



**TI Technology Days 2010**

# **Low-power Embedded Processing Solutions for Industrial Automation**

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**Industrial Automation Lab**

# Agenda

- Industrial Automation Architecture
- Industrial Communication
- Programmable Logic Control
- Human Machine Interface
- TI Solutions - Current
- 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
  - Special standards and features

# Embedded processing portfolio

## TI Embedded Processors

### Microcontrollers (MCUs)

16-bit ultra-low power MCUs

32-bit real-time MCUs

32-bit ARM Cortex™-M3 MCUs

ARM Cortex-A8 MPUs

DSP  
DSP+ARM

Multi-core DSP

Ultra Low power DSP

**MSP430™**

Up to 25 MHz

Flash  
1 KB to 256 KB

Analog I/O, ADC  
LCD, USB, RF

Measurement,  
Sensing, General Purpose

\$0.25 to \$9.00



**C2000™  
Delfino™  
Piccolo™**

40MHz to 300 MHz

Flash, RAM  
16 KB to 512 KB

PWM, ADC,  
CAN, SPI, I²C

Motor Control,  
Digital Power,  
Lighting,

\$1.50 to \$20.00



**Stellaris®  
ARM® Cortex™-M3**

Up to 100 MHz

Flash  
8 KB to 256 KB

USB, ENET  
MAC+PHY CAN,  
ADC, PWM, SPI

Connectivity,  
Motion Control,  
Industrial Auto.

\$1.00 to \$8.00



**Sitara™  
ARM® Cortex™-A8  
& ARM9**

300MHz to >1GHz

Cache,  
RAM, ROM

USB, CAN,  
PCIe, EMAC

Industrial comp,  
POS & portable  
data terminals

\$5.00 to \$20.00



**C6000™  
DaVinci™  
video processors  
OMAP™**  
300MHz to >1GHz  
+Accelerator

Cache  
RAM, ROM

USB, ENET,  
PCIe, SATA, SPI

Floating/Fixed Point  
Video, Audio, Voice,  
Security, Conferencing

\$5.00 to \$200.00



**C6000™**

24,000  
MMACS

Cache  
RAM, ROM

SRIO, EMAC  
DMA, PCIe

Telecom  
media gateways,  
base stations

\$40 to \$200.00



**C5000™**

Up to 300 MHz  
+Accelerator

Up to 320KB RAM  
Up to 128KB ROM

USB, ADC  
McBSP, SPI, I²C

Audio, Voice  
Medical

\$3.00 to \$10.00



## Software & Dev. Tools



MPUs – Microprocessors



# Sitara™ ARM® microprocessors

Available Now

## ARM9

AM1705

AM1707

AM1806

AM1808



**Low Power ARM9 with flexible peripherals**

- Power efficient (down to 7mW standby, 182mW active)
- Cost efficient
- Flexible industrial I/O PRU (CAN, UART)
- Integrated peripherals, 10/100 Ethernet, USB, SATA, and more

## ARM Cortex™ -A8

OMAP3503

OMAP3515

AM3505

AM3517



**Cortex-A8 with system integration**

- Up to 1440 DMIPS
- Integrated interfaces to display, USB, 10/100 Ethernet, SD card, Wi-Fi®, CAN, and many others
- Integrated graphics for rich user interface functions

In Development

## ARM Cortex-A8

AM3703 (2Q10)

AM3715 (2Q10)

“AM38x Next” (2011)

“AM33x Next” (2011)



**Advanced Cortex-A8 with high performance & integration**

- Up to 2000 DMIPS
- Power efficient (down to 10mW standby, 1W active)
- Enhanced graphics/UI
- Enhanced integrated peripherals, 1Gb Ethernet, PCIe
- Security

