Industry 4.0:

Innovative Communication and Sensing Technologies.

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Agenda

- From IoT to Industry 4.0
- Networking and Protocols
- Critical system parameters
- Cyber Physical Production System

Industry 4.0

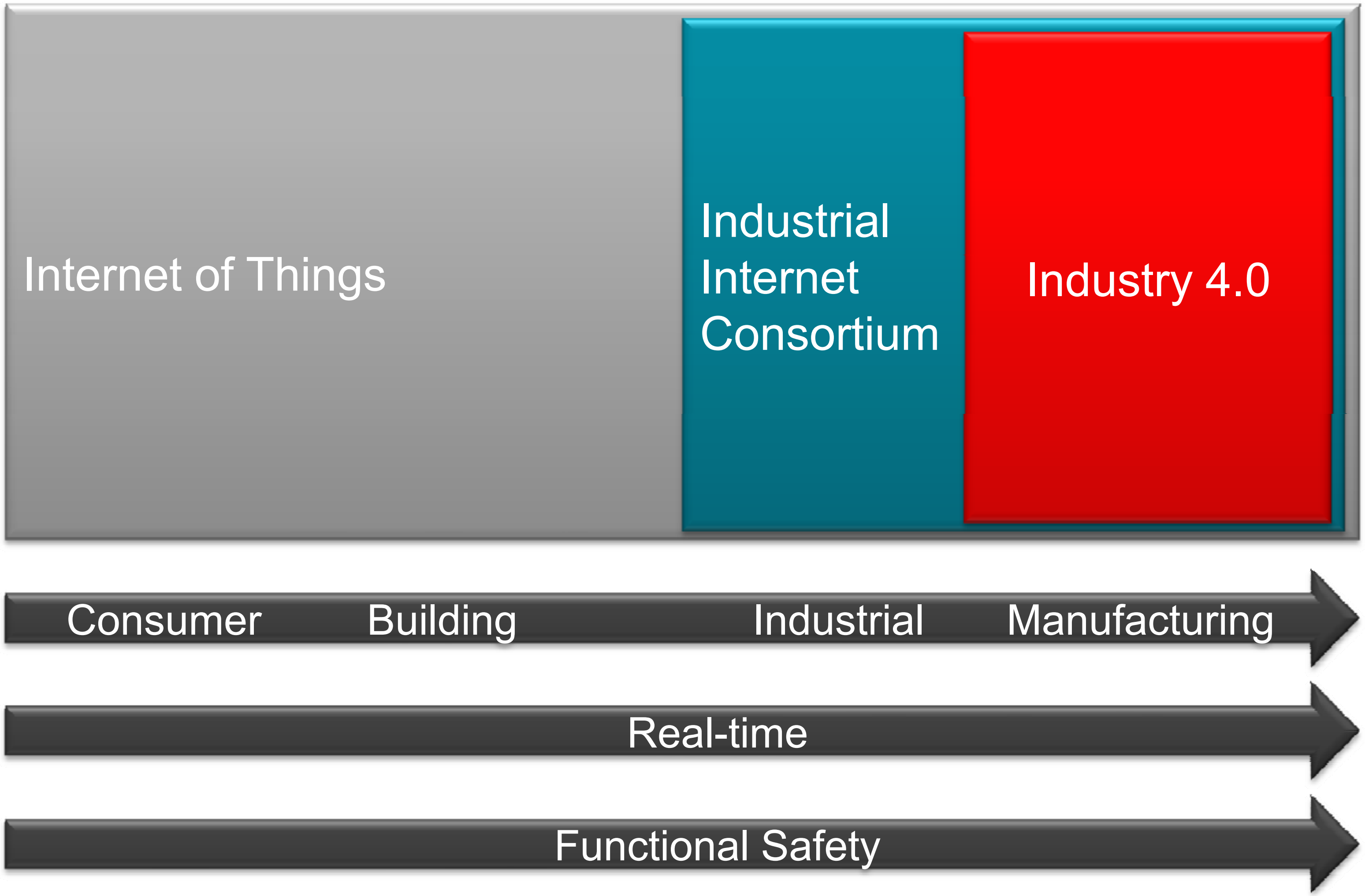
- Industrial Communication Technologies
- More Intelligence on Field level
- Industrial Sensing Technologies
- Expanding Communication towards Material and Product

Technology

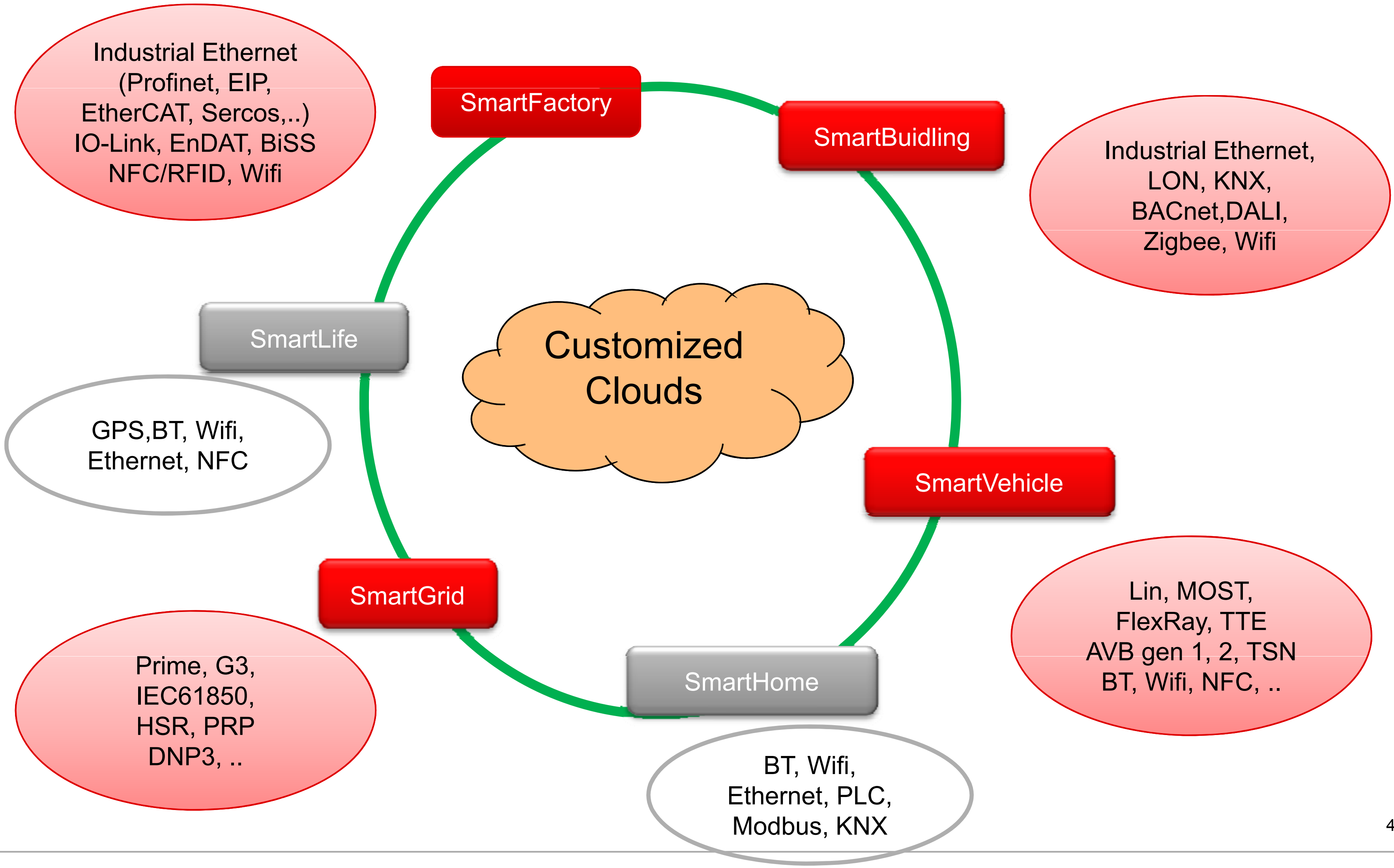
- Industrial Communication
- Industrial Sensing

