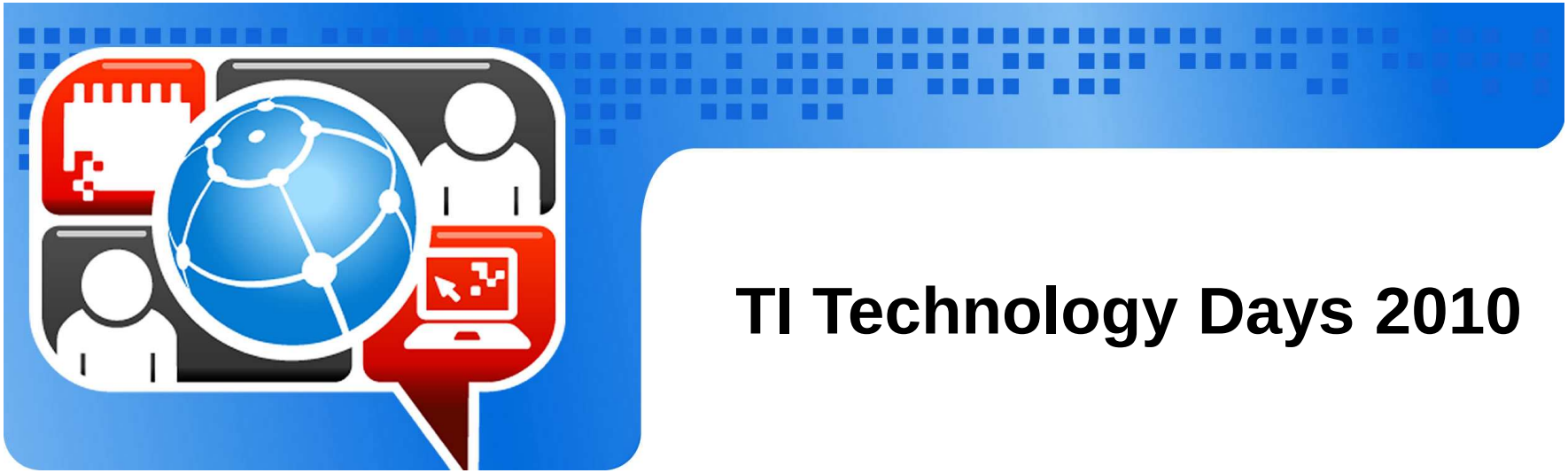


TI Technology Days 2010

Low-power Embedded Processing Solutions for Industrial Automation

Frank Walzer

System Engineer - Industrial Automation Lab

Agenda

- Embedded Processing Portfolio
- Industrial Automation Architecture
- Industrial Communication
- Programmable Logic Control
- Human Machine Interface
- TI Solutions - Roadmap

Problem Definition

- Common challenges in electronic industry
  - Smaller
  - Cheaper
  - Reduce power consumption
  - Shorter time-to-market
- Industrial Automation specific
  - Wide operating conditions
  - Long-term availability
  - Deterministic and safe
  - Special standards and features

Embedded processing portfolio

TI Embedded Processors

Microcontrollers (MCUs)			ARM®-Based Processors	Digital Signal Processors (DSPs)		
16-bit ultra-low power MCUs	32-bit real-time MCUs	32-bit ARM Cortex™-M3 MCUs	ARM Cortex-A8 & ARM9™ MPUs	DSP DSP+ARM	Multi-core DSP	Ultra Low power DSP
MSP430™	**C2000™ Delfino™ Piccolo™**	**Stellaris®** ARM Cortex-M3	**Sitara™** ARM Cortex-A8 & ARM9	**C6000™ DaVinci™** video processors **OMAP™**	**C6000™**	**C5000™**
Up to 25 MHz	40MHz to 300 MHz	Up to 100 MHz	375MHz to >1GHz	300MHz to >1Ghz +Accelerator	24,000 MMACS	Up to 300 MHz +Accelerator
Flash 1 KB to 256 KB	Flash, RAM 16 KB to 512 KB	Flash 8 KB to 256 KB	Cache, RAM, ROM	Cache RAM, ROM	Cache RAM, ROM	Up to 320KB RAM Up to 128KB ROM
Analog I/O, ADC LCD, USB, RF	PWM, ADC, CAN, SPI, I^2C	USB, ENET MAC+PHY CAN, ADC, PWM, SPI	USB, CAN, SATA, SPI, PCIe, EMAC	USB, ENET, PCIe, SATA, SPI	SRIO, EMAC DMA, PCIe	USB, ADC McBSP, SPI, I^2C
Measurement, Sensing, General Purpose	Motor Control, Digital Power, Lighting, Ren. Energy	Connectivity,Security, Motion Control, HMI, Industrial Automation	Industrial automation, POS & portable data terminals	Floating/Fixed Point Video, Audio, Voice, Security, Conferencing	Telecom test & meas, media gateways, base stations	Audio, Voice Medical, Biometrics
$0.25 to $9.00	$1.50 to $20.00	$1.00 to $8.00	$5.00 to $25.00	$5.00 to $200.00	$40.00 to $200.00	$3.00 to $10.00

Texas Instruments

Sitara™ ARM® microprocessors

Available Now

ARM9™

AM1808
AM1806
AM1707
AM1705

Low Power ARM9 with flexible peripherals

- Power efficient (down to 7mW standby, 182mW active)
- User configurable interfaces through the programmable real-time unit (PRU)
- Integrated peripherals, 10/100 Ethensrnet, USB, SATA, CAN, UART and many others

ARM Cortex™-A8

AM3715
AM3703
AM3517
AM3505
OMAP3515
OMAP3503

High-performance Cortex-A8 with system integration

- Up to 1GHz (2000 DMIPS)
- Power efficient (down to 12mW standby, 1W active)
- Integrated graphics for rich user interface functions
- Integrated interfaces to display, USB, 10/100 Ethernet, SD card, Wi-Fi®, CAN, and many others

In Development

ARM Cortex-A8

"AM38x Next" (2011)
"AM33x Next" (2011)

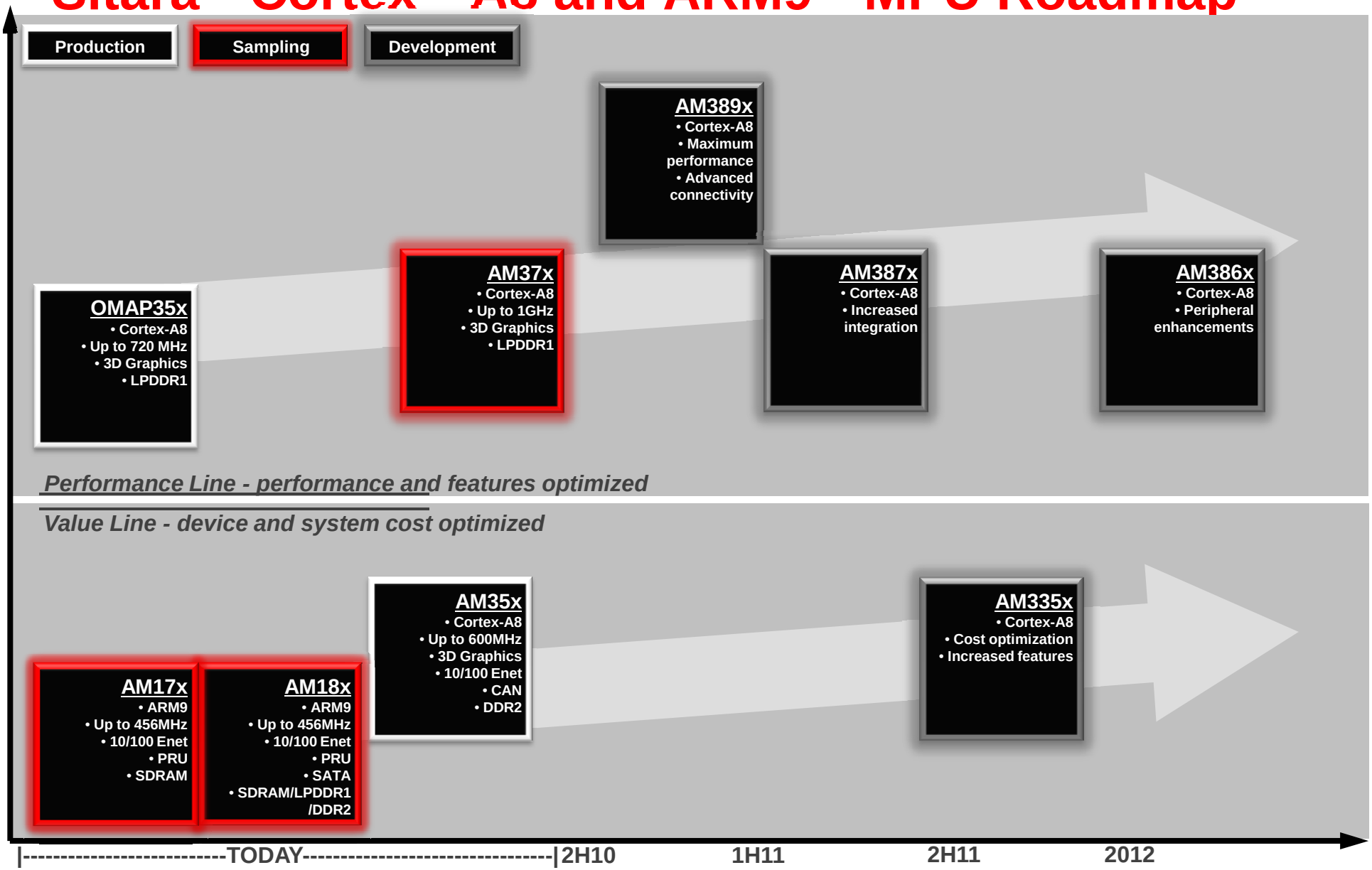
Advanced Cortex-A8 with performance and value options

- Greater than 1GHz core performance
- 1080p display support
- Enhanced graphics for superior user interface functions
- Peripheral integration of 1Gb Ethernet, PCIe, and many others

Support for Linux, Windows® Embedded CE, Android, & RTOS

Texas Instruments

Sitara™ Cortex™-A8 and ARM9™ MPU Roadmap



Speeds shown are for commercial temperature. Dates approximate initial samples. Not all peripherals shown. Limitations apply among package and pin muxing.

Texas Instruments

AM3517/05 Core and Accelerators

Features

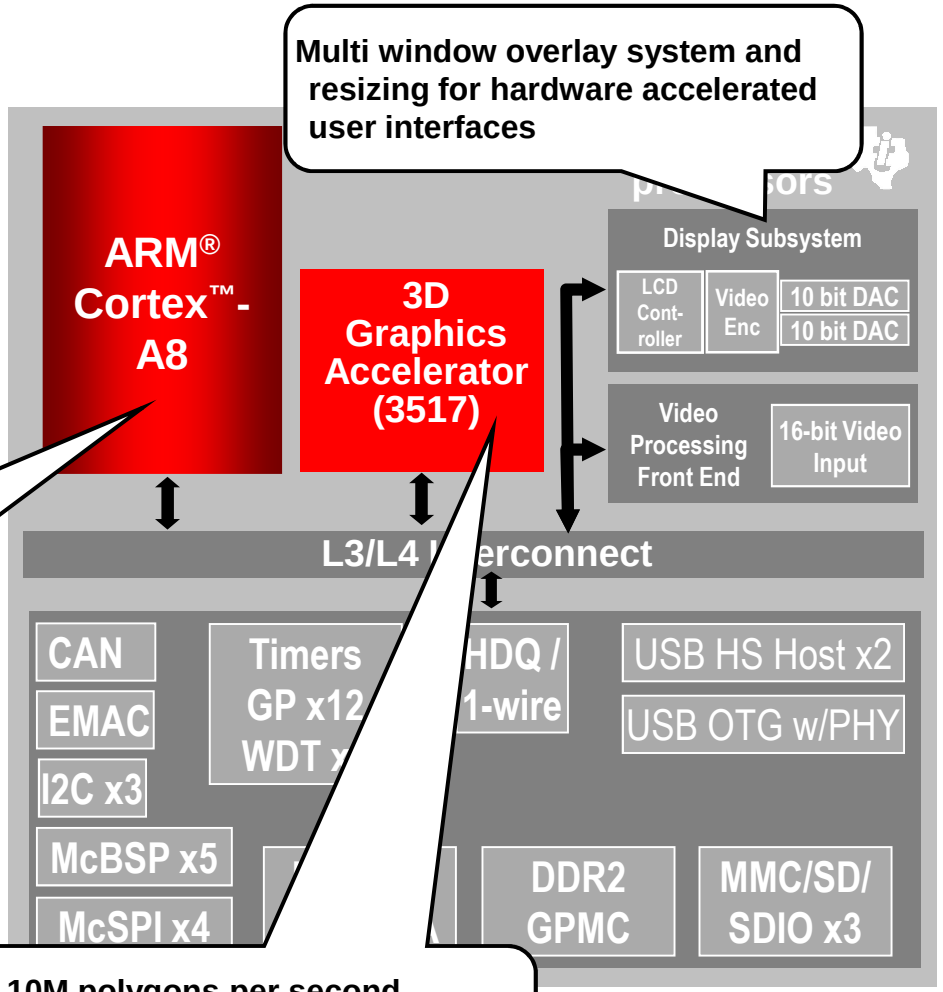
Cores

- 500 MHz Cortex A-8 with NEON™ Coprocessor
- 3D Graphics Engine – up to 10 polygons / second