**Support for Linux & Windows® Embedded CE**

# AM3517/05 Core and Accelerators

## Features

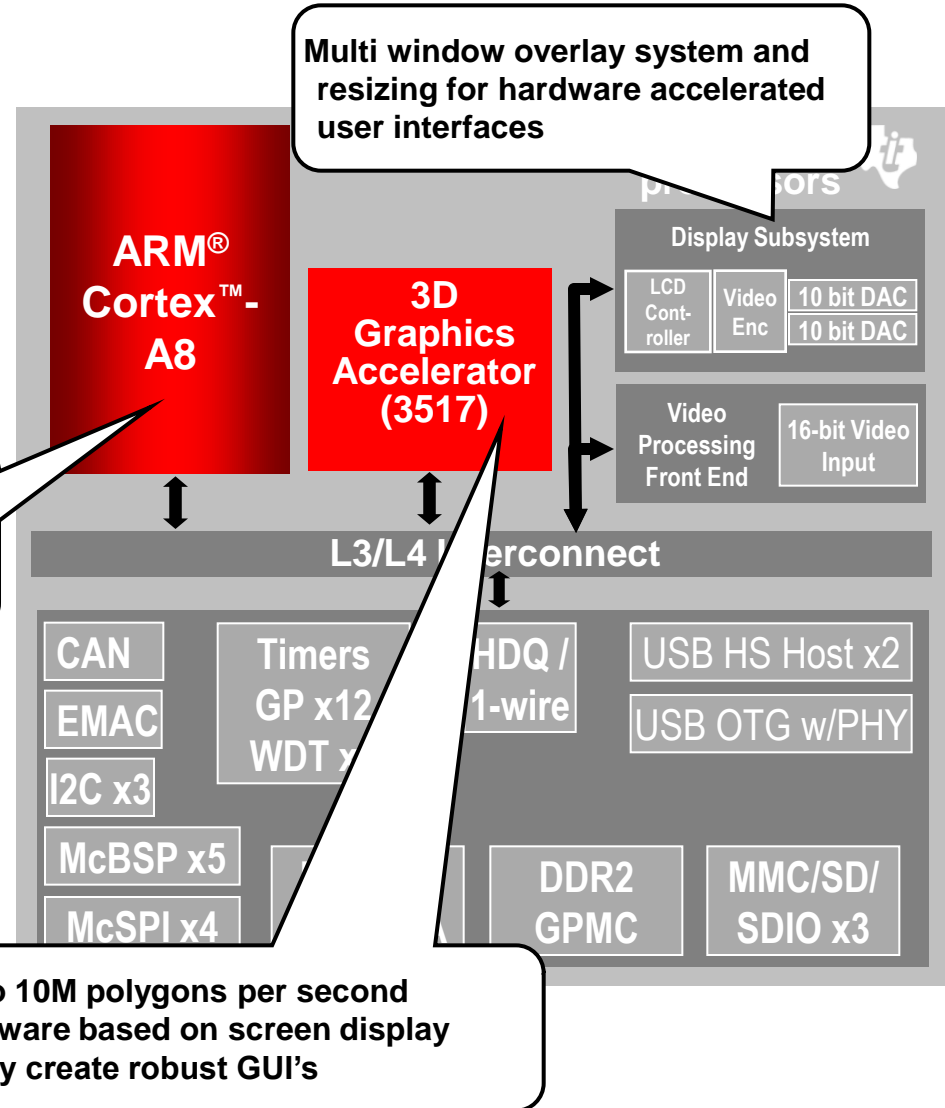
### ■ Cores

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

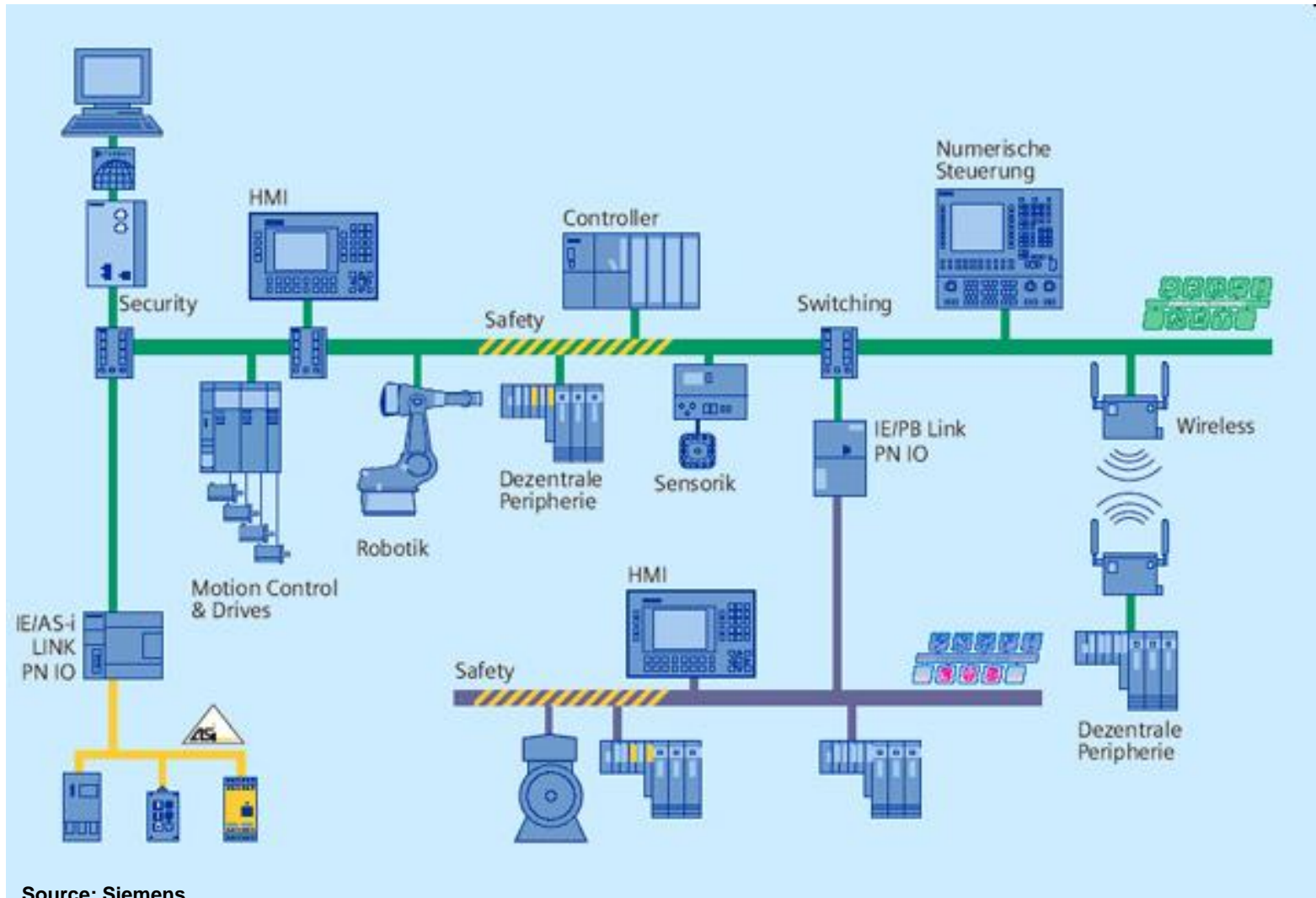
Up to 1000 Dhrystone MIPS:  
• OS's like Linux or WinCE  
• Excellent web experience

### ■ Memory

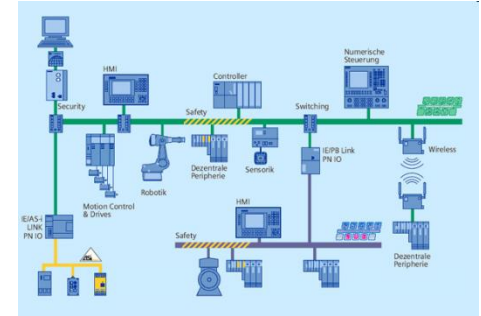
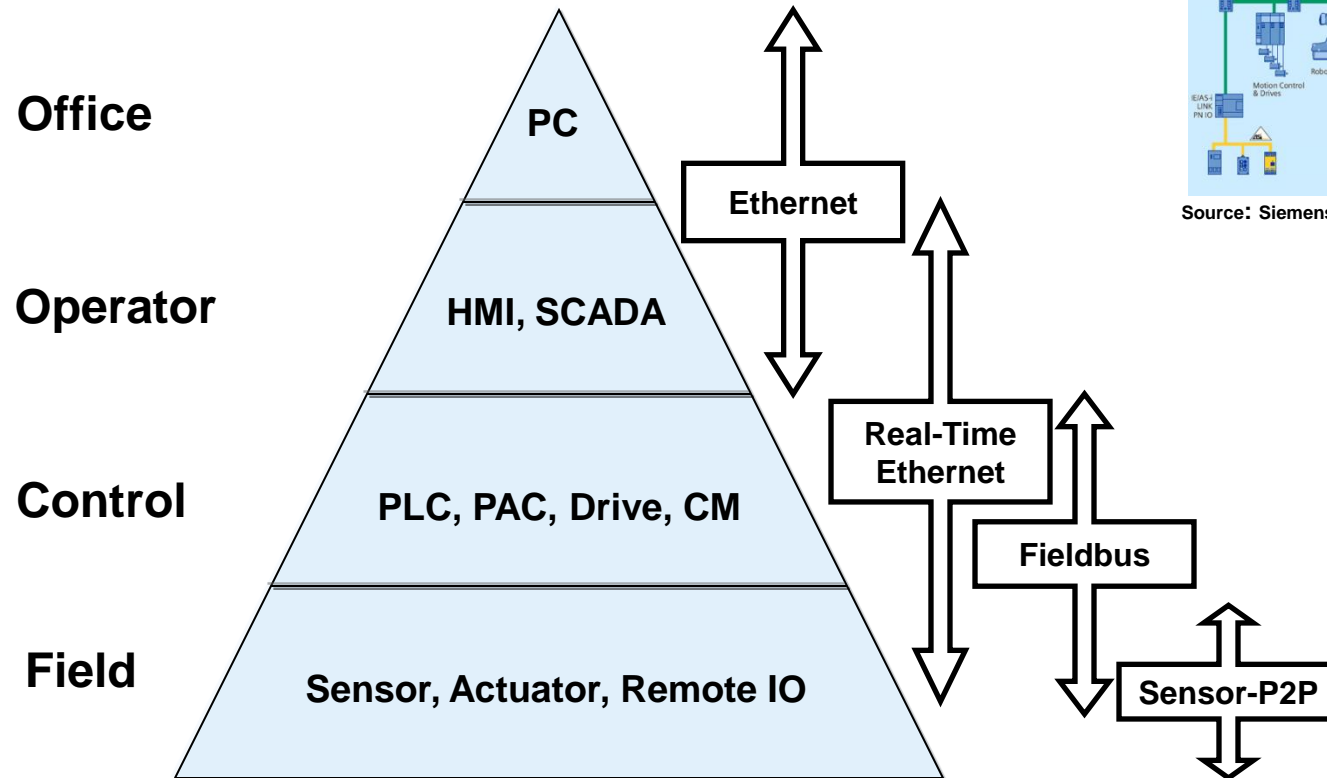
- ARM:
  - 16 kB I-Cache; 16 kB D-Cache; 256kB L2 Cache
- On Chip: 64kB SRAM; 128kB ROM
- DDR2 interface
- GPMC: NAND/NOR interfaces



# Industrial Automation Architecture



# Industrial Automation Pyramid



Source: Siemens



# Industrial Automation Software Solutions

## Operating System

Linux  
WinCE  
QNX  
VxWorks  
Integrity  
freeRTOS  
eCos  
DSP BIOS  
custom

### Applications Level Software

Sensor

Drive

Remote  
IO

PLC /  
PAC

HMI

Gateway

### Middleware

Virtual  
Machine  
(PLC, Java)

Graphics  
Framework  
(Stellarisware,  
Qt, X11)

Communication  
Stacks  
(TCP/IP,  
CANopen,  
Profibus,..)

Control  
Libraries  
(DMC, Digital  
Power, ..)

