

Real-Time Open Industrial Linux

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May 2019 | AMF-IND-T3538



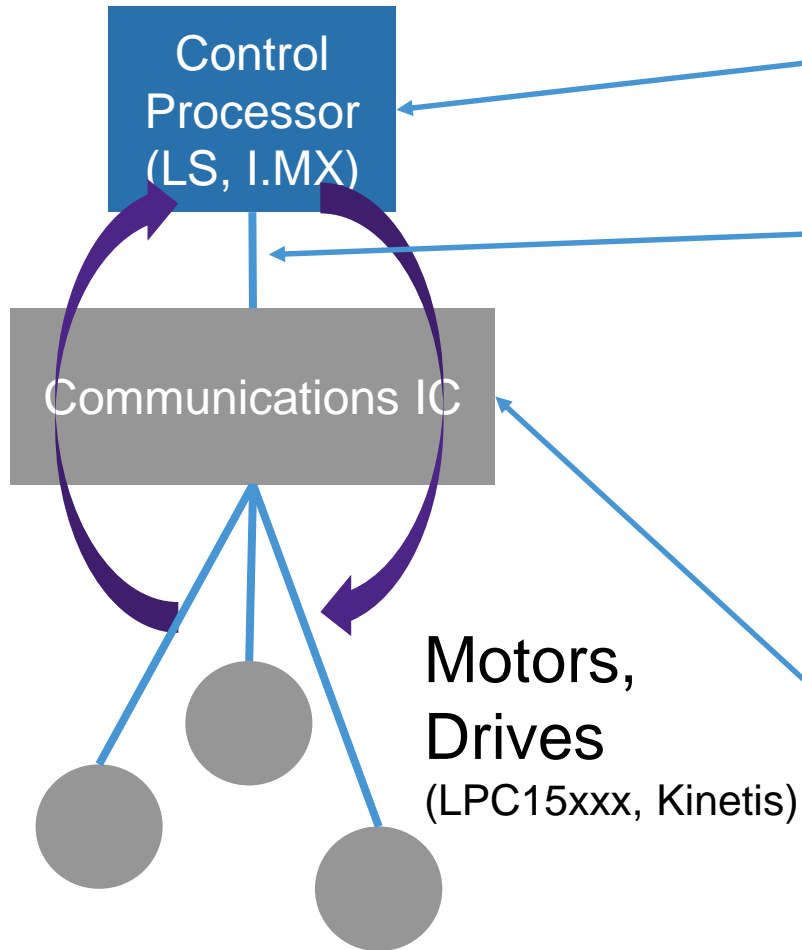
SECURE CONNECTIONS
FOR A SMARTER WORLD

Agenda

- Industrial Application Requirements
- Deterministic Computing
- Protecting Industrial Devices
- Time Synchronization
- Deterministic Networking