Up to 1000 Dhrystone MIPS:
- OS's like Linux or WinCE
- Excellent web experience

Memory

- ARM:
  - 16 kB I-Cache; 16 kB D-Cache; 256kB L2 Cache
- On Chip: 64kB SRAM; 128kB ROM
- DDR2 interface
- GPMC: NAND/NOR
- interfaces

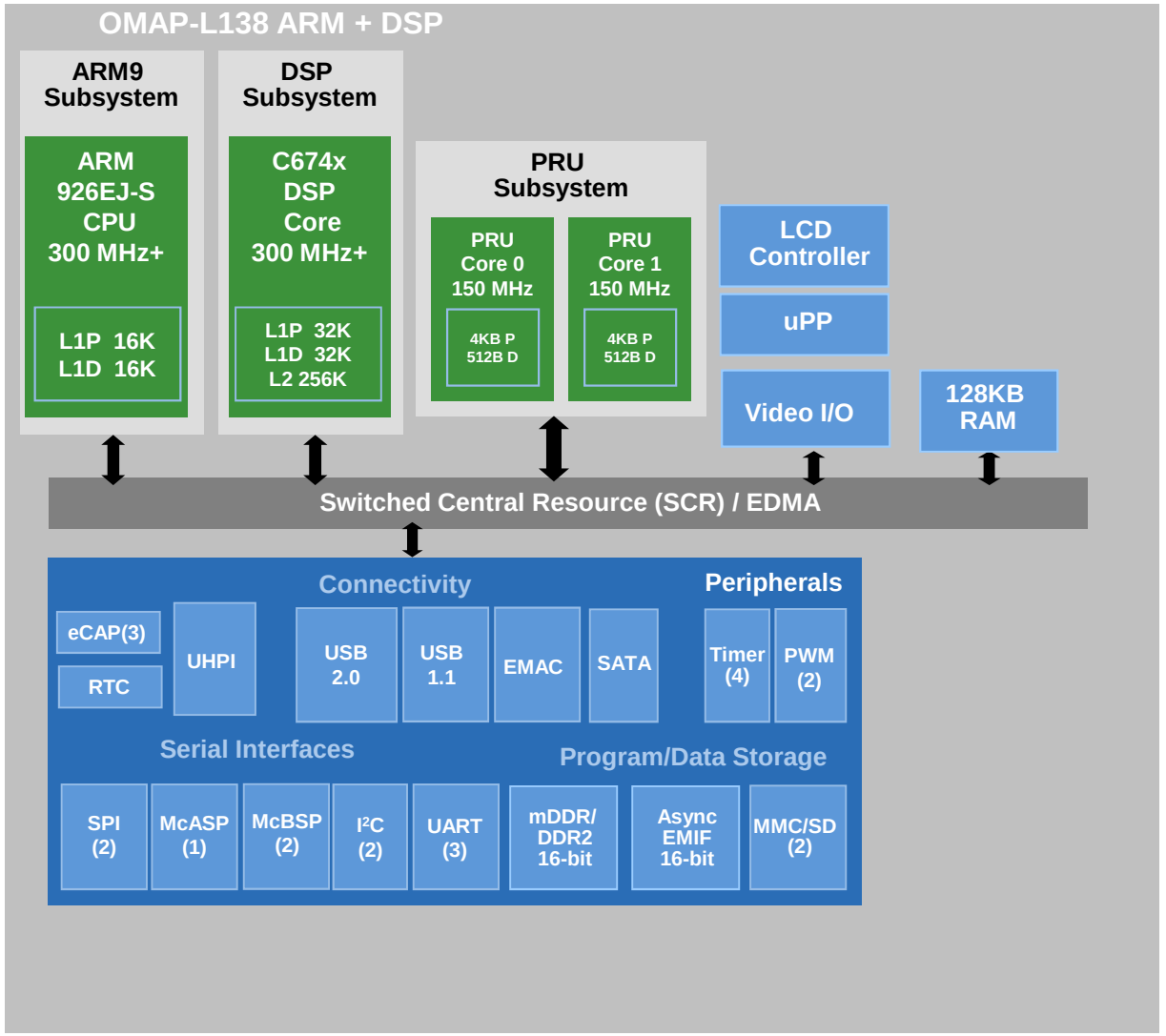


OMAP-L138 (ARM9 + C674x DSP)

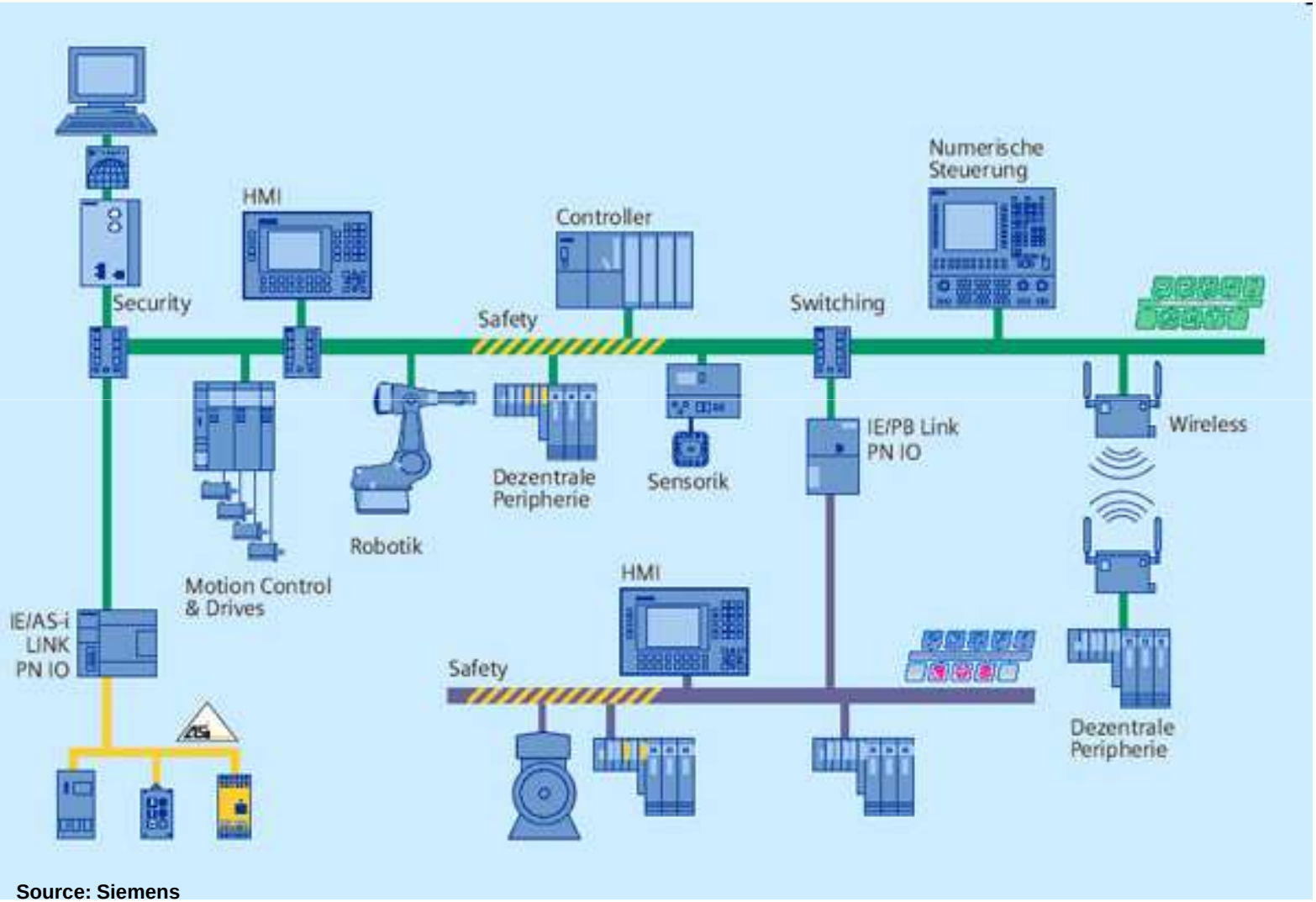
- CPU Cores
  - ARM926EJ-S™ (MPU) 300MHz+
  - C674x DSP Core 300MHz+
  - 2 PRU Cores upto 150 MHz each
- Peripherals (1.8/ 3.3V IOs)
  - 10/100 Ethernet MAC
  - EMIFA - SDRAM/NAND Flash
  - EMIFB – DDR (mDDR/DDR2)
  - Video Port I/F, SATA, uPP, LCDC
- Power (1.0-1.2V Core, 1.8/3.3V IOs)
  - Total Power < 440 mW @ 300Mhz, 1.2V, 25C

    For DSP at 70% loading, ARM at 50% loading; mDDR 50% active at 135MHz
  - Standby Power

    < 9mW @ 1.2V/ 25C
- Package
  - 13 x13mm nFBGA (0.65mm), 16x16mm BGA (0.8mm)
  - Pin to pin compatible with C6748/6/2, AM1808/6
- Applications
  - Power Protection Systems, Test & Measurement, SDR, Bar Code Scanners, Portable Communications, Portable Medical, Portable Audio

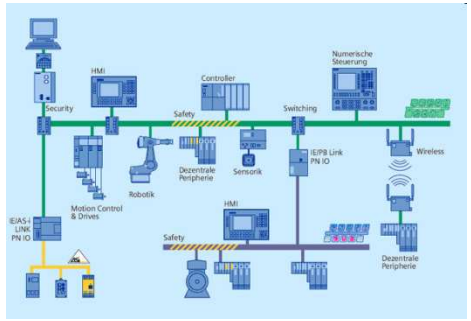


Industrial Automation Architecture

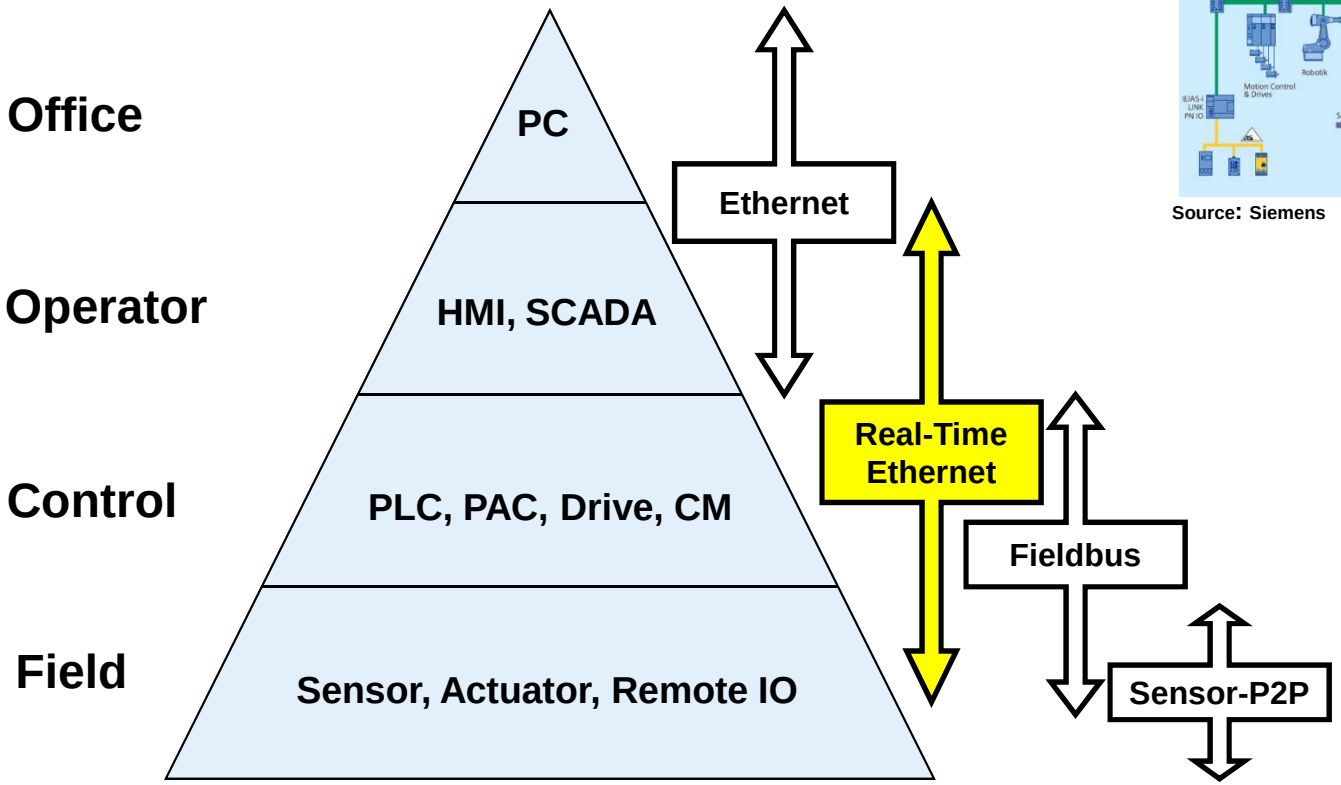


Source: Siemens

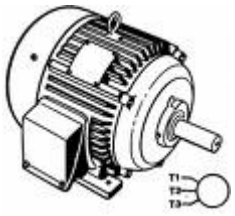
Industrial Automation Pyramid



Source: Siemens



Programmable Automation Controller



IGBT drivers

Isolated Current Measurem.