### Device Driver

Memory

Serial  
Interfaces

Fieldbus  
(CAN,  
Profibus)

Industrial  
Ethernet

Control  
(PWM,  
CAP,QEP)

Display  
(framebuf,  
DSS)



**TI Base Support  
Package**



**Open Source / 3<sup>rd</sup> Party  
/ TI**



**3rd party /  
Customer**

Industrial Communication

**IA-COM**



# Industrial Communication Standards

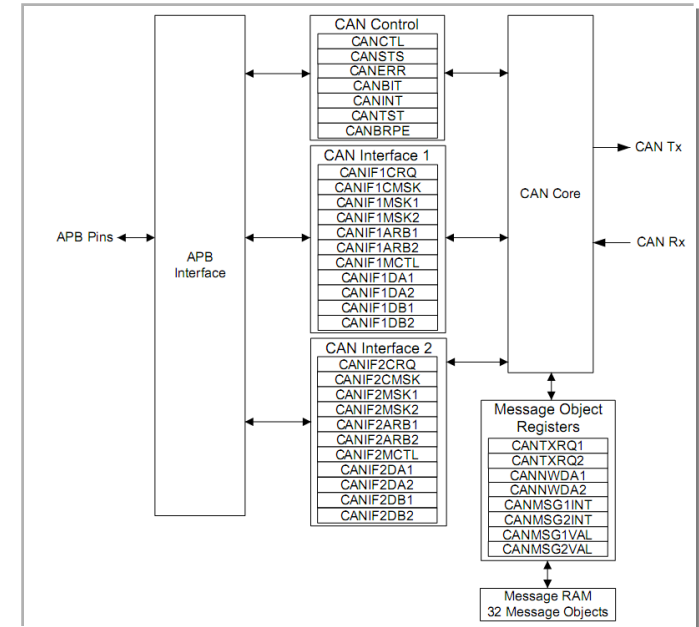
- “Fieldbus”
  - **ProfiBus**
  - IO-Link
  - **Controller Area Network (CAN)**
  - ...
- Industrial Ethernet
  - **EtherCAT**
  - Ethernet/IP
  - ProfiNet
  - ...

# ProfiBus Integration

- HW:
  - Serial port(s) up to 12Mbit
  - RS-485 transceiver
- SW:
  - Data Link Layer
  - Application Layer
    - ProfiBus master/slave stacks
- Device:
  - AM18xx – Integrated ProfiBus with ARM9 based uP

# CAN Integration

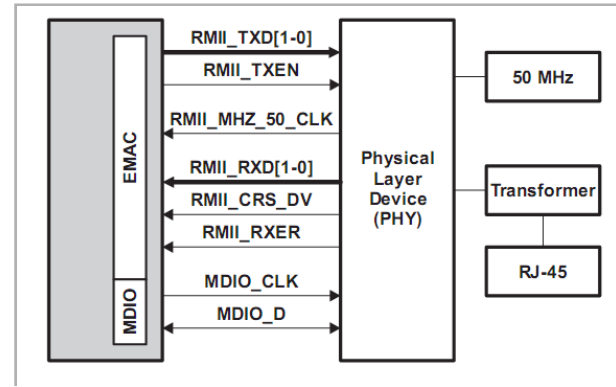
- HW:
  - Dedicated CAN Controller(s)
  - CAN 2.0A/B support
  - CAN transceiver
- SW:
  - Device driver for OS
  - CANopen, DeviceNet – highlevel stack
- Devices:
  - AM3505/17
  - Stellaris family with Cortex-M3 cores
  - C2800 family of MCUs



# 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



# EtherCAT Master & CoDeSys

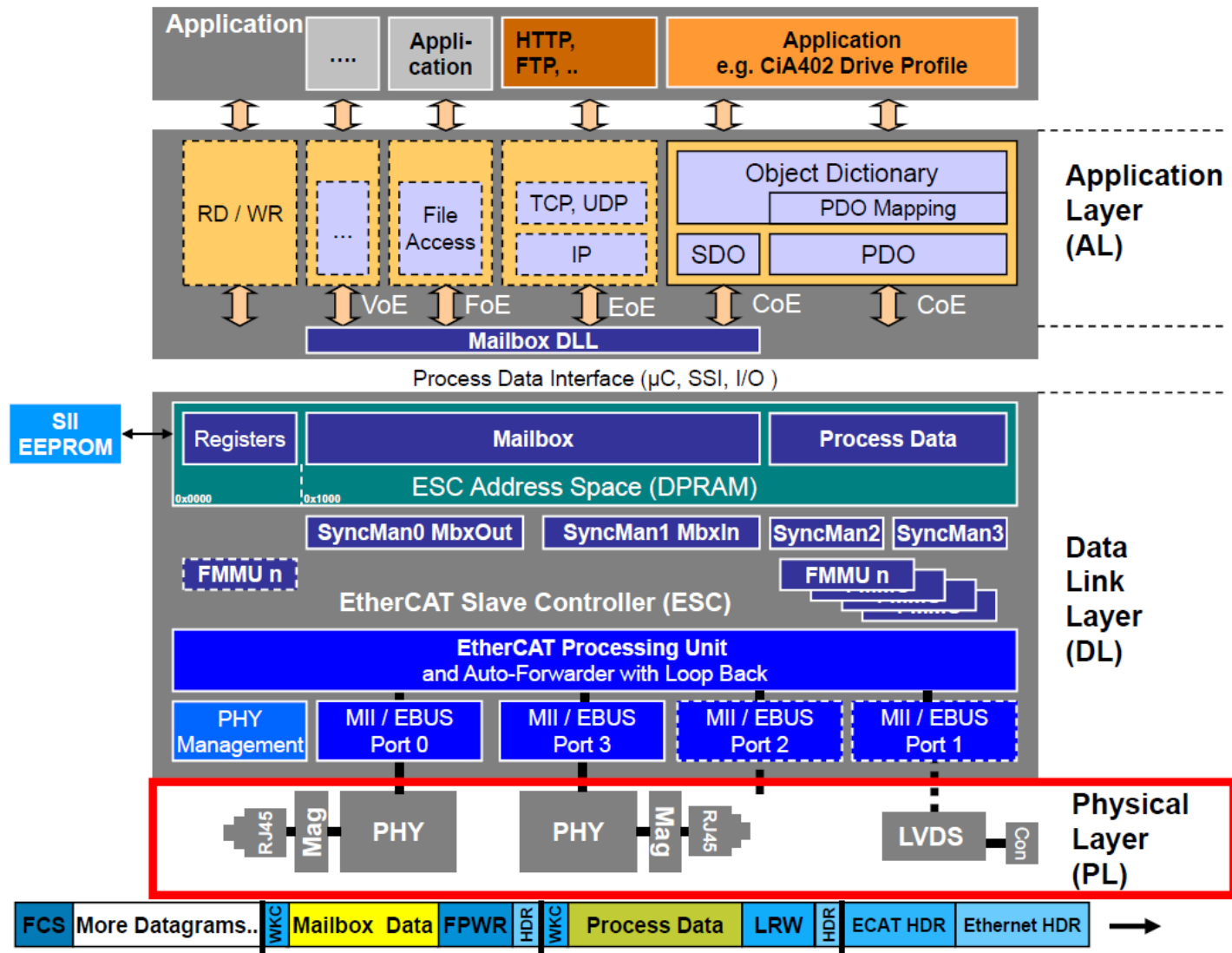
The screenshot displays the CoDeSys IDE interface for a project named "EthCatLinu\_eval.project - CoDeSys". The left pane shows the project tree structure:

- EthCatLinu\_eval
  - Device (CoDeSys SP Lin V3 - TI)
    - PLC Logic
      - Application
        - Library Manager
        - PLC\_PRG (PRG)
        - Task Configuration
          - EtherCAT\_Master
          - MainTask
    - EtherCAT\_Master (EtherCAT Master)
      - EK1100 (EK1100 EtherCAT Coupler (2A E-Bus))
        - EL1004 (EL1004 4Ch. Dig. Input 24V, 3ms)
        - EL2004 (EL2004 4Ch. Dig. Output 24V, 0.5A)
      - EK1100\_1 (EK1100 EtherCAT Coupler (2A E-Bus))
        - EL3001 (EL3001 1Ch. Ana. Input +/-10V)
        - EL4001 (EL4001 1Ch. Ana. Output 0-10V, 12bit)