Trend

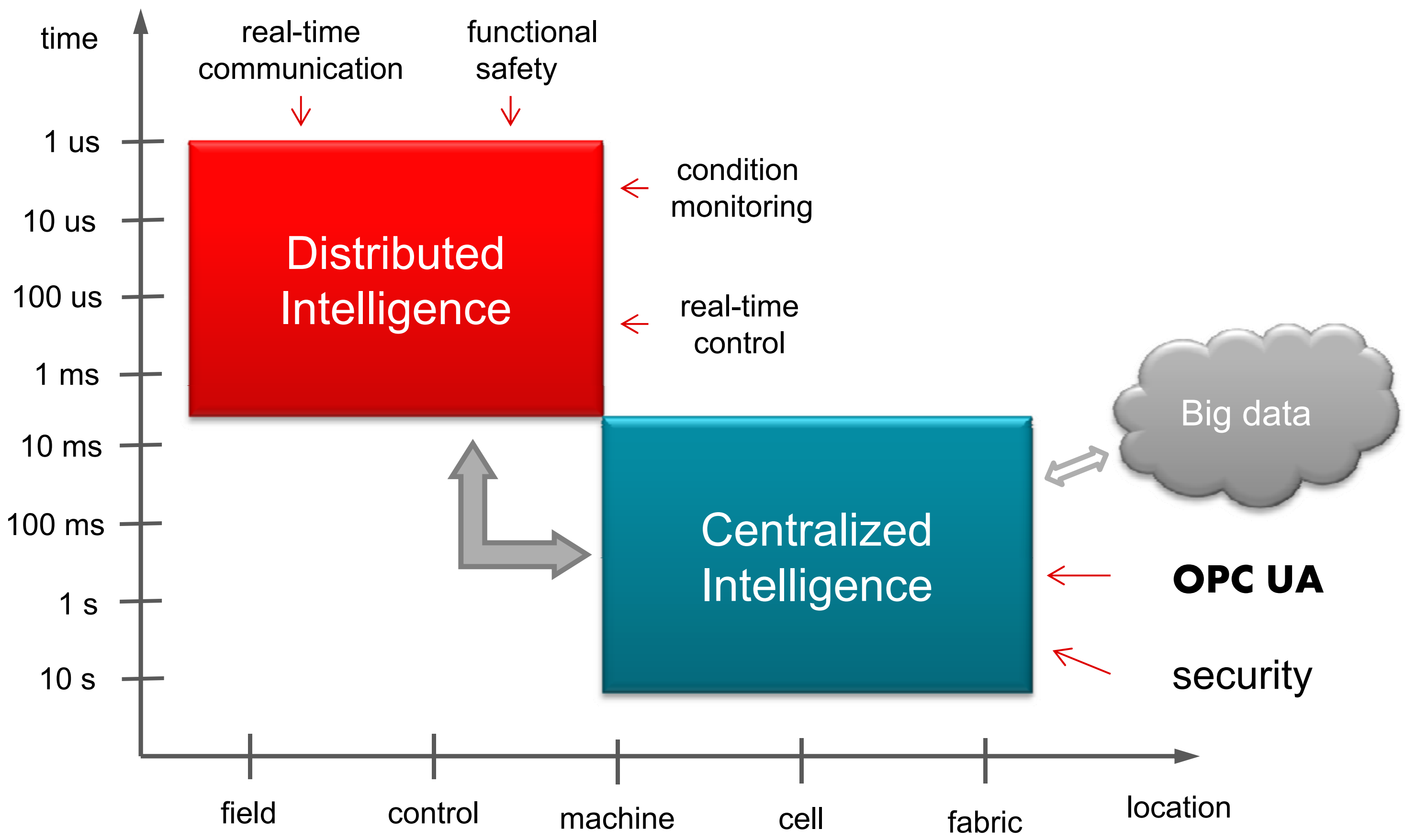
Industry 4.0 -> Factory Automation



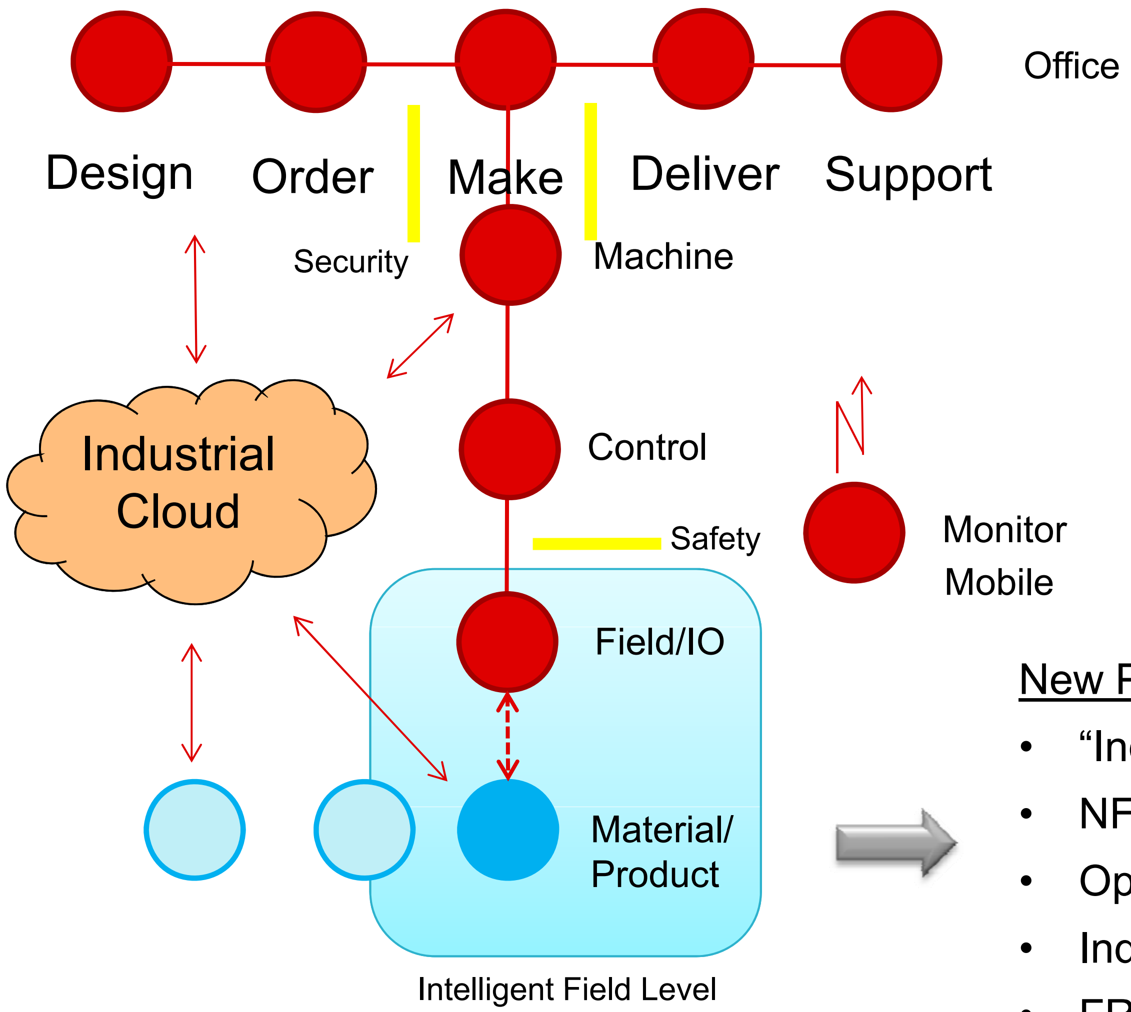
The “Internet of Things” has many Protocols



Intelligence in Factory Automation



Cyber Physical Production System



Key attributes:

- Heterogeneous Network
- Real-time communication
- Secure access and coms

New Potential:

- "Industrial" Energy Harvesting
- NFC, RFID, Sensor tag
- Optical sensing
- Inductive sensing
- FRAM data logging

Industrial – Critical System Parameters

Feature	Latency	Jitter	Safety	Energy
Plant	s	s	24/7	MW
Machine	ms	ms	24/7	kW
Subsystem	us	us	SIL	W
Function	ns	ns	FIT, POH	Harvesting - mW

