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Connected Motion and Robotics: Systems, Platforms and Solutions for Industry 4.0

DARA O'SULLIVAN

ROGER YU

MOTOR CONTROL SHENZHEN CONFERENCE

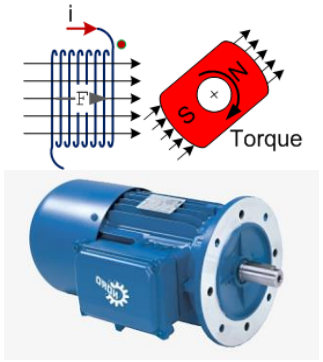
NOV. 2019

FAE TRAINING

ANALOG DEVICES, INC.

What is Motor Control?

Electrical Energy



Drive/Servo

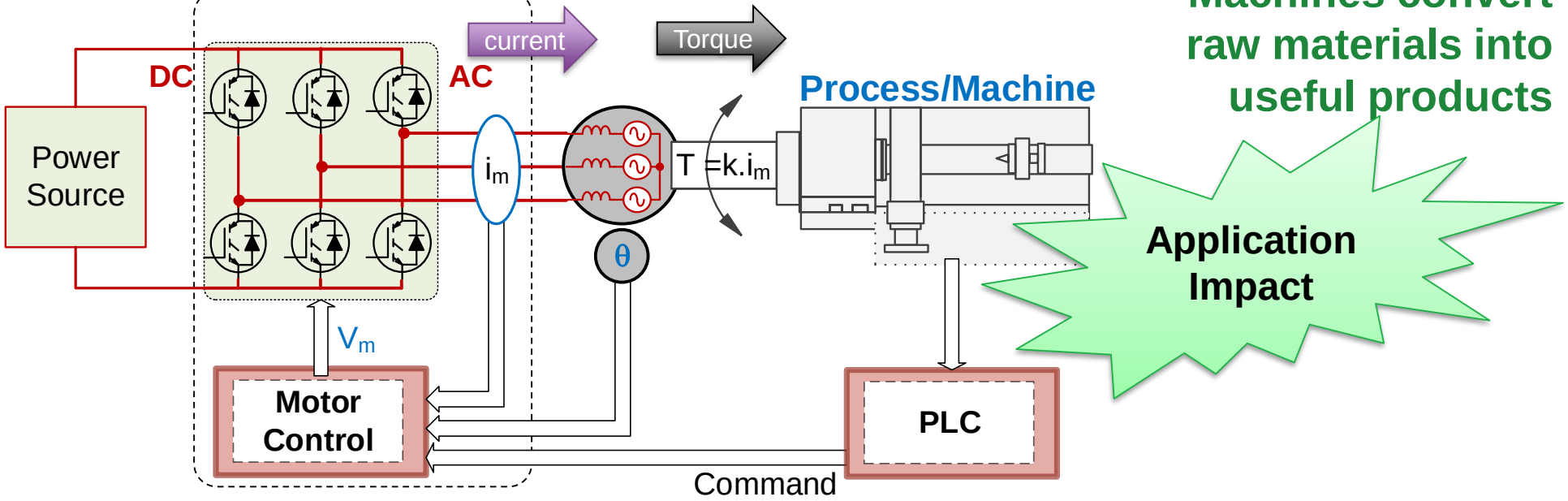
AC Motor

Mechanical Work

Motors convert *Current* into *Torque*

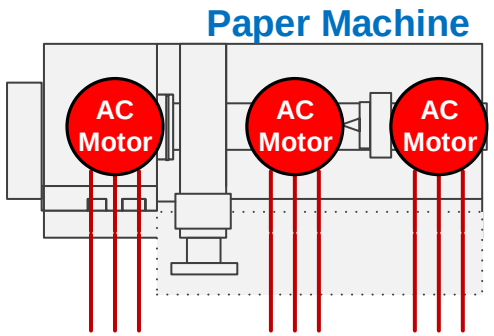
Drives control the motor current to meet the Machine Control demand for *Torque, Speed or Position*

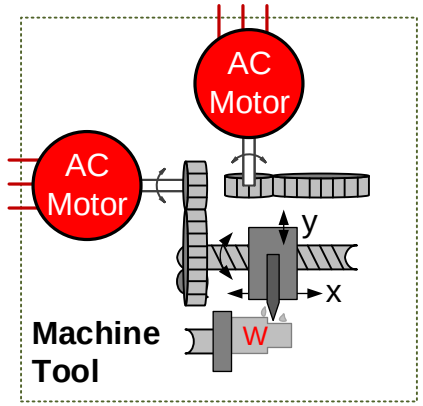
Machines convert raw materials into useful products

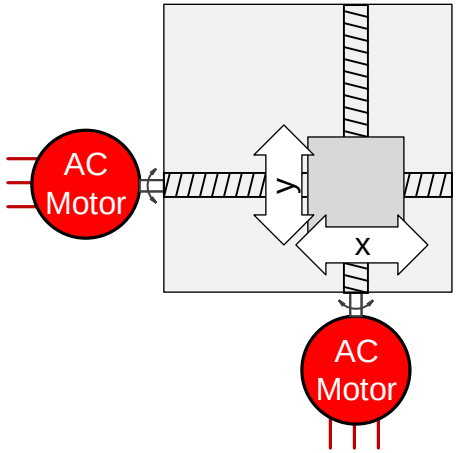


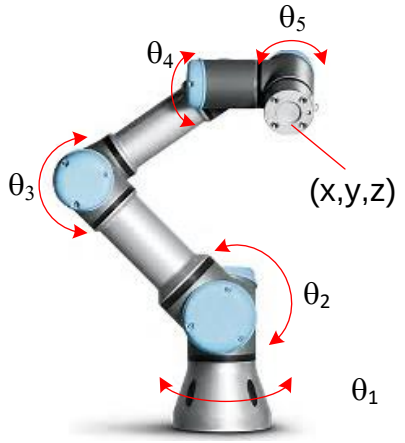
Multi-Axis *Synchronized* Motor Control

- Sheet or Wire Production (paper, steel, plastics, rope, cables etc.)
  - Synchronized speed of multiple rollers/drums.
  - Variable electronic gearing to maintain tension
- Metal Processing (Turning, Milling, Grinding, Drilling)
  - Continuous motion of cutting tool relative to work piece
  - Synchronized control of tool position along multiple axes
- Electronic Assembly (Circuit boards/wire bonding)
  - Rapid motion of tool in Cartesian plane.
  - Precision control of tool (x,y) position and vertical force
- Automotive and general assembly (cars, consumer goods etc.)
  - Synchronized motion control of multiple axes
  - Flexible programming and fast response









Motor Drives and Servos in Industrial Automation

- Process Automation
  - Oil and Gas; Mining; Cement; Chemicals; Steel; Paper; Food and Bev; HVAC etc.

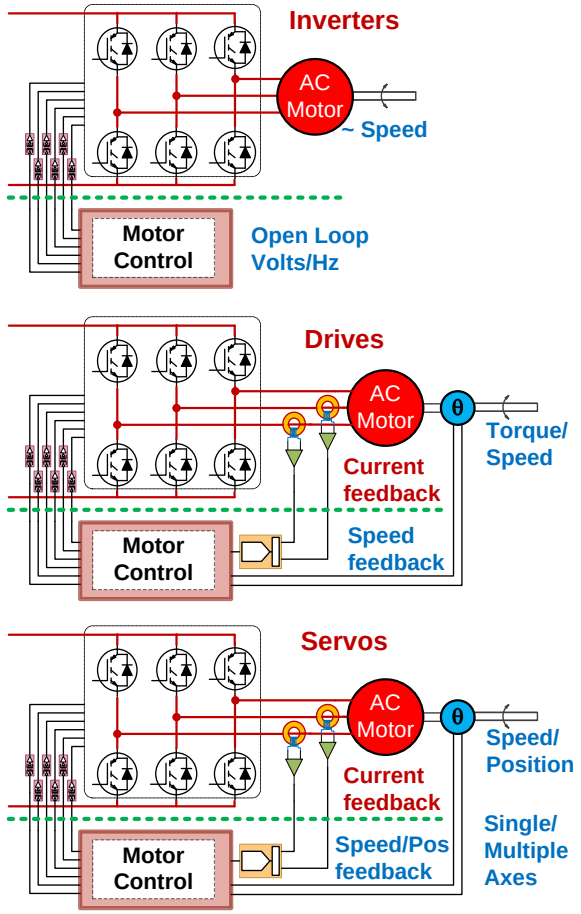
Continuous Motion

Assembly Automation

- Semiconductor; Automotive; Metal processing; Molding; Textiles; Packaging; etc.