Manufacturing Automation/Smart Grid Requirements



Processor Requires Real-Time Performance
Traditionally supported via RTOS

PCIe or 16 bit parallel bus

Depends on data sizes and system architecture

Control loops run every 25-150 usecs

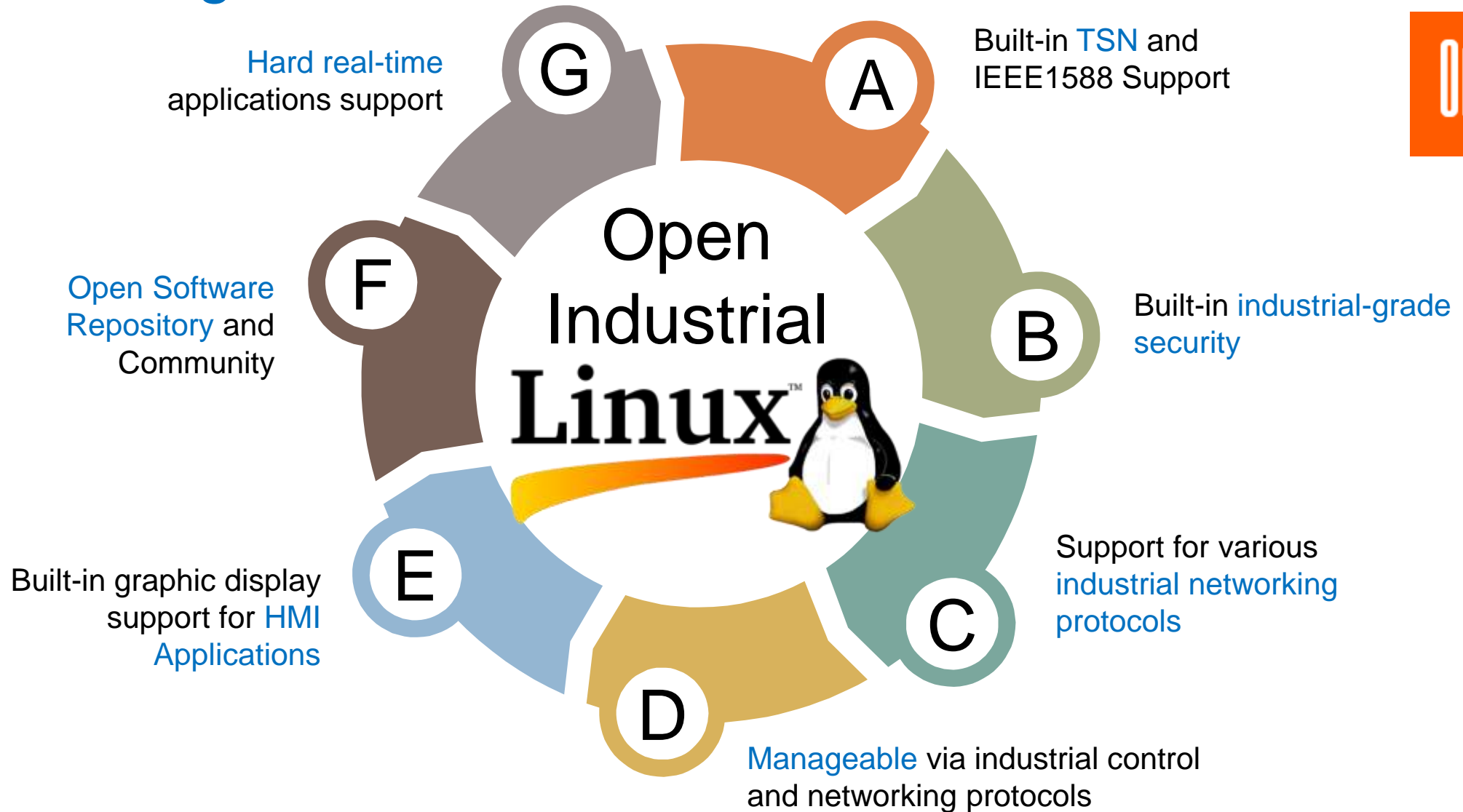
Requires low, deterministic latency

All elements must be synchronized

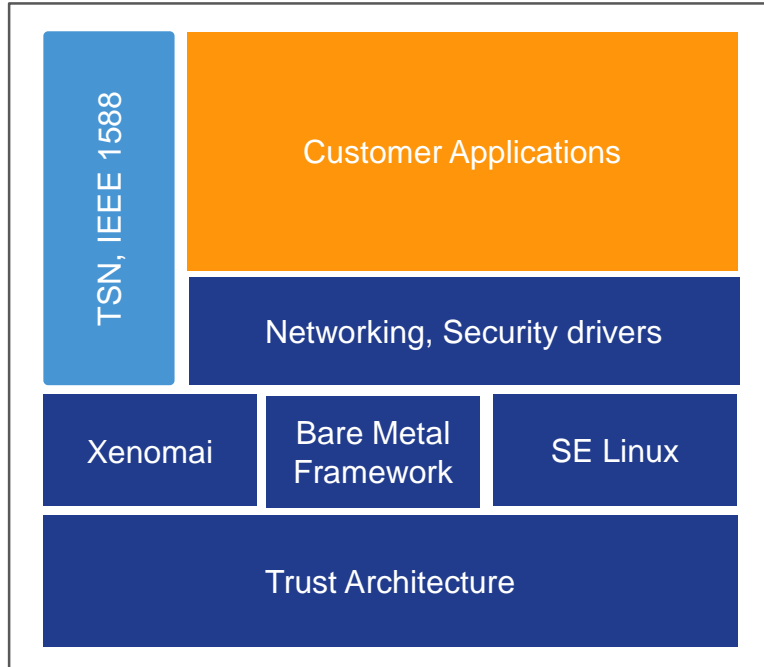
Control loop period determines how fast and how smoothly a mechanical system can run

Communications IC

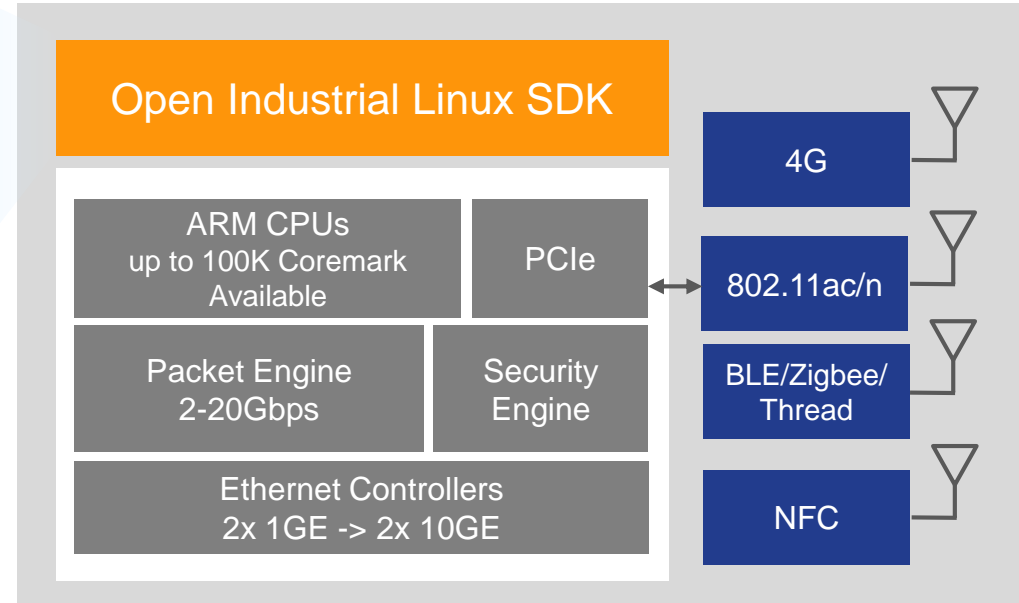
Will be replaced by TSN



OpenIL for Industrial Automation



Scalable Hardware



Determinism

Xenomai Linux, Bare Metal Framework
IEEE 1588, TSN

Security

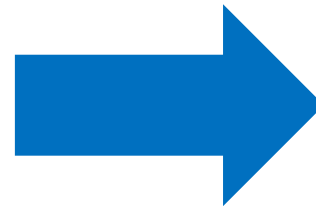
SE Linux
OP-TEE



OpenIL Running on Scalable Portfolio of Devices

Currently Supported Devices
Single to Quad Core
32 and 64 bit Arm

LS1043A	LS1046A
<ul style="list-style-type: none">• Cortex-A53• 2-4 cores• 1.6GHz• 1/10G Ethernet, USB, PCI• 5-10W	<ul style="list-style-type: none">• Cortex-A72• 2-4 cores• 1.8GHz• 1/10 G Ethernet, USB, PCI• 10-12W
LS1012A	LS1021A
<ul style="list-style-type: none">• Cortex-A53• 1 core• 1GHz• 1-2W• Ethernet, USB, PCI	<ul style="list-style-type: none">• Cortex-A7• 2 cores• 1.2GHz• 2W• Ethernet, USB, PCI



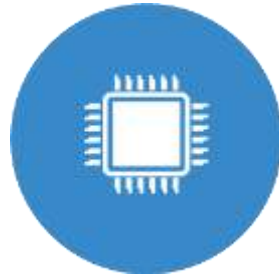
New Device Support
Adding 3D GPU
Adding Integrated TSN

i.MX 6Dual/6Quad	LS1028A
<ul style="list-style-type: none">• Cortex-A9• 2-4 cores• 800 MHz (Industrial)• <i>2D/3D GPU</i>	<ul style="list-style-type: none">• Cortex-A72• 2 cores• 1.3GHz• 4-9W• <i>Integrated TSN switch</i>• <i>2D/3D GPU</i>

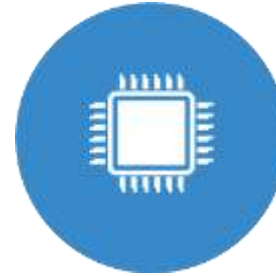
One Package – Four SoC Options

4x A53 1.6 GHz
4.2 W Typical
26,650 Coremark
Per core SpecINT
Per core SpecFP

LS1043



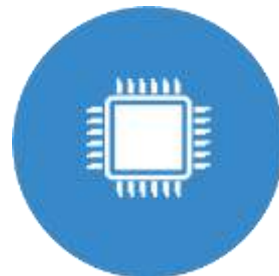
LS1046



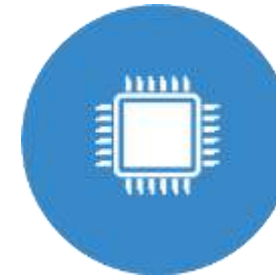
4x A72 1.8 GHz
8.5 W Typical
45,330 Coremark
Per core SpecINT
Per core SpecFP