The right pane shows the PLC Logic for the "Application" task, specifically the "PLC\_PRG" program. The logic is as follows:

```
1 PROGRAM PLC_PRG
2 VAR
3     IN1: BOOL;
4     IN2: BOOL;
5     IN3: BOOL;
6     IN4: BOOL;
7
8 cycle := cycle + 1;
9 OUT1 := NOT(IN1);
10 IF IN1 THEN
11     OUT2 := state2;
12     state2 := NOT(state2);
13 END_IF;
14 IF state2 THEN
15     OUT3 := state3;
16     state3 := NOT(state3);
17 END_IF;
```

# EtherCAT Slave - Architecture





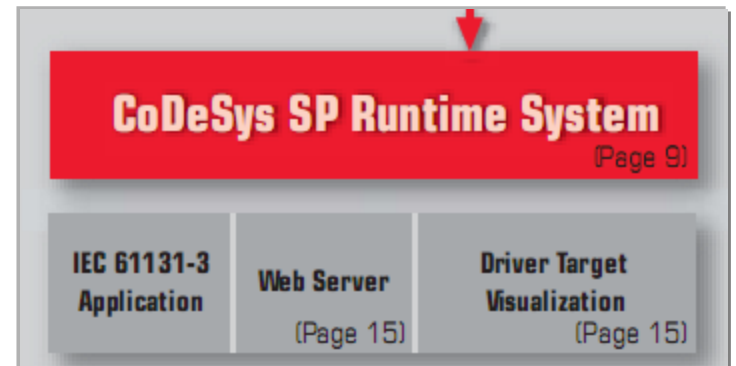
# EtherCat Slave Integration



- 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:
  - Future Stellaris and Sitara devices

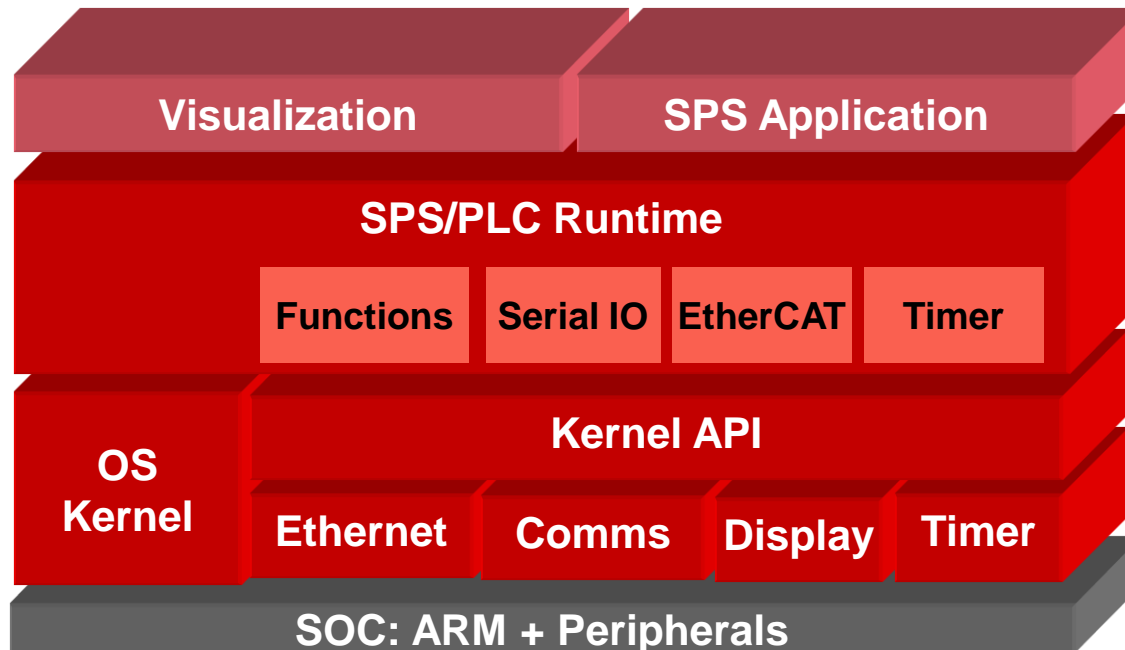
Programmable Logic Controller

**SPS/PLC**



Source: 3S

# SPS/PLC Architecture

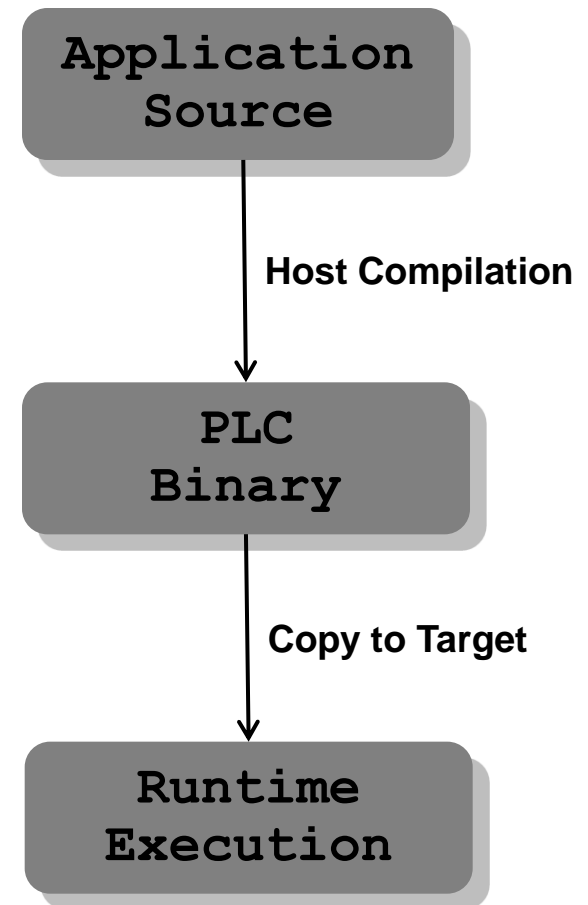


## Performance Criteria

- 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



# CoDeSys 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
- CoDeSys v3.x ARM port availability
  - Cortex-A8 (OMAP3/AM35xx)
  - ARM9 (AM17xx/18xx/OMAP-L1xx)
  - Cortex-M3 (Stellaris family)