Efficiency

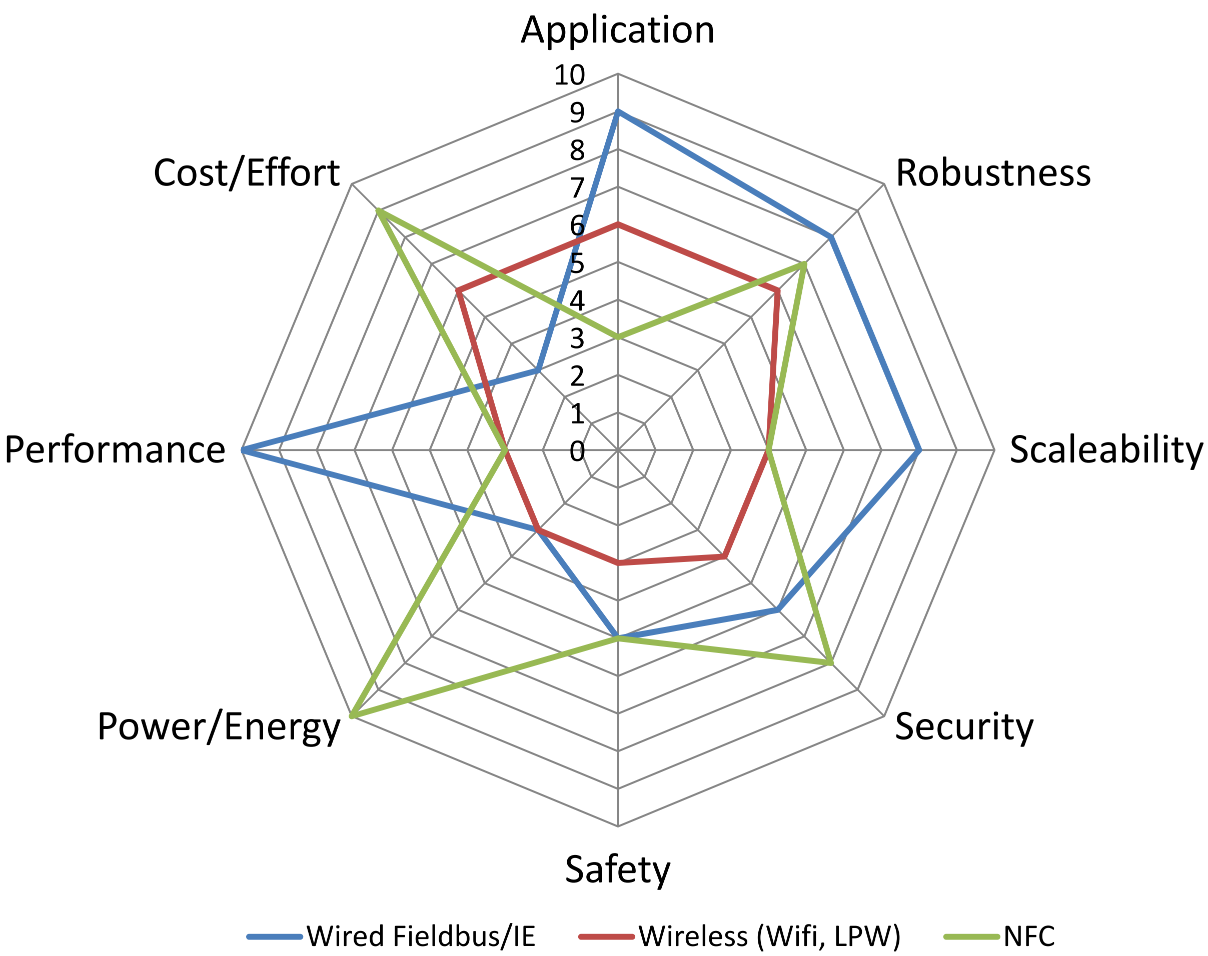
More critical parameters are:

- form factor
- scalability
- robustness
- multi-protocol
- isolation

and

Flexibility

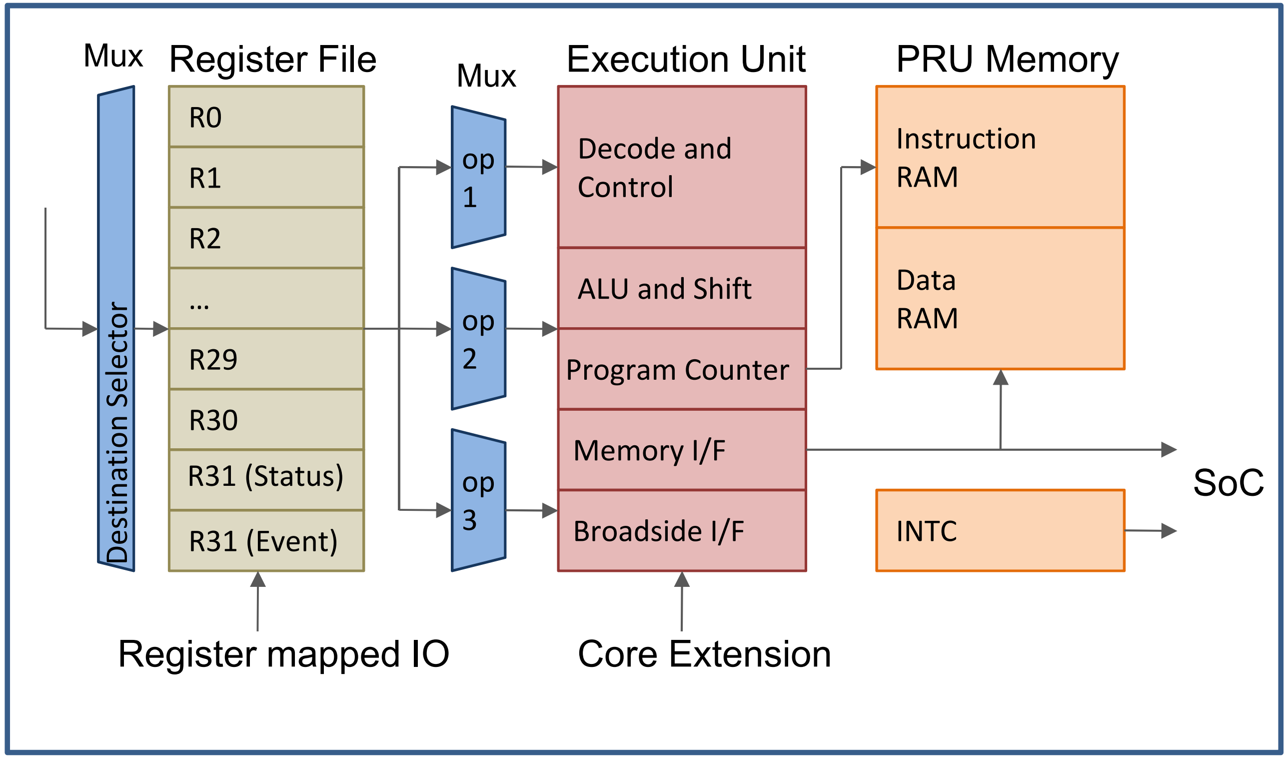
Industry 4.0 - Networking Technologies



Communication between product, machine, operator and cloud requires different feature profiles.

All three communication technologies are required in Industry 4.0

PRU optimized for low latency and jitter



Programmable

Real-time

Unit

Example:
Count number of 1s in byte

1001'1010

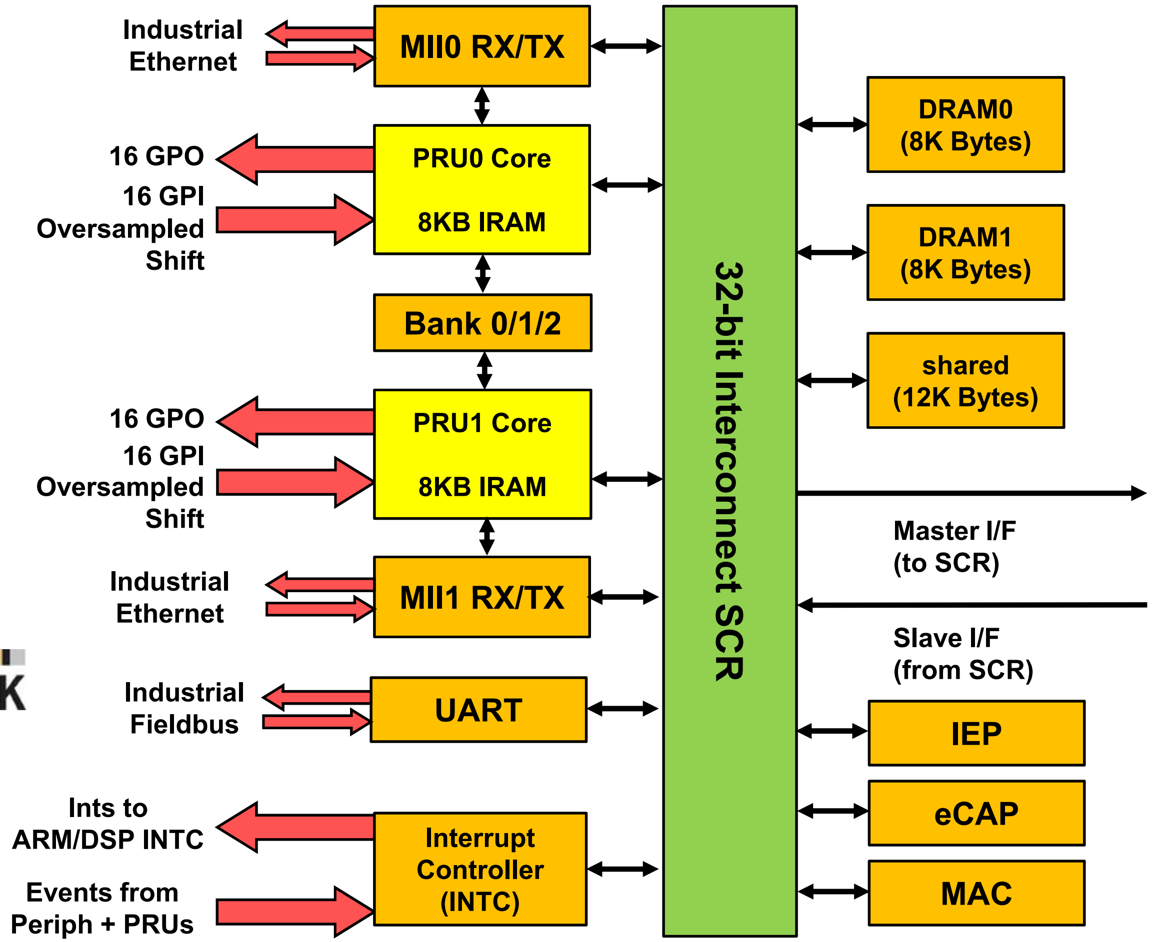
takes 8 instructions
=> 40ns

- Non pipelined CPU is 100% deterministic – **no jitter** in real-time execution
- Broadside interface with 1000 bit wide data bus supports **lowest latency** transfers
- Register mapped IOs and bit-wise addressing provide **max interface flexibility**
- 200 MHz design allows for **scalable integration** on Analog, MCU and MPU products