2x A53 1.0 GHz
2.5 W Typical
8,360 Coremark
Per core SpecINT
Per core SpecFP

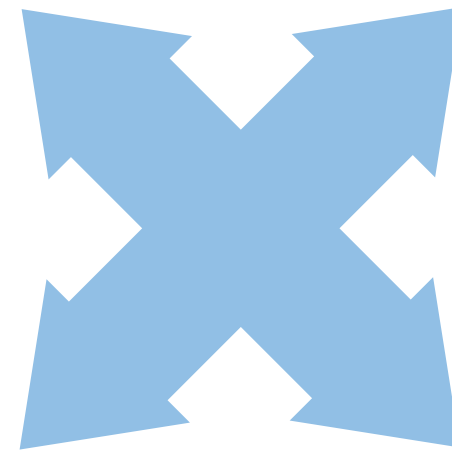
LS1023



LS1026



2x A72 1.2 GHz
5.6 W Typical
15,000 Coremark
Per core SpecINT
Per core SpecFP

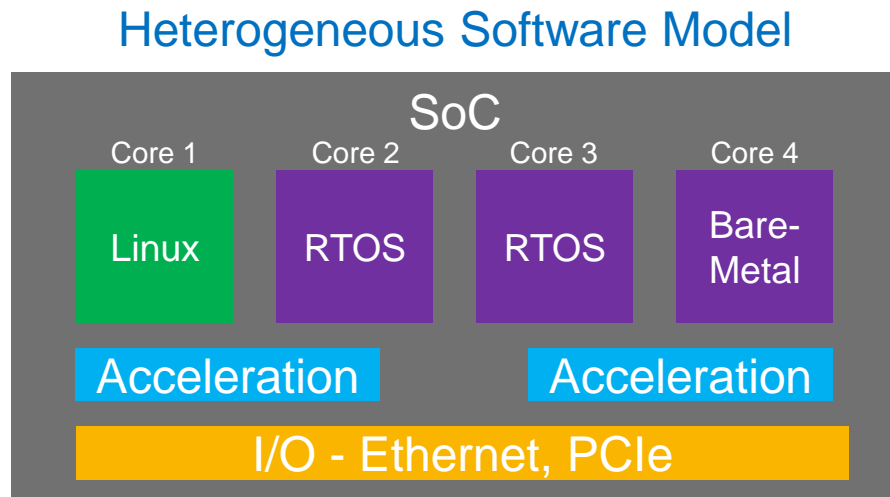


23mm x 23mm
780 pin
FC-PBGA Package

Deterministic Computing



Deterministic Computing for Industrial Workloads

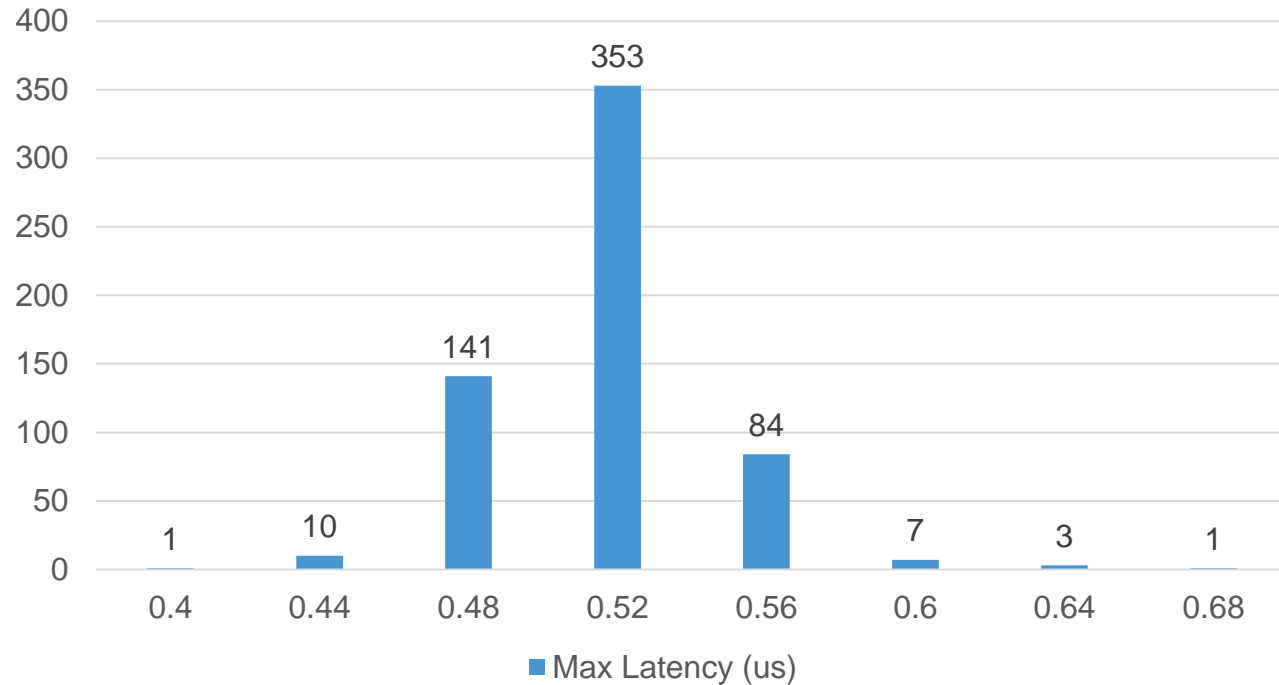


3 Levels of Real-Time Performance:

- Xenomai Mercury (PREEMPT-RT Patches)
- Xenomai Cobalt (Real-Time Co-Kernel)
- Bare-Metal Framework
- Run management, communication software in Linux on 1 core
- Real-time applications running with RTOS (Xenomai) or Bare-Metal on other cores

Xenomai Latency Distribution on LS1043A

Max Latency Samples Distribution



- Xenomai Cobalt 64-bit mode on LS1043A @ 1.6 GHz
- Measured using Xenomai latency tool
- Jitter < 450 ns
- Max latency of 680 ns

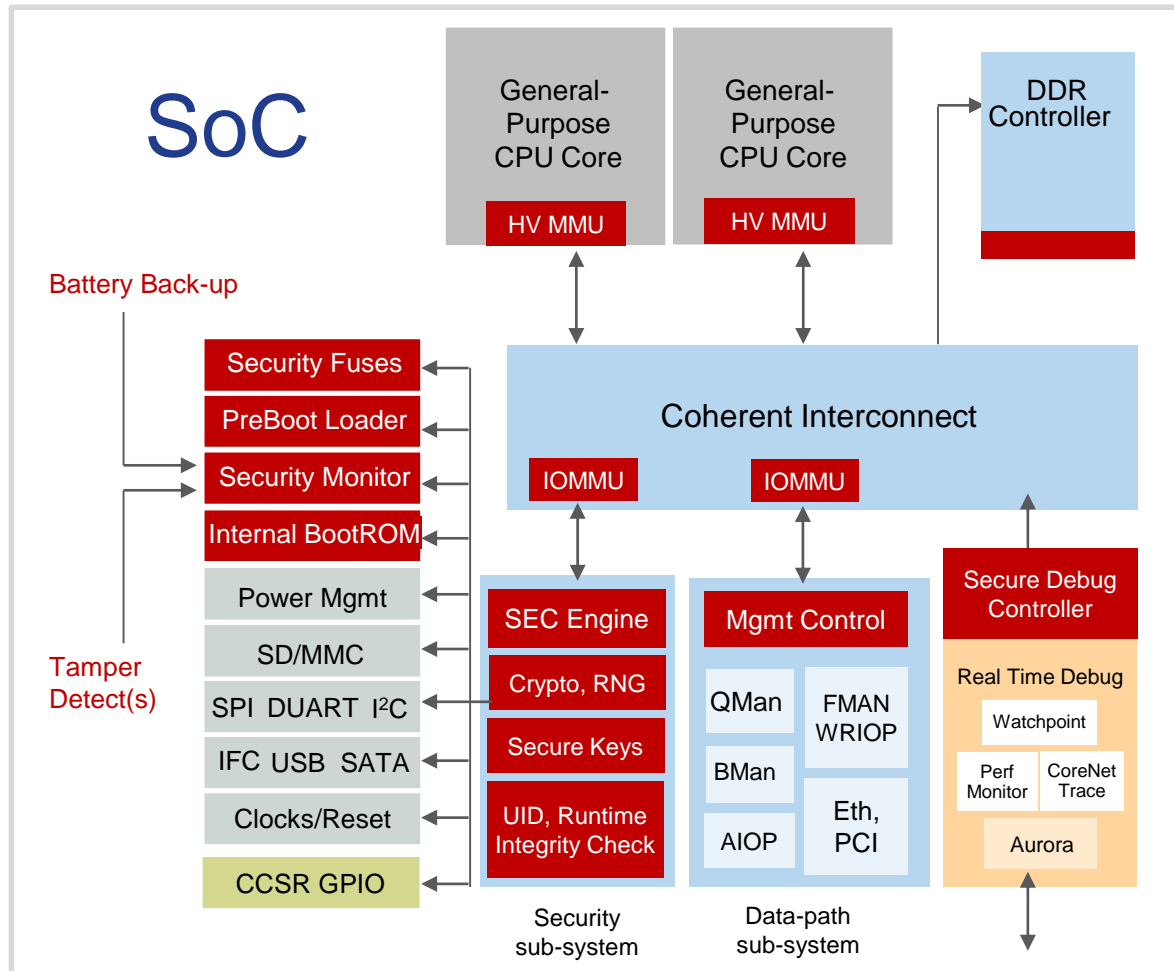
latency min (us)	latency avg (us)	latency max (us)	Duration
0.24	0.279	0.68	00:10:00