# Human Machine Interface

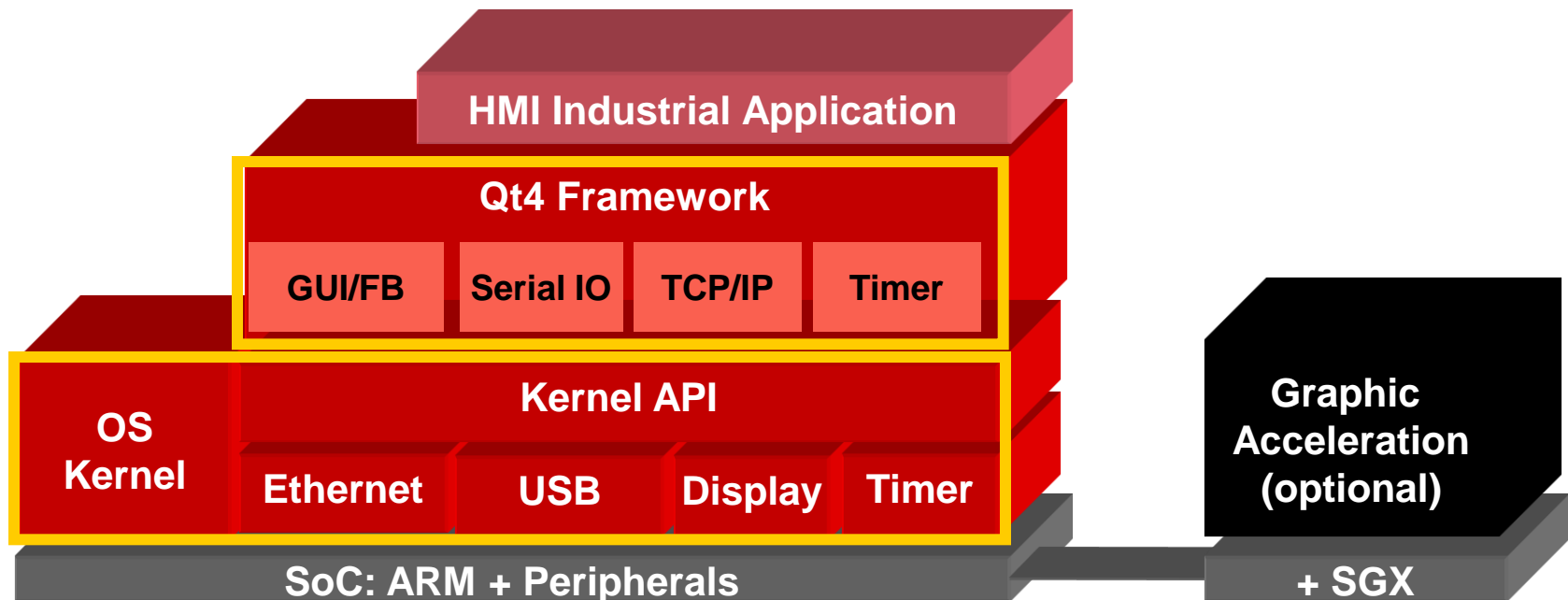
# HMI



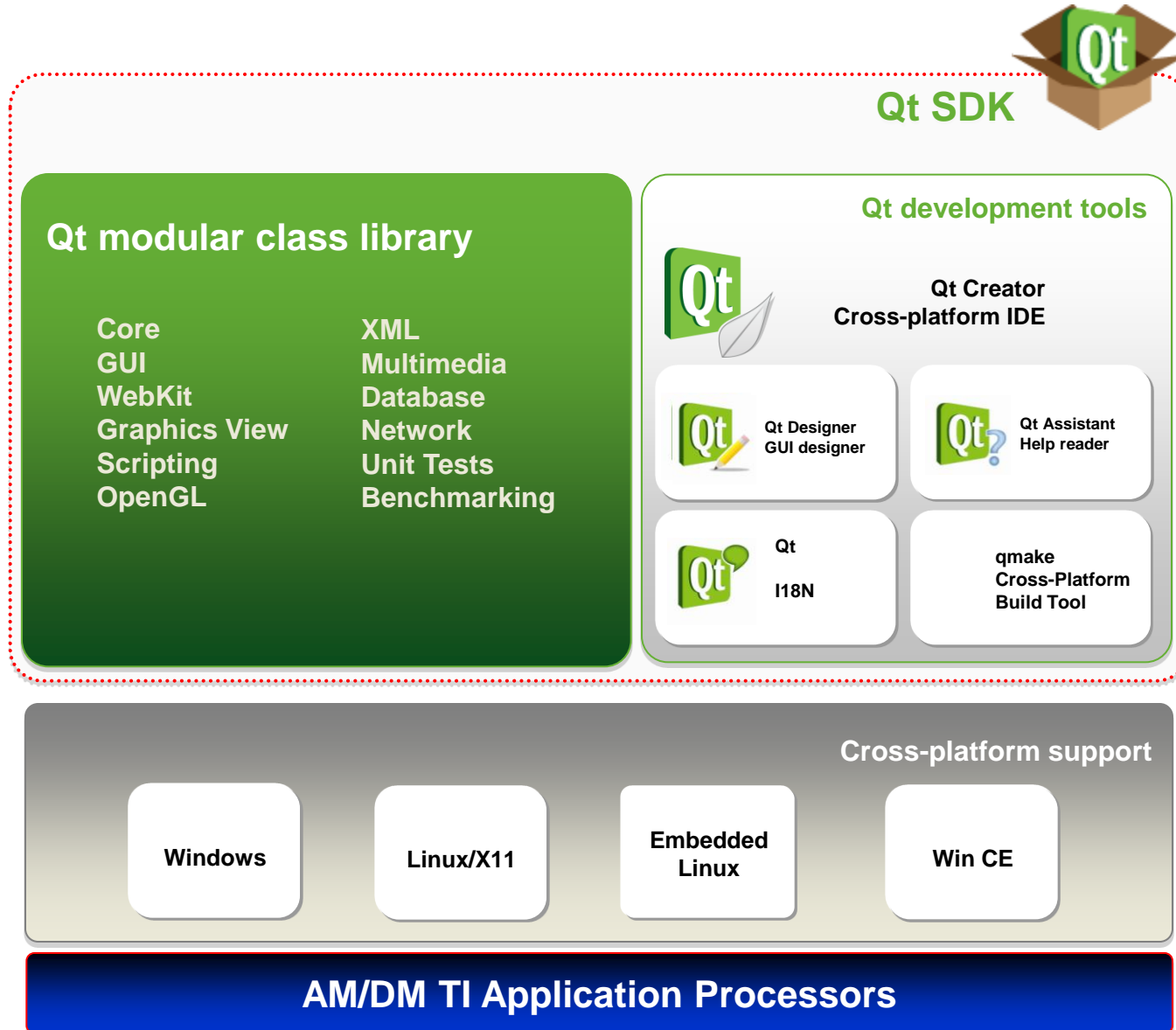
Source: 3S

# 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



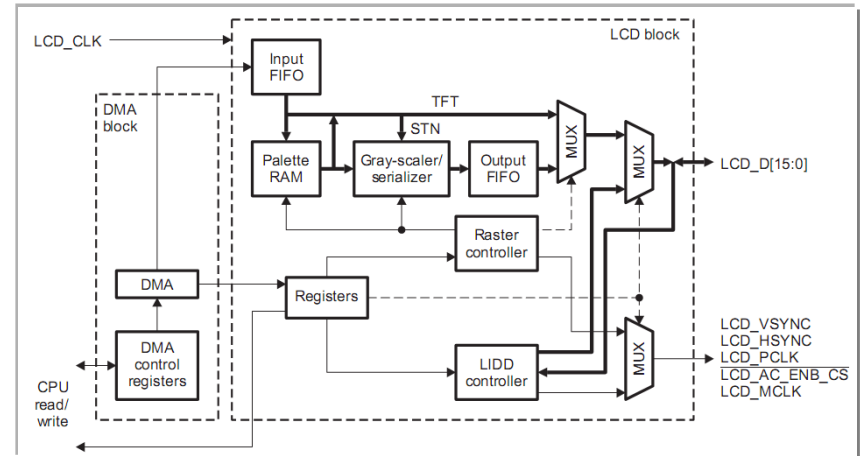


# Qt Application Framework

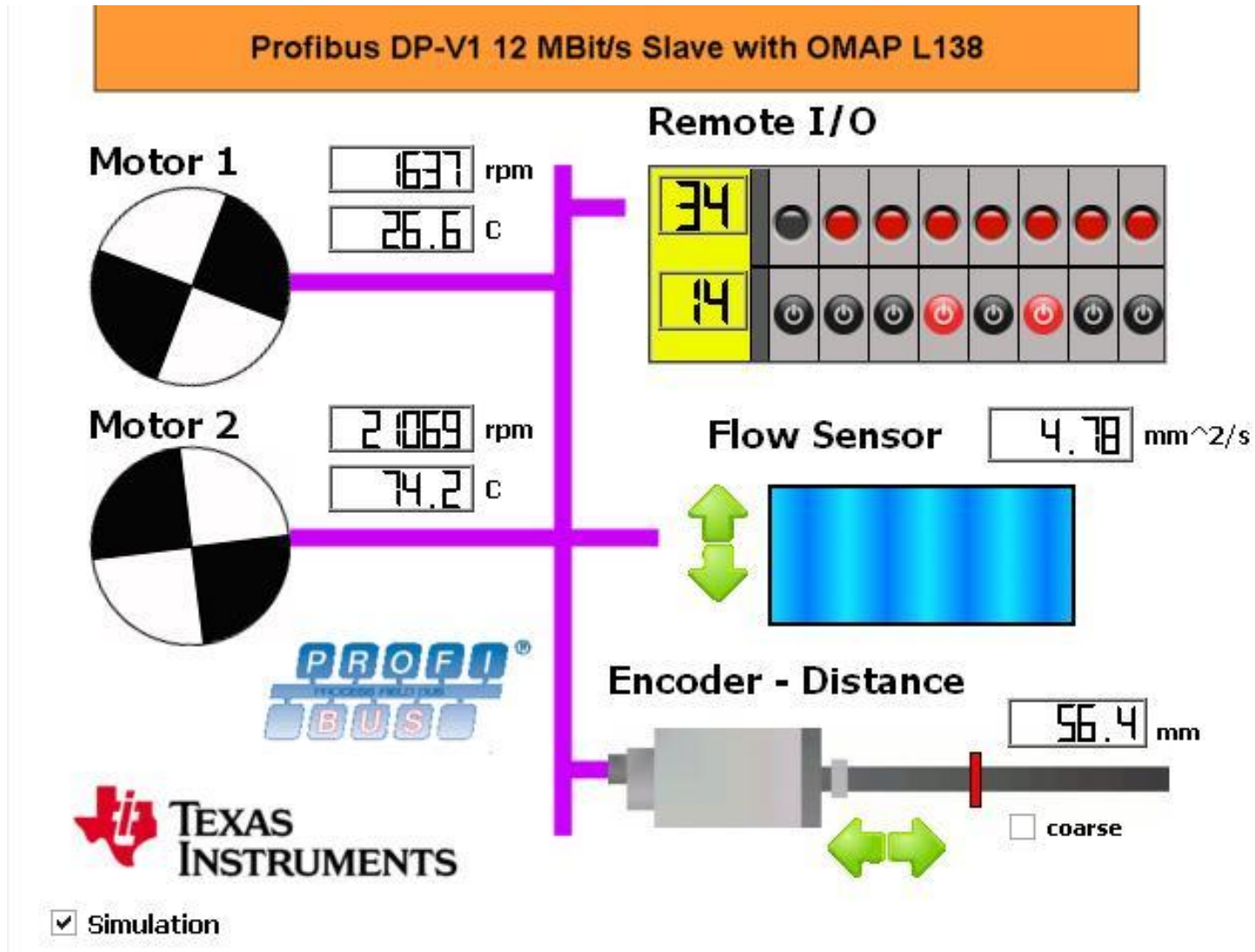
- Rich feature set due to ~800 C++ classes
  - Windows, widgets, buttons,...
  - Ethernet, Web browser, animation,...
- Embedded Linux support