OMAP L137

Motion Control
C674x DSP
3x ePWM
2x eQEP
3x eCAP
Isolated current

HMI / Monitor
LCD Controller
Touchscreen
GPIOs

Safety

Application - softPLC
ARM9
L1P/D 16k/16k
MMU
128K RAM

Communication
Profibus
RT Ethernet
Master (Ethercat)
GSM Interface
CAN i/f
RS485

Profibus RS485

RTE Slave ASIC

CAN transceiver

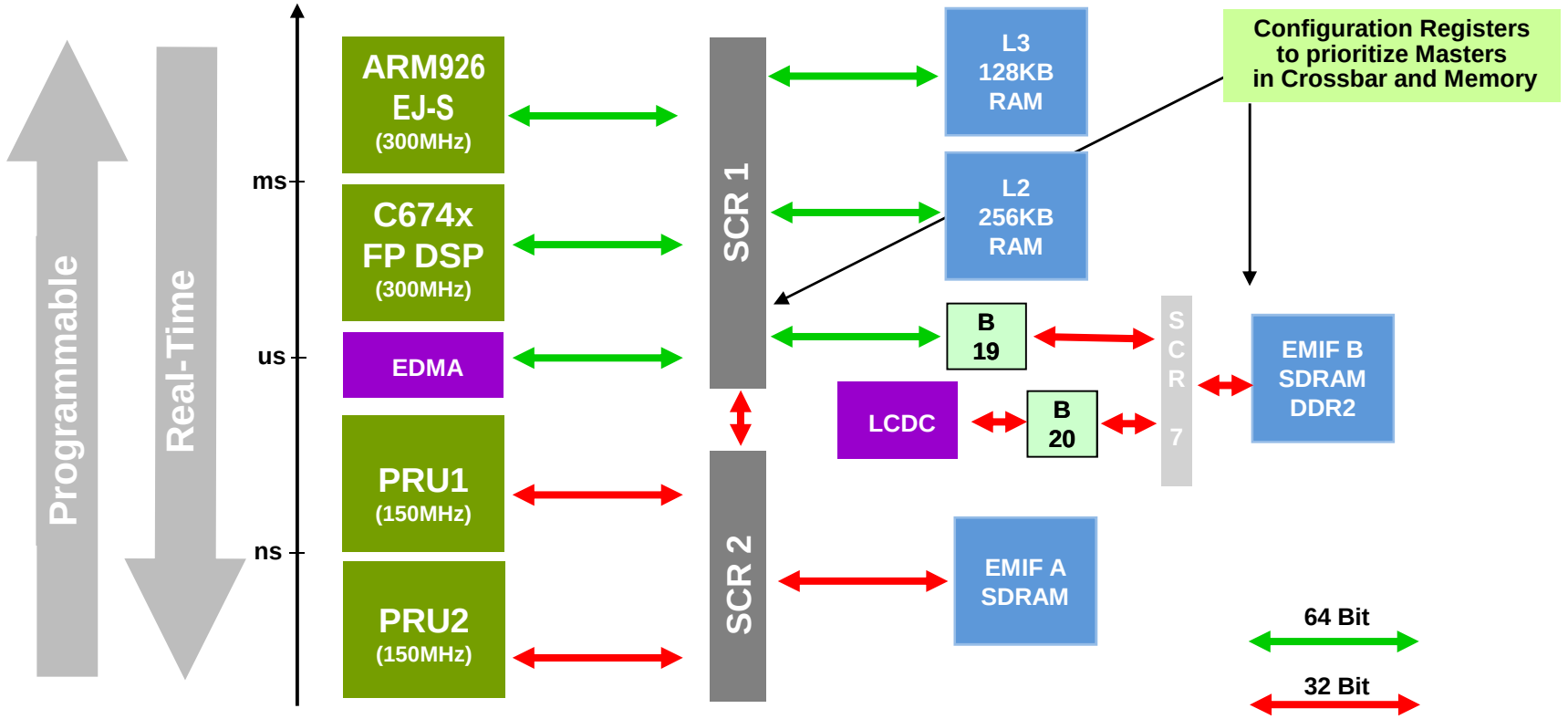
GSM Module

CoDeSys:
IEC 61131-3
softPLC
softMotion
Visualization

RT LINUX
2.6.31+

Standards:
IEC 61131-3
IEC 61508
RT-Ethernet

OMAP L1 Multi-Core Architecture



"Multi-Issue" Switched Central Resource 1 has 12x4 crossbar with 64 bit path at 150MHz.

With concurrent operation of up to 4 slaves the peak throughput is 4,8 GB/s!

OMAP L1 vs x86

Core SoC	ARM926 OMAP L1	C674x OMAP L1	PRU1 OMAP L1	PRU2 OMAP L1	x86 + "Northbridge"
MHZ	300	300	150	150	1600
Cache, Local Memory	16k I, 16k D, 8K RAM, 64 K ROM	32 k I, 32 k D 256k L2 1M L2 ROM	4K I, 512 D	4k I, 512 D	24k I, 32k D 512k L2
Multiscalar	1	8, 2.4 GMAC, 1.8 GFLOPS	1	1	2 HT SSE3
Pipeline	5	13	0	0	16
Interconnect	"multi issue" SCR1 4,8 GB/s		"single issue" SCR2		FSB 3,2 GB/s
Power Consumption	SoC < 500 mW				Incl. Chip Set < 5 W
Form Factor	13x13 mm (0.65 pitch) 16x16 mm (0.8 pitch)				13x14 mm + 22x22 mm (NB)

OMAP L1 competes against x86 through flexibility, high level of integration and Interconnect

Industrial Communication

IA-COM

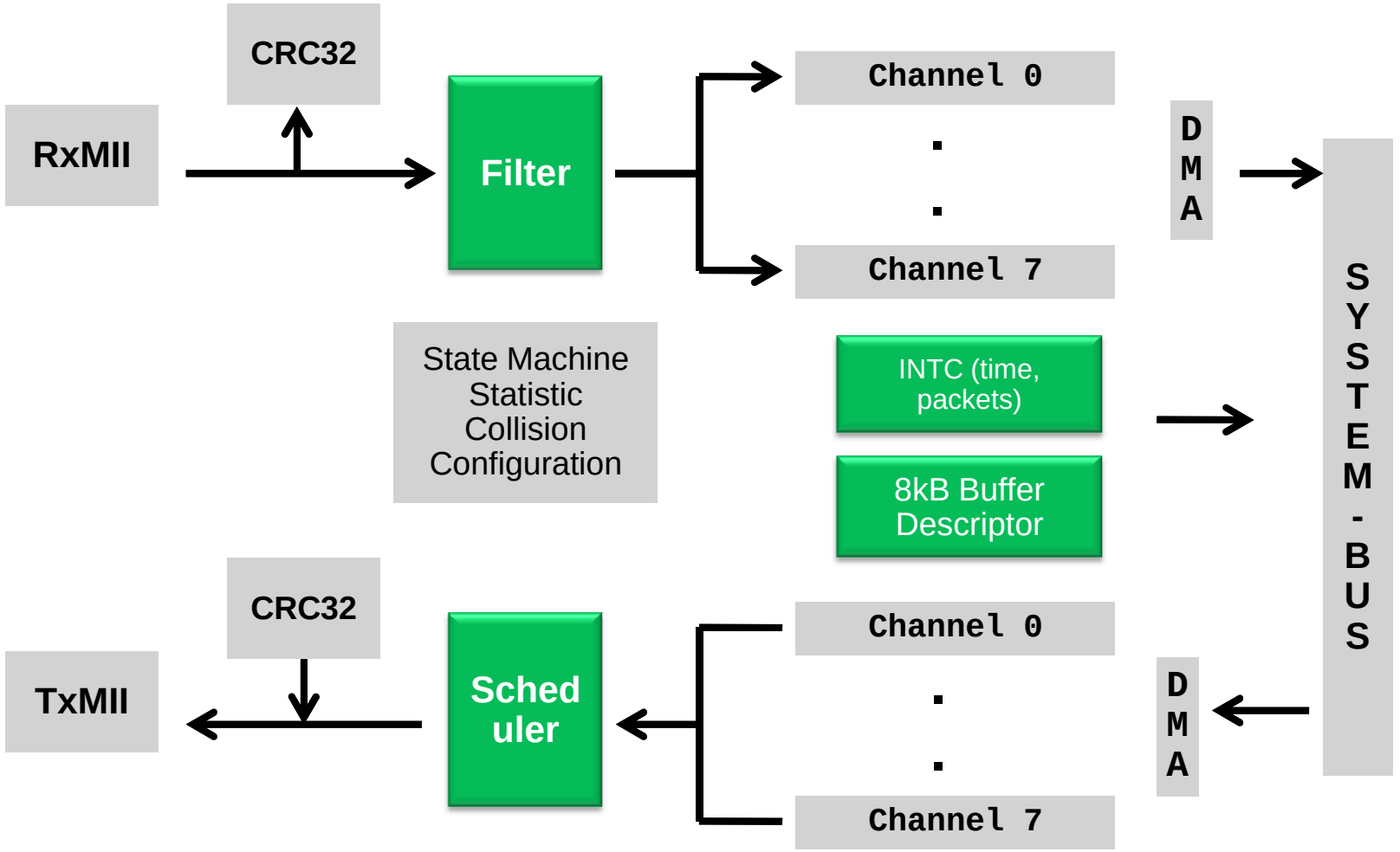
Industrial Communication Standards

- Industrial Ethernet
  - **EtherCAT**
  - Ethernet/IP
  - ProfiNet
  - …(28 standards)
- “Serial Fieldbus”
  - **ProfiBus**
  - Interbus
  - Controller Area Network (CAN)
  - Modbus
  - …
- Sensor Interface
  - ASi Bus
  - **IO-Link**
  - HART