Protecting Industrial Devices

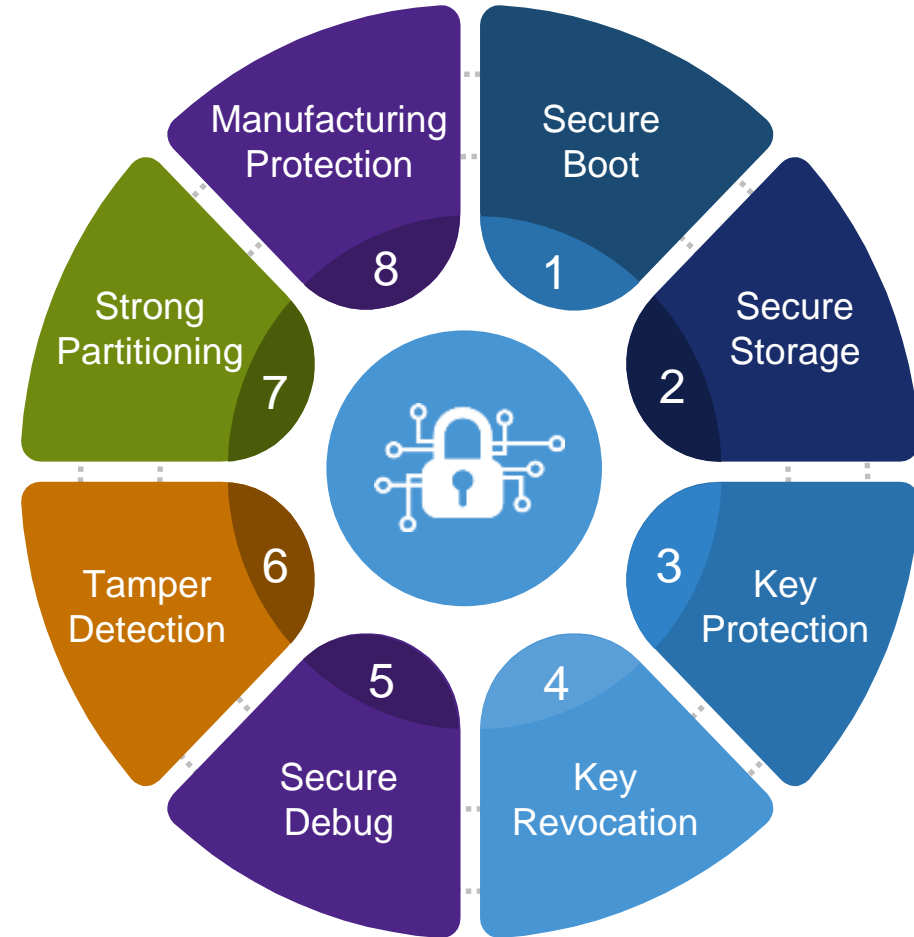


Trust Architecture Provides a Trusted Platform

Hardware based security features to ease the development of trustworthy systems



All QorIQ SoCs support Trust Architecture



Runtime Access Control With SELinux

- Improved access control
- Policies control file access, network resources, and IPC
 - Finer grain access control
- Use cases:
 - Prevent remote login for certain types of users
 - Restrict access to files from the web



Time Synchronization



IEEE 1588 for Timing Synchronization

linuxptp support:

LS1021A

LS1043A

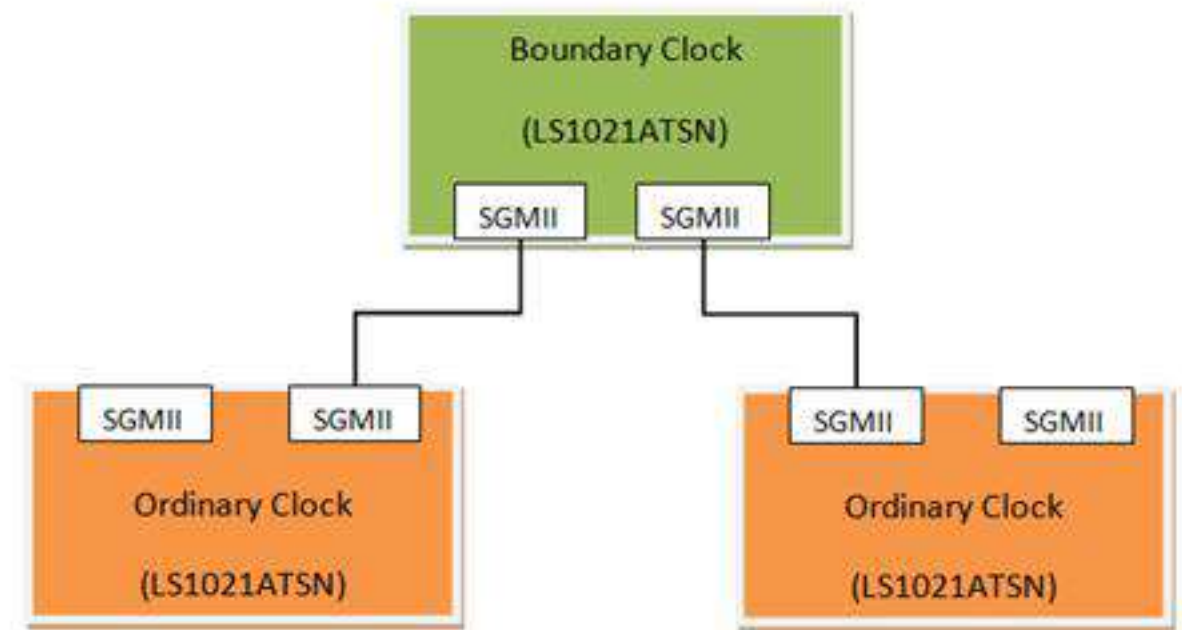
LS1046A

LS1028A

Master/Slave
Boundary Clock Mode
802.1AS End Station

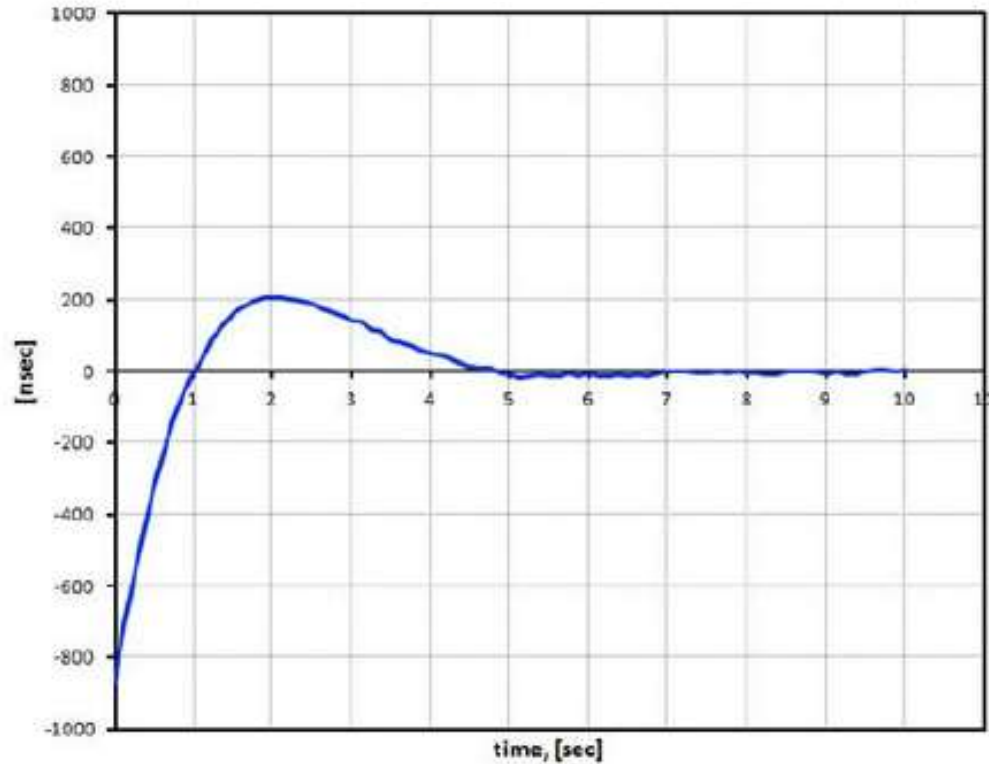
Synchronization within +/- 23 nsec for
back to back boards

Example configurations and test results



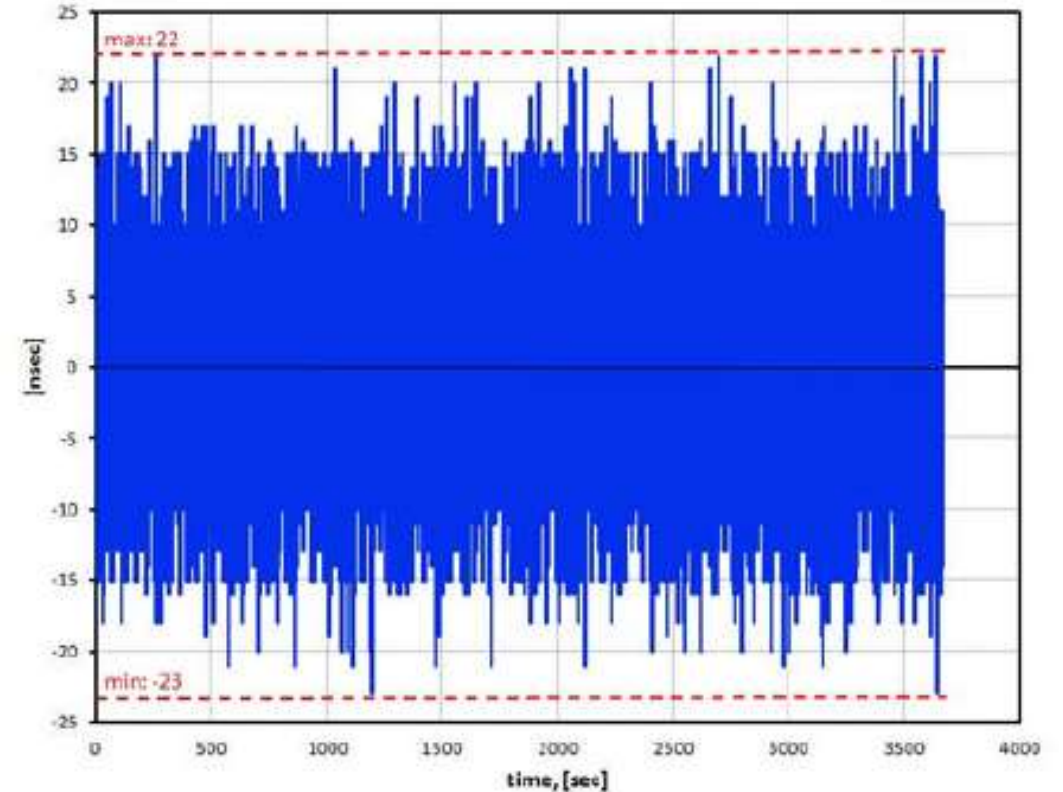
1588 Performance

Offset from Master, Startup



Timing settles within 5 seconds

Offset from Master, Stable State



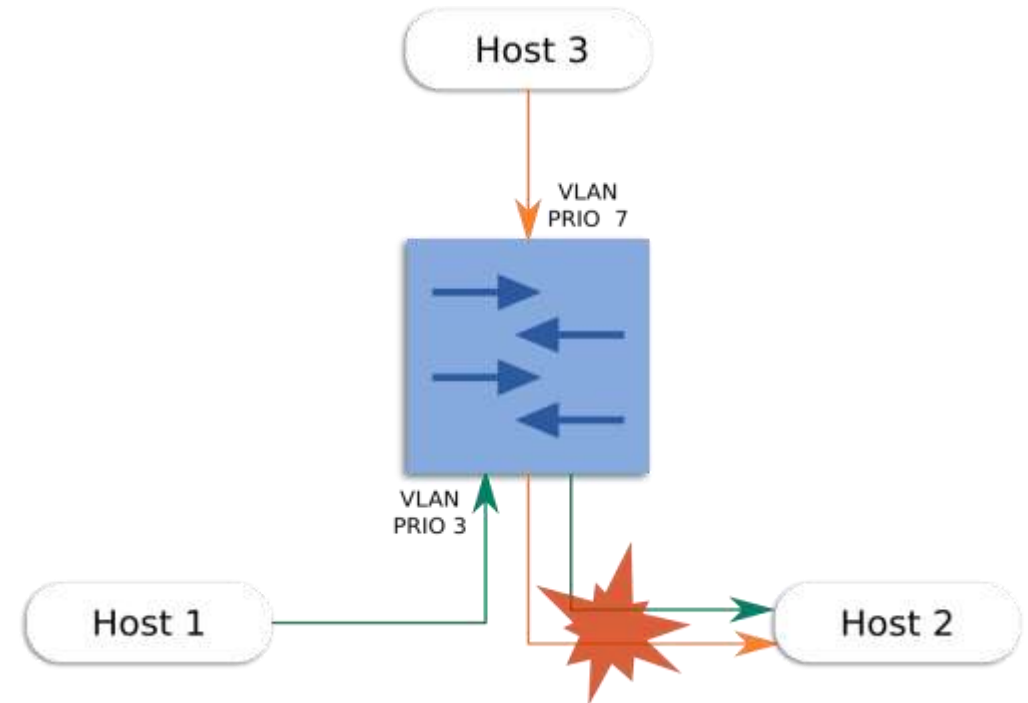
Accuracy within ± 23 nsec

Deterministic Networking



Single Board TSN Demonstration

- 3 host Linux machines connected through a switch
- 2 TCP flows competing for bandwidth
- Flows bottlenecked because they are sharing the same link towards Host 2
- Combined throughput cannot exceed 1000Mbps
- Utilize TSN features to isolate flows
 - *Ingress Policing*: rate-limit traffic coming from Host 3
 - *Time Gating*: schedule the 2 flows on different time slots



