AM64x Multi-Core Networking Arm Processors

Supporting Industrial Networking, Real-time Control and Multi-Axis Motor Control on a Single Device

Sitara MPU

July 2024

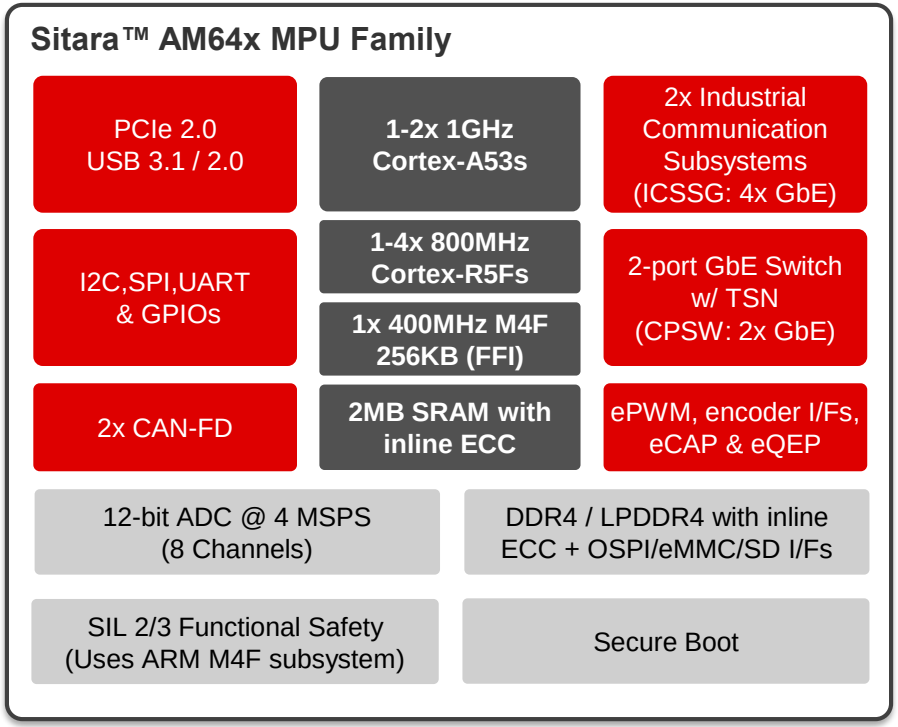
AM64x: Target Markets

- ❑ **FAC Industrial Communication**
- ❑ **Multi-Axis Motor Control**
- ❑ **Power / Grid Infrastructure**
- ❑ **Industrial PC / Gateways**
- ❑ **AM243x applications that want to add Linux support**

PROFINET EtherNet/IP EtherCAT IO-Link TSN Time Sensitive Networking **1Gbps HSR/PRP**

Industry 4.0 Image Credit: "Data.zero"

AM64x: Multi-Core Industrial Networking Arm Processor



Performance

- ❑ Up to two A53 application cores with up to 6.0k DMIPs
- ❑ Up to four R5F real-time cores with up to 6.7k DMIPs
- ❑ Functional Safety & secure boot + run-time security support

Gigabit Industrial Ethernet

- ❑ Up to 5x independent GbE ports
- ❑ Up to 2x 2-port GbE TSN, cut-through switches (2-ext, 1-int port)

2x Industrial Communication Subsystems (ICSSG)

- ❑ Programable real time peripheral connectivity
- ❑ Multi-protocol industrial networking support

PROFINET · EtherNet/IP · EtherCAT · IO-Link · TSN Time Sensitive Networking · 1Gbps HSR/PRP

Motor Control

- ❑ > 3 axis motor control (FOC)
- ❑ Up to 12x multi-protocol position encoders
- ❑ Up to 36x on-chip sigma delta filters for current measurement