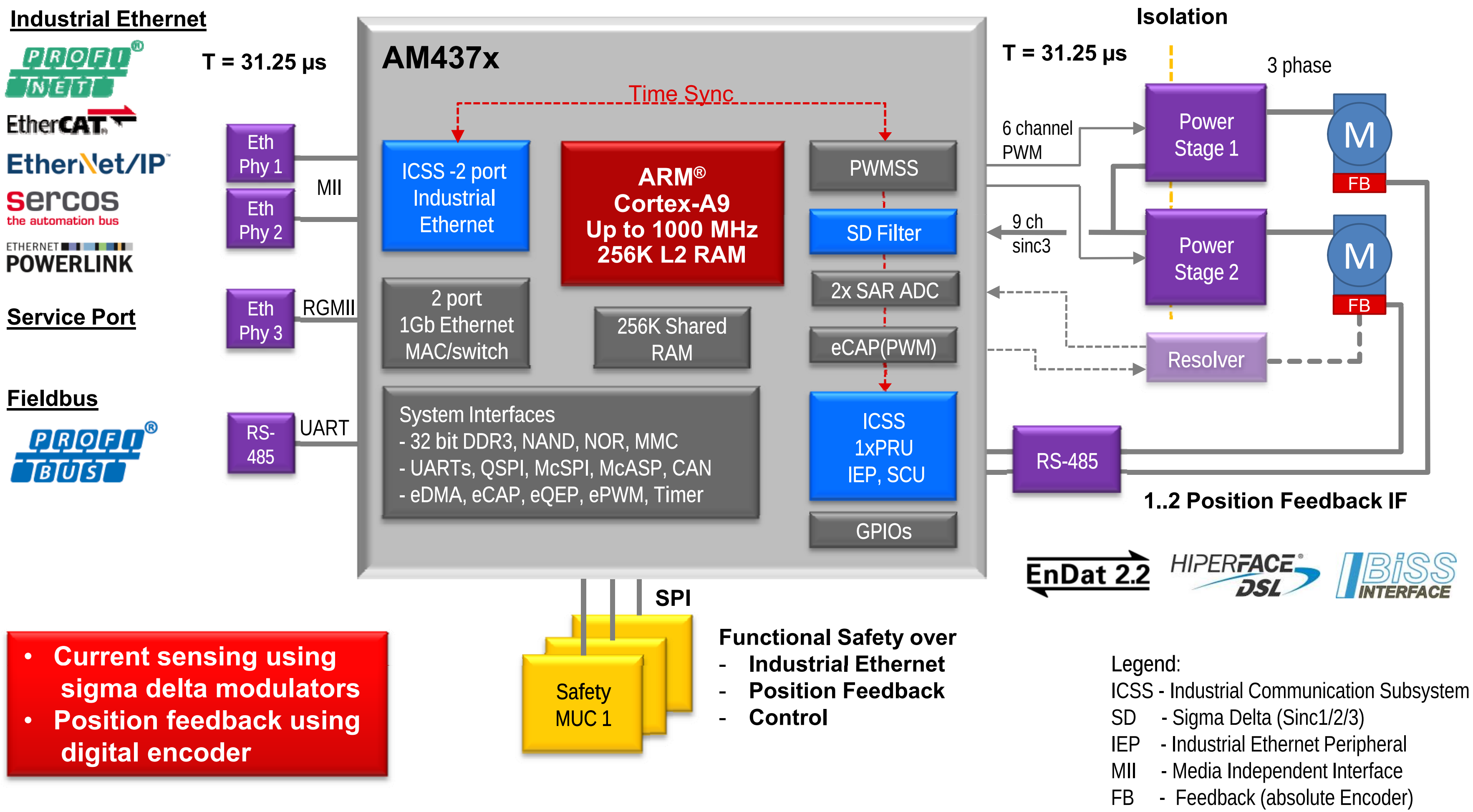
Industrial Communication Subsystem (ICSS)

- Industrial Ethernet
- Serial Fieldbus
- Encoder Feedback
- Backplane Communication
- Sigma Delta filter
- Custom interfaces
- Signal Processing
- Application Synchronization

ICSS Functional Block Diagram



Motor side Sensing goes Digital



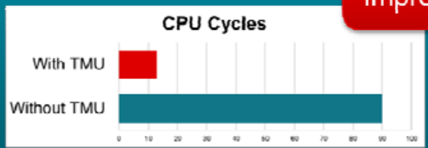
More Intelligence on Embedded Controllers

App Acceleration

- Trigonometric math acceleration
- Single/few cycle sin, cos, arctan, divide, square root
  - Park & Inverse Park
  - Space Vector Generation
  - DQ0 Transform & Inverse DQ0
  - FFT Magnitude & Phase Calculations
- Complex math, FFT, and Viterbi algorithm acceleration
- CRC, AES acceleration
  - Complex FFT, CRC and AES
  - Motor Vibrational Analysis
  - Power Line Communications

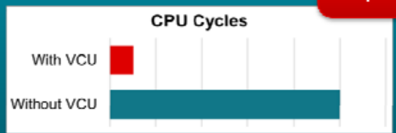
Park Transform Example:

85% Improvement

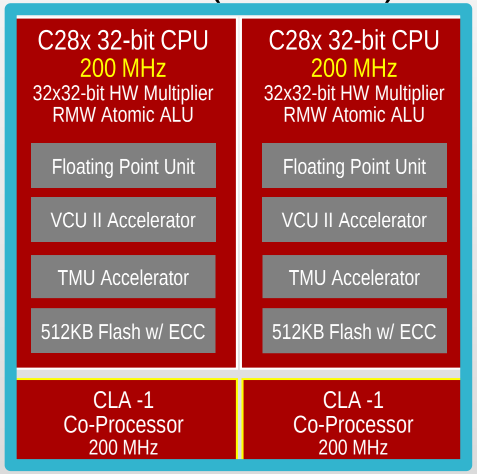


G3-FCC PLC Example:

90% Improvement



Platform (F2837x)



DSP Math Efficiency

- Up to 300 MIPS per core
- 800 MIPS MCU available today
- Single cycle execution across pipeline; Atomic R-M-W operations
- 32x32 fixed-point MAC, doubles as dual 16x16 MAC
- IEEE Single-precision floating point hardware and MAC
- 16-bit / 32-bit instructions for density / performance
- Blended Control + DSP instruction set architecture

Parallel Processing

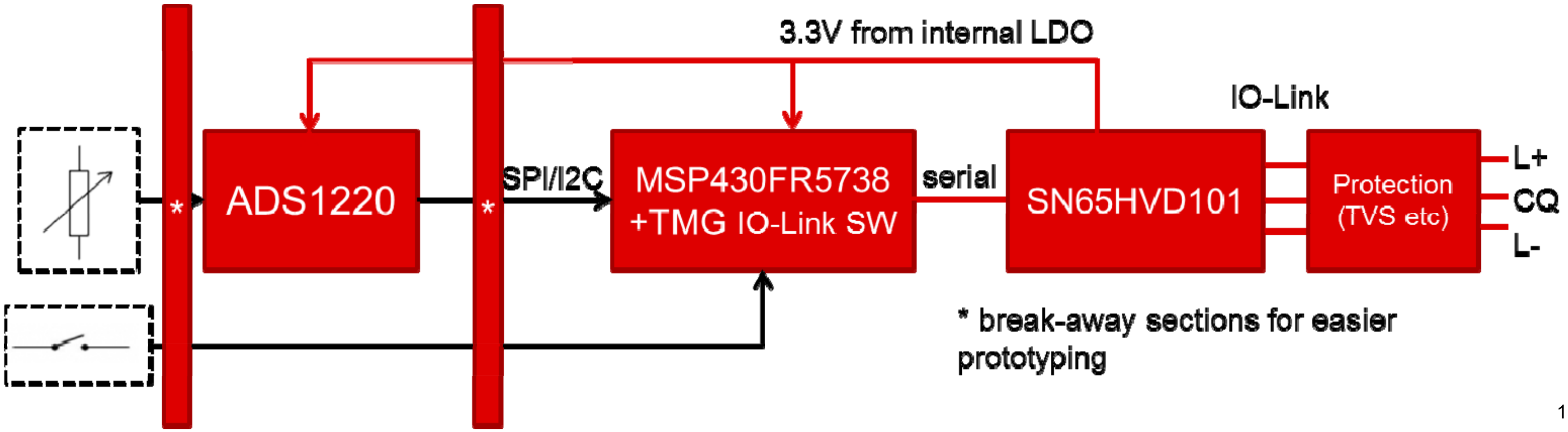
- CLA co-processor is a streamlined C28x processor
- Independent processing of multiple control loops
- IEEE Single-precision 32-bit floating point math operations
- Direct access to control peripherals