Industrial Ethernet - Overview

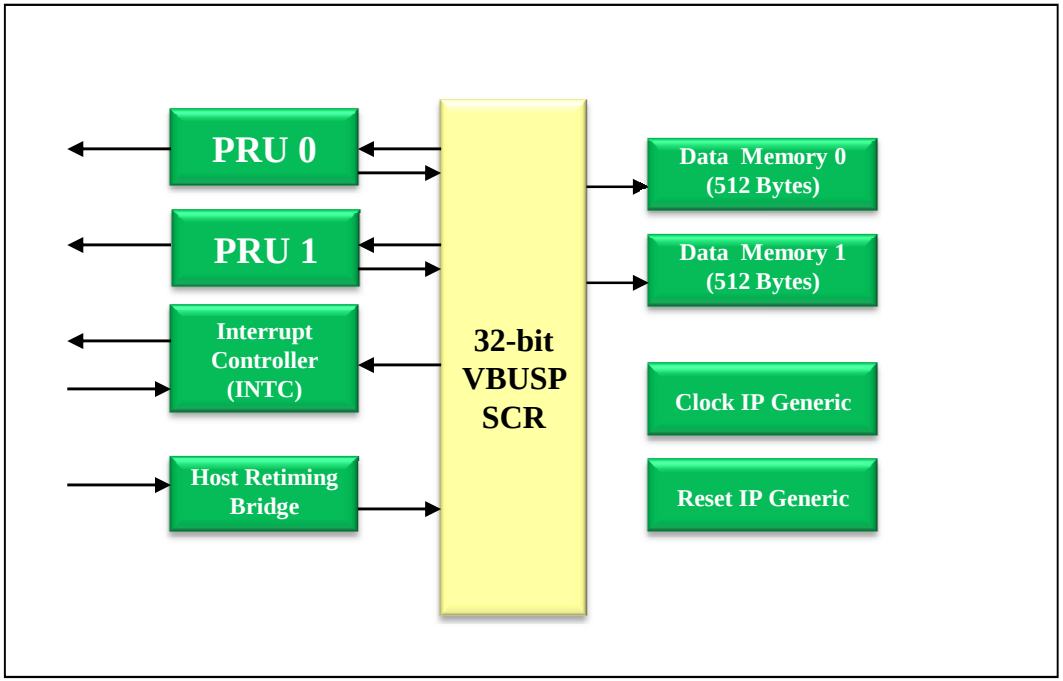
Features	Ethernet (IEEE)	Industrial Ethernet
Standard	IEEE802.3 (Cisco) CSMA/CD (EMAC) 10Mbit-10Gbit Half/Full duplex Unicast, multicast, broadcast VLAN, Rapid Spanning tree (QoS)	Profinet (PNO/Siemens) Ethernet/IP (ODVA/Rockwell) EtherCAT (ETG/Beckhoff) Powerlink (EPSG/ B&R) Sercos III (Sercos/Bosch Rexroth) Modbus TCP (Modbus-IDA/Schneider)
Time Sync	IEEE 1588	IEEE 1588 PTCP, Distributed clocks
Min Cycle Time (PLC application)	> 10ms	31 us, 62us, 250us, 1ms
Jitter (>100 nodes)	>1 ms (MAC Fifo, stack software)	+- 20ns (timer resolution, phy jitter)
Latency per node (line 2 line)	10us (switch)	700ns, 1 us, 3.5us (cut through switch)
Throughput RTE	< 100 Mbit (limited by host performance)	100 Mbit (hardware supported)

TI Ethernet MAC – MultiChannel QoS



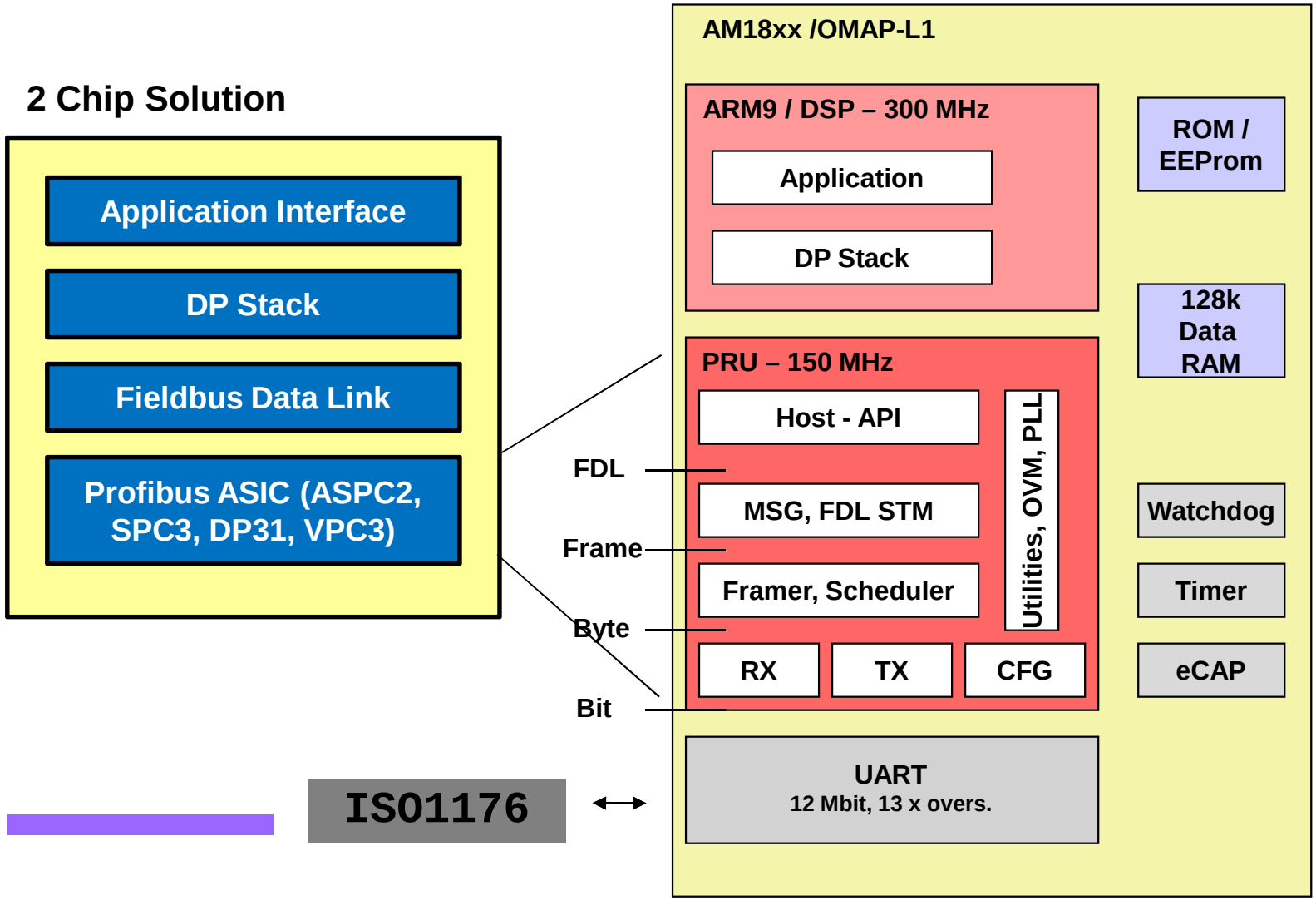
PRU Subsystem on OMAP L1/AM1x

- Provides 2 Independent Programmable Realtime Units (PRU)
  - 32-Bit Load/Store RISC architecture
  - 4K Byte instruction RAM per core
  - 512 Bytes data RAM per core
  - Register 30 of each PRU is exported from the subsystem in addition to the normal R31 output of the PRU cores.
  - Each core runs at half of main processor speed (150MHz)

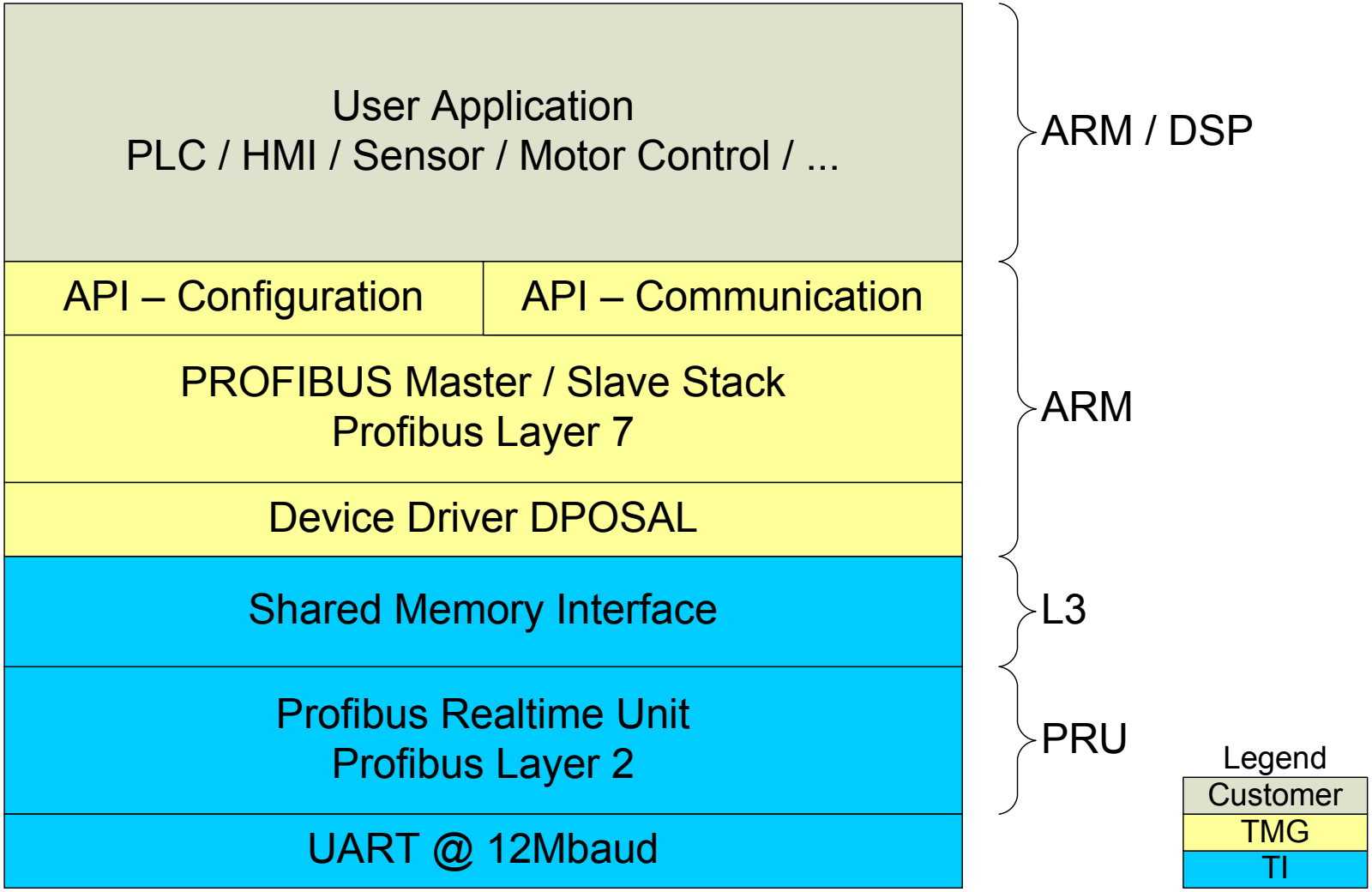


- PRU intended operation is little endian similar to ARM and DSP processors.
- Provides standard power management mechanism
  - PRU can be disabled via software to save power
  - Entire subsystem under a single PSC clock gating domain
- Provides interrupt controller for system events handling(No vectorization supported)

Profibus DP Integreation with PRU



SW Layer Architecture Block Diagram

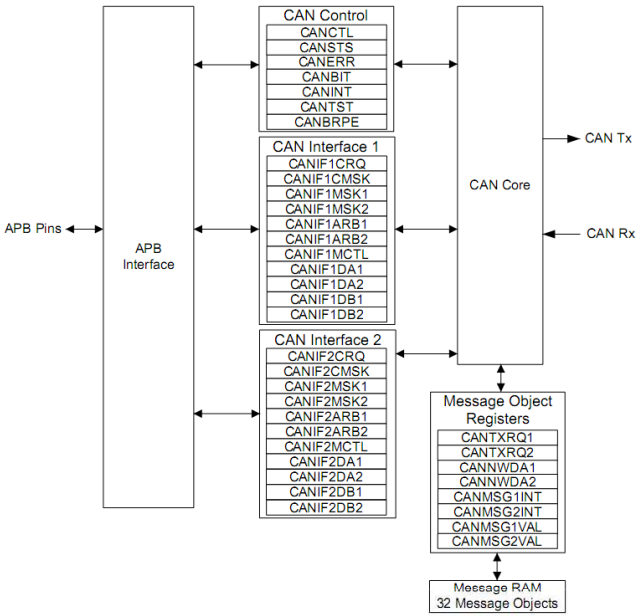


PROFIBUS Solutions in the Market

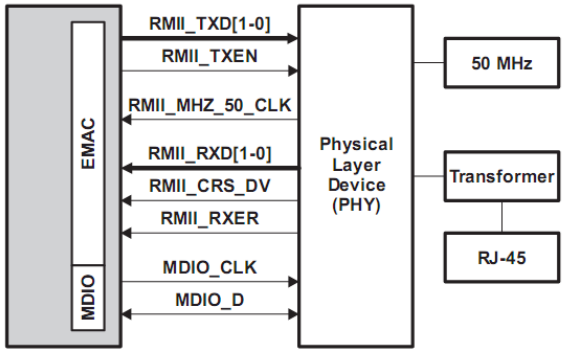
SoC	AM1810	Hilscher NetX50	Siemens SPC3	ProfiChip VPC3+S
Description	Profibus DP (v0, v1, v2(TBD)) Slave and Master; 12Mbps	PROFIBUS, Master, Slave	Profibus DP (v0, v1, v2) Slave; 12Mbps	Profibus DP (v0, v1, v2) Slave; 12Mbps
Processor	**385/312MHz ARM926E**	200MHz ARM966E	NA	NA
Host Interface	seamless integrated (SCR)	integrated	parallel	SPI, IIC, parallel
Power Consumption Profibus only				
	20mW (PRU, eCAP, UART)	NA	NA	160mW 48mA @ 3.3V
System	**<182mW** @ 300MHz, 1.2V, 25C	800 to 1200mW		
Form Factor	13x13mm	19x19	10x10mm (TQFP 44pin)	6x8mm (BGA 48pin)