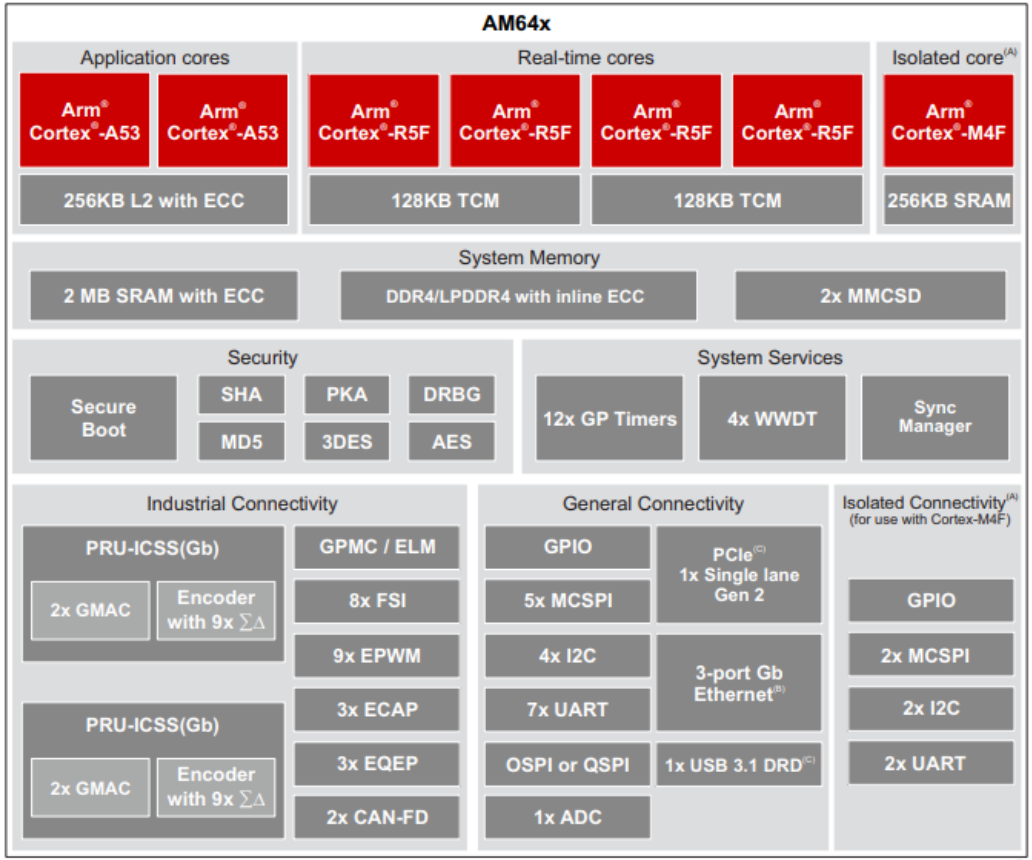
Processing Scalability

- ❑ P2P compatibility with AM243x MCU family (17mm package)