  - Ported to all TI embedded processors
  - Easily configurable for custom targets
  - Well documented process
- Free dedicated development tools
  - Qt Creator – 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 SPS Fair



# **SOLUTIONS & ROADMAPS**

# 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

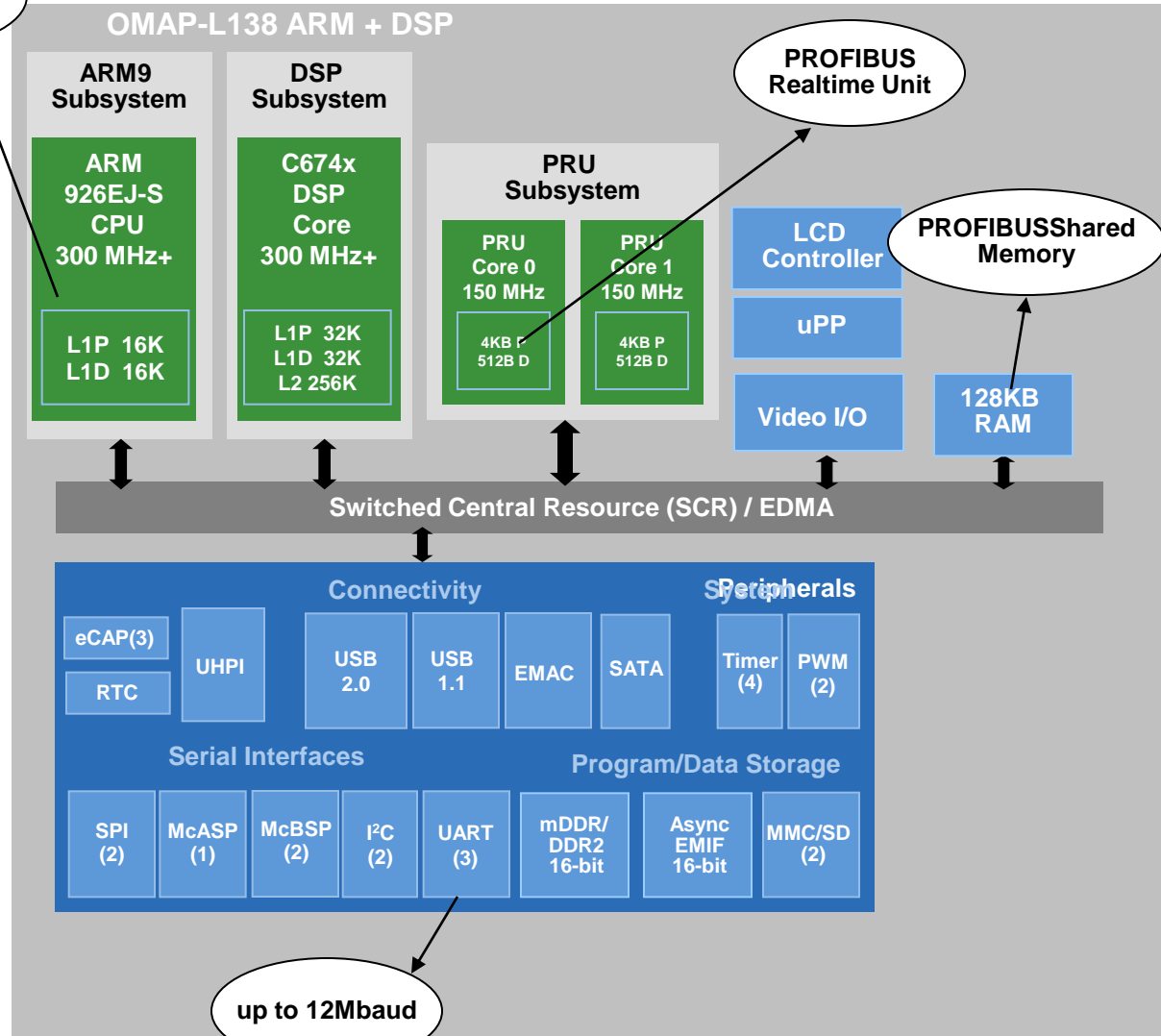
## Package

- 13 x13mm nFBGA (0.65mm), 16x16mm BGA (0.8mm)
- Pin to pin compatible with C6748/6/2, AM1808/6