CAN Integration

- HW:
  - Dedicated CAN Controller(s)
  - CAN 2.0A/B support
  - CAN transceiver
- SW:
  - Device driver for OS
  - CANopen, DeviceNet – highlevel stack
- Devices:
  - AM3505/17
  - Stellaris family with Cortex-M3 cores
  - C2800 family of MCUs
  - ISO 1050 CAN transceiver

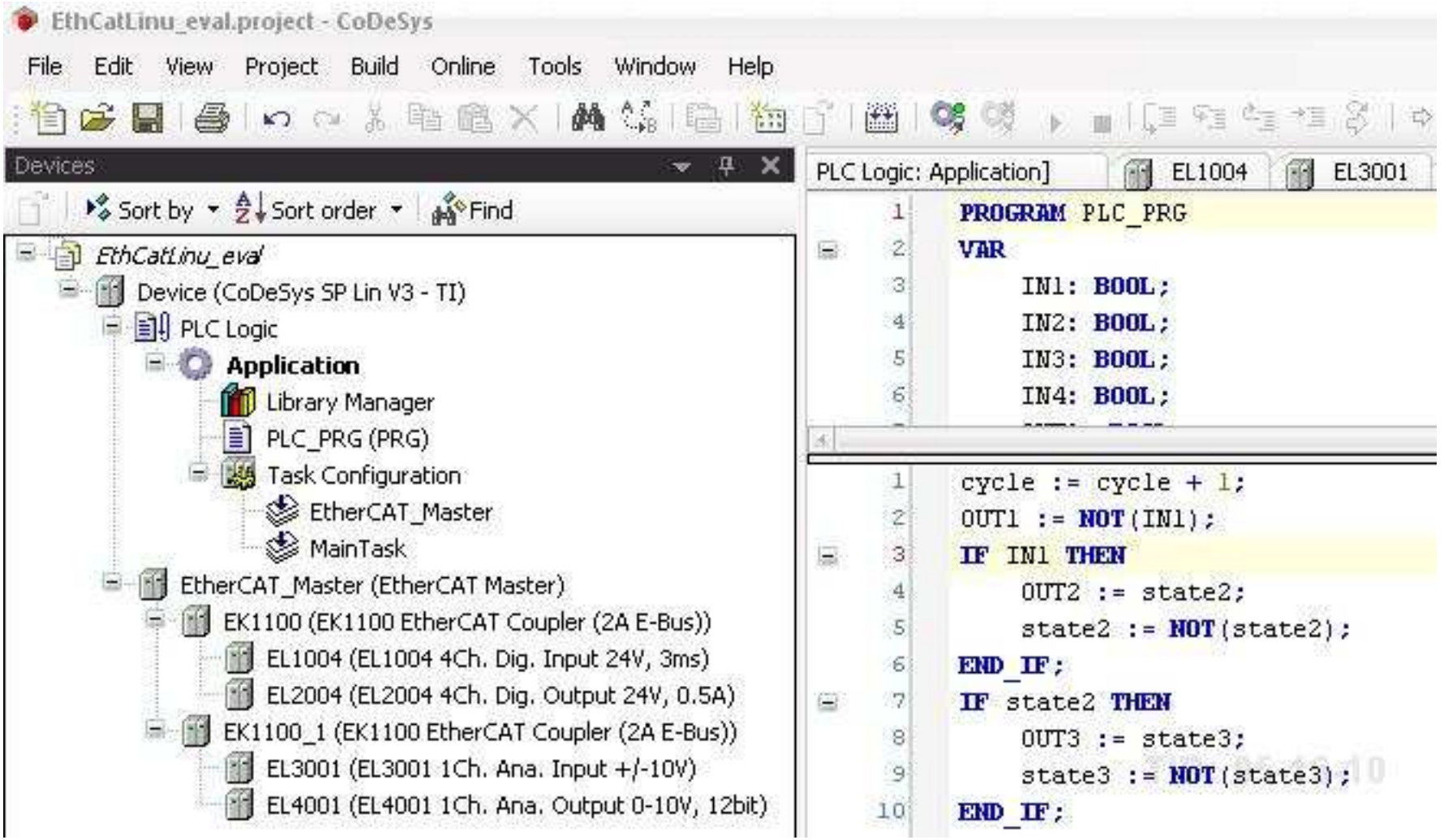


EtherCat Master Integration

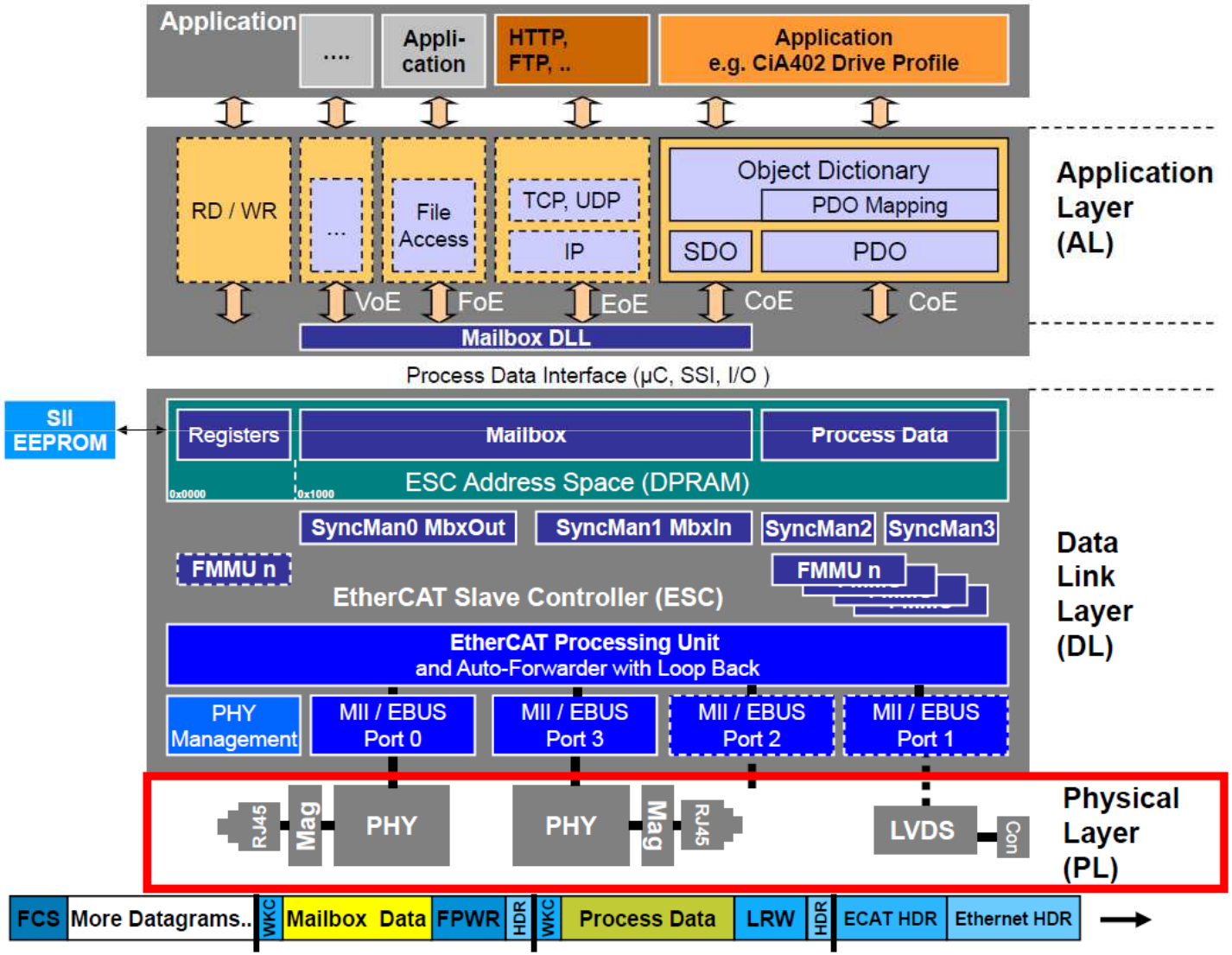


- HW:
  - Standard Ethernet port(s)
  - Integrated EMAC/Phy
- SW:
  - Standard Ethernet driver – silicon vendor/open source
  - EtherCAT master stack – SW third party
    - 3S/CoDeSys
    - OSADL
- Devices:
  - AM3505/17
  - AM18xx/17xx
  - TLK100 Industrial Ethernet PHY

EtherCAT Master & CoDeSys



EtherCAT Slave - Architecture

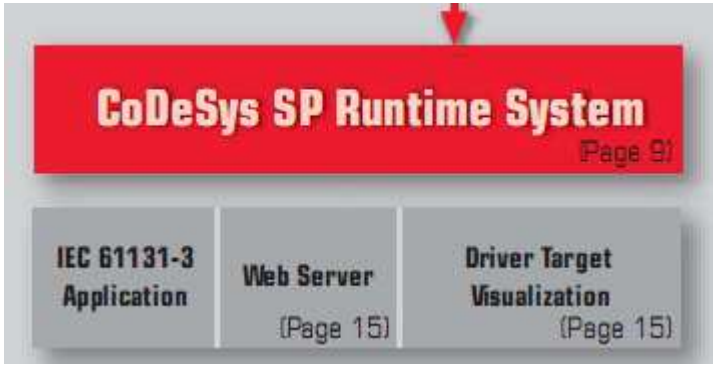


EtherCat Slave Integration

- HW:
  - EtherCAT unit with 2 ports, FMMU and SyncManager
  - Distributed Clocks and Shared Memory support
- SW:
  - EtherCAT driver
    - Data Link Layer implementation
    - Provided by silicon vendor
  - EtherCAT slave stack
    - Application layer implementation
    - Provided by SW third party/user
- Devices:
  - TLK100 (listed in Beckhoff application note)
  - Future C2000, Stellaris and Sitara devices