AM64x Cortex®-A53 based processors

** *Released* **

- **Compute Processing Power**
  - 1-2x Cortex-A53 up to 1.0GHz (up to 6K DMIPS), total 256KB L2$
  - 1-4x Cortex-R5 up to 800MHz (up to 6.7KDMIPS)
  - 2x PRU-ICSS-Gb
    - Enables up to 2x Gb industrial Ethernet protocols or 1x industrial Ethernet protocol + motor control current and position feedback
- **Integrated Analog**
  - 8-channel, 12-bit ADC with 4 MSPS
  - Simplified power solution, Integrated Voltage Monitors and SD card LDO
- **Memory IO**
  - 1x 16-bit LP/DDR4-1600, up to 3.2GB/s, inline ECC (2GB max memory)
  - 1x Octal-SPI w/ execution-in-place support, 2x MMC/SD, 1x GPMC (32-bit data)
- **Automotive IO**
  - 2x CAN-FD
- **High Speed IO**
  - 1x USB3.1 Gen 1/2.0 (5Gbps SS)
  - 2-port Gb Ethernet switch (AVB & TSN) (2 ext, 1 int port)
  - Up to 5x Gb Ethernet ports
  - 1x PCIe 1-Lane, Gen2 (Note: PCIe and USB 3.0 share the same SerDes)
- **Safety & Security**
  - SIL-2 device / SIL-3 System with the addition of a safety processor
  - 1x Cortex-M4F (400MHz) MCUSS with Freedom from interference (FFI), dedicated peripherals & 256KB SRAM
  - Diagnostic toolkit (entire SoC), voltage, temp, clock, ECC monitors & error signaling
  - Secure boot, on-chip Crypto accelerators
    - Dedicated Cortex-M3 running at 333MHz with 128KB of SRAM
- **Package**
  - 17.2mm x 17.2mm, 0.8mm ball pitch (Metal Lid)
  - 17.2mm x 17.2mm, 0.8mm ball pitch (Plastic) – Samples in Jan 2025



AM64x Family | Pin-to-pin compatibility

Scalable:

- Multiple A53/R5F core options
- Maintain real-time performance even with Linux services running simultaneously

Industrial:

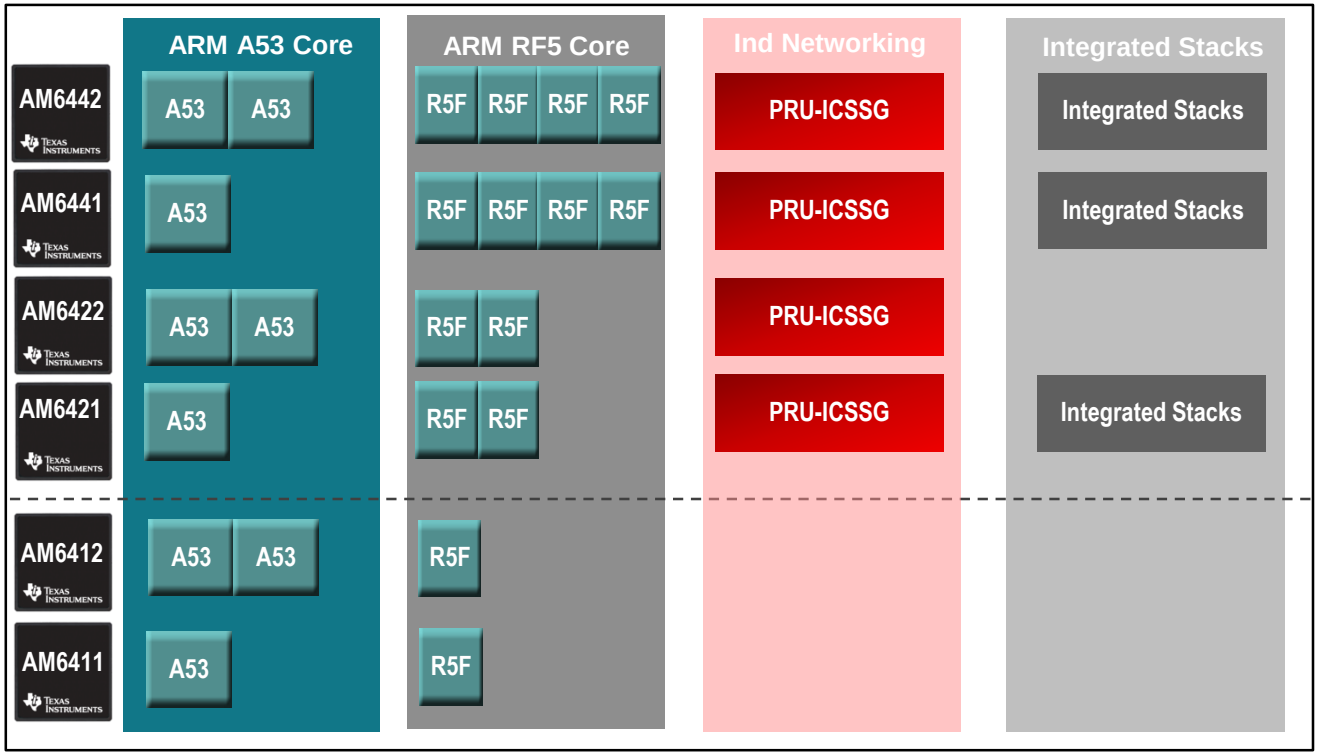
- Rated for -40 to 105C
- Industrial communications support (Profinet, EtherCAT, EtherNet/IP, and IO-Link)
- 100K Power-on-hours @ 105C
- SIL-3 FuSa with additional safety processor