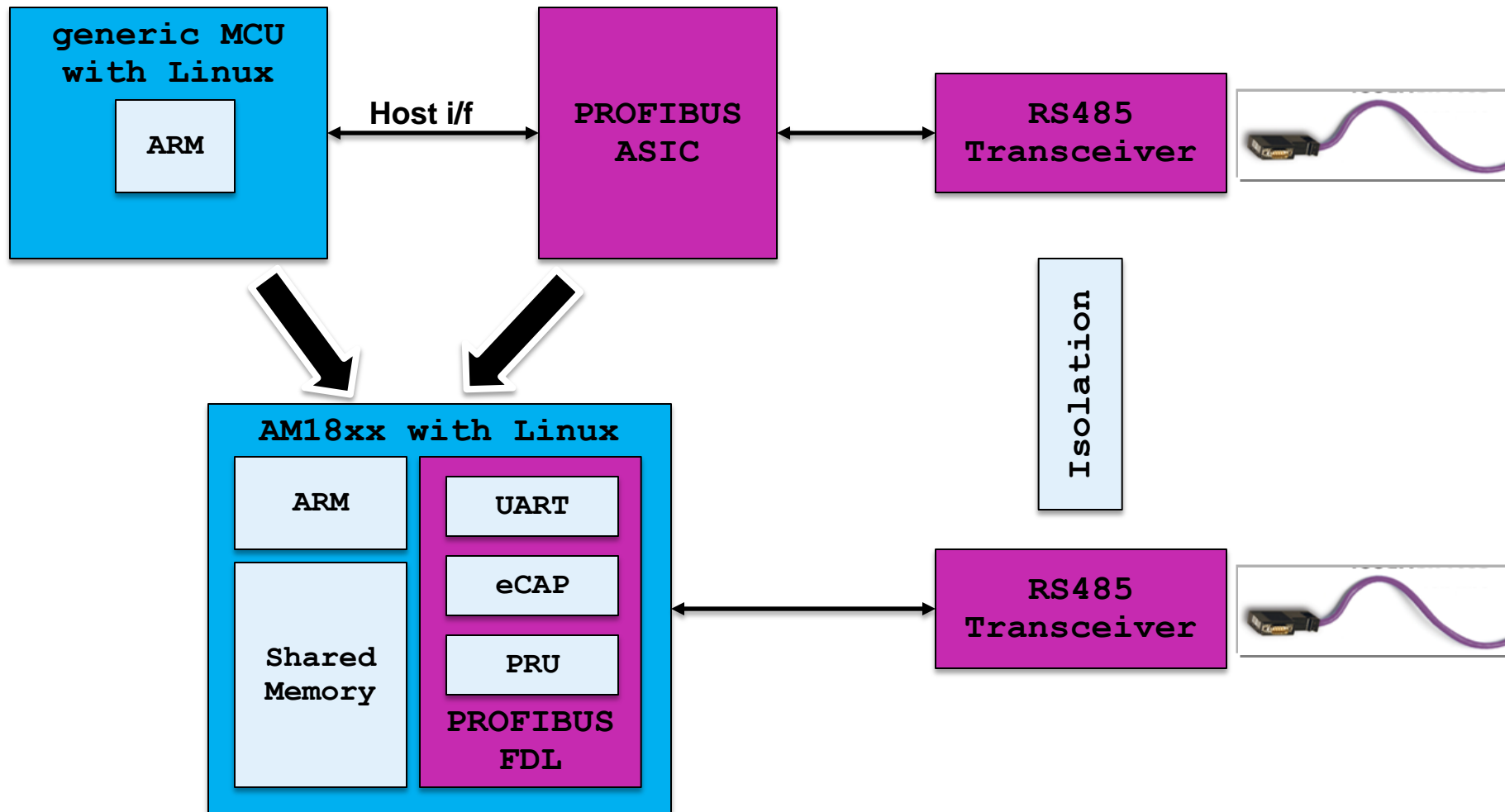
## Applications

- Power Protection Systems, Test & Measurement, SDR, Bar Code Scanners, Portable Communications, Portable Medical, Portable Audio