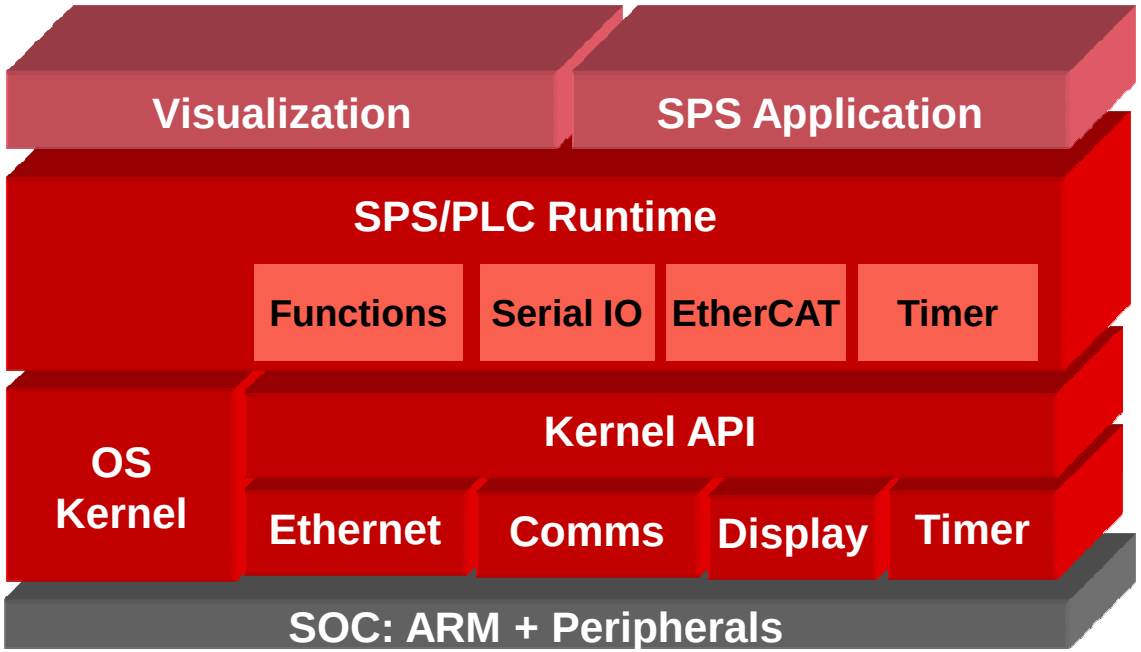
Programmable Logic Controller

SPS/PLC



Source: 3S

SPS/PLC Architecture

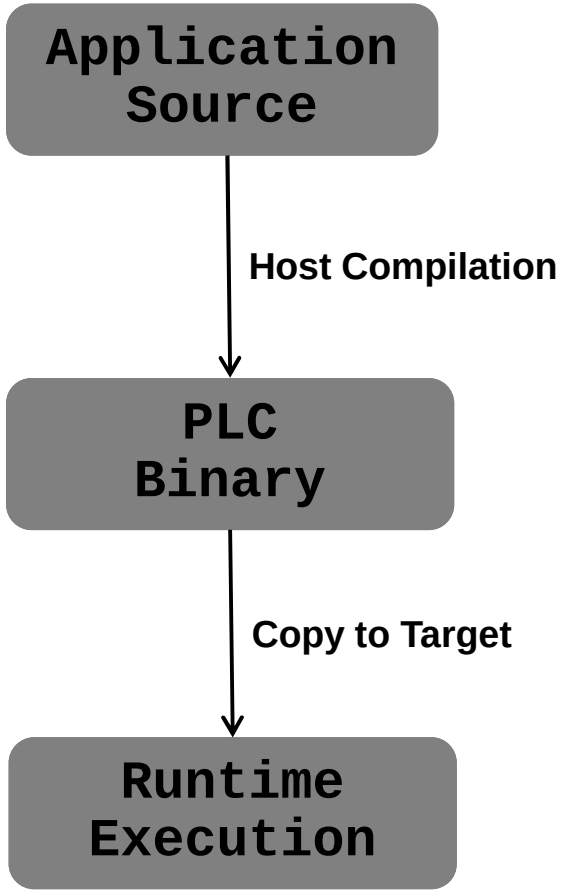


Performance Criteria

- Master Cycle Time
- Interrupt Latency
- SPS Performance - Integer/Float/LD+ST Operations

PLC Application Development Flow

- IEC 61131-3
  - 7 graphical and textual programming languages
- CoDeSys by 3S
  - Host development and debug tool
  - ARM runtimes & compiler
- Communication stacks
  - CAN
  - EtherCAT

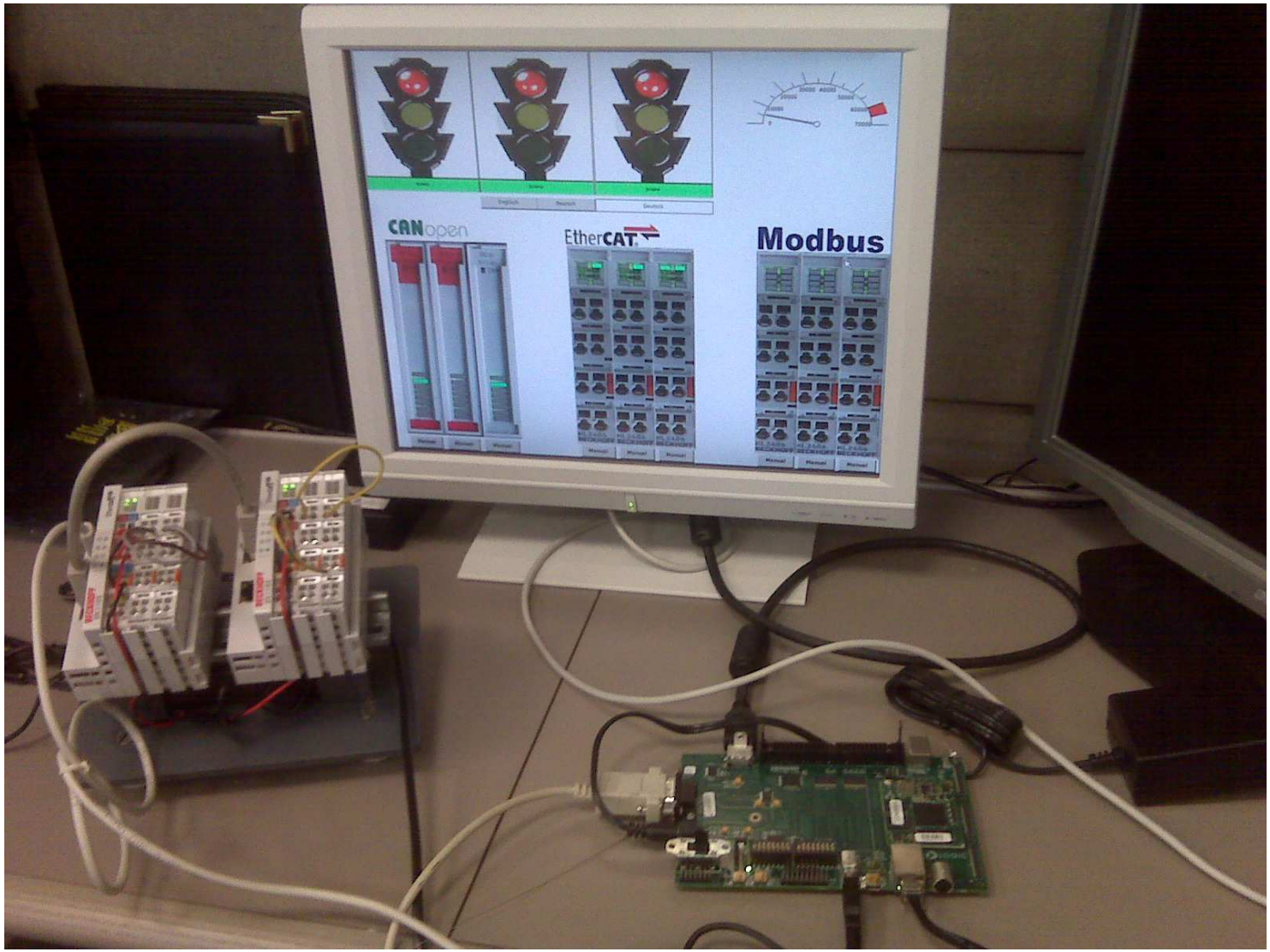


CoDeSysSP on TI devices

- Demonstrator or System packages
  - E.g. AM3517 EVM based demo for evaluation
  - Board vendor packages
- Customer integration
  - TI: hardware support
  - 3S: CoDeSys licensing & support
  - Third party: integration support
- CoDeSysSP v3.4 runtime availability:
  - Cortex-A8 (OMAP3/AM35xx)
  - ARM9 (AM17xx/18xx/OMAP-L1xx)
  - Cortex-M3 (Stellaris family)
  - C28xx (Digital Signal Controller)

CoDeSysSP on Stellaris-M3

CoDeSysSP on AM3517



CoDeSys Benchmark

PLC Benchmarking Report

TI Information - Selective Disclosure

TEXAS INSTRUMENTS

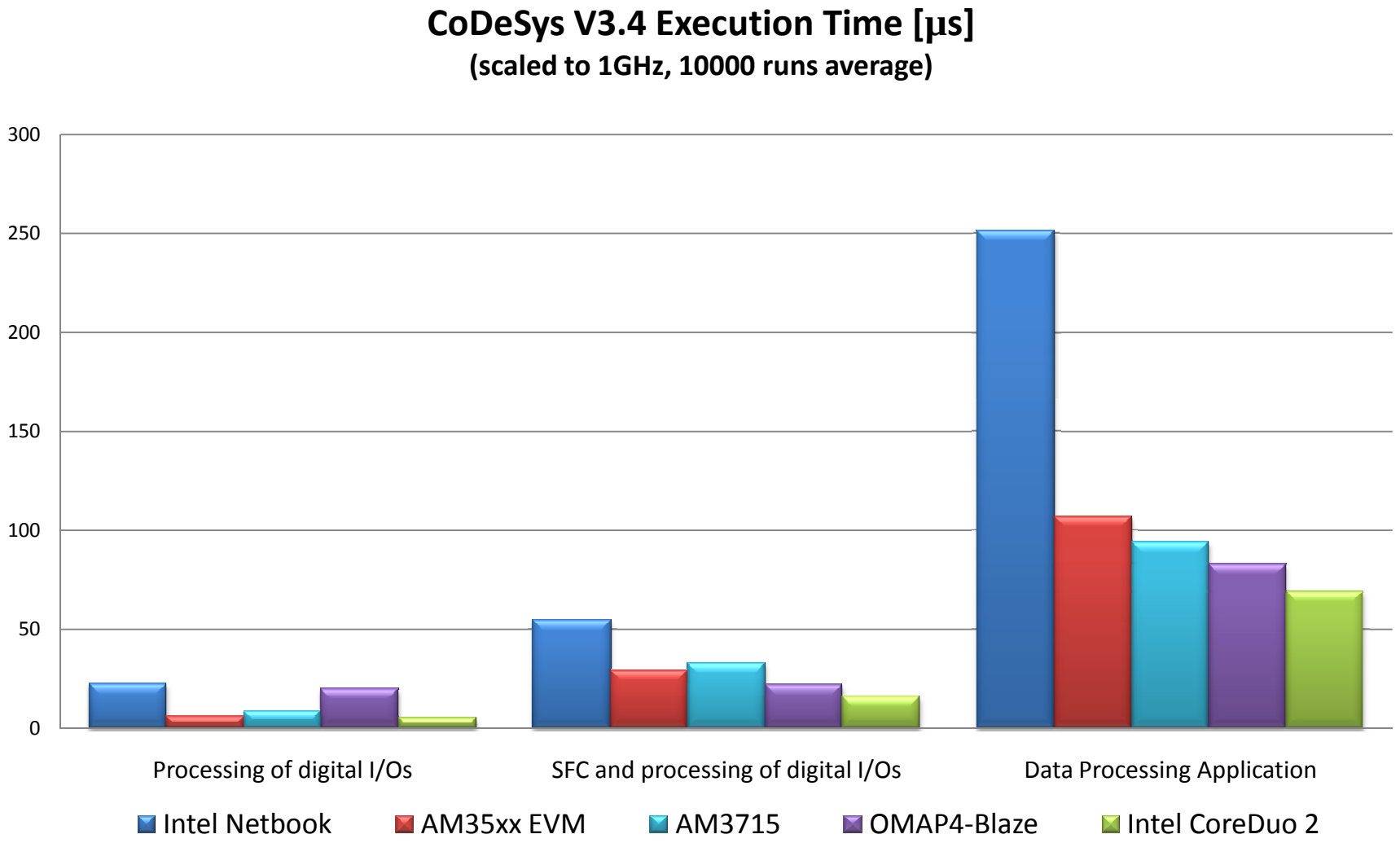
AM35xx EVM	**CoDeSys runtime v 3.4 SP1**

Tested by:	Frank Walzer	Test date:	25.09.2009

Results Table

	AM35xx EVM				**AM3715**			
Execution time [us] Benchmark	Min.	Max.	Average	Size [bytes]	Min.	Max.	Average	Size [bytes]
Application oriented								
Processing of digital I/Os	0	122	**12**		0	30	**9**	
SFC and processing of digital I/Os	30	213	**59**		0	92	**33**	
Data Processing Application	183	306	**214**		91	122	**94**	
Language oriented								
POU calls	244	457	**284**		122	213	**158**	
Function block	152	275	**174**		61	92	**64**	
Function	122	275	**147**		61	91	**64**	
ST Control Statements	2349	2960	**2506**		1159	1465	**1251**	
CASE	30	213	**57**		30	61	**33**	
FOR	91	396	**141**		61	214	**82**	
IF	30	183	**36**		0	91	**18**	