Demonstration Setup

LS1012A-FRDM



LS1021ATSN



ubuntu



Standard Ethernet Switch Settings



Standard Switch Settings

Both streams compete for bandwidth

High variation

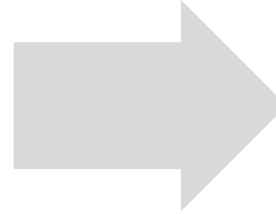
Roughly equal distribution
standard.xml

Start TSN on LS1021A-TSN – Enhance with LS1028A

LS1021A-TSN

TSN Features

- Time Aware Shaper (802.1Qbv)
- Per-Stream Filtering & Policing (802.1Qci)
- Credit Based Shaper (802.1Qav)
- Time Synchronization (802.1AS)



LS1028A

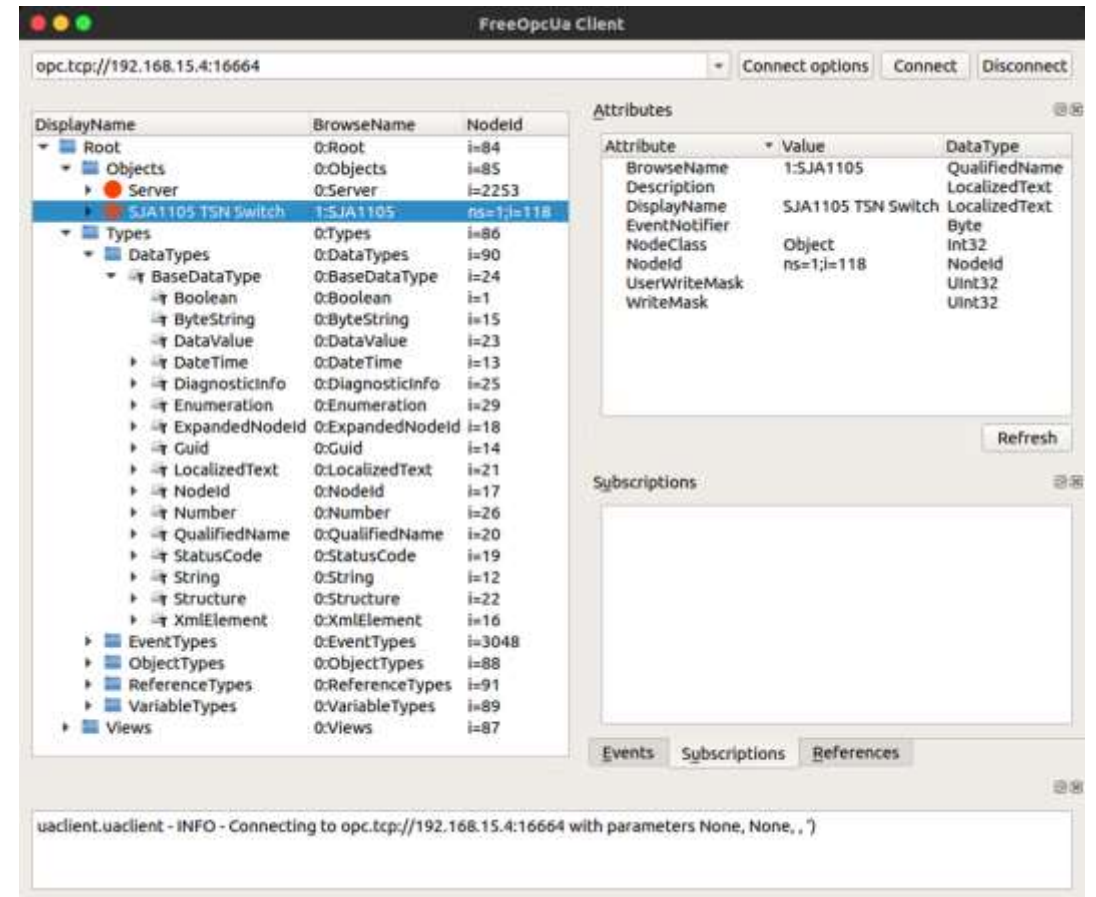
New TSN Features

- Frame Pre-emption (802.1Qbu)
- Frame Replication and Elimination (802.1CB)
- Cut-through Switching
- Cyclic Queuing and Forwarding (802.1Qch)
- 802.1AS-Rev

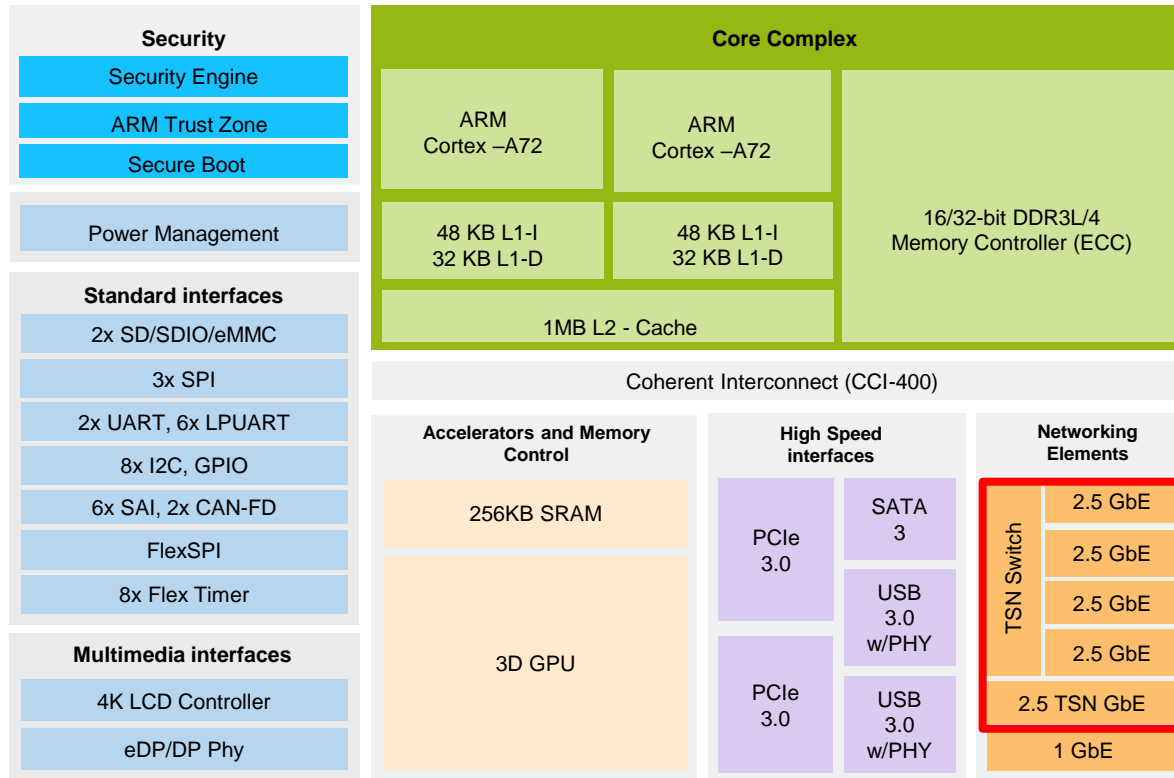
Supported by one SDK – Open Industrial Linux