"High-end MCUs provide x86 like algorithm performance at the sensor level"

IO-Link – Sensor Interface

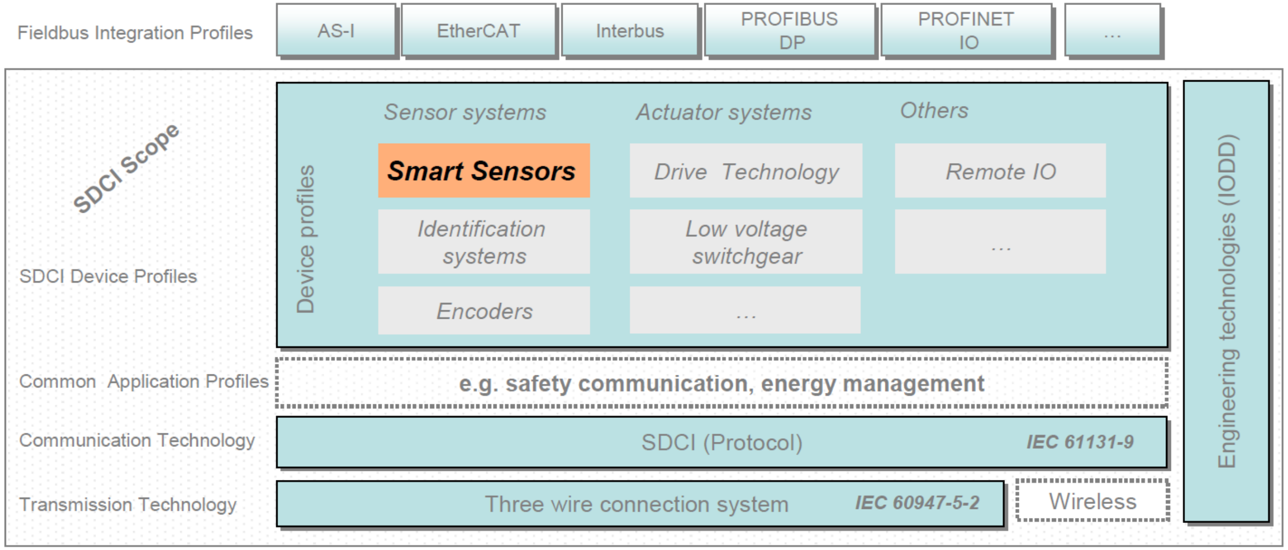
Technical Specification:

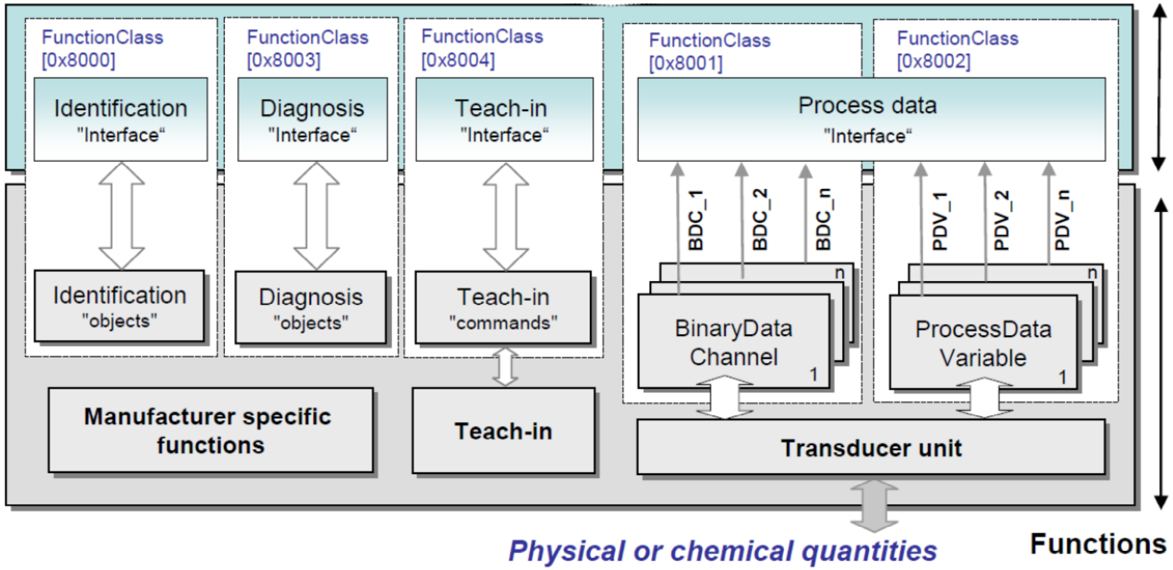
Data rate:	4.8kB, 38.4kB, 230.4 kB
Cable length:	20 m, unshielded
Cycle time:	2ms
Communication:	point to point, serial, half-duplex
Signal:	500mA (80us) start pulse, 24 V pulse modulation



IO-Link: Smart Sensor Profile

"Point to point sensors are concentrated and mapped into industrial communication protocols"





"Data representation is independent of measurement type"

Innovative Sensing Technologies

Sensing Innovation

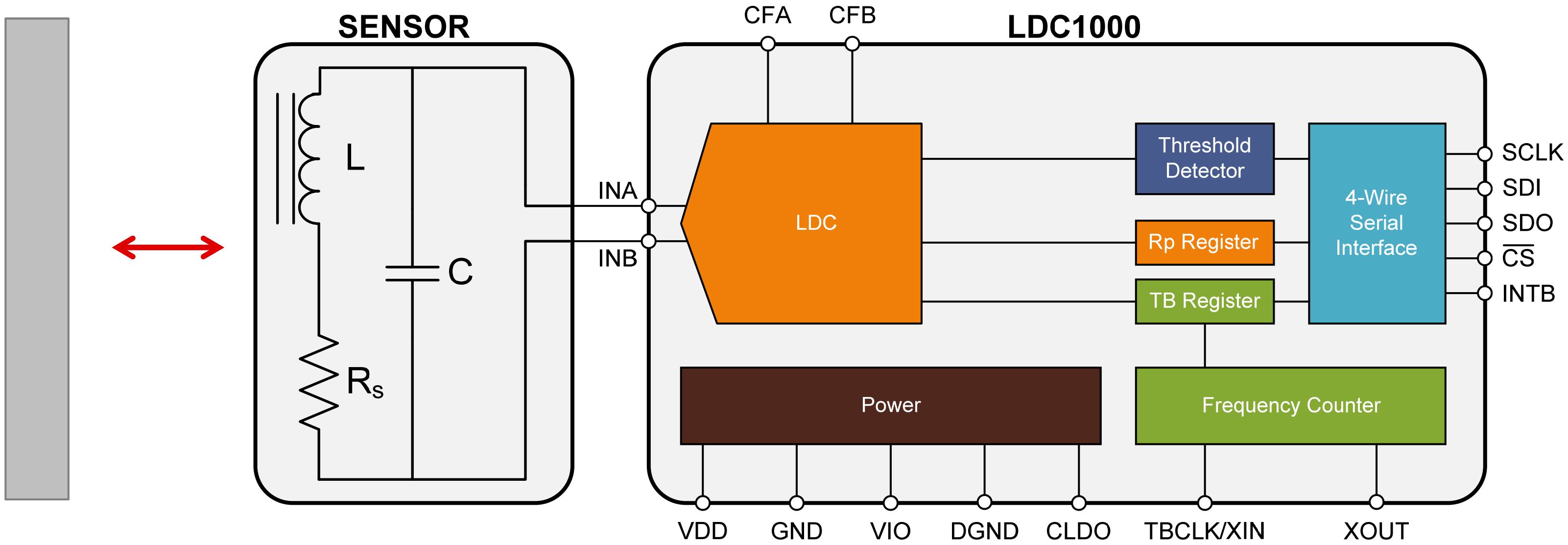
Delivering better solutions for today & tomorrow's sensor designs

- Inductive Sensing – LDC 1000
- Optical Sensing – 3D TOF OPT8241
- "Smart Sensor Tag" - RF430FRL15x

Inductive Sensing

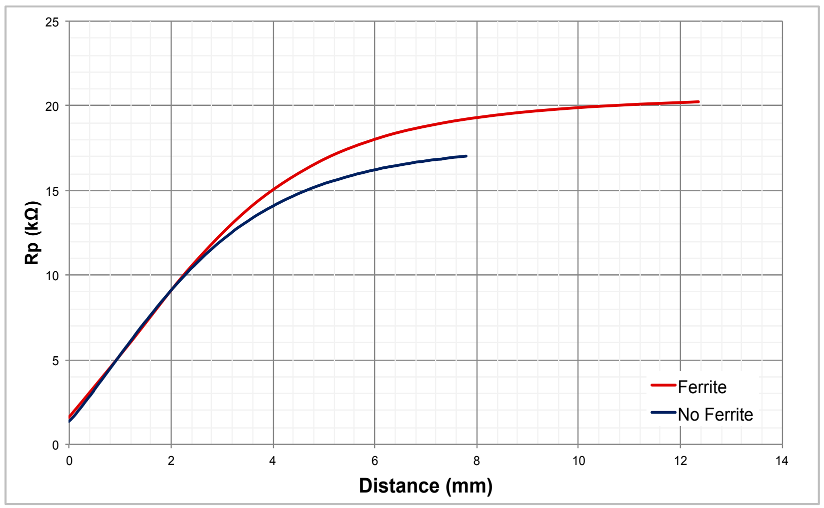
"Product and material sensing beyond identification"

