN switches are integral to any application requiring deterministic networking because they ensure that data is transmitted with minimal delay and high reliability.

## Components of a TSN Switch

The key types of semiconductors typically found in TSN switches with Power over Ethernet (PoE) include:

- **Ethernet Physical Layer Transceivers (PHYs):** These semiconductors handle the physical layer of the Ethernet communication, converting digital data into electrical signals and vice versa. They are essential for both data transmission and reception over Ethernet cables.
- **Switching Application-Specific Integrated Circuits (ASICs):** These are specialized chips designed to handle the high-speed switching and routing of data packets within the network switch. They ensure low latency and high throughput, which are critical for TSN applications.
- **Timing and synchronization ICs:** TSN requires precise timing and synchronization across the network. These ICs ensure that all devices in the network are synchronized to a common time base, which is essential for time-sensitive applications.
- **Microcontrollers (MCUs) or Microprocessors (MPUs):** These are used for the overall control and management of the switch, including running the operating system, managing network protocols and handling user interfaces.
- **Power Management ICs (PMICs):** These are crucial for managing the power delivery over Ethernet cables. They handle the negotiation of power levels between the Power Sourcing Equipment (PSE) and the Powered Device (PD), ensuring safe and efficient power transfer.
- **PoE controllers:** These are specialized ICs that manage the PoE functionality, including power negotiation, power delivery and protection mechanisms to prevent overloading and short circuits.

By integrating these various semiconductors, PoE-enabled TSN switches can provide both power and precise, low-latency data communication, making them suitable for applications in industrial automation, professional audio/video and other time-sensitive environments.

Building a TSN switch also requires software, which typically includes:

- **Operating System (OS):** A Real-Time Operating System (RTOS) like Linux® is often used to ensure low latency and deterministic behavior on the management side
- **TSN protocol stack:** These stacks are used to implement TSN standards such as IEEE 802.1Qbv (Time-Aware Shaper), IEEE 802.1Qbu (Frame Preemption), IEEE 802.1Qcc (Stream Reservation Protocol), IEEE 802.1AS (Timing and Synchronization) and IEEE 802.1CB (Frame Replication and Elimination for Reliability)
- **Network management software:** Software for configuring and managing TSN features, such as network configuration tools, monitoring tools and diagnostic tools
- **Device drivers:** Custom or vendor-specific drivers to support other hardware components supporting TSN features
- **Firmware:** Firmware for the switch hardware that supports TSN features
- **Development tools:** Integrated Development Environments (IDEs), compilers, debuggers and other development tools for writing and testing the switch software
- **Simulation and testing tools:** Tools for simulating TSN traffic and testing the switch's performance and compliance with TSN standards
- **Security software:** Software to ensure secure communication and protect against cyber threats, including encryption, authentication and access control mechanisms

## Getting Started

We offer a wide variety of TSN technologies. To reduce development costs and expedite time to market, we offer a fully built, ready-to-customize family of TSN switches:

- PD-IESxxx Family of TSN Switches

We also offer discrete components to customers to design and build a TSN switch. A sample of some of the many components available are listed below:

- LAN9668x 8-Port TSN Gigabit Ethernet Switch
- LAN8814 4-Port GbE Cu PHY With QSGMII/Q-USGMII
- ZK30772 2-Channel IEEE 1588/SyncE Network Synchronizer
- PD69208 IEEE 802.3 at/bt Type 4/PoH, 8 Ports, Fully Integrated PSE Manager
- VSC6817 IStaX VSC6817SDK Linux Application Software Package
- VSC6816 SMBStaX VSC6816SDK Linux Application Software Package; Fully Managed L2 Switch Application
- VSC6819 WebStaX VSC6819SDK Linux Application Software Package; Fully Managed L2 Switch Application Managed Enterprise Switches

We also offer an evaluation board and reference design to assist you in getting started:

- EV18W53 8-Port Gigabit Ethernet With LAN9668 Switch and LAN8814 PHYs; WebStaX, SMBStaX and IStaX board files are available at https://www.microchip.com/mymicrochip

Contact a Microchip TSN expert for more information.