Discontinuous Motion

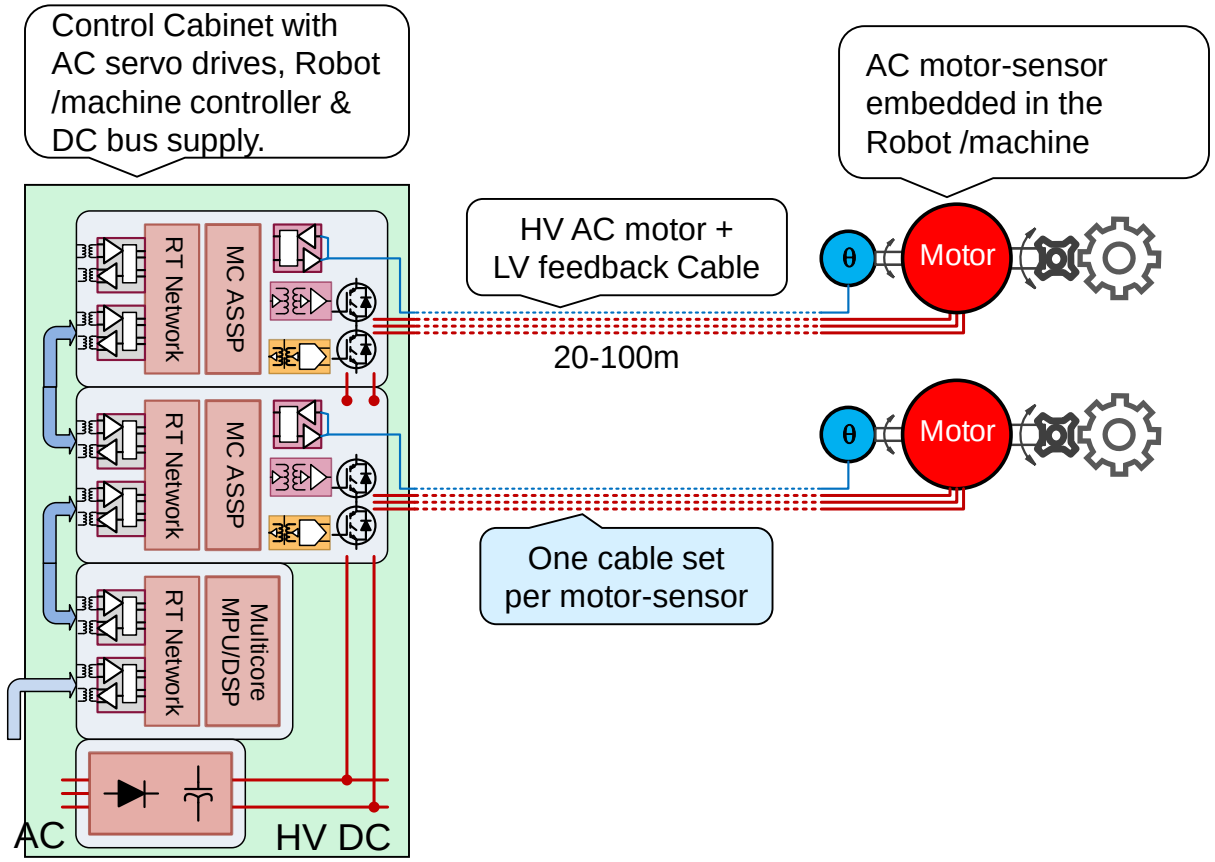
- Motor Drive Types



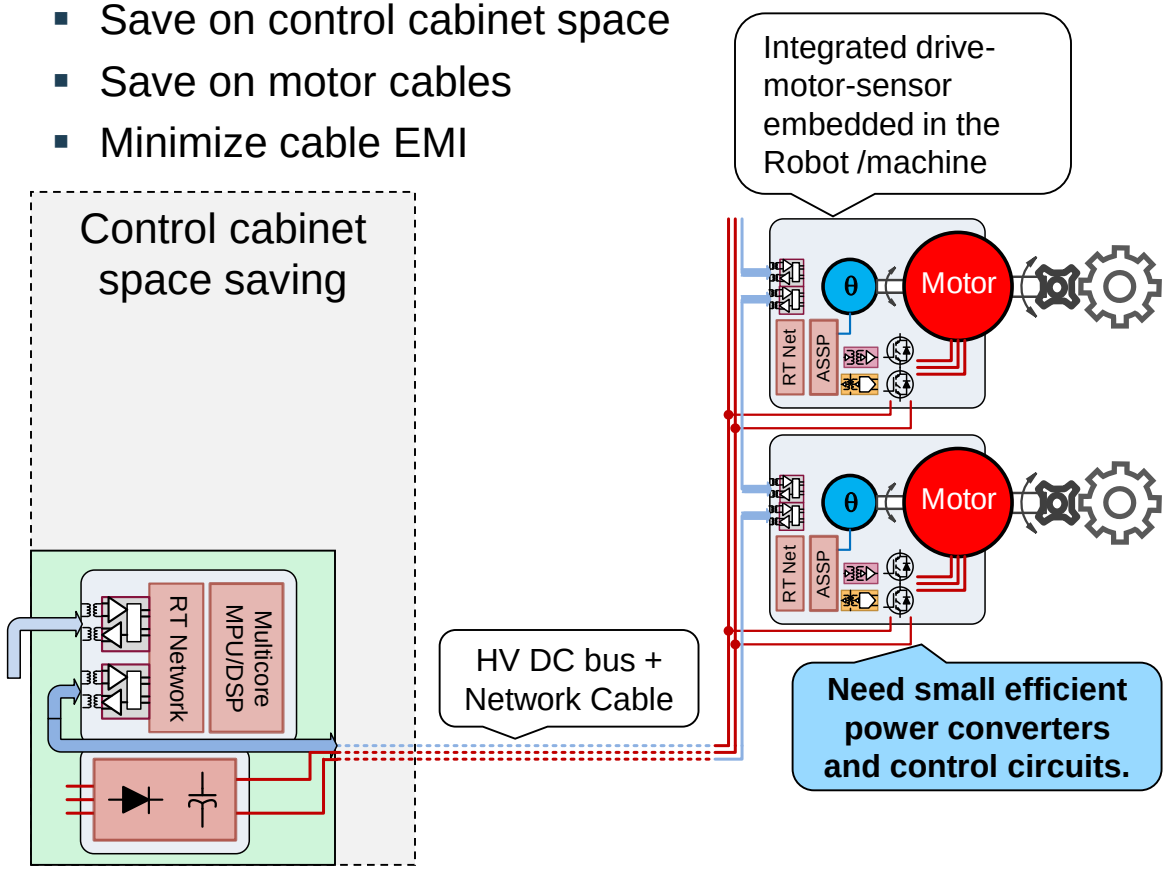
- **Process Industry** focus on reducing **Energy consumption ($$)** by efficiently controlling fluid and material flow.
  - Connectivity supports plant optimization.
  - Acoustic noise and smooth operation in some applications
- **Assembly Industry** focus on **maximizing ROI** by increasing quality and throughput.
  - Faster response and higher motion precision (in space & time)
    - Precise Machine synchronization
  - Integrated safety functions for operational efficiency
- **General trends**
  - Maximize plant uptime
  - Minimize cabinet size
  - Maximize product flexibility
  - Minimize installation cost etc.

Architecture trend: Integration of drive and motor to simplify wiring.

- Traditional drive architecture



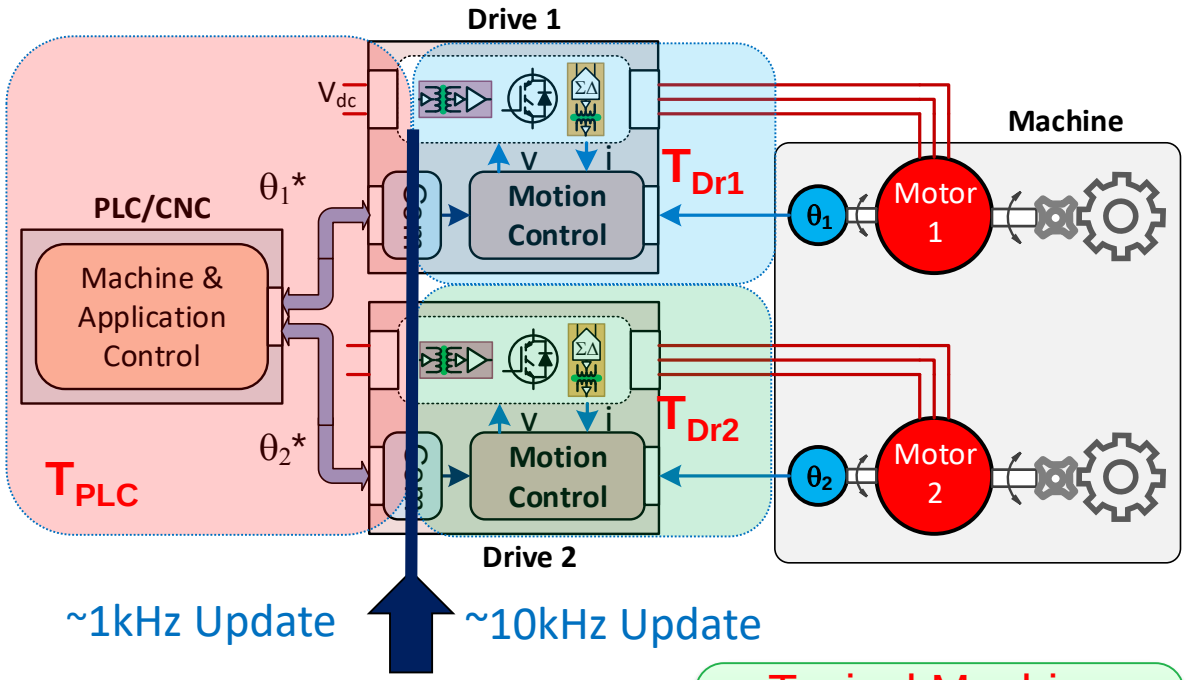
- Integrated Drive Motor (IDM)
  - Save on control cabinet space
  - Save on motor cables
  - Minimize cable EMI



Architecture Trend: Reference- vs. I/O Synchronization

Deterministic Ethernet with synchronized commands only

Independent processing and clock domains

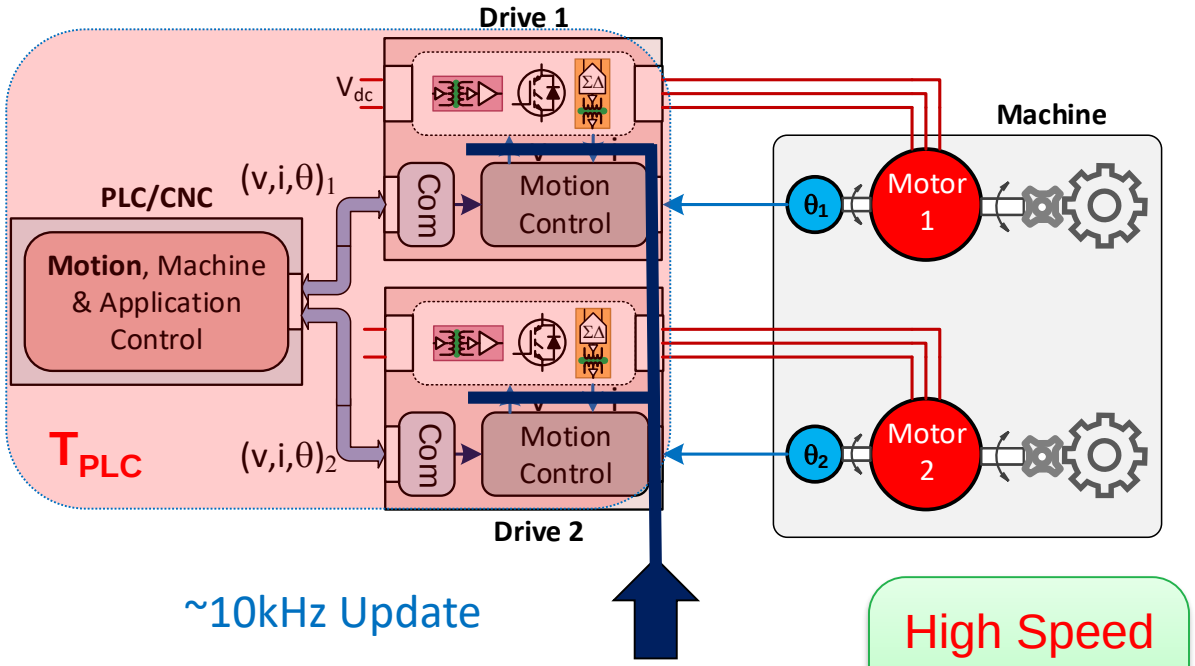


Synchronized command

Typical Machine Tools and General Automation

Deterministic Ethernet with synchronized I/O

Common clock domain. Scalable processing within PLC or drive nodes.



Synchronized control I/O

High Speed Assembly & Robots

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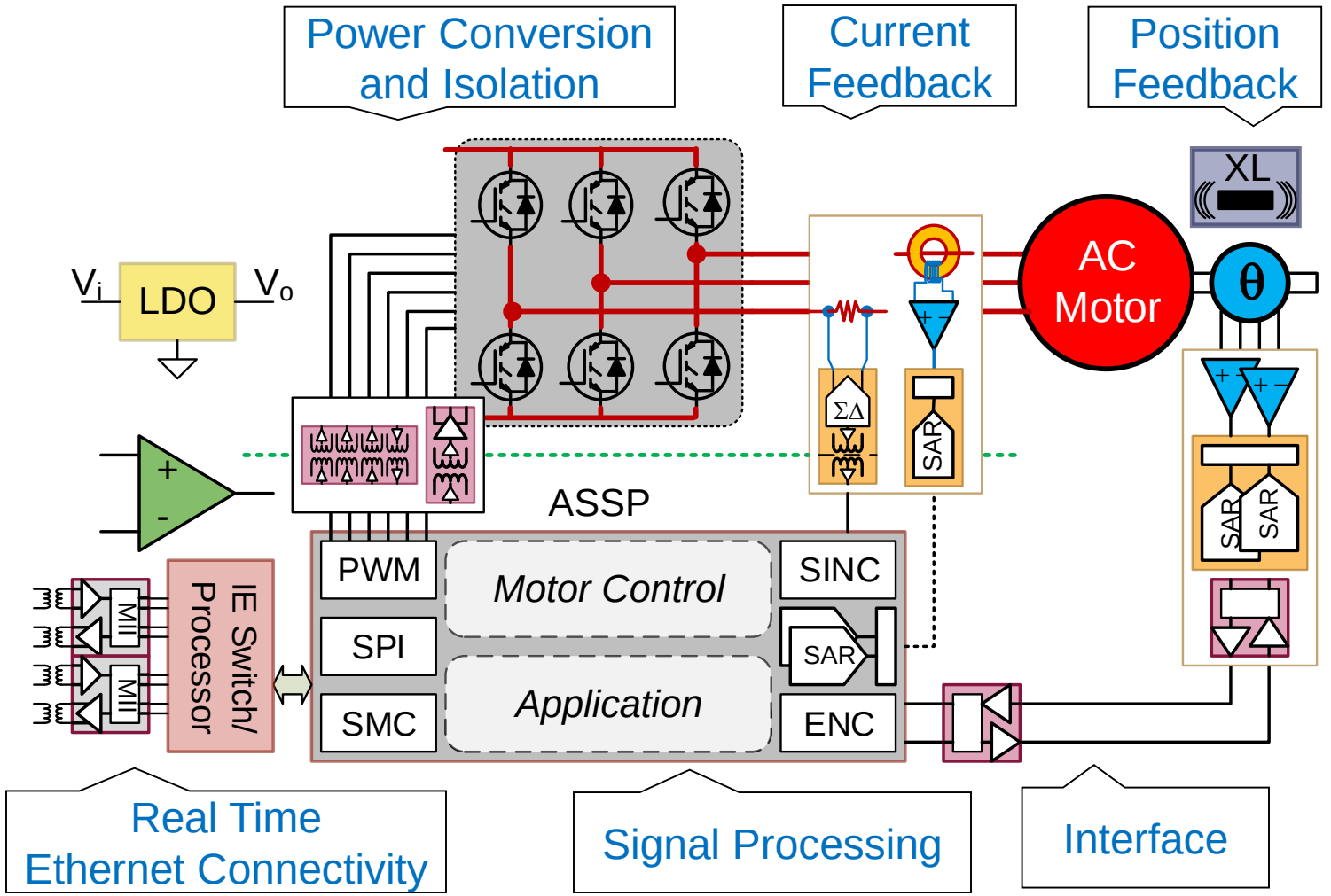
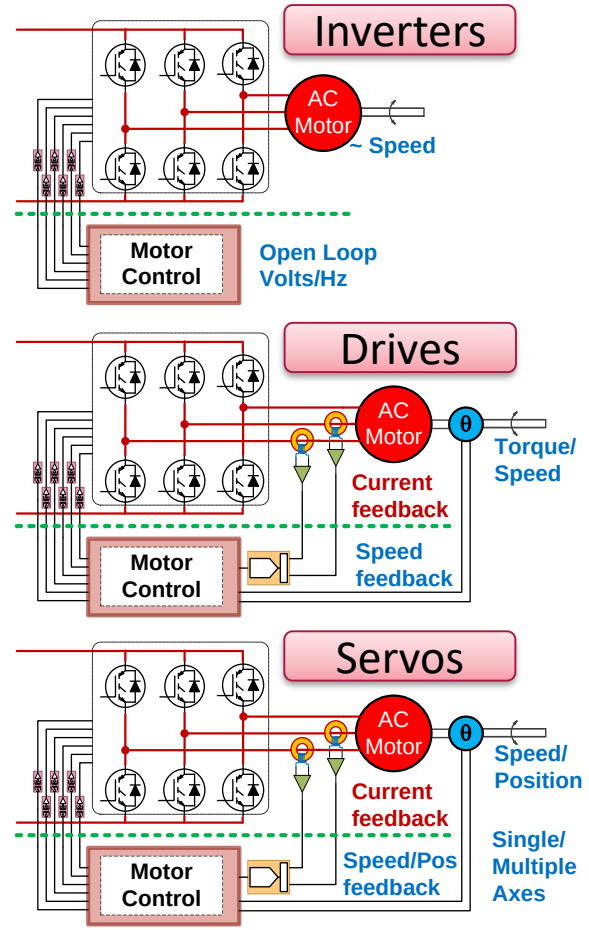
ADI Solutions for the CMR Market