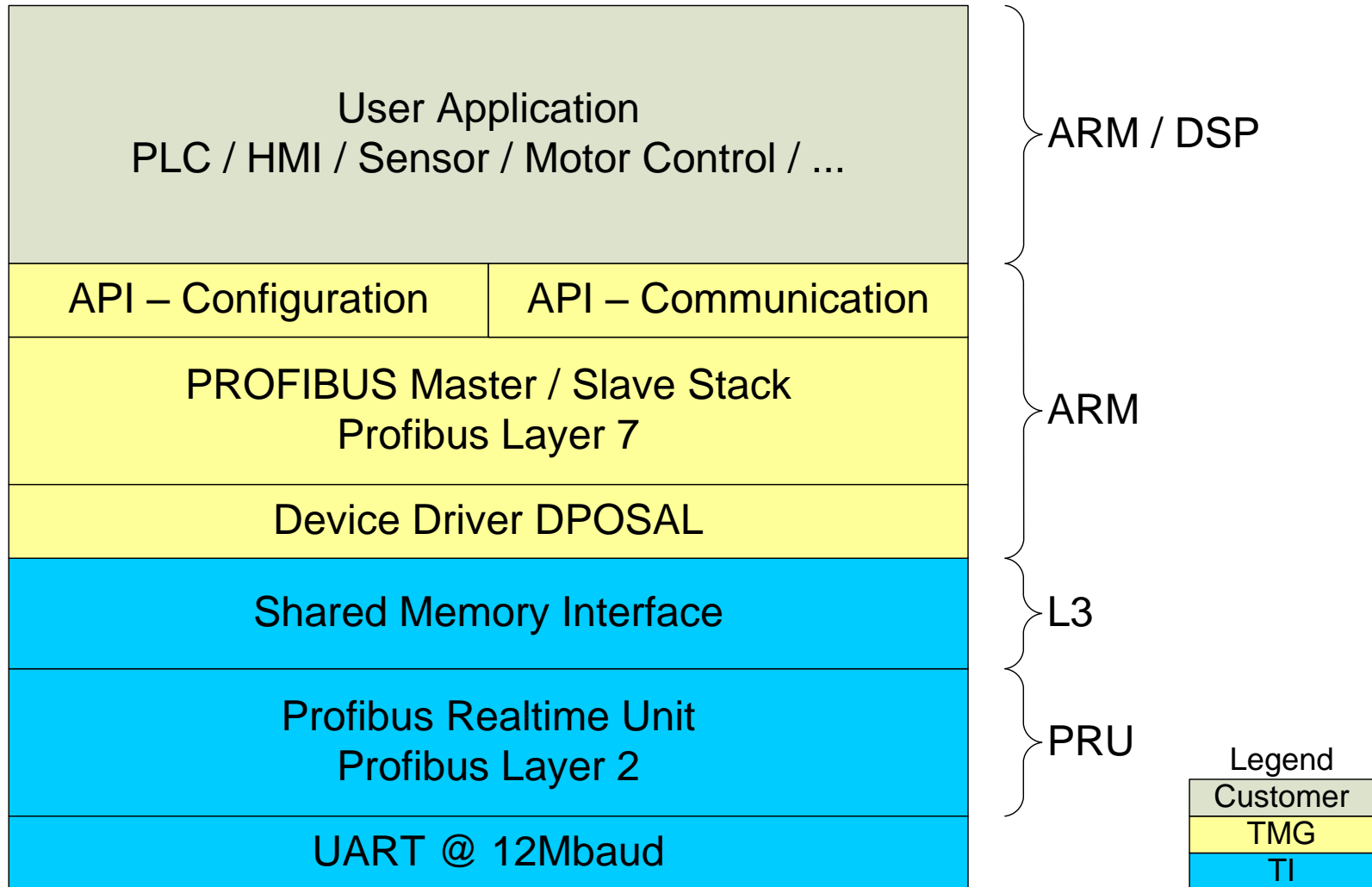
PROFIBUS Stack



# Industrial Example: Integrating a PROFIBUS FDL real-time layer into PRU



# SW Layer Architecture Block Diagram

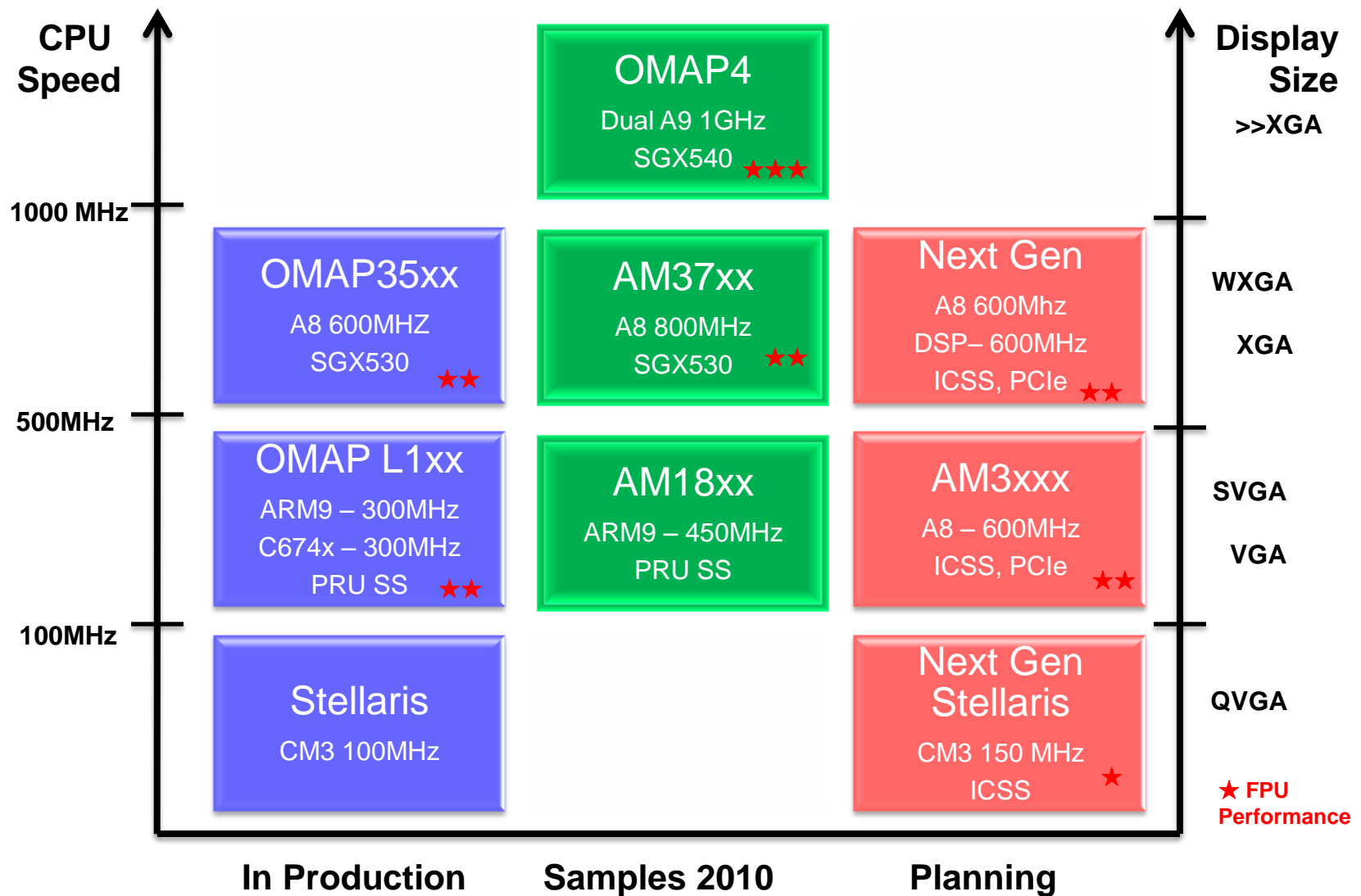


# PROFIBUS Solutions in the Market

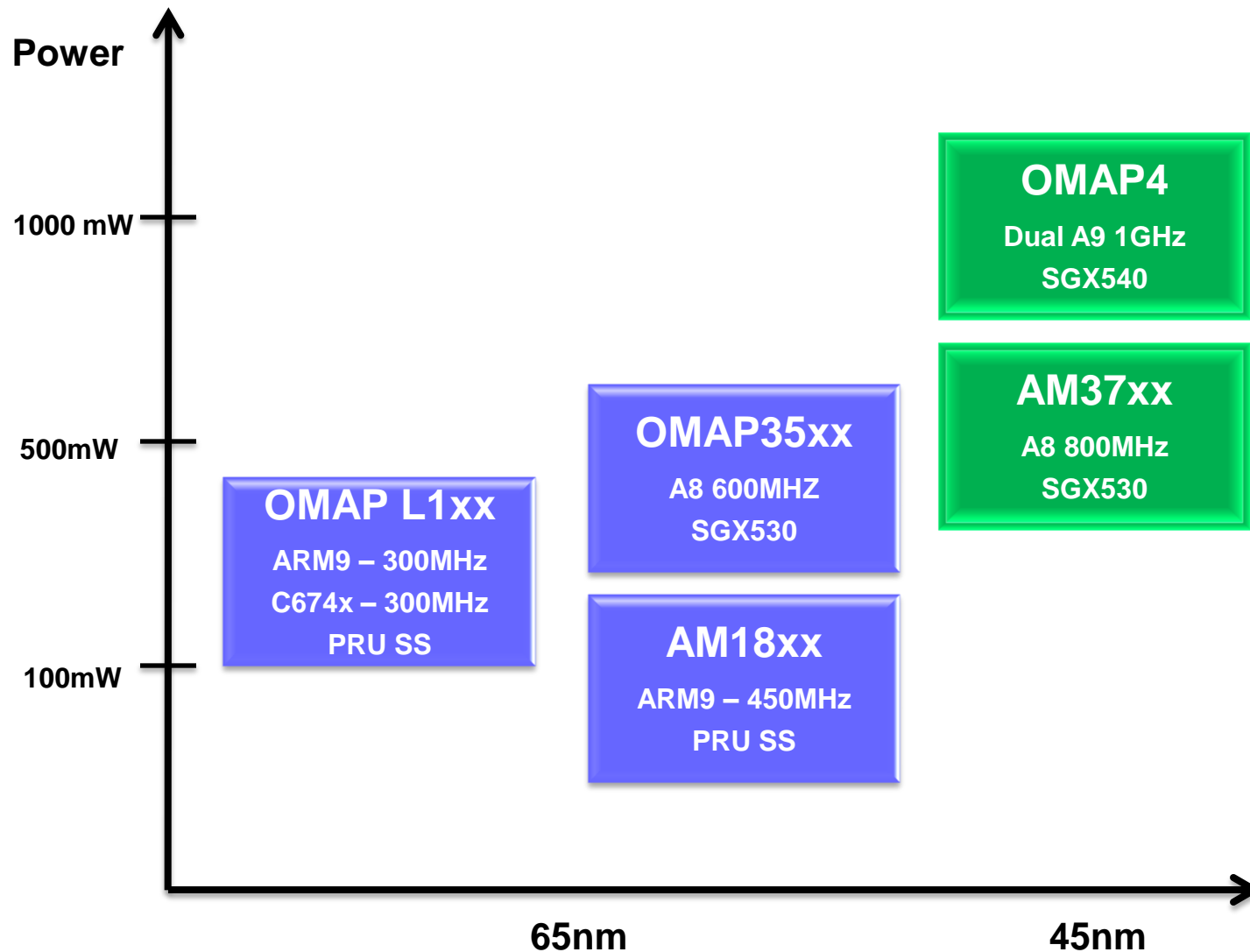
SoC	AM1810	Hilscher NetX50	Siemens SPC3	ProfiChip VPC3+S
Description	Profibus DP (v0, v1, v2(TBD)) Slave and Master; 12Mbps	PROFIBUS, Master, Slave	Profibus DP (v0, v1, v2) Slave; 12Mbps	Profibus DP (v0, v1, v2) Slave; 12Mbps
Processor	<b>385/312MHz</b> <b>ARM926E</b>	200MHz ARM966E	NA	NA
Host Interface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



# Industrial Control/HMI Roadmap



# ARM MPU - Power Consumption



# SUMMARY

# How to solve your problems:

- System & technology approach
  - ❖ More than CPU core and MIPS/MFLOPS
- Size
  - Increased integration
- Power consumption
  - Low-power architectures and designs
- Cost
  - Reduced amount of devices and board space
- Short time-to-market
  - Availability of all needed HW/SW components based on a range of competitive processing platforms
  - Evaluation and development kits
  - Full Eco system for integration and support

# Q&A