Benchmark Results – Example Graph



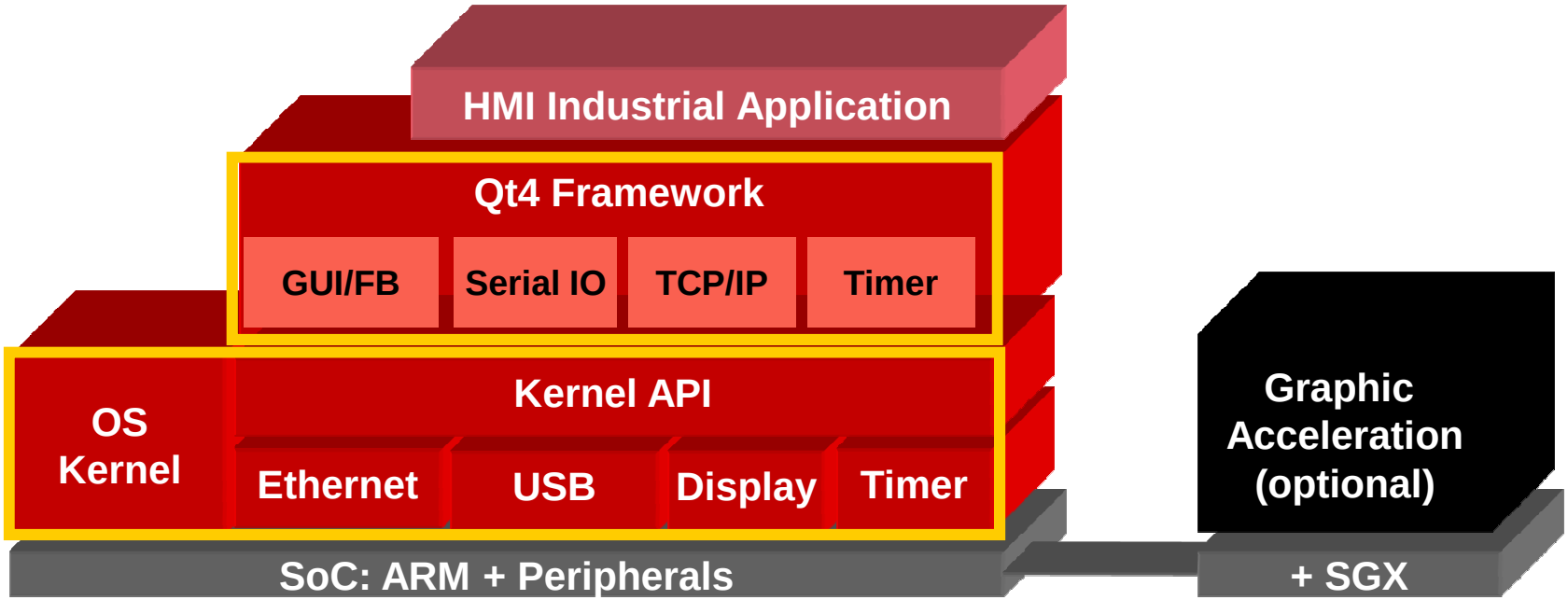
Human Machine Interface

HMI

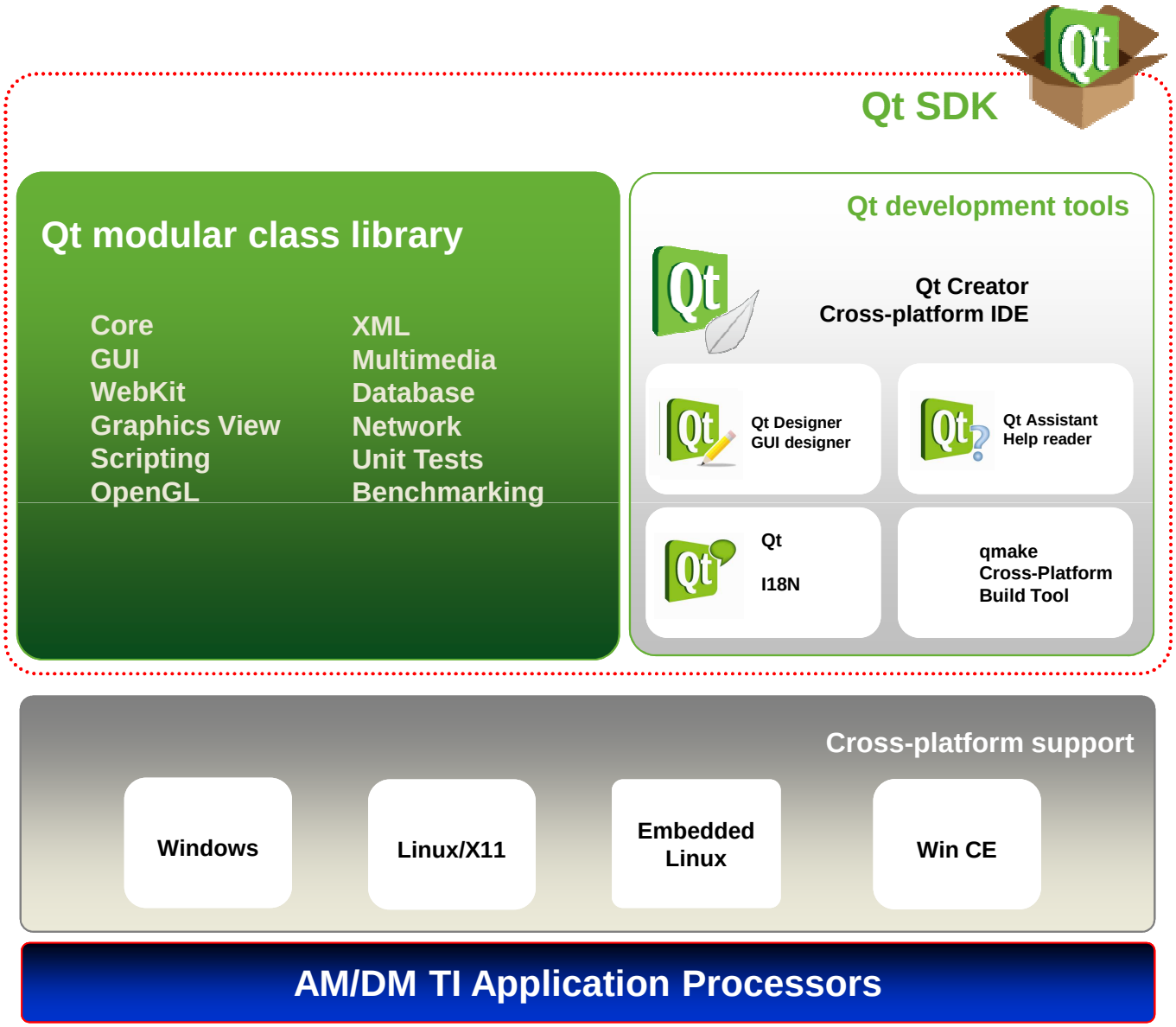
Source: 3S

HMI Applications

- OS: Embedded Linux Kernel 2.6.xx or Microsoft Windows CE 6.0 R3
- Qt 4.6.x framework abstracts OS API
- Application program using C++ Object Oriented Programming
- Debug on other platforms due to Qt4 cross-platform support
- High abstraction on application level leads to fast development



Qt SDK

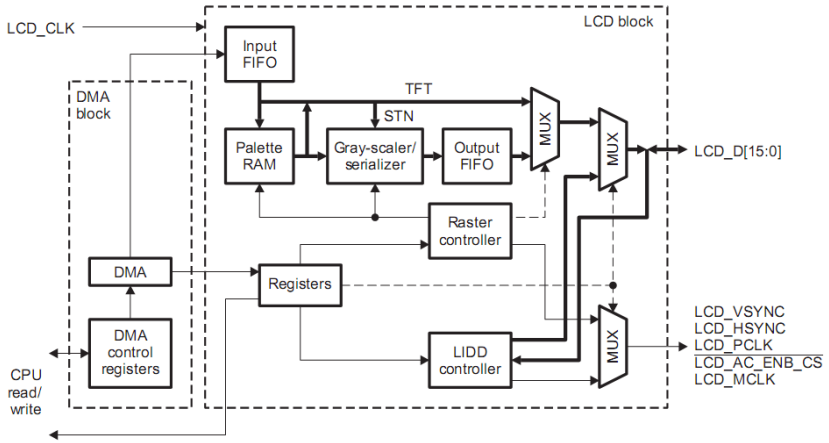

Qt SDK
Qt modular class library
Core
GUI
WebKit
Graphics View
Scripting
OpenGL
XML
Multimedia
Database
Network
Unit Tests
Benchmarking
Qt development tools
Qt Creator
Cross-platform IDE
Qt Designer
GUI designer
Qt Assistant
Help reader
Qt
I18N
qmake
Cross-Platform
Build Tool
Cross-platform support
Windows
Linux/X11
Embedded
Linux
Win CE
AM/DM TI Application Processors

Qt Application Framework

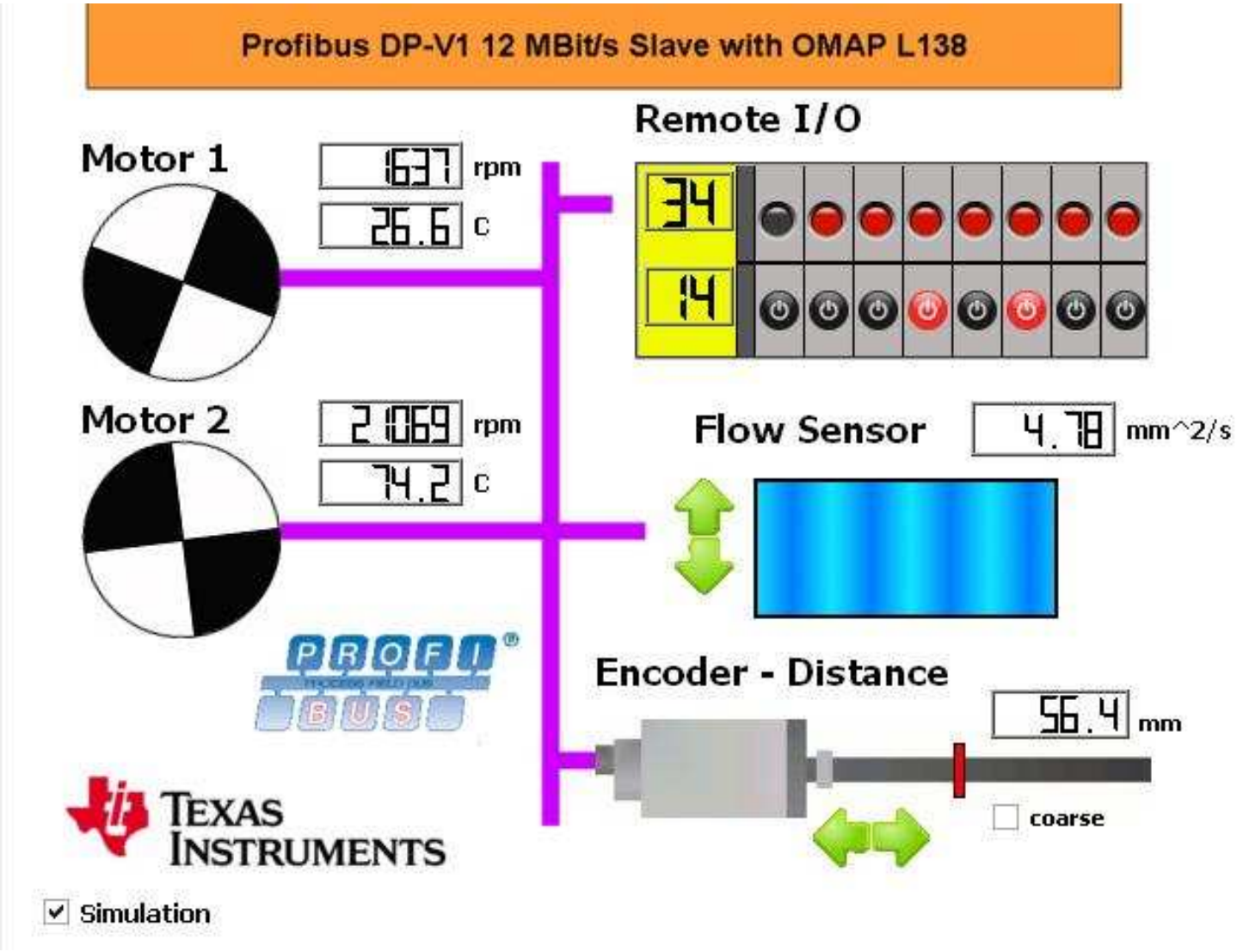
- Rich feature set due to ~800 C++ classes
  - Windows, widgets, buttons,…
  - Ethernet, Web browser, animation,…
- Embedded Linux support
  - Ported to all TI embedded processors
  - Easily configurable for custom targets
  - Well documented process
- Free dedicated development tools
  - Qt Creator – full featured IDE
  - Qt Designer – graphical GUI design
  - Eclipse & Visual Studio plugins – standard tools integration
  - Build process support
- Open Source – LGPLv2