Inductive Sensing: Basic Theory



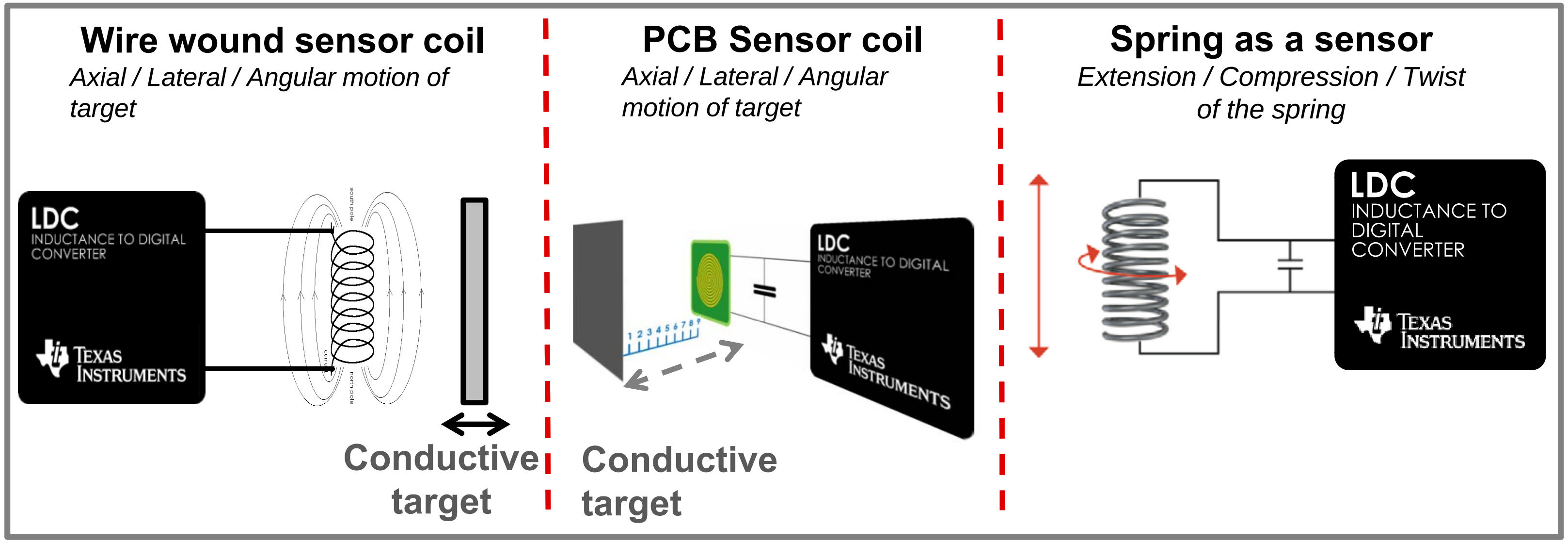
1. *Operate LC resonator in closed loop.*
2. *Magnetic field on target causes circulating current (eddy currents)*
3. *Eddy current from target generates magnetic filed which changes impedance on sensor*

$$Rp = \frac{1}{Rs}\frac{L}{C}$$



Inductive Sensing - Benefits

Inductive sensing



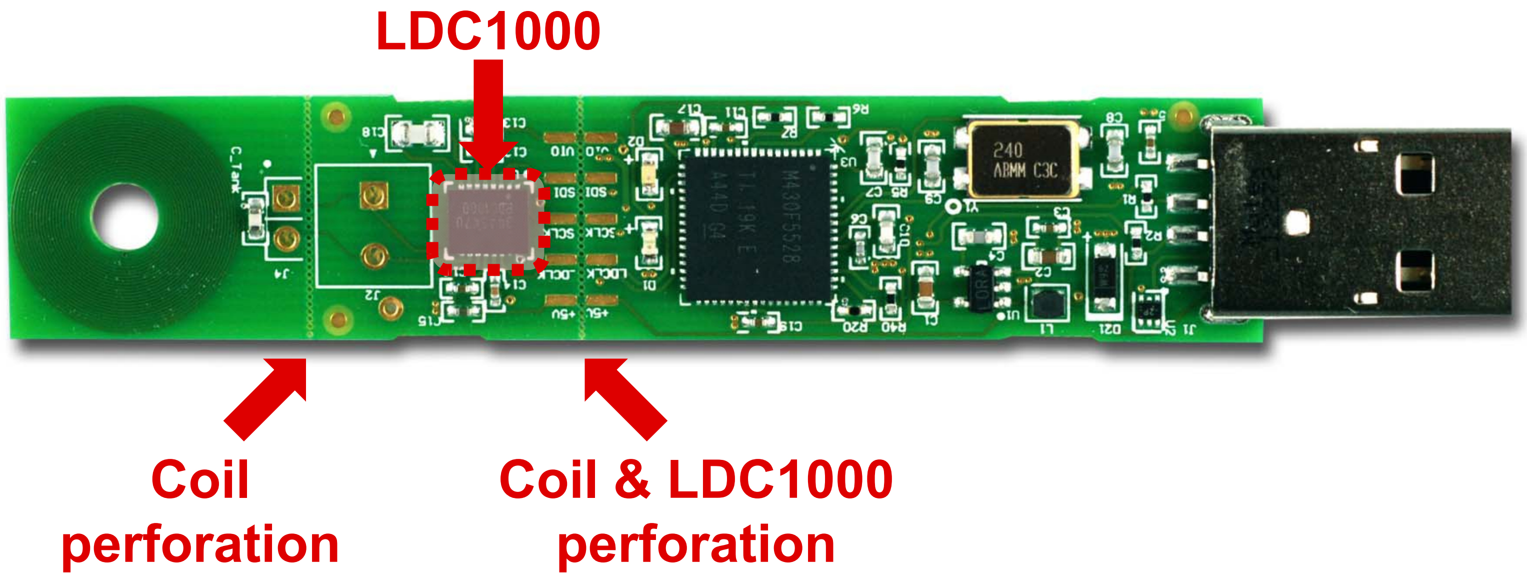
Benefits

Advantages of Inductive Sensing:

- Does not require magnets
- Reliable by virtue of being contactless
- Insensitive to environmental contaminants (dust, dirt, etc.)
- Sub-micron resolution (16 bit on Rb, 24 bit on L)
- Sensor is low-cost
- Electronics can be located remotely from the sensor