Drives and Servos Signal Chain



Motor Drive Types

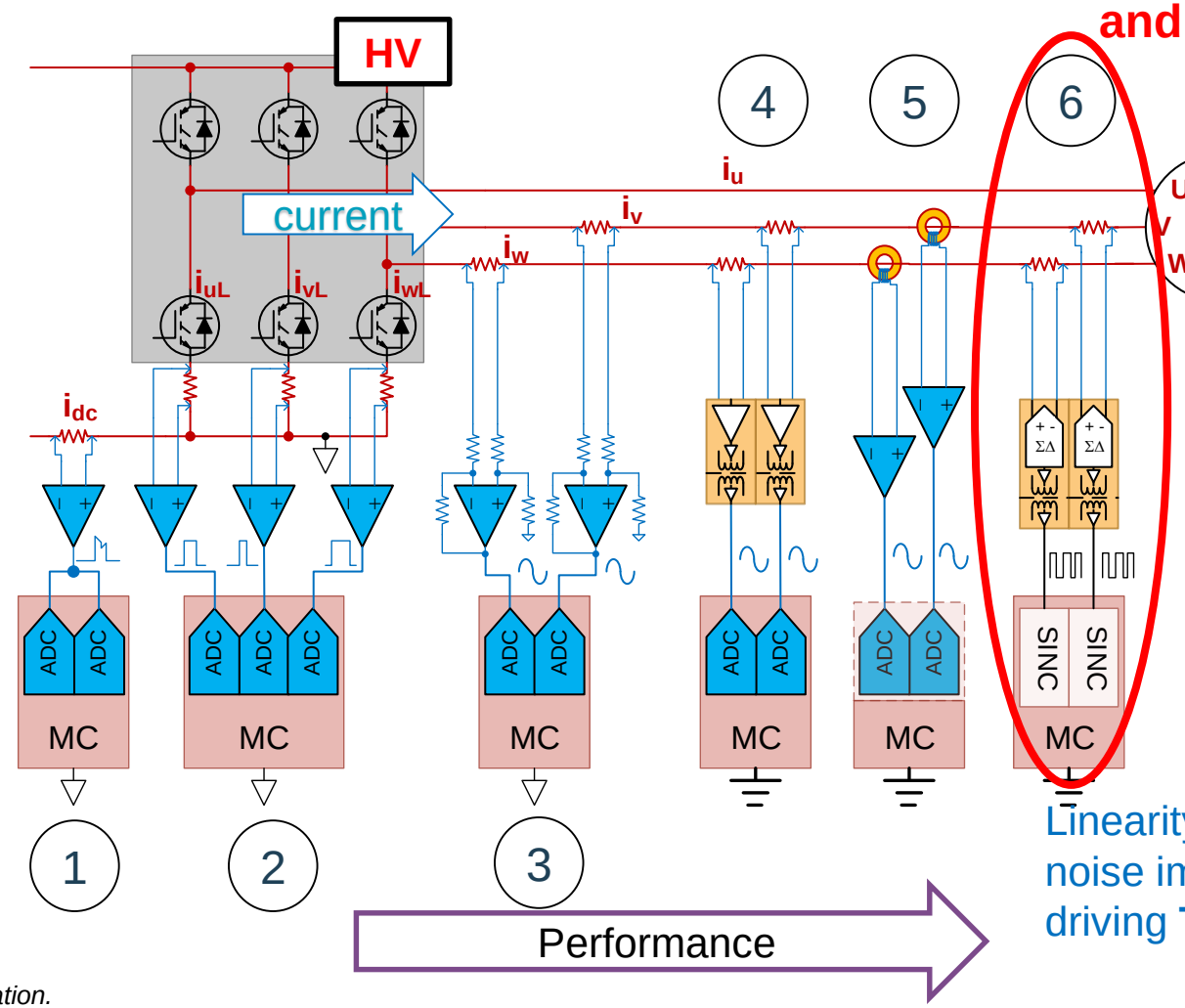


Isolated and non Isolated Current Feedback Architectures

Non isolated current feedback:

1. dc link shunt
2. inverter leg shunts
3. HV current diff amps

Current feedback for Torque control and inverter switch protection



Isolated current feedback:

4. Current shunt with isolation amplifier
5. Isolating magnetic current sensor
6. Current shunt with isolating sigma delta modulator

Linearity, gain match, offset [esp.drift] and noise immunity are critical parameters driving **Torque** quality

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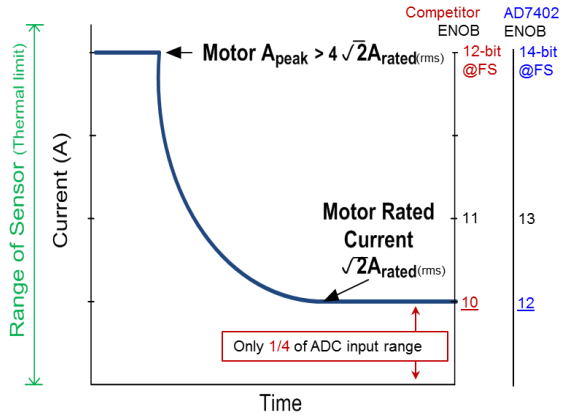
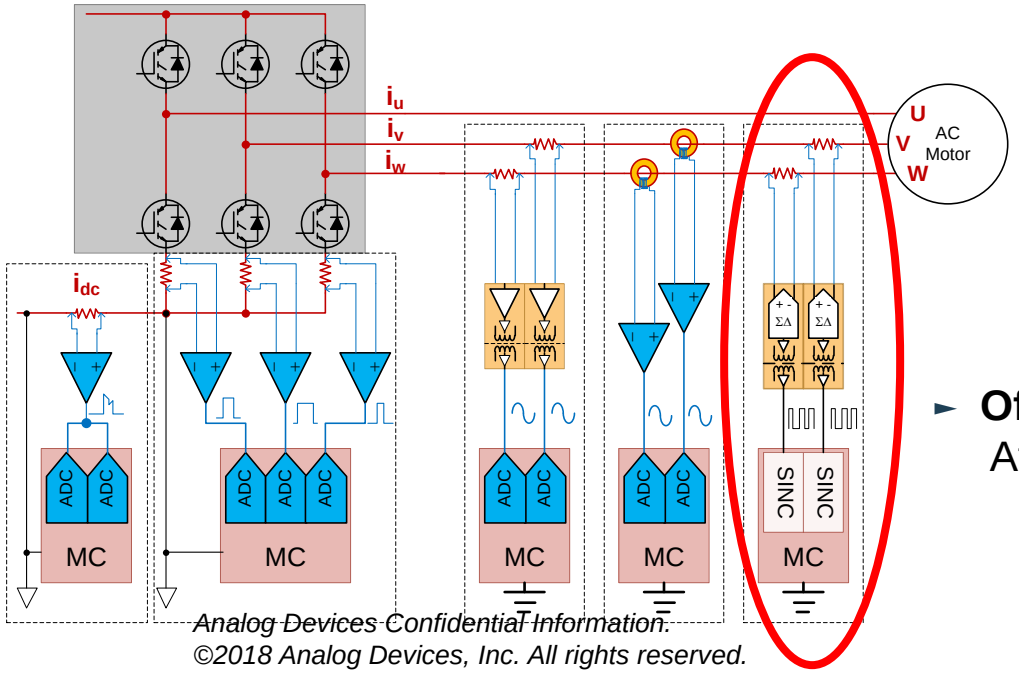
Feedback Signal Scaling requires Dynamic Range





- Significant trend towards Shunt current measurement vs. CT/Hall.
  - **Dynamic range** required to measure both Peak and Nominal currents. Rated currents may be fraction of ADC dynamic range.
  - Same drive services range of motor sizes. Dynamic range lost in lowest rated motor.
- Demand for lower shunt values requires even higher DR. ~+/-250mV->+/-50mV
  - Thermal losses
  - Power transfer efficiency
  - Integration densities
  - Self heating effects and solder joint stress
  - Desire to extend power rating of shunt based systems, further reducing CT usage.
- **Offset Drift** and Gain Drift contribute directly to torque ripple on the motor shaft. Affects many applications, surface effect on milling/etching; vibration effects etc.

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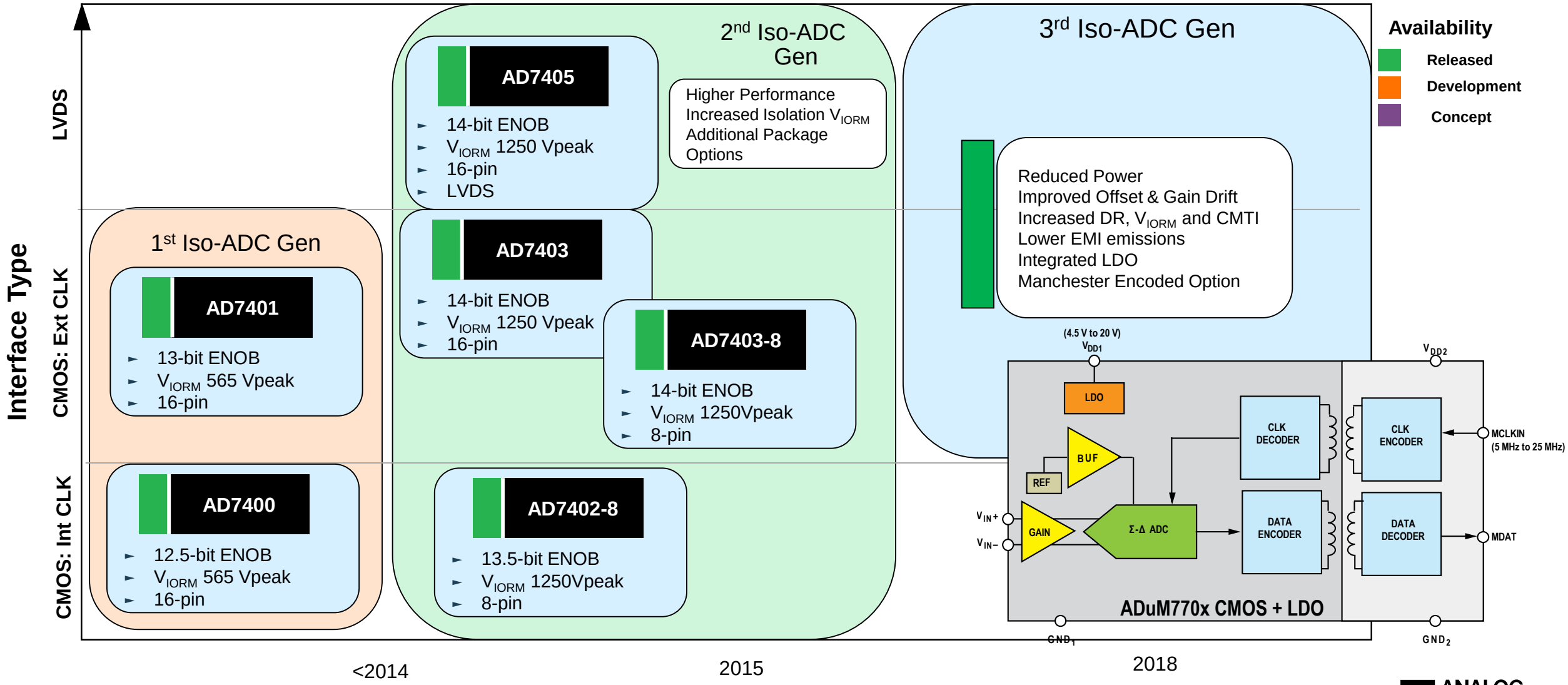
Isolated ΣΔ Modulator Roadmap