HMI Integration

- HW:
  - LCD Controller
  - DMA support
- SW:
  - Device driver for OS
  - High-Level Graphics – open source
  - Possible combination with SPS/PLC
- Devices:
  - AM3505/17 – 24 bit color, high resolution
  - AM17xx/18xx – 16 bit color, medium resolution
  - Stellaris family with Cortex-M3 cores - small displays

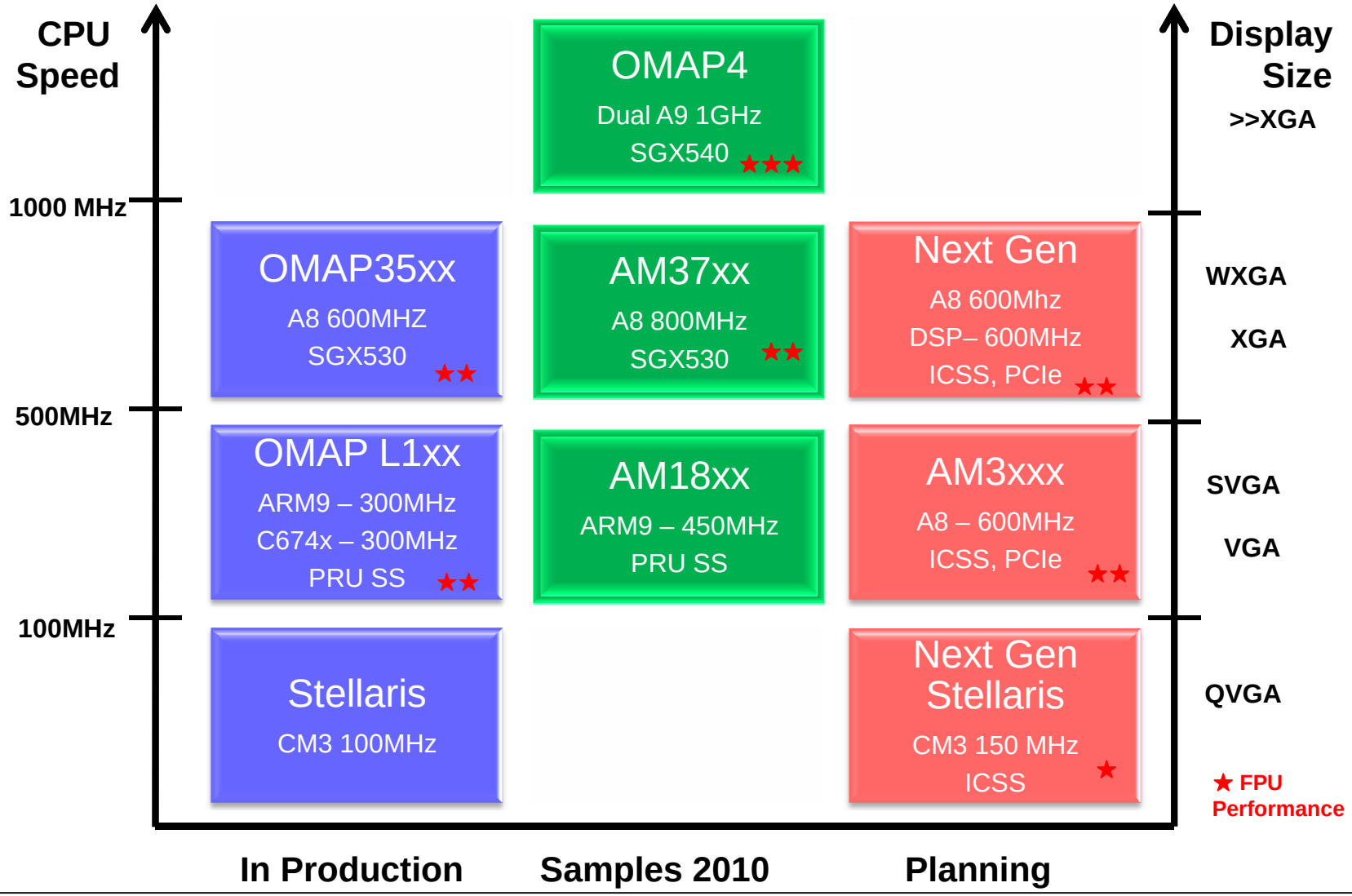


ProfiBus Demo

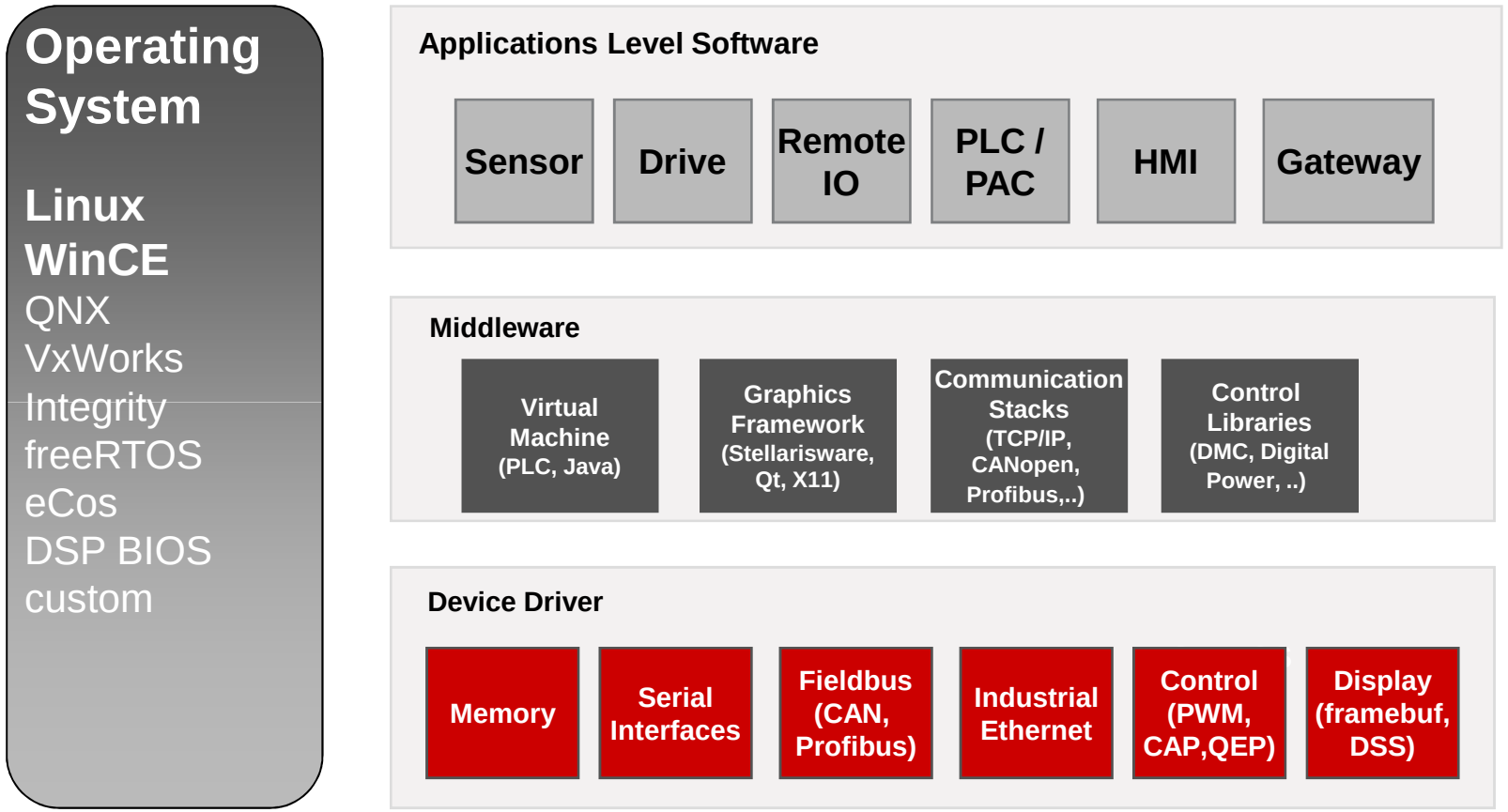


ROADMAP

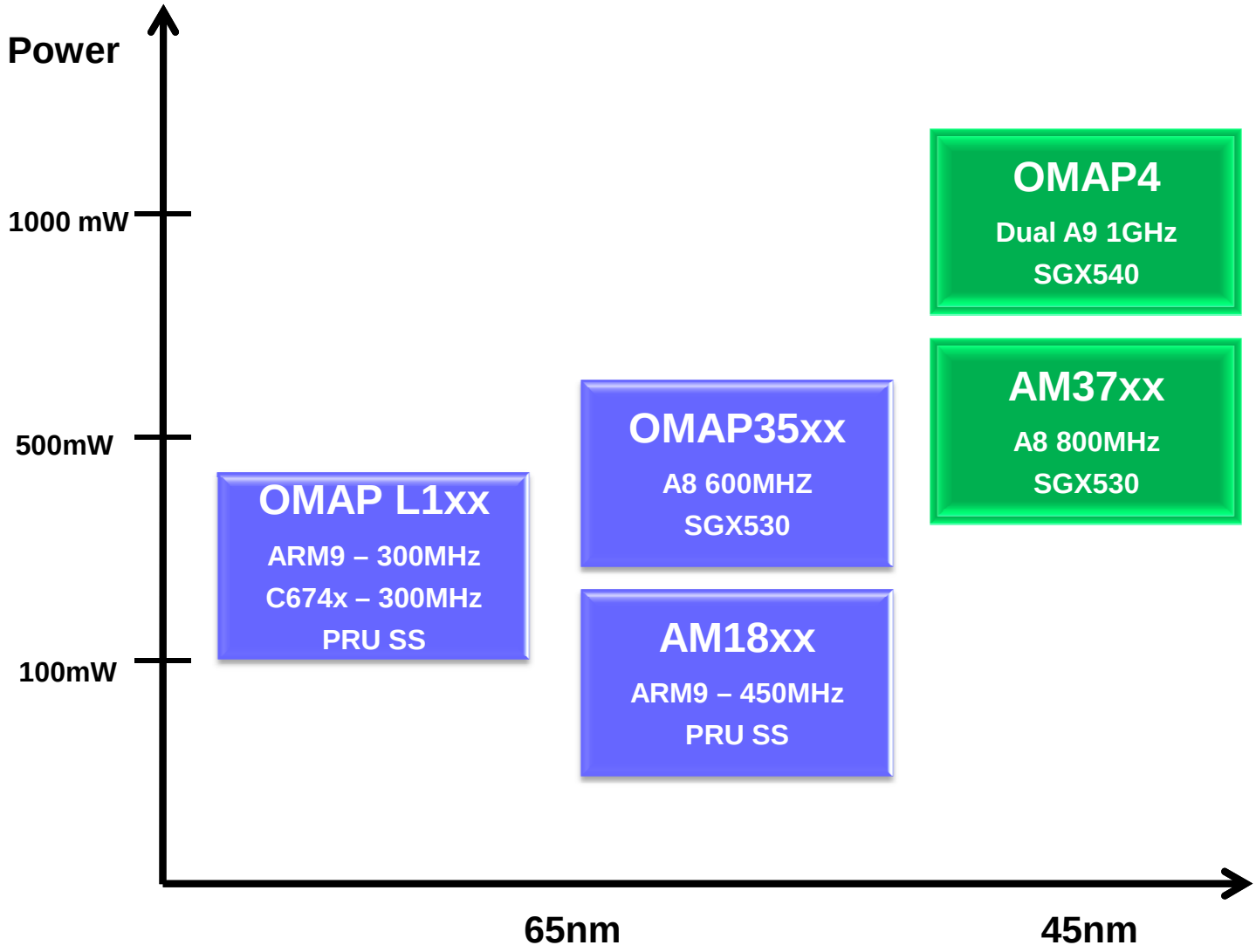
Industrial Control/HMI Roadmap



Industrial Automation Software Solutions



ARM MPU - Power Consumption



THANK YOU!