OPC UA over TSN for Industry 4.0 Communications

- OpenIL integrates with Open62541
 - Open source C implementation of OPC UA
 - Mozilla Public License v2.0
 - server side capabilities
- LS1021A Running OPC UA Server
 - Providing switch statistics
 - Access via FreeOpcUa Client GUI



LS1028A: Dual ARM Cortex A72 Processor



Core Complex

- 2x 64-bit Cortex-A72 with Neon SIMD engine
- Speed up to 1300 MHz
- Parity and ECC protected 48 KB L1 instruction and 32 KB L1 data cache
- 1 MB L2 cache with ECC protection

Basic Peripheral and Interconnect

- 2x USB 3.0 OTG controllers with integrated PHY
- 2x eSDHC controllers supporting SD/SDIO 4.0
- 2x CAN-FD controllers
- 8x UART serial ports

Networking Elements

- Four Port TSN Ethernet Switch up to 2.5 Gbps on each port
- Up to four SGMII supporting 1 Gbps
- Up to one USXGMII supporting 2.5 Gbps
- Up to one QSGMII
- Up to one RGMII
- 2x PCI Express Gen 3 controllers
- 1x SATA Gen 3.0 controller

Accelerators and Memory Control

- 1x 16/32-bit DDR3L/4 Controller with ECC support up to 1.6 GT/s
- Time Sensitive Networking (TSN) Ethernet Switch
- Security Engine (SEC)
- QorIQ Trust architecture: Secure boot, ARM Trust zone and security monitor

Qualification

- Commercial and extended temperature (support for 125C Tj)

Power

- 5W TDP

Target Applications:

- Industrial Control, PLCs, Gateways
- Automotive
- Professional Audio/Video
- IoT Gateways
- Human Machine Interface

Package

- 17x17mm, 0.75mm pitch FC-PBGA

LS1028A Reference Design

Front Panel

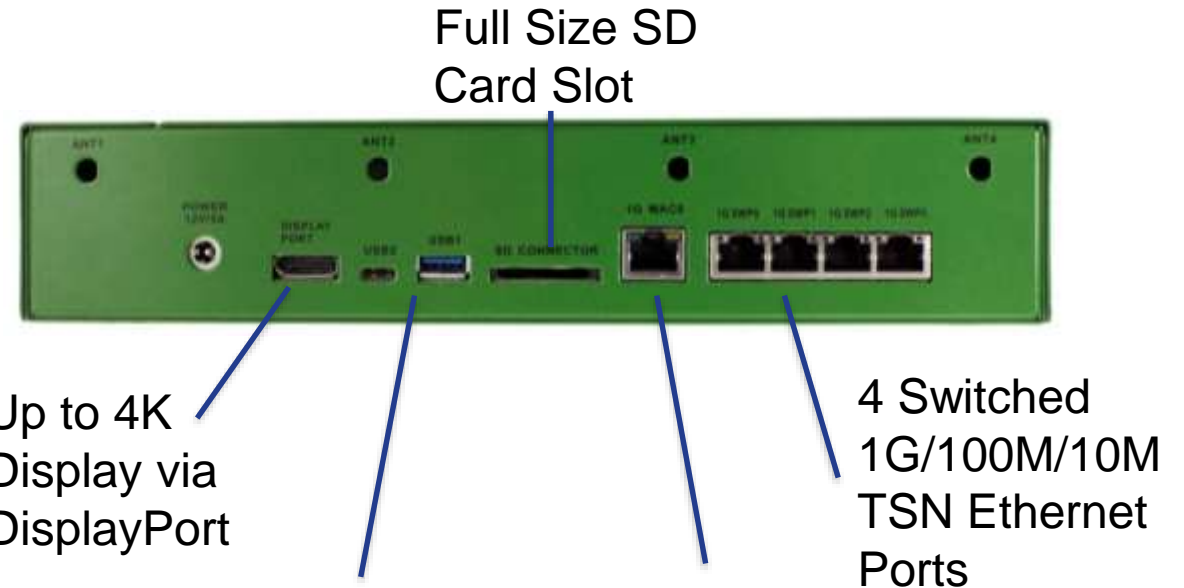


2x CAN FD Interfaces

2x UART

- Internal M.2 PCIe, SATA slots
- 2x mikroBUS™ sockets for Click Boards

Back Panel



Full Size SD
Card Slot

Up to 4K
Display via
DisplayPort

USB 3.0
Type C and Type
A

1G/100M/10M
TSN Ethernet
Controller

4 Switched
1G/100M/10M
TSN Ethernet
Ports

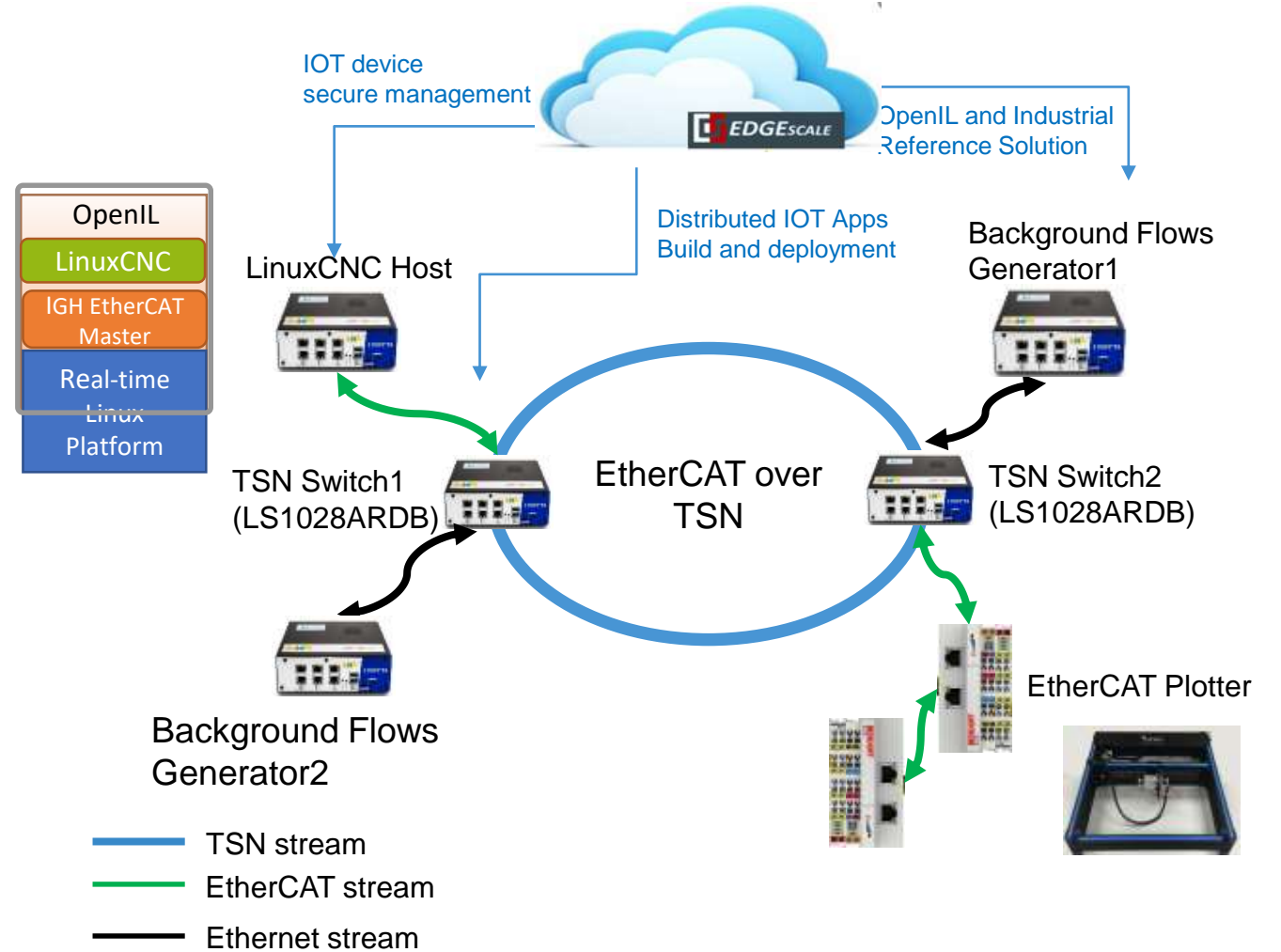
Compelling Combination of IO, Computing and TSN