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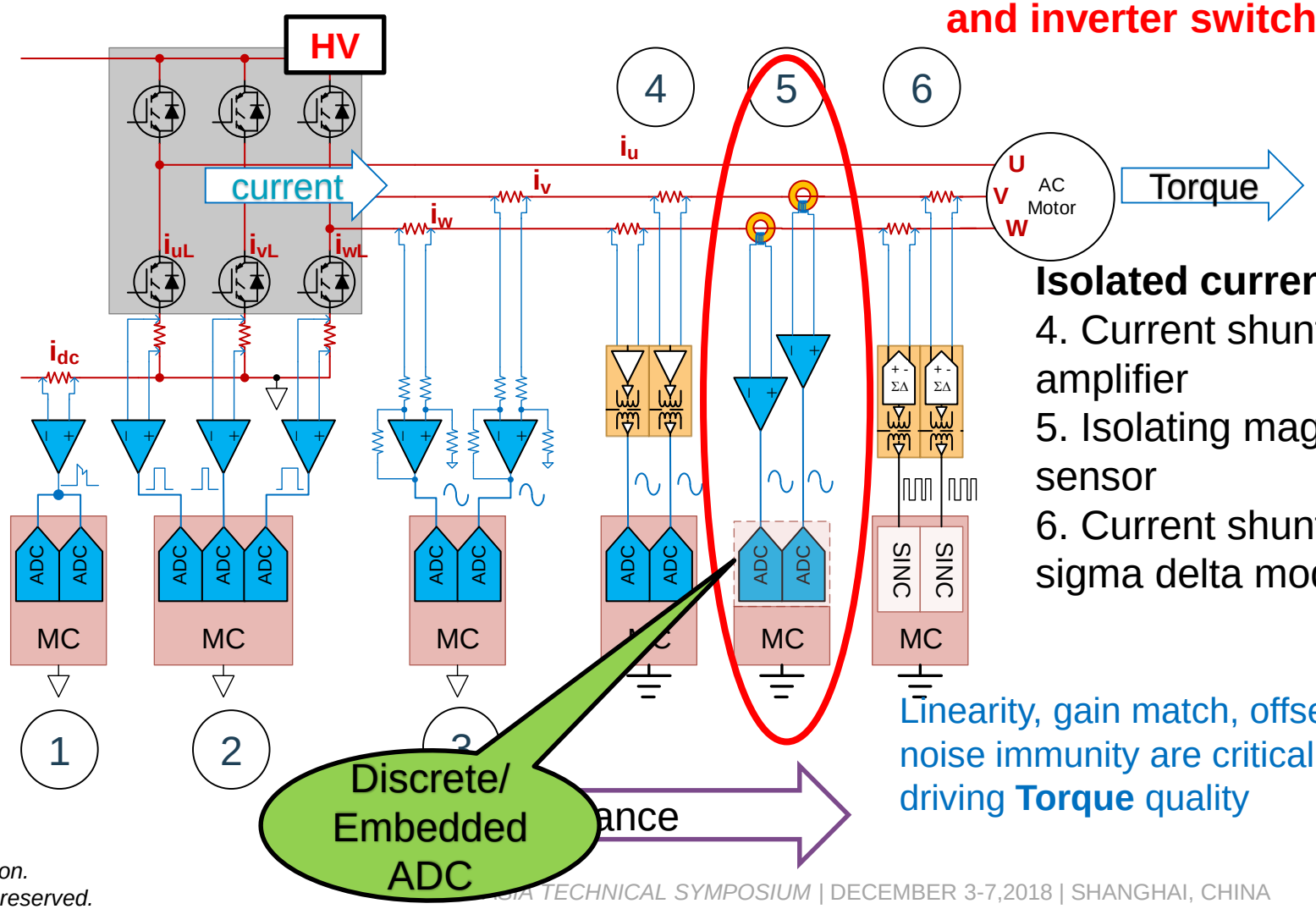

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Simultaneous Sampling, SAR ADC Roadmap (18 to 12-Bits)

Availability
Released
Development
Concept

Buffered Input

Direct interface to high and low impedance sensors

8-Ch DAQ
125kSPS/Ch
ADAS3023

8/4/2-Ch DAQ
200/350/550 kSPS/Ch
LTC2358/7/3

Resistive Input

Direct interface to low impedance sensors

8-Ch DAQ
200kSPS/Ch
AD7606

16-Ch, Dual Sim-Sampling
125kSPS/Ch
AD7616

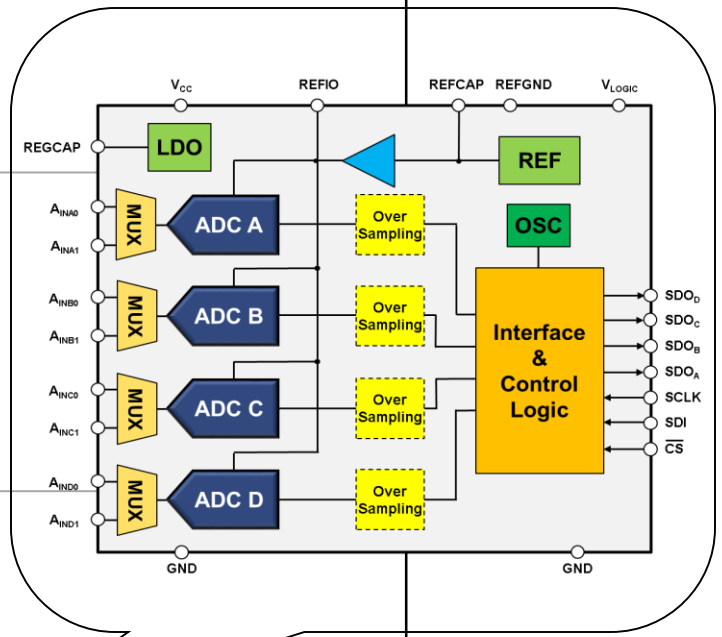
8-Ch DAQ Subsystem
- Bandwidth 22kHz: 1MSPS/Ch AD7606B
- Bandwidth 400kHz: 1MSPS/Ch AD4606

SC Input

Dual ADCs
4.2MSPS
AD7357
- 14, 12-Bit

8/4/2-Ch ADCs
200/400/666 kSPS/Ch
LTC2345/4/1
- 18-Bit

High Sampling Rate, High density
- Dual ADC: AD7380
- Quad ADC: AD7380-4



<2017 | 2018 | 2019 | >2020

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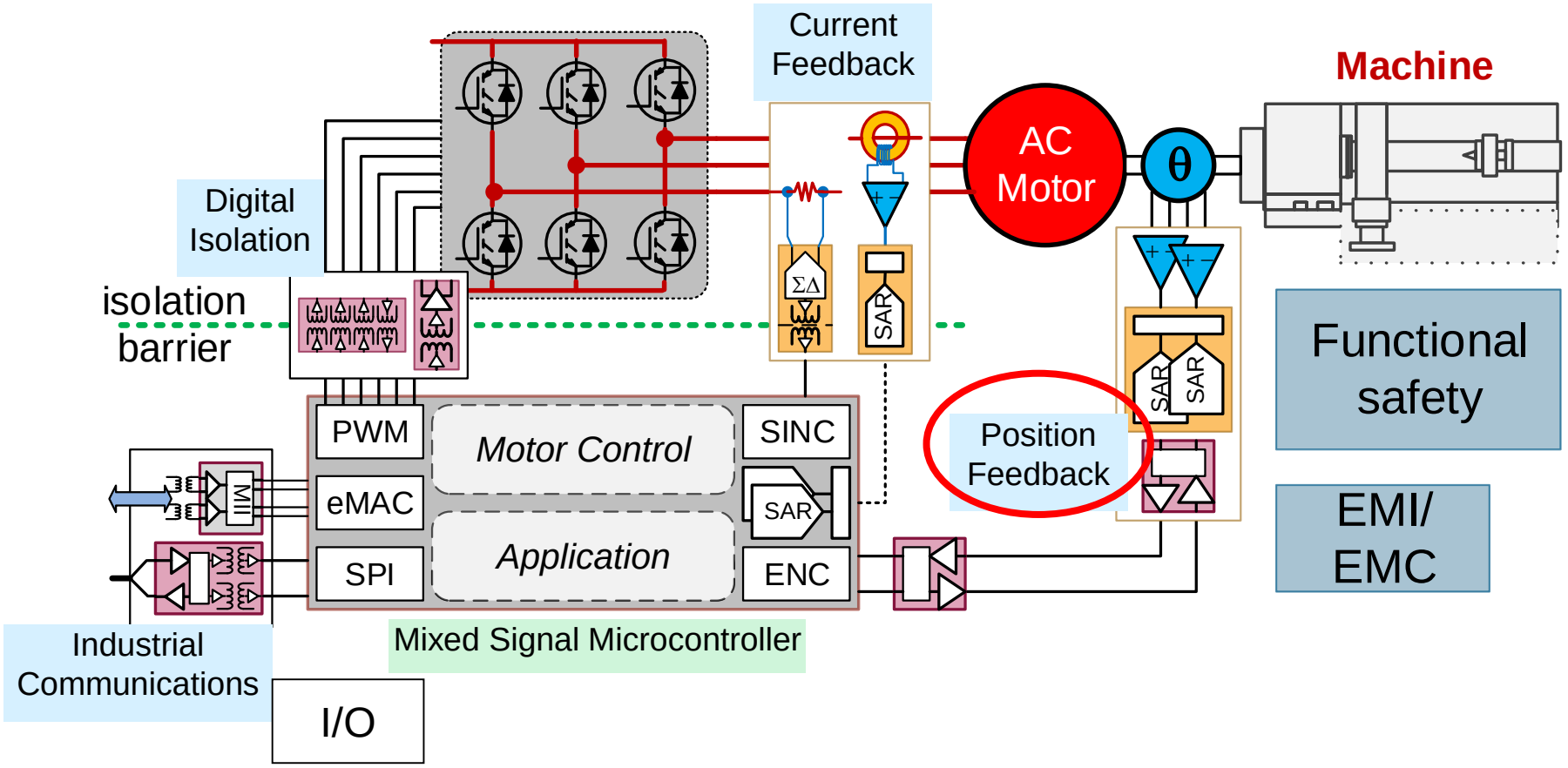
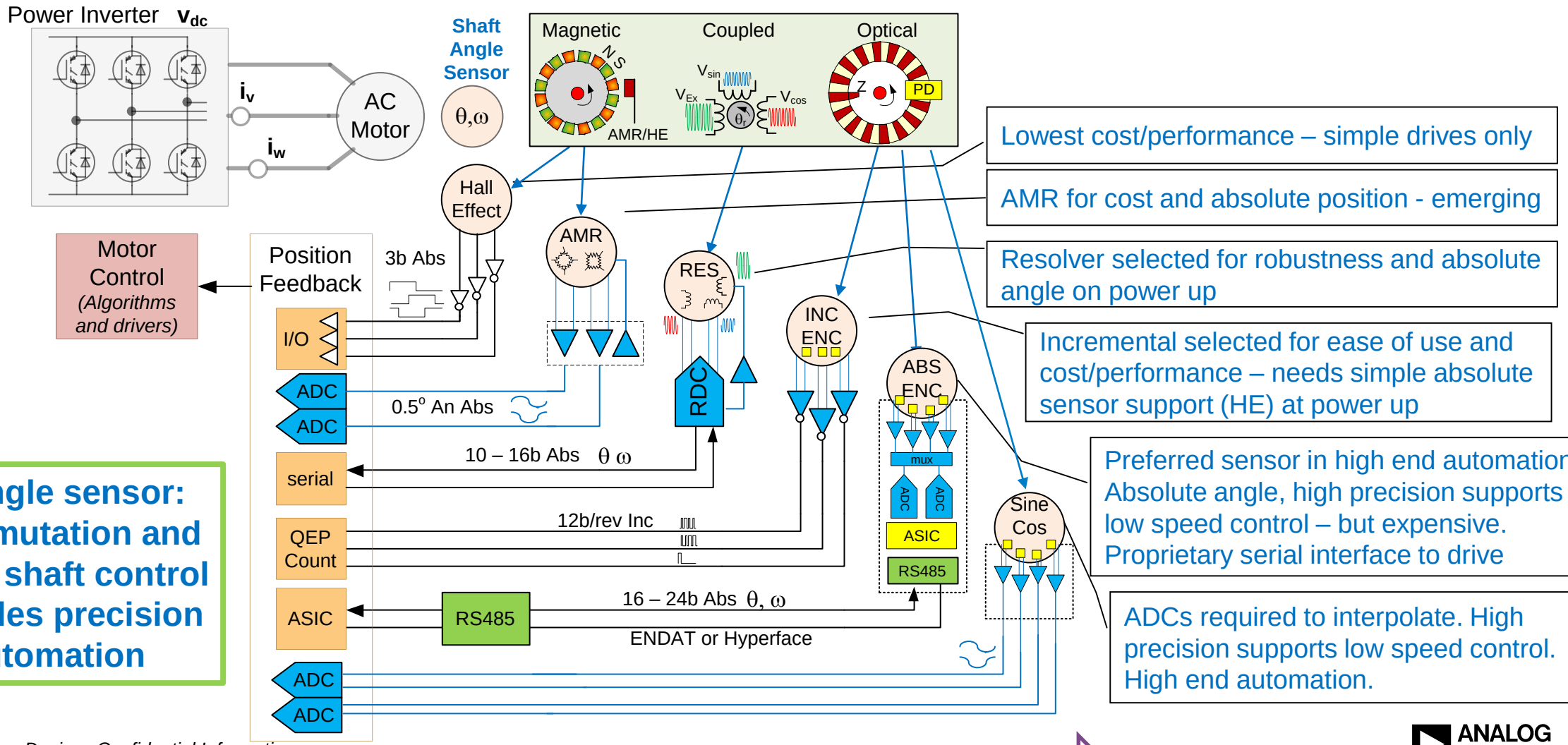
Motion Control High Level Signal Chain