Package Options:

- 17x17mm package (Metal Lid) P2P with the AM243x MCU family
- 17x17mm package (Plastic) (Jan 2025 samples)

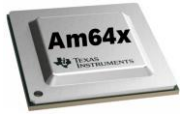
Secure boot and runtime security

Low power consumption (1 to 2W)



Pin-to-pin and Software Compatible Family of Processors

AM64x: Feature / Benefits



Feature	Benefit
Application & real-time processing on a single chip	- Improved performance, reduce board space and lower BOM costs - Up to two **1GHz Cortex-A53** cores with **Linux** SDK support speeds up software development - Up to four **800MHz Cortex-R5F** cores with FreeRTOS SDK support for real-time control loops
Gigabit industrial networking	- **EtherNet/IP, Profinet, EtherCAT, I/O-Link + other stack support** - Programable ICSSGs support evolving standards as well as legacy / custom protocols. - Hardwired 2-port Gigabit Ethernet switch (2 ext + 1 int port) with **cut-through and TSN support** - Up to **5x Ethernet ports** when using the on-chip switch and both ICSSG subsystems
Programmable real-time I/Os	- 2x on-chip ICSSGs support up to 80 real-time GPIOs with **3ns GPIO Toggles & 6ns ISR.** - Direct connect high-speed / high-precision ADCs and other devices **eliminating the need for an FPGA** - Support evolving Motor Encoder I/Fs (Hiperface DSL, EnDat 2.2, IBISS, Tamagawa, + others)
Robust connectivity options	- **Gigabit Ethernet, PCIe 2.0 & USB 3.1**, CAN-FD, SPI, UART, I2C, and position encoder I/Fs - Parallel NOR/NAND, SDIO Card and eMMC Flash interfaces; GPMC interface to system FPGAs
Functional Safety support	- Supports customer's system designs up **to SIL 3**. (IC targeting SIL 2)
Enhanced Security features	- On chip security subsystem supports **secure boot & run-time security**, firewalling of memory, eFuse key storage, crypto accelerators and other security features.
Low power consumption	- Enables smaller PCB design & reduced overall power consumption ranging from **1 to 2W**.

A53 Example Applications (AM64x)

Cortex-A53 (10 to > 100us control loops)	**Linux applications**	*Leverage the extensive Linux software eco system and large number of Linux programmers to speed up and simplify software development.*
	Secure remote configuration & management	*Web server application for remote configuration and management. Linux security is robust / well supported.*
	OPC UA secure management	*OPC UA supports "connecting" factory floor devices to factory floor management (i.e. SCADA/HMI) or cloud based management services. OPC UA is a platform/vendor independent client-server protocol which enables the IT world to talk to the OT world.*
	Network protocol stacks in Linux	*Depending on the specific function or application, it may be easier to support in Linux vs. RTOS. (i.e. TSN Netconf)*
	Industrial Ethernet device & controller	*Device protocols can run on the R5F, but Controller protocols are more common & easier to implement in Linux*
	Motion path / profile commands	*Support simple motion profile / path calculations in Linux (x86 is high end; Jacinto is mid-end)*
	PLC ladder logic	*CPU (PLC Controller) could run on the R5F (micro-PLC) or A53; the more computation required, the better suited for an A53. I.E. Codesys PLC (IEC 61131-3)*
	General management / house keeping	*Monitor voltages, system/ASIC/FPGA configurations, etc.*