Industrial Solution



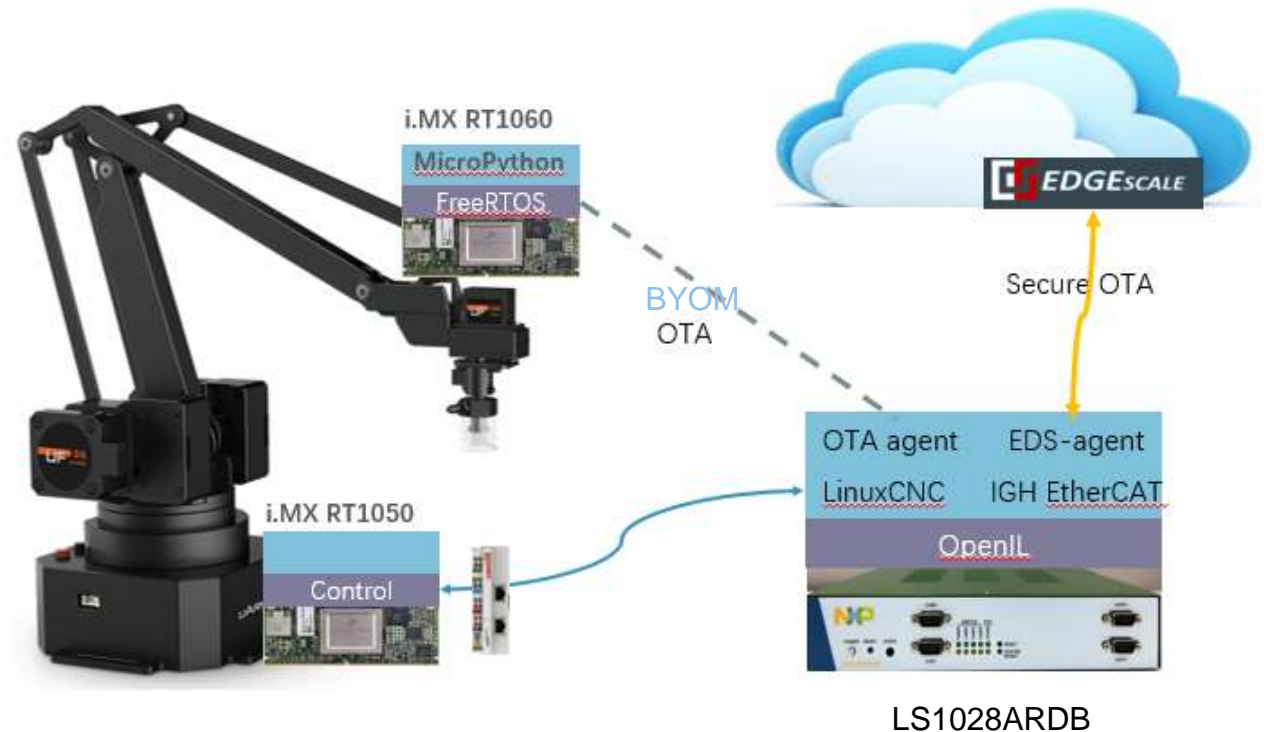
EtherCAT Over TSN

- EtherCAT IGH Master
- Industrial control system based on EtherCAT over TSN
- Real-time Linux system support – Xenomai
- Hard real-time Baremetal framework support
- Different industrial protocols support – TSN, EtherCAT, OPC-UA



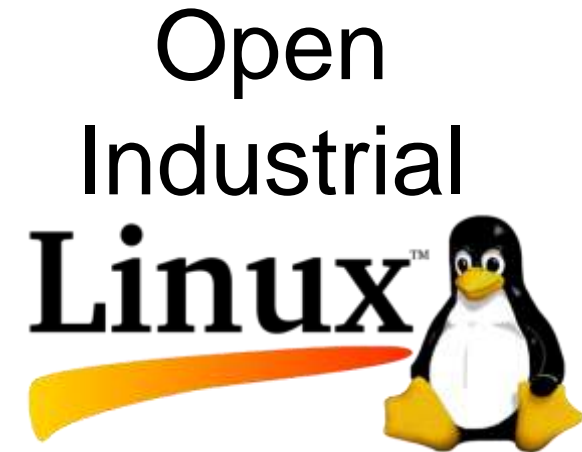
Robot ARM

- Secure OTA with objection detection model
- FreeRTOS and MicroPython dual systems swap
- i.MX RT1050 stepper drive with EtherCAT



Open Industrial Linux Driving Industrial Control

- **Growing Set of Supported Processors**
 - Coverage across Layerscape and i.MX
- **Deterministic Processing**
 - Xenomai Linux
 - Bare Metal Framework
- **Secure Industrial Systems With Root of Trust and SELinux**
- **Synchronized and Deterministic Networking**
 - 1588
 - TSN



References and Additional Information

- [Open Industrial Linux User Guide](#)
- [Open Industrial Linux Bare Metal Framework Developer Guide](#)
- [Application Note: AN3423 – Support for IEEE™ 1588 Protocol in PowerQUICC and QorIQ Processors](#)
- [LS1046A Reference Design Board](#)
- [LS1043A Reference Design Board](#)
- [LS1012A Reference Design Board](#)
- [LS1021ATSN Reference Design Board](#)
- [LS1028A Reference Design Board](#)
- [LS1028A Layerscape SoC with integrated TSN](#)



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FOR A SMARTER WORLD**