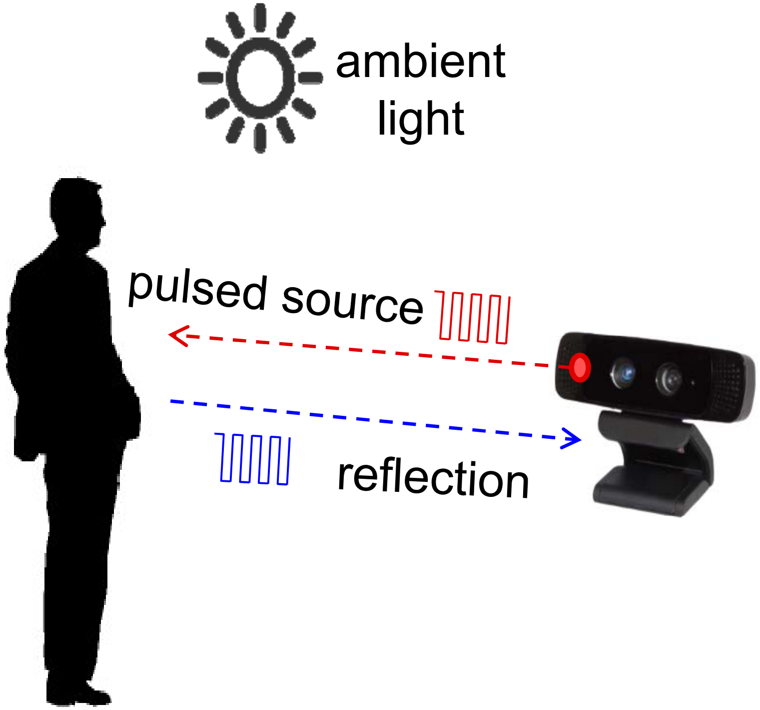
LDC1000 Evaluation Module

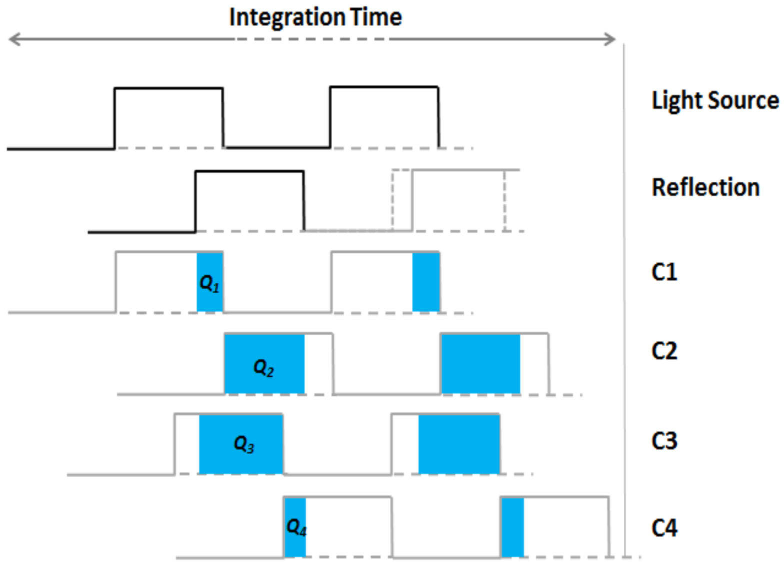
LDC1000EVM

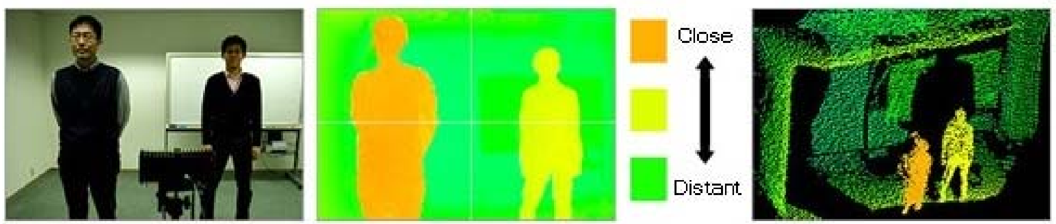


- EVM and GUI provide complete prototyping and evaluation platform
- USB interface allows control and evaluation of LDC1000 with GUI
- Includes 14-mm, 2-layer PCB coil sensor
  - Coil can be removed to allow prototyping with other coils, springs or inductors
- Coil and LDC1000 board section can be removed
  - Interface with other MCUs
  - Implement multi-channel prototyping

3D Imaging/TOF Sensor Operation





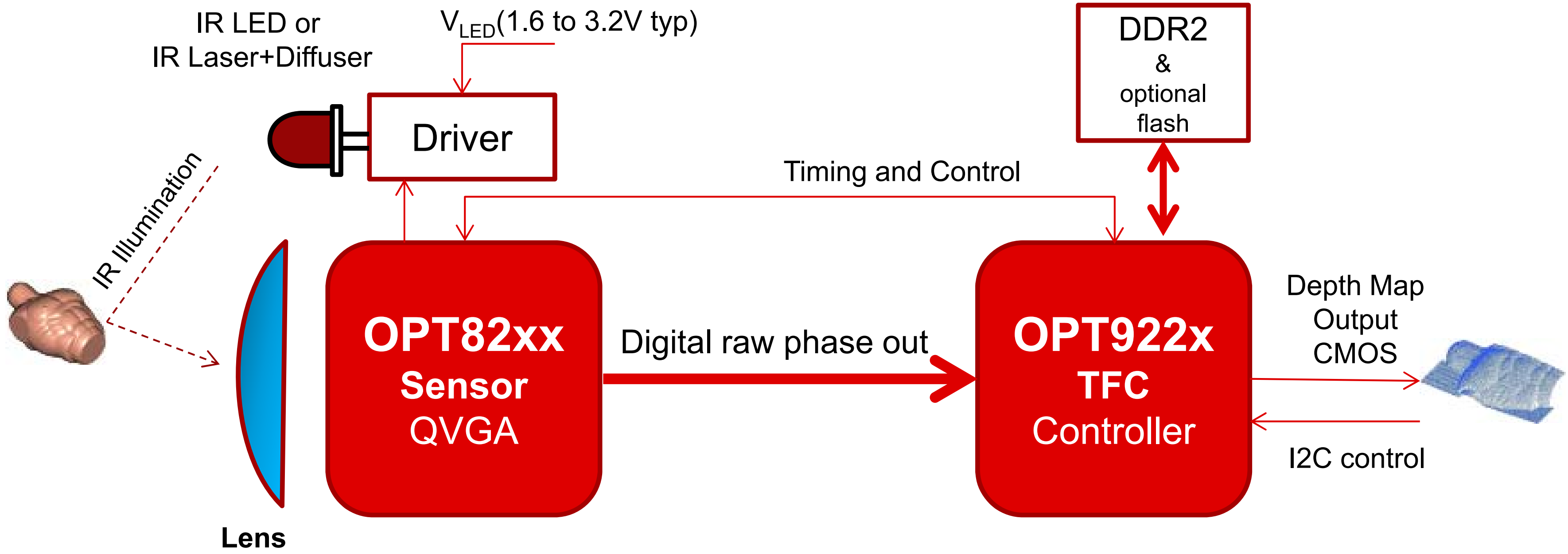


General 2D image | Color Range image (depth information) | 3D image

$$\phi = \arctan\left(\frac{Q_3 - Q_4}{Q_1 - Q_2}\right)$$

$$d = \frac{c}{2f} \cdot \frac{\phi}{2\pi}$$

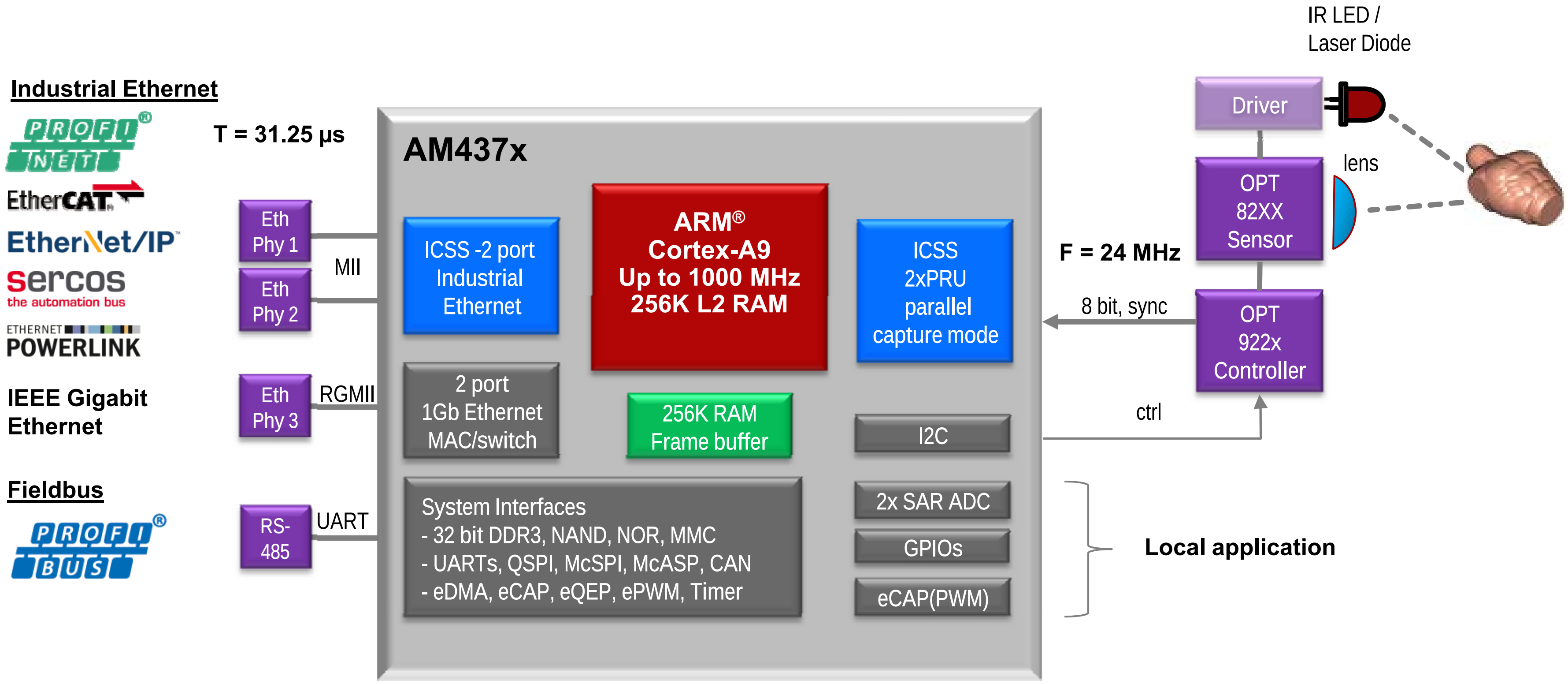
3D ToF Chipset Diagram



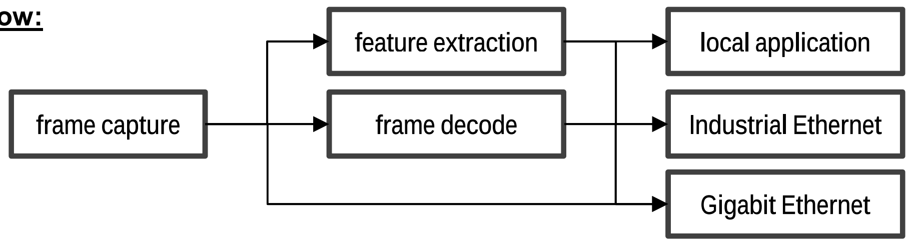
Features:

- Pixel resolution: up to QVGA (320x240, 76k pixels)
- Max Frame Rate: 60 fps … 1000 fps (lower resolution)
- IR Filter: (820-865nm), support HDR,
- Distance: 10-20mm, 1-2 meter (machine vision) , 10-15 m (safe island)
- Pulse frequency: up to 20MHz (LED), up to 50MHz (laser)
- Output: DVP – 8bit parallel , hsync, vsync, pixel clk (24 MHz)

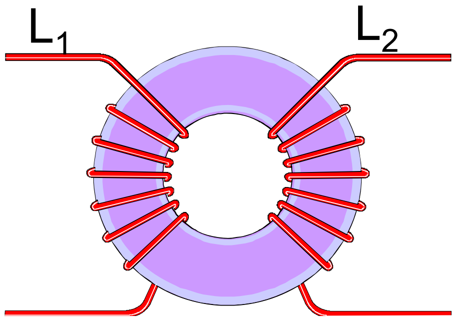
Machine Vision Example

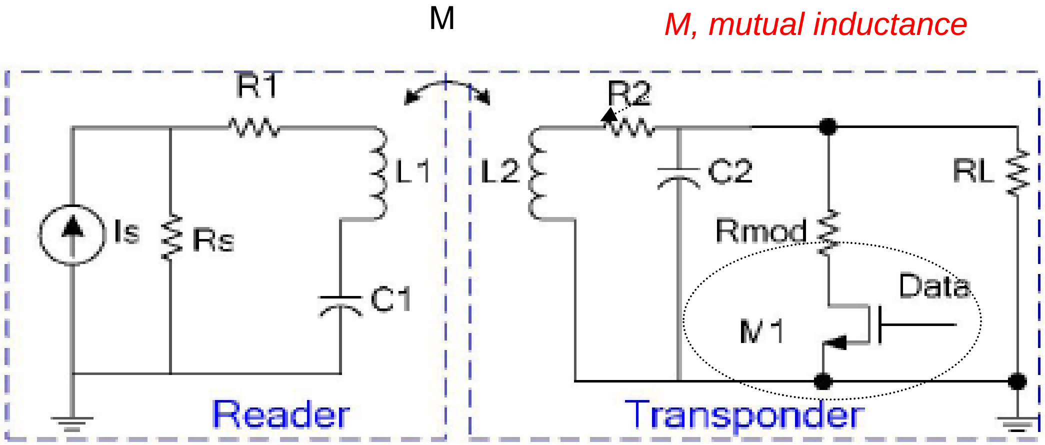


Processing Flow:



NFC / RFID Operating Model





K, coupling coefficient is related to M as:

$$k = \frac{M}{\sqrt{L_1 L_2}}$$

k (typical) = 1% to 10 %

H – Field from Reader coil vs. distance

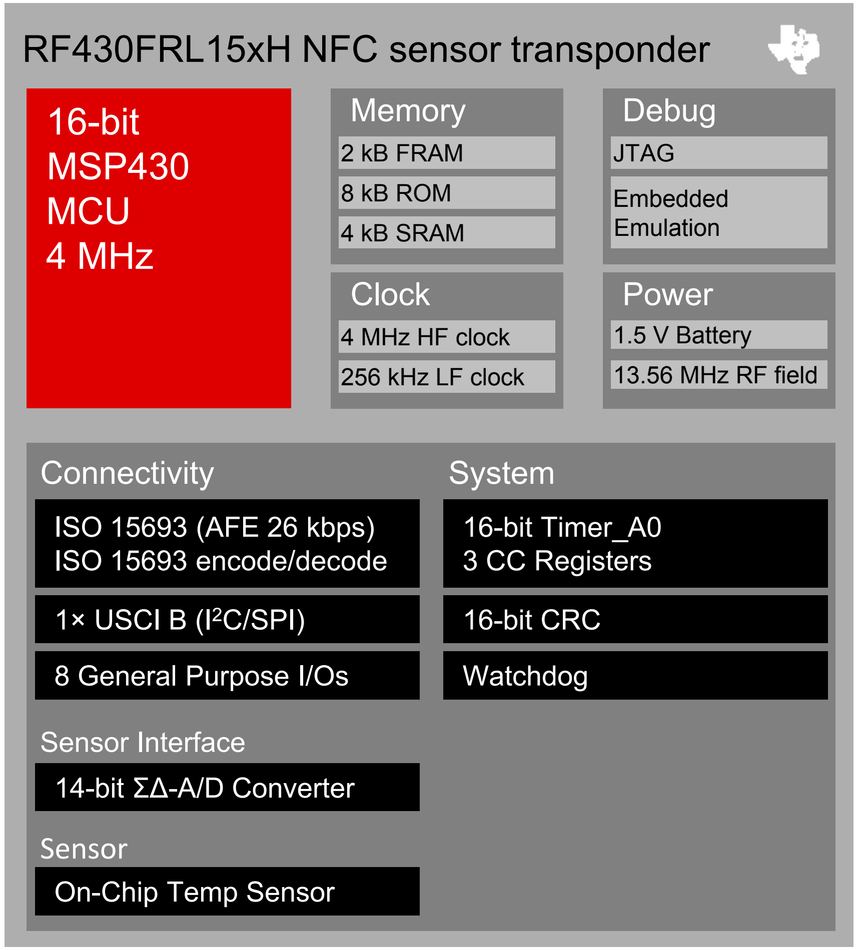
$$H(d) = \frac{N_r I_r r_r^2}{2\left(r_r^2 + d^2\right)^{\frac{3}{2}}}$$

Induced voltage in parallel coil vs. distance

$$V_{id} = 2\pi f N_T Q_T S_T \mu_o H(d)$$

Introducing RF430FRL15xH sensor transponder

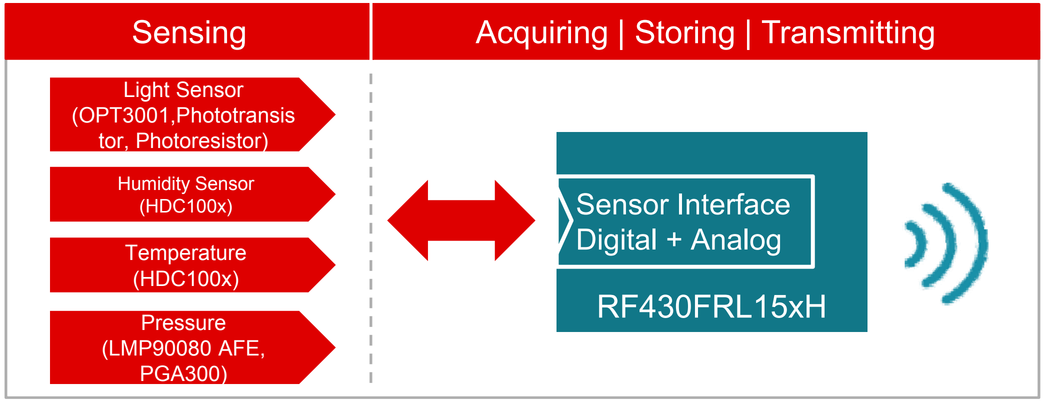
ADC	• Analog sensor interface • Integrated temp sensor
NFC	• Secure proximity pairing • Secure data transfers
Serial IF	• Digital sensor interface • Connection to a gateway
FRAM	• Non-volatile / fast access • Data & program storage
CPU	• Collection setup • Data processing
Low power	• Passive operation • 1.5V battery



Expand the uses and lifetimes of industrial sensors

NFC provides reliability and endurance for sensors:

- Putting the sensor into material and product for condition monitoring over lifetime.
- Allow hermetically encapsulated industrial sensors to be placed in space-constrained areas and dangerous or hash environments
- Ultra-low-power FRAM eliminates the need for battery changes, or enables battery-free sensors
- Easily transfer data within close proximity without physically accessing sensor
- Ideal for applications and areas where workers can't physically access sensors to collect data



Summary – Industrial Sensor

- The factory of the future needs sensors which are
  - Intelligent
  - Functional safe
  - Real-time in communication and control
  - Compliant to sensor profiles
  - Robust in harsh environments
- Communication interfaces for sensors need to support
  - Wireless
  - Wired
  - Remote powered (wired and wireless)
- Product/Material attached sensor need
  - energy harvesting
  - encapsulation which works over product life time

Summary Industrial Communication

- Dedicated protocols for real-time, deterministic and safe delivery of IO sensor data in factory automation
- Concentration of point to point sensor interface into fieldbus and Industrial Ethernet
- Motor side communication goes digital for current sensing and position feedback.
- Industrial sensor communication goes digital with IO-Link
- Encapsulation of real-time protocols into socket based communication using UPC UA at higher layers
- Trend towards gigabit Industrial Ethernet to add more service capability
- Modulated data over power saves expensive cables
- Wireless on non-real-time setup (process automation)

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