Position Feedback Architectures and sensors



Shaft angle sensor:

- **Commutation and drive shaft control**
- **Enables precision in automation**

Simultaneous Sampling, SAR ADC Roadmap (18 to 12-Bits)

Availability
Released
Development
Concept

Buffered Input

Direct interface to high and low impedance sensors

8-Ch DAQ
125kSPS/Ch
ADAS3023

8/4/2-Ch DAQ
200/350/550 kSPS/Ch
LTC2358/7/3

Resistive Input

Direct interface to low impedance sensors

8-Ch DAQ
200kSPS/Ch
AD7606

16-Ch, Dual Sim-Sampling
125kSPS/Ch
AD7616

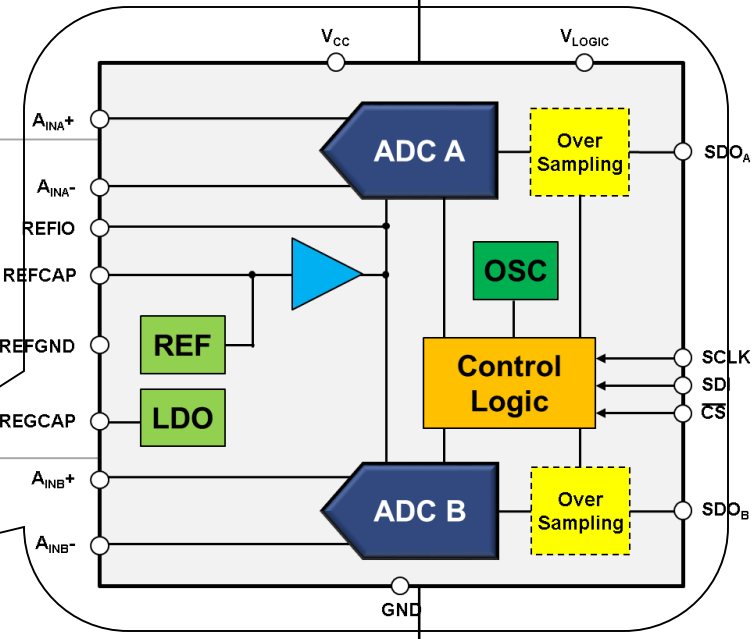
8-Ch DAQ Subsystem
- Bandwidth 22kHz
1MSPS/Ch
AD7606B
- Bandwidth 400kHz
1MSPS/Ch
AD4606

SC Input

Dual ADCs
4.2MSPS
AD7357
- 14, 12-Bit

8/4/2-Ch ADCs
200/400/666 kSPS/Ch
LTC2345/4/1
- 18-Bit

High Sampling Rate, High density
- Dual ADC
AD7380
- Quad ADC
AD7380-4



Facilitates existing
Analog/ Digital ASIC usage
Ease of Adoption

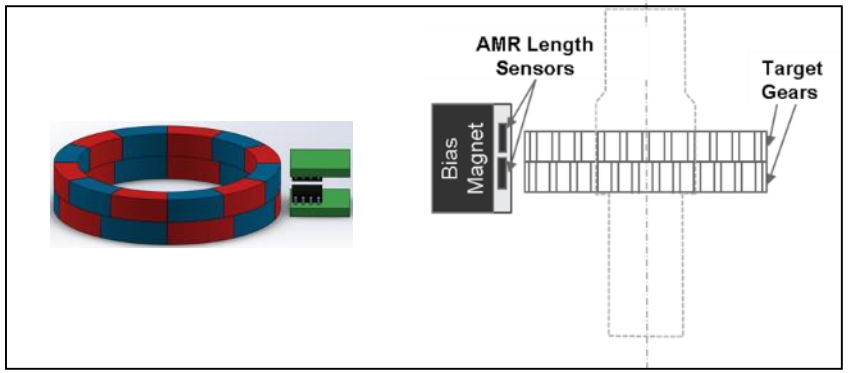
<2017 2018 2019 >2020

xMR Sensors for Position Feedback

- AMR with 180° absolute position is a released product (ADA4571)
- GMR and TMR (both 360° absolute) are being qualified and sampled
  - 0.1°-0.5° accuracy
- AMR off-shaft length sensor for industrial applications
- Accuracies of 0.05° and lower achievable -> mechanical construction tolerance
  - Different measurement principle to standard AMR
- Zero power multiturn sensor

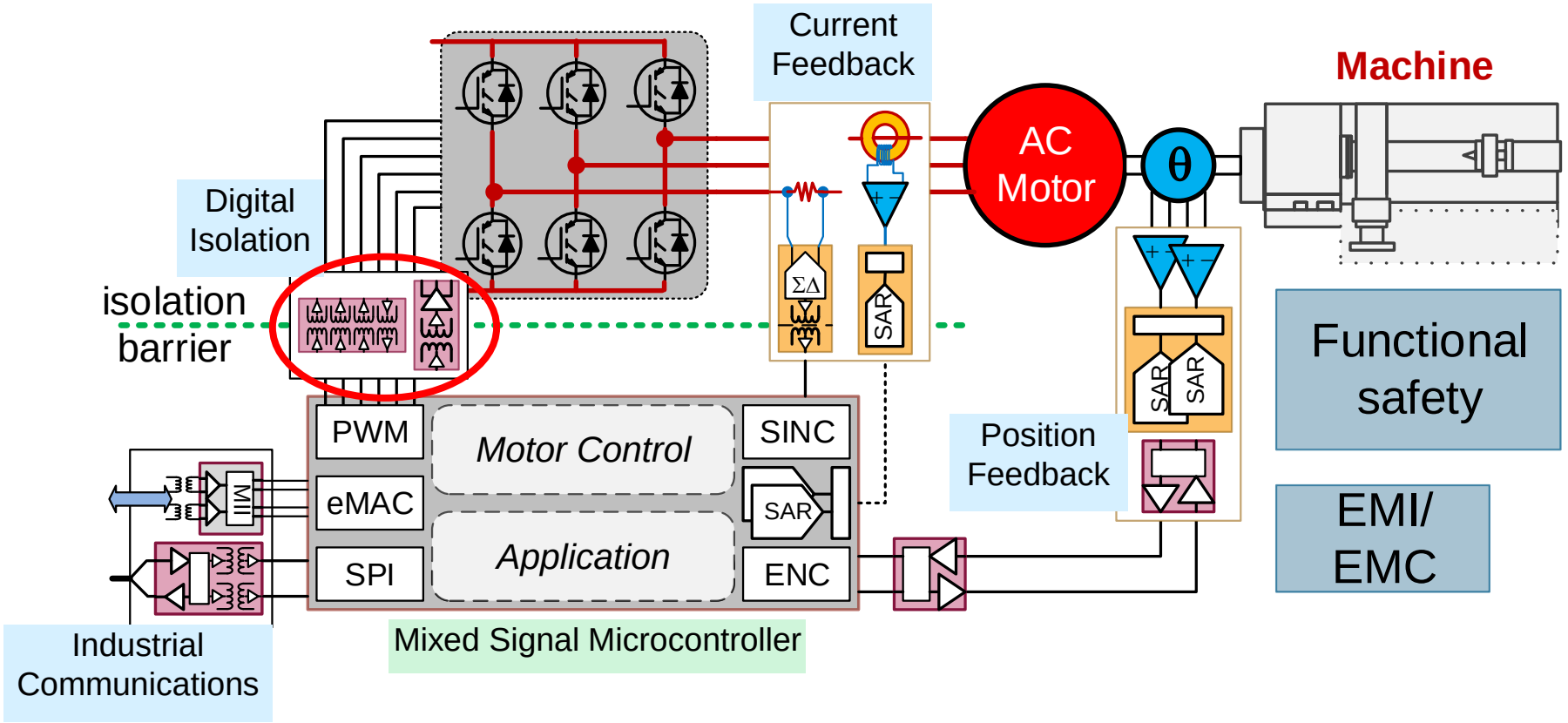
End of shaft

Off-shaft length sensor



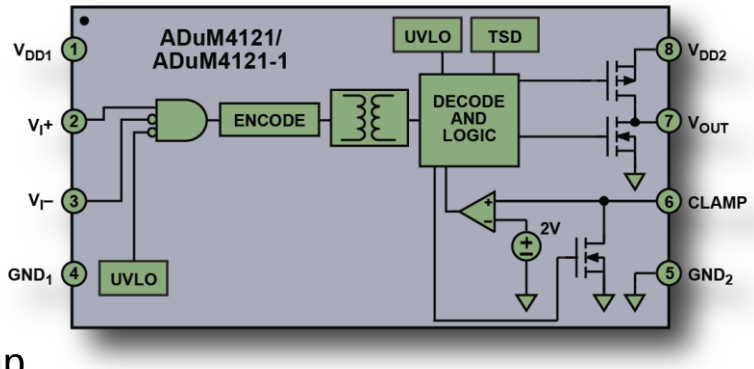
- Potential fit for mid-precision machines, collaborative robots, high speed machines such as spindles
  - Robust, high speed, 10-14bit precision
  - Zero power multi-turn for shutdown position awareness
  - Will customers be willing to design and integrate position sensing?