R5F Example Applications (AM243x / AM64x)

Cortex-R5F (<= 1us control loops)	**Industrial Ethernet slave protocols**	*TI or 3rd Party Profinet RT/IRT, EtherCAT, EtherNet IP, I/O Link, + others*
	Motor control	*Up to 3 axis motor control (Torque / FOC control loo); Speed & Position control loops*
	Real-time control loops	*RTOS or bare metal support for real-time control loops with ≤ 1us timing requirements*
	Drive control interface & FuSa applications	*Profidrive, CiA402, CIP Motion, CIP-Safety (both EtherNET IP), ProfiSafe, FSoEtherCAT (FSoE), etc.*
	PLC ladder logic program output file	*Could run in R5F (micro-PLC) or A53; the more computation required, the better suited for an A53*
	Real-time sensing measurements	*Voltage sensing for GRID/Power, Test and Measurement (Temp/Pressure, etc)*
	Predictive Motor Maintenance	*Run real-time predictive maintenance algorithms to eliminate sensors / lower system cost*

AM64x: Low Power Consumption

AM6441 example application:

- Secure webserver + predictive maintenance
  - Running on the Arm Cortex A53
- 3 axis FOC motor control
  - Running on the Cortex R5Fs cores (1 per axis)
  - Position Encoders / Delta Sigma filters on ICSSG1
- EtherCAT Industrial communications
  - Running on one Cortex R5F core & ICSSG0.
- Functional Safety
  - Cortex M4F supporting SIL 2/3

Worst Case Power Consumption
< 1.5 Watts @ 105C Junction

Power Calculation Details *Power Calc Link*

Operating Performance Point (OPP)		Processor Core Utilization (%)	
MPU A530/1 Frequency (MHz)	1000	MPU-A530	80%
MCU R5F0/1 Frequency (MHz)	800	MPU-A531	0%
MCU R5F2/3 Frequency (MHz)	800	MCU-R5F0	80%
MCU M4F Frequency (MHz)	400	MCU-R5F1	80%
ICSSG Frequency (MHz)	333	MCU-R5F2	80%
		MCU-R5F3	61%
		MCU-M4F	50%
		PRU-ICSSG0	50%
		PRU-ICSSG1	50%
		Security Accelerator	0%

LVCMOS IO	Mode	IO Utilization (%)	Peripherals	Mode	Utilization (%)
MCU UART	112kbps	10%	DDR Type/Rate	LPDDR4 1066	25%
MCU UART	112kbps	10%	DDR WR %	50%	-
MCU SPI	Slave, 12.5Mbd	5%	High Speed IO	Off	0%
MCU SPI	Slave, 12.5Mbd	5%	USB2	1.8V on	0%
ICSSG0	Dual Port RGMII 1Gbps	50%	SD card	HS200	5%
ICSSG1	Single Port MII 100Mbps	50%	eMMC	HS200	5%
Ethernet (CPSW) Port 0	RGMII 100Mbps	10%	ADC	on	-
OSPI	OSPI DDR 160Mbd	0%			
GPMC	GPMC 16b 125 MHz	0%			

Estimated Power				General	
	Power Supply	Voltage (V)	Power (W)	Junction Temperature (°C)	105
	VDD_CORE	0.75	1.080	Power Estimation Mode	Max
	VDDAR_CORE	0.85	0.097		
	VDDA_1V8	1.8	0.063		
	VDD_DDR4 (without DIMM)	1.1	0.082		
	SOC_DVDD1V8	1.8	0.050		
	SoC_DVDD3V3	3.3	0.110		
	Total		1.481		