Motion Control High Level Signal Chain



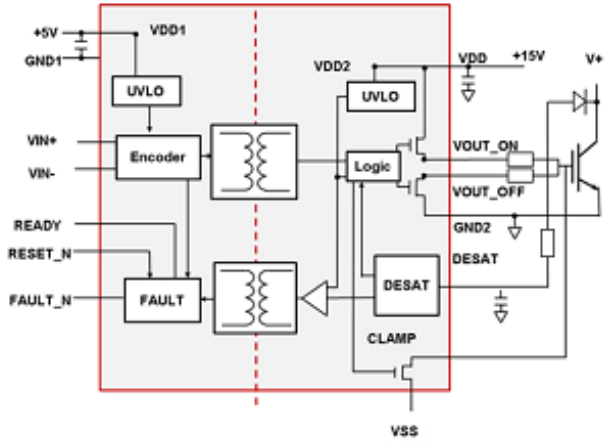
Isolated Gate Driver for Industrial Motor drives

- Basic Gate Drivers (ADuM4120/4121)
  - Support the most common industrial working voltage and power range (400V <50kW)
    - Miller clamp to prevent spurious turn on
    - 5 kV isolation, working voltage 600 V rms
    - 6 and 8 pin version with 8 mm creepage
  - Very suited to driving new & faster GaN/SiC switches
    - CMTI: 150 kV/µs
    - Prop delay 38 ns typical, prop delay skew <15 ns



  - Roadmap
    - Slew rate selection to manage EMI/efficiency trade-off
    - Insulation and packages for 690V and higher power
    - Integrated Gate drive supply for GaN switches

- Advanced Gate drivers (ADuM4135/4136)
  - Support the most common industrial working voltage and higher power range (<100kW)
    - Also very suited to driving new & faster GaN/SiC switches
    - Includes embedded SC protection and other features
      - DESAT function detects short circuit fault without current measurement
      - Fault reporting and reset pins



  - Roadmap
    - Over temperature monitor of the power switch
    - Flyback controller for gate drive power supply
    - Full gate power supply integration for IGBT/SiC
    - Fast short circuit fault detection for GaN/SiC
    - Programmable slew rate

Slew Rate Controlled Gate Drive

- Some customers looking to use faster IGBTs in new designs
  - Faster switching transitions -> reduced switching loss -> smaller heat sink size
  - Faster switching transitions -> increased EMI problems -> larger EMI filter
- EMI worst-case is at light load/motor standstill
- Lower Gate Drive Impedance *minimises losses*
- Higher Gate Drive Impedance *slows the switching transitions reducing emissions*

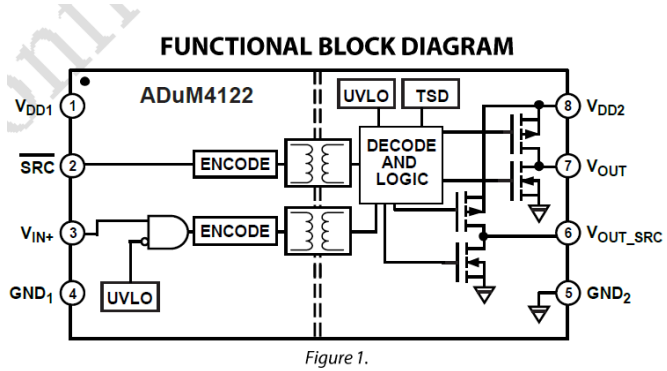
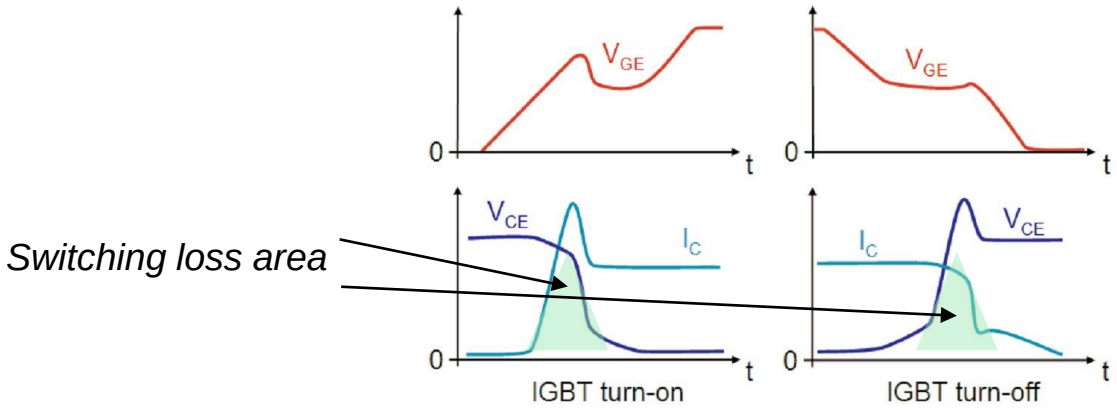
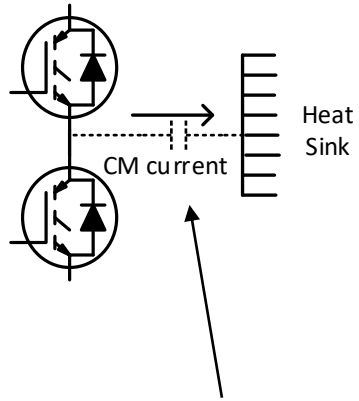


Figure 1.





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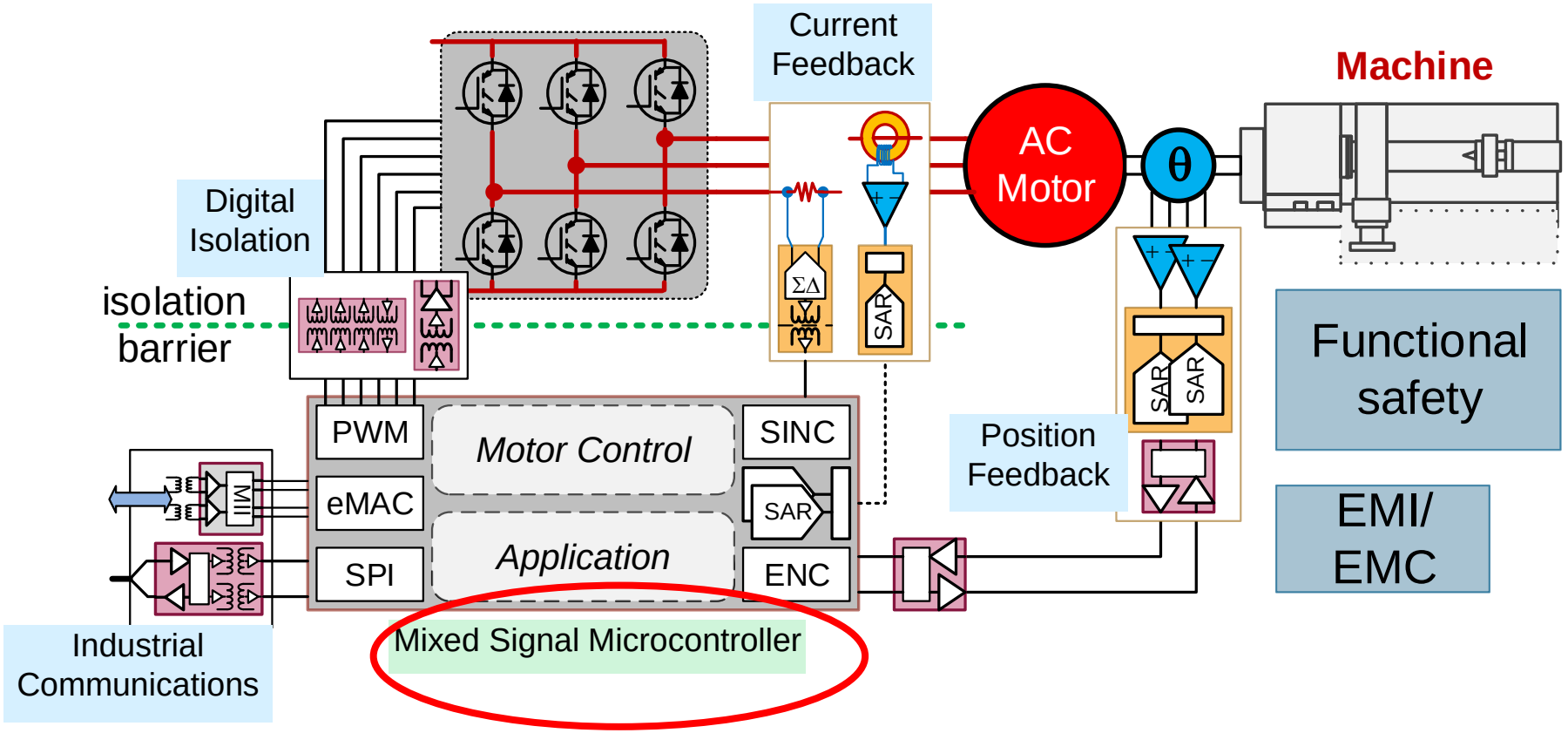


ADSP-CM40x Overview: ‘Slater’