Power Estimate @ 105C Junction

Industrial Communication Software Engagement Models

Buy Direct from TI	Buy from Third-party
Fully bundled solution directly from TI	Stacks licensed from third parties
One license for all TI-offered stacks	Separate license per protocol
Licensing included with device	Licenses available as buyout, per project, and per family
Stack support directly from TI	Stack support from third party
Pre-certified solutions	Pre-certified solutions

TI provides the total solution for industrial protocols:
Easy engagement starting with Sitara AM243x and AM64x families

AM243/AM64x: Certified Stacks from TI

Protocol	Certified	Min. Cycle Time	Conformance Test /Certification	Key features supported
EtherCAT (Device/client)	Yes	31.25 us	2.5.0	CiA402, CAN over EtherCAT (CoE), Servo Drive Profile (SoE), Ethernet over EtherCAT (EoE), File Access over EtherCAT (FoE),Distributed Clocks
EtherNet/IP (Device/client)	Yes	1 ms	20.1	Address Conflict Detection (ACD), Quality of Service (QoS), Device Level Ring (DLR), Precision Time Protocol (PTP)
PROFINET (Device/client)	2H24 Certification	1 ms (RT) 250 us (IRT)	2.44.1	Conformance Class A, B (RT), and C (IRT), Precision Time Control Protocol (PTCP), Media Redundancy Protocol (MRP)
IO-Link (Controller/Host)	Yes	All communication classes supported	1.1.3	Up to 8 channel IO Link Master per ICSS, IO-Link standard-compliant with Standardized Master Interface (SMI)

Detailed feature set for each protocol available in the Industrial Communications Toolkit
Release datasheets EtherNet/IP EtherCAT PROFINET IO Link

AM64/AM243x: Industrial Communications support

Master/Controller		Acontis	Codesys	IBV	IGH	Molex	Port
CC-Link	Linux		--	--	--	--	Yes (Proof of Concept)
EtherCAT	Linux	Yes (Native Driver)	Yes	Yes (Native Driver)	Yes (Native Drive)	--	--
	RTOS	Yes	--	Yes	--	--	--
EtherNet/IP	Linux	--	Yes	--	--	Yes	--
	RTOS	--	--	--	--	Yes	--
PROFINET	Linux	--	RT	--	--	CC-A/B v2.44	--
	RTOS	--	--	--	--	CC-A/B v2.44	--

Slave/Device		TI	Beckhoff	Codesys	Molex	PORT	TMG
EtherCAT	Linux		--	--	--	--	--
	RTOS	Yes	Yes	--	--	--	Yes
EtherNet/IP	Linux	--	--	Yes	Yes	--	
	RTOS	Yes	--	--	Yes	--	Yes
ProfiBus	Linux	--	--	--	--	--	
	RTOS	--	--	--	--	--	Yes
PROFINET	Linux	--	--	RT	CC-A/B/C v2.44	RT	--
	RTOS	Yes	--	--	CC-A/B/C v2.44	CC-A/B/C v2.43	CC-A/B/C v2.44

Linux = A53 Core
RTOS = R5F Core

How do I get started?

AM64 Starter Kit ($129)
Low cost option with wireless support

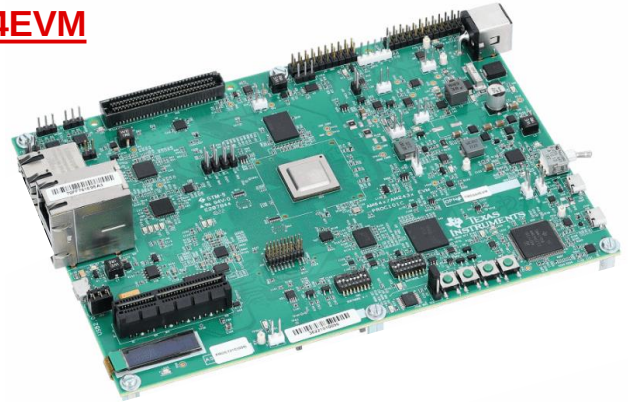
SK-AM64B

Best for:

- Linux code development
- 2-port Gigabit Ethernet with TSN support
- USB 3.0 + wireless connectivity (both hotspot and endpoint)
- Industrial communication Controller support

AM64 Development Platform ($299)
***Industrial comms** support + expansion port*

TMDS64EVM



Best for:

- Linux and MCU+ SDK code development
- 3-port Gigabit Ethernet with TSN support
- PCIe support / Secure Boot / key-programming
- Industrial communication Device & Controller support
- HSE (high speed extension) connector for advanced HW development.

AM64x: Getting Started Design-in Resources

Tool	Link
AM64x SDK	https://www.ti.com/tool/PROCESSOR-SDK-AM64X
Linux SDKs release notes	AM64x Linux Release Notes (9.2) AM64x Linux RT Release Notes (9.2)
AM64x MCU+ SDK 9.0	AM64x MCU+ SDK 9.1
Industrial communications SDK	AM64x Industrial Communications SDK (9.1)
Linux Academy	Linux Academy for AM64x
Power estimation calc	https://www.ti.com/lit/zip/sprm779
Board design app notes	High Speed Interface Layout Guidelines Hardware Design Guide for AM64x Devices AM64x Schematic Checklist AM64x/AM243x BGA Escape Routing (17m package)
Pin mux / pin out configuration tool	https://www.ti.com/tool/SYSCONFIG
PRU feature set app note	PRU Subsystem Features and Comparison
Functional safety documentation	Available under NDA on the My Secure server (Includes Safe Torque Off Safety Function White Paper)
Security documentation	Available under NDA on the My Secure server
Performance benchmarks app note	Sitara AM64x Benchmarks

AM64x: Getting Started Design-in Resources

Tool	Link
Servo Motor Control on AM64x App note	AM64x Single Chip Servo Motor Control Implementation and Benchmark
Single Pair Ethernet + AM64x Reference design	Four-port single-pair Ethernet with power over data line reference design

AM64x Videos	**Link to all AM64x Videos:**
	• AM64x Videos
	AM64x Individual Videos:
	• Building cloud-connected industrial machines
	• Inter-Processor Communication (IPC) for AM64x processors
	• Codesys PLC Controller on AM64x
	• Foundries Factory AM64x cloud-based Linux development
	• Wired and Wireless Networking on the AM64x
	• TSN using Linux on the AM64x
	• Sitara SK-AM64-out-of-box demo
	  • *Video covers wired and wireless Linux Networking*
	  • *Latest EVM revision is the SK-AM64B*

Industrial Communication Support App Note	Industrial Communication Protocols Supported on Sitara™ Processors and MCUs
TPS65220 vs TPS65219 PMIC App note	Powering the AM64x with the TPS65220 or RPS65219 PMIC
Industrial Comms including TSN and HSR	Industrial Communication Protocol Support for Arm®-based Microcontrollers and Processors
Functional Safety White Paper	Functional Safety Support for Arm®-based Microcontrollers and Processors

Processor HW Ecosystem | AM64x

PhyGate – IBV Joint – IOT Gateway

3P Vendor	Form Factor	Location	Details
PHYTEC	HDI Connectors	Germany	Available NOW (Link) phyCORE-AM64x/AM243x p2p compatible
SolidRun	HDI Connectors	Israel	Available NOW (Link) Pre-order DevKit, Cellular + Sub1G optional
TQ	LGA	Germany	Available NOW (Link) TQMa64xxL / TQMa243xL p2p compatible
Tronlong®	HDI Connectors	China	Prototypes available NOW (Link) SOM-TL64x
beacon EmbeddedWorks	HDI Connectors	U.S.	TBD
beagleboard.org	SBC	U.S.	BeagleBone Blue 64-bit, schedule TBD