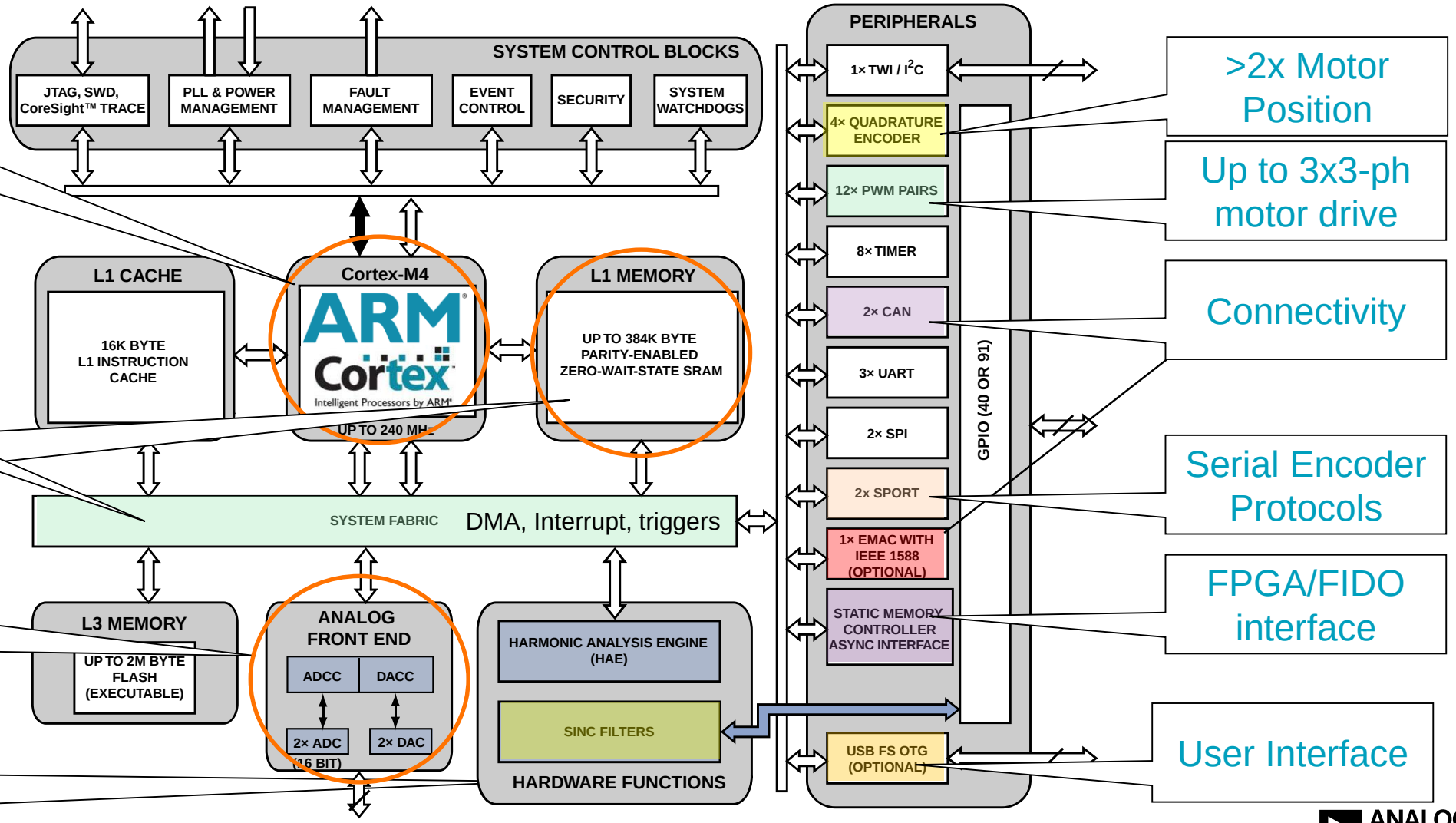
Cortex-M4F 240MHz ARM Ecosystem

Real-time execution at min overhead

Real-time routines

Current, Voltage, Position Feedback

Σ–Δ Current Feedback & OCP



>2x Motor Position

Up to 3x3-ph motor drive

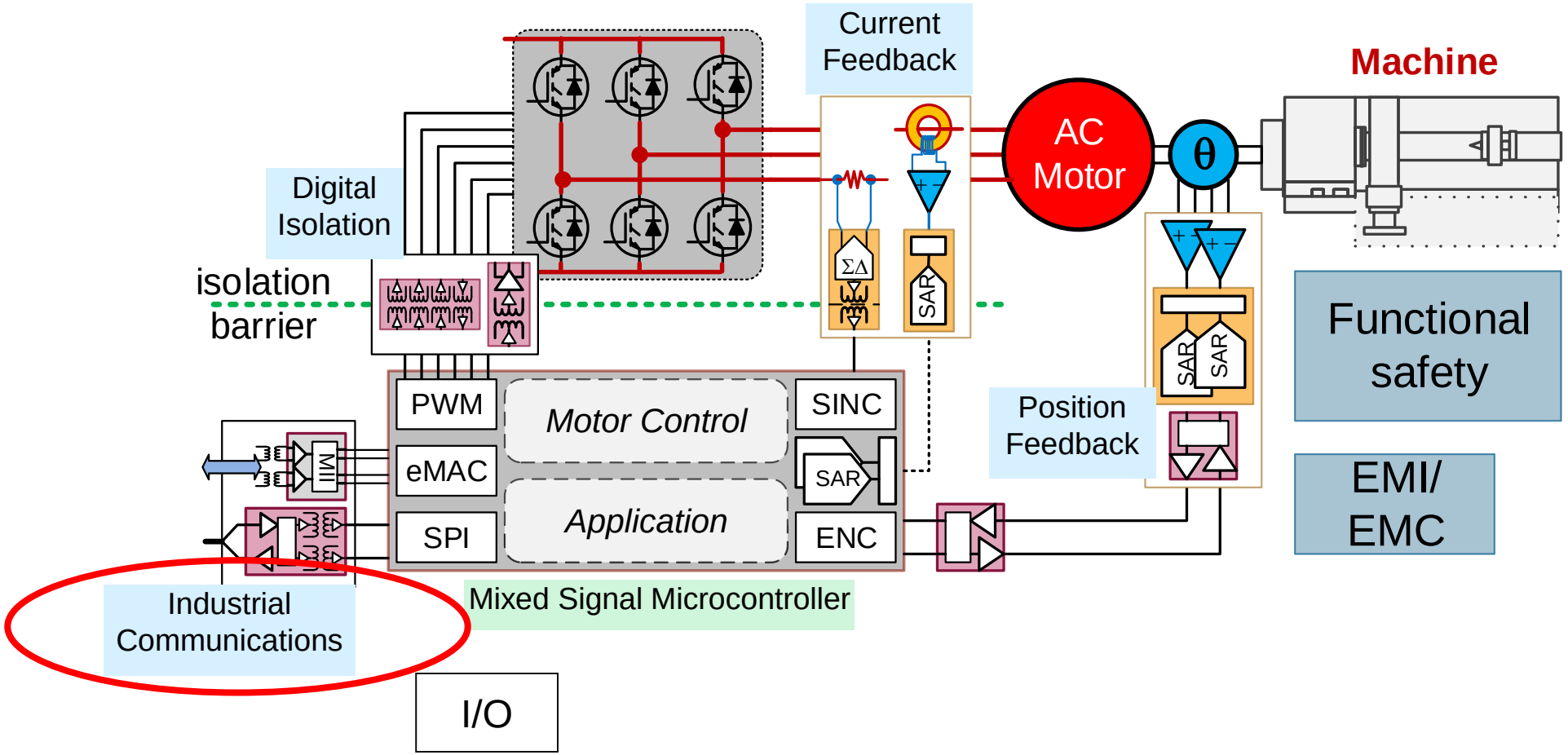
Connectivity

Serial Encoder Protocols

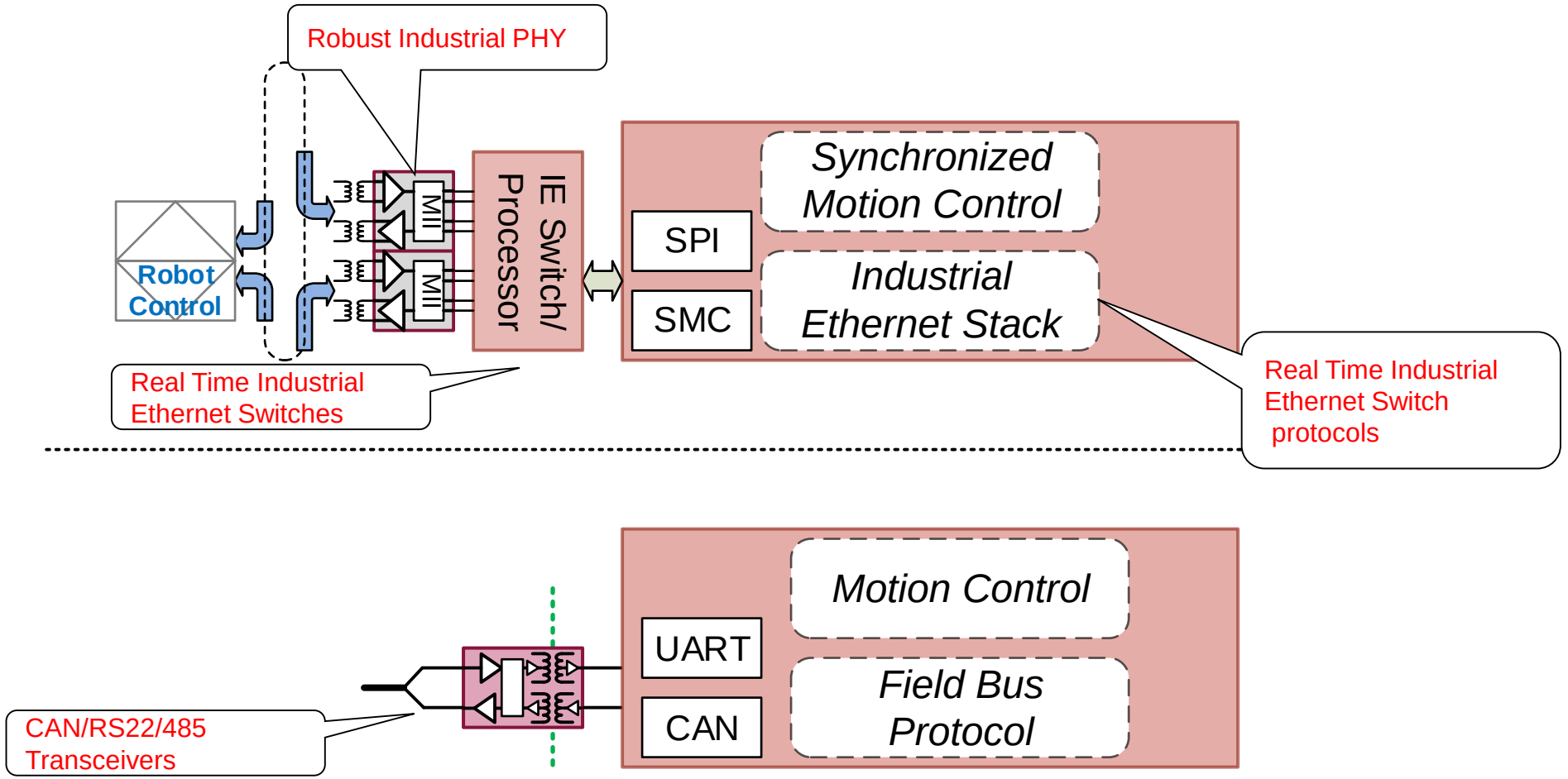
FPGA/FIDO interface

User Interface

Motion Control High Level Signal Chain

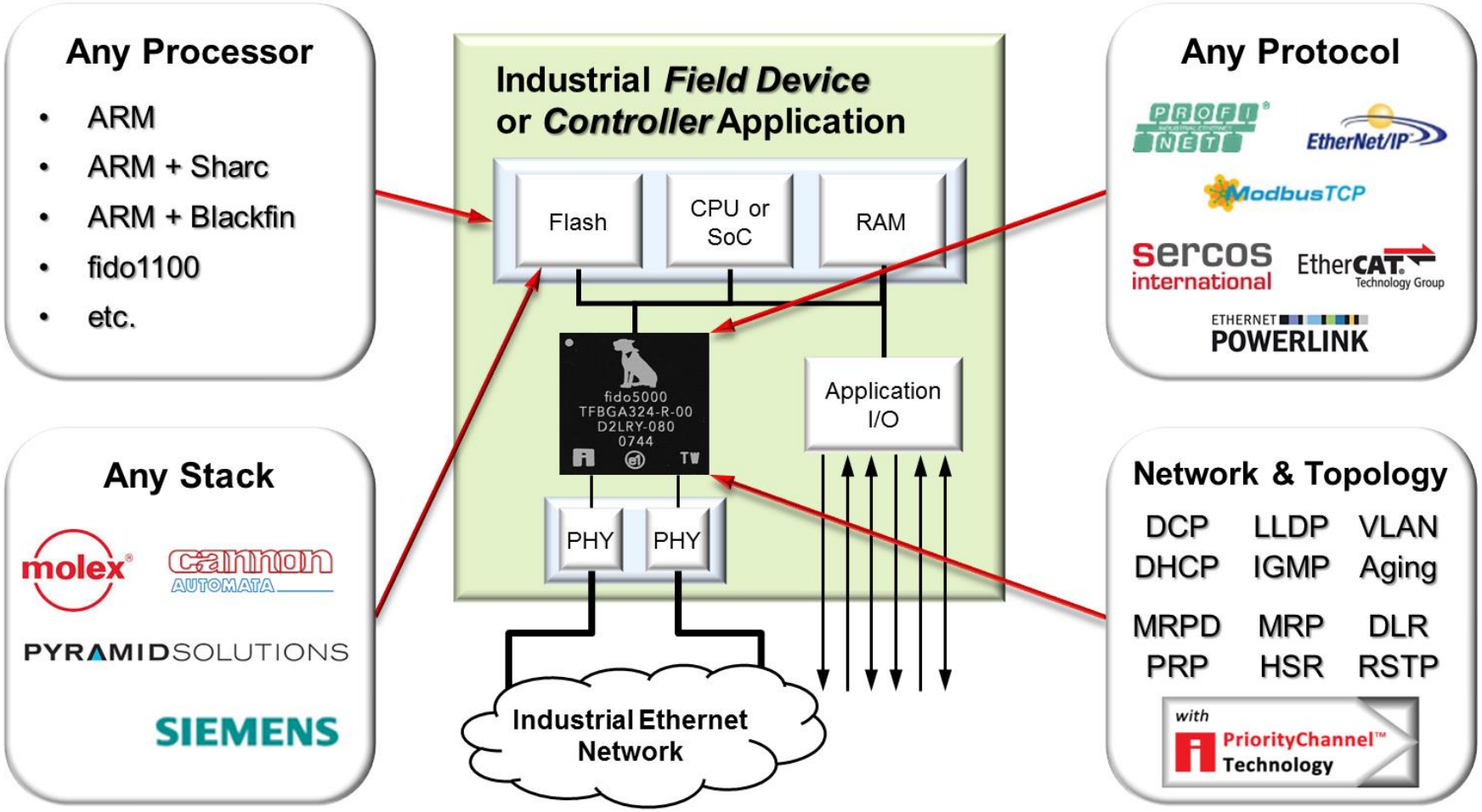


Industrial Communications

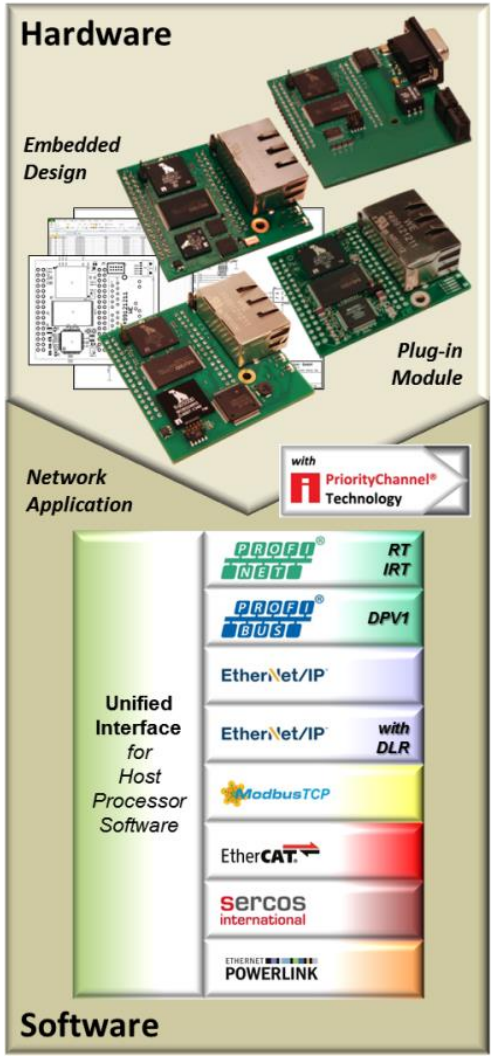


FIDO5000 REM Switch

Multiprotocol Real-Time Ethernet Switch Chip



Easy Evaluation with Complete Service and Support



The RapID Platform is a <u>pre-tested</u> Industrial Ethernet Network Interface Card that processes the industrial protocol and network traffic

- Unique architecture with Innovasic's PriorityChannel® technology eliminates the effects of network traffic
- Available as a card that plugs into your PCB or as schematics to integrate circuit/chips into your PCB
- Common hardware interface supports all protocols
- Common software interface supports all protocols
- No licensing fees or royalties
- Guaranteed first-pass certification

Next Generation RapID platform release: ~Q2 2019

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ADIN1200 / ADIN1300 Robust, Industrial, Low Latency, Low Power Ethernet PHY

- ADIN1300 10/100/1000 Gigabit PHY
  - Robust Temperature Range: -40 to 105C
  - Robust EMI / EMC / ESD performance
  - Small Footprint: 6x6mm 40-LFCSP
  - Low Power: 365mW
  - Low Latency: 290ns Tx & Rx (RGMII)
- ADIN1200 10/100 Fast Ethernet PHY
  - Robust Temperature Range: -40 to 105C
  - Robust EMI / EMC / ESD performance
  - Small Footprint: 5x5mm 32-LFCSP
  - Low Power : 175mW
  - Low Latency : 300ns Tx & Rx (MII)

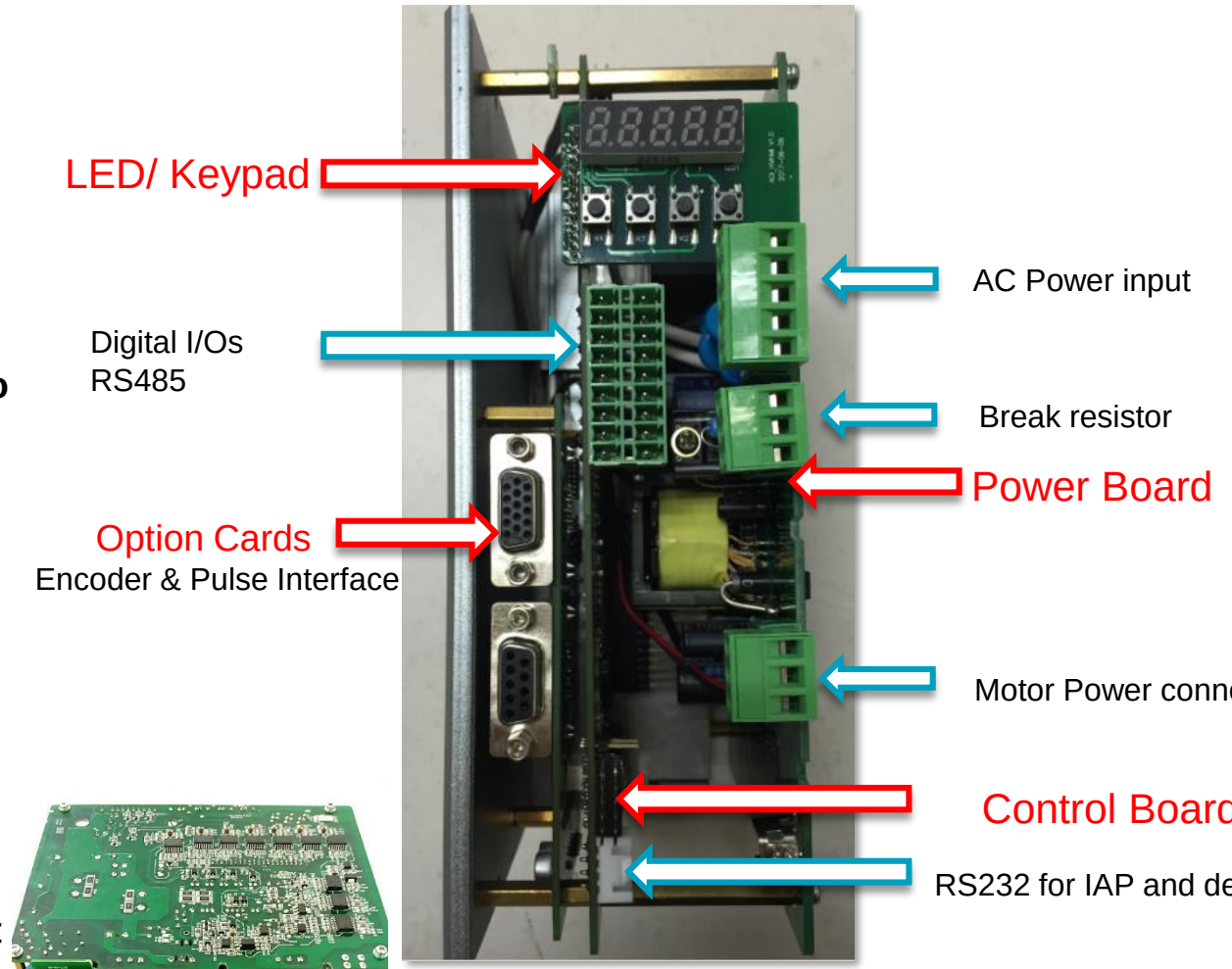
Generic	Package	Temp Range
ADIN1300	40 Lead LFCSP	-40C to 105C
	40 Lead LFCSP	-40C to 85C
ADIN1301	64 Lead LGA	-40C to 105C
	64 Lead LGA	-40C to 85C
ADIN1200	32 Lead LFCSP	-40C to 105C
	32 Lead LFCSP	-40C to 85C

- PHY Samples
  - ADIN1300 Dec 2018
  - ADIN1200 Jan 2019
- PHY Production Release
  - ADIN1300 Dec 2019
  - ADIN1200 Jan 2020.

System Solutions

220V 1kW AC Servo ADP with Option Cards
also supports general motor drive development (IM, BLDC)

- **System demonstrations**
  - To show what key ADI devices can be used in a motor drive
  - To show basic capabilities of ADI motor control solutions
- **Key parts' evaluation**
  - Evaluation in a system environment that is most similar to typical drive products
  - ADI sigma delta ADC performance
  - ADI isolation technologies
  - ADI gate driver
- **Flexible extensions**
  - Generic interface to new functionalities in motor drive systems
- **Software development**
  - A HW platform that can run almost all motor control related software

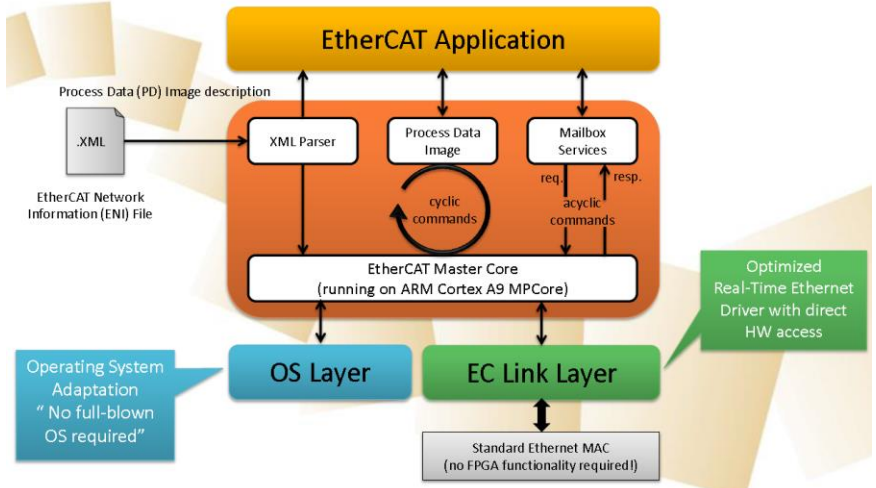


- 220V/400W PMSM
- 2500 line incremental encoder

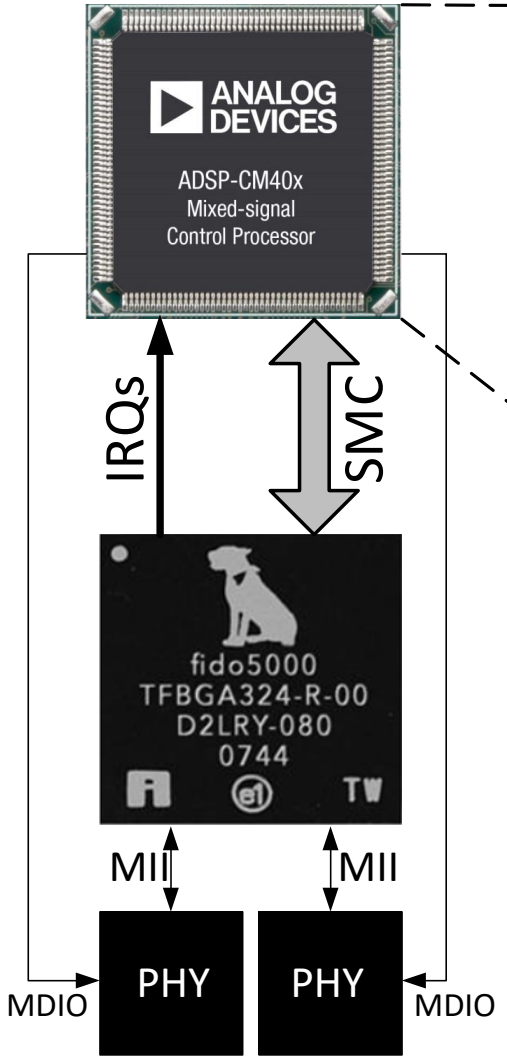
- 220V induction motor

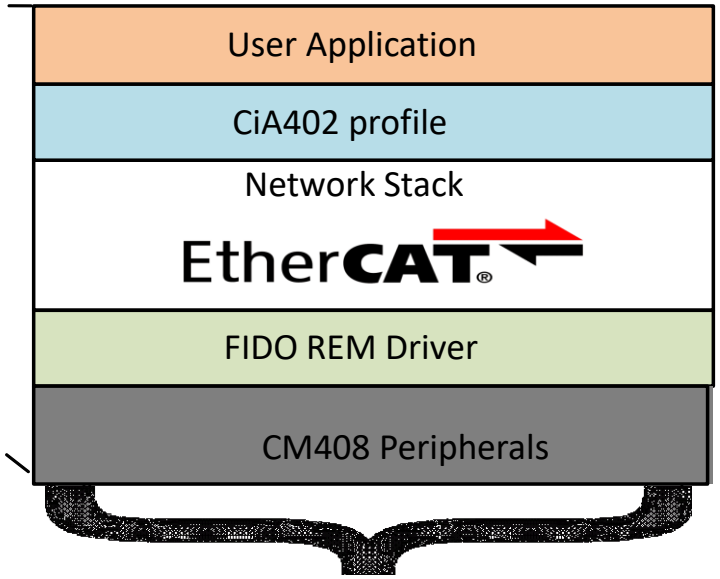
Bare Metal Ethercat Slave Solution

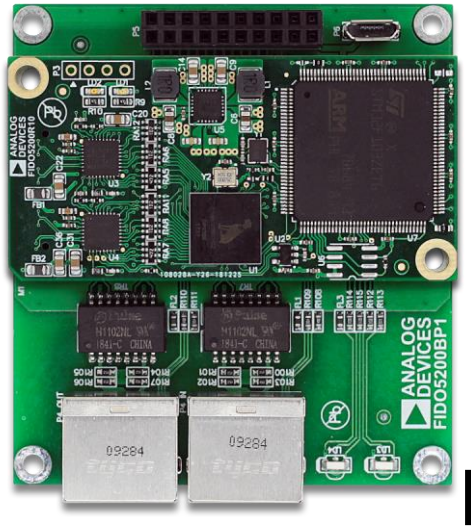
TwinCAT



ARM9 Core







Thank you!