PHYTEC **phyCORE-AM64x**

SolidRun **Hummingboard-T**

TQ **TQMa64xxL**

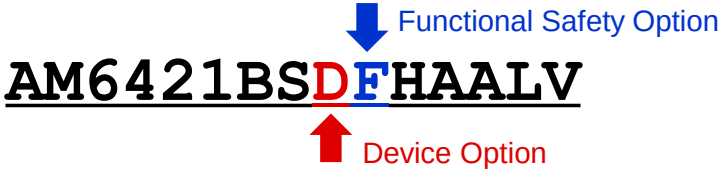
Tronlong **SOM-TL64x**

AM64x Family Device Options

Device Options	AM6442	AM6422	Low Cost PCIe Option AM6412*	AM6441	AM6421	Low Cost PCIe Option AM6411*
A53 Cores @ 1GHz	Dual 256KB L2	Dual 256KB L2	Dual 256KB L2	Single 256KB L2	Single 256KB L2	Single 256KB L2
R5F Cores @ 800MHz	Quad 256KB TCM	Dual 256KB TCM	Single 128KB TCM	Quad 256KB TCM	Dual 256KB TCM	Single 128KB TCM
M4F Cores @ 400MHz (256KB)	MF4 with FFI	MF4 with FFI	M4F	MF4 with FFI	MF4 with FFI	M4F
12-bit, 8-Channel, 4 MSPS ADC	Yes	Yes	No	Yes	Yes	No
Functional Safety *(SIL 2 device / SIL 3 system)*	Yes	Yes	No	Yes	Yes	No
ICSSG Industrial Communication Support *(4x 10/100/1000 Gigabit Ethernet MAC's with MII/RGMII, 36x ΣΔ decimation filters, & 12x multi-protocol encoder I/Fs)*	Yes	Yes	No	Yes	Yes	No
Industrial Communication Software Stacks (Profinet, EtherCAT, EtherNet/IP, & I/O Link)	Yes	No	No	Yes	Yes	No
Dual CAN-FD	Yes	No	No	Yes	Yes	No
1K Price	$18.39 - $12.59	$12.18 - $11.12	$8.80 - $8.03	$17.34 - $11.85	$15.24 - $10.38	$7.99 - $7.30

** AM6412 and AM6411 have lower speed options for the A53, R5F, and PRU-ICSSG processors*

AM243/64x Device Options



Device Option	Feature	Comment
C	Two Programmable Real-Time Unit Subsystems	Up to 80 real-time GPIOs with 3ns toggles and 6ns ISR. Direct connect high-speed / high-precision ADCs and other devices eliminating the need for small FPGAs. The ICSSG industrial communication features are not supported but the 2-port CPSW Ethernet switch/dual MAC is enabled and supports TSN
D	Option C + Industrial Communication Support	Device option D adds support for the ICSSG industrial communication features including up to 4x ICSSG 10/100/1000 Ethernet MACs (MII/RGMII), 36x sigma delta decimation filters, and 12x multi-protocol encoders I/Fs (HDSL, EnDat 2.2, Tamagawa etc. support). Supports HSR / PRP
E	Option D + EtherCAT and CAN-FD Support	Adds EtherCAT Device hardware accelerator and CAN-FD support. (CAN-FD and EtherCAT Device licenses are included). Option E or F is required to run the EtherCAT Device protocol.
F	Option E + Integrated Industrial Communication stacks	Includes EtherNet/IP, EtherCAT, Profinet RT/IRT, and IO-Link certified industrial networking software stacks (R5F binaries) powered by KUNBUS

Functional Safety	Feature	Comment
G	Non-Functional Safety Support	
F	Functional Safety Support	Device targeting SIL 2 / System Level SIL 3 with external safety processor

* *Standard CAN is supported on all device options*