



AHEAD OF WHAT'S POSSIBLE™

Analog Devices Industrial Robotic

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Industry Automation Segment Marketing Manager GC

Jul. 2022



AHEAD OF WHAT'S POSSIBLE™

ADI Focus for Industry 4.0

Industry 4.0 Delivers on Increased Productivity

See where ADI is accelerating the transition to the secure connected enterprise

Flexibility

The shift to more flexible architectures allows for greater capacity and faster reconfiguration. Using universal analog I/O (input/output) brings integration, robustness, flexibility, and efficiency with significant time and cost savings. All of which create opportunities for virtualization utilizing AI and digital twin technologies.

Efficiency

Even a 1% reduction in energy use can bring tremendous savings to a factory operator. These savings can be realized through the adoption of inherently lower power solutions that are then augmented by condition-based machine monitoring analytics.

Communications

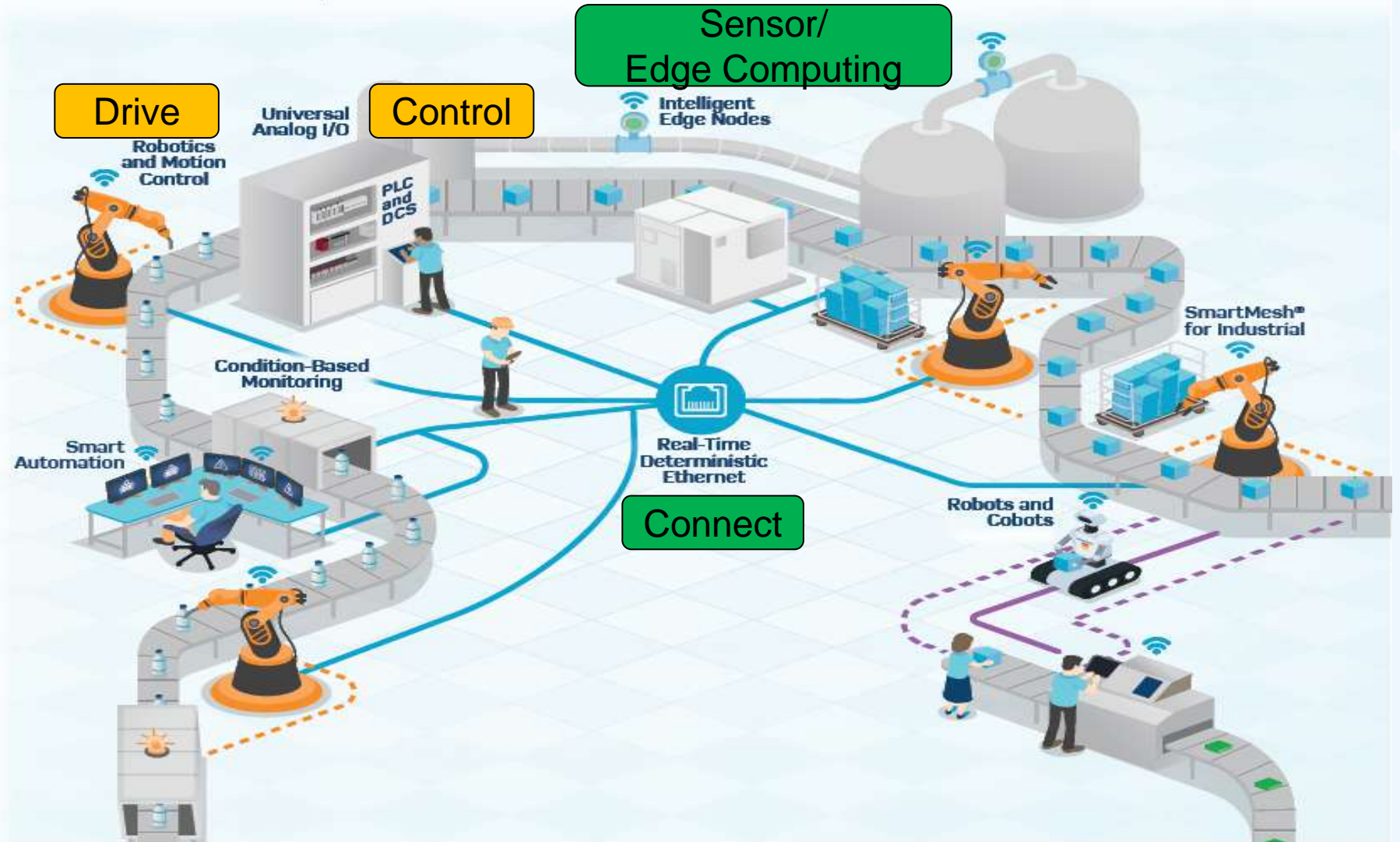
Central to the execution of Industry 4.0 is robust and secure wired and wireless communication that must support legacy standards and provide a clear path to Ethernet to the Edge and time sensitive networks (TSN).

Safety

A system is not smart if it is not safe. Functional safety is ubiquitous in automation systems with strict standardization and certifications requirements.

Security

Greater connectivity of smart machines with Industry 4.0 brings with it risks from cyber attacks. Factory operators and solution providers need to develop stronger cybersecurity strategies that are more vigilant and resilient to attack.



Content

- ▶ Industry robotic system architecture

- ▶ ADI Solutions Offer
 - Motor and motion control -- Trinamic
 - Current & Voltage sensing
 - Position
 - Power conversion
 - Interface
 - Networking
 - Sensor
 - ToF
 - iTMU
 - Power
 - Solution and platform

ADI IND Robotics Focus

Traditional Industrial Robots



Key Challenges

- ▶ Multi-axis synchronisation
- ▶ High Precision motion control
- ▶ Space constraints
- ▶ Efficient Power Conversion
- ▶ Functional Safety
- ▶ Reliability, Uptime

Collaborative Robots



Key Challenges

- ▶ Functional Safety
- ▶ Proximity Sensing
- ▶ Cabling
- ▶ Mid range motion control
- ▶ Efficient Power Conversion
- ▶ Orientation Sensing

Automated Guided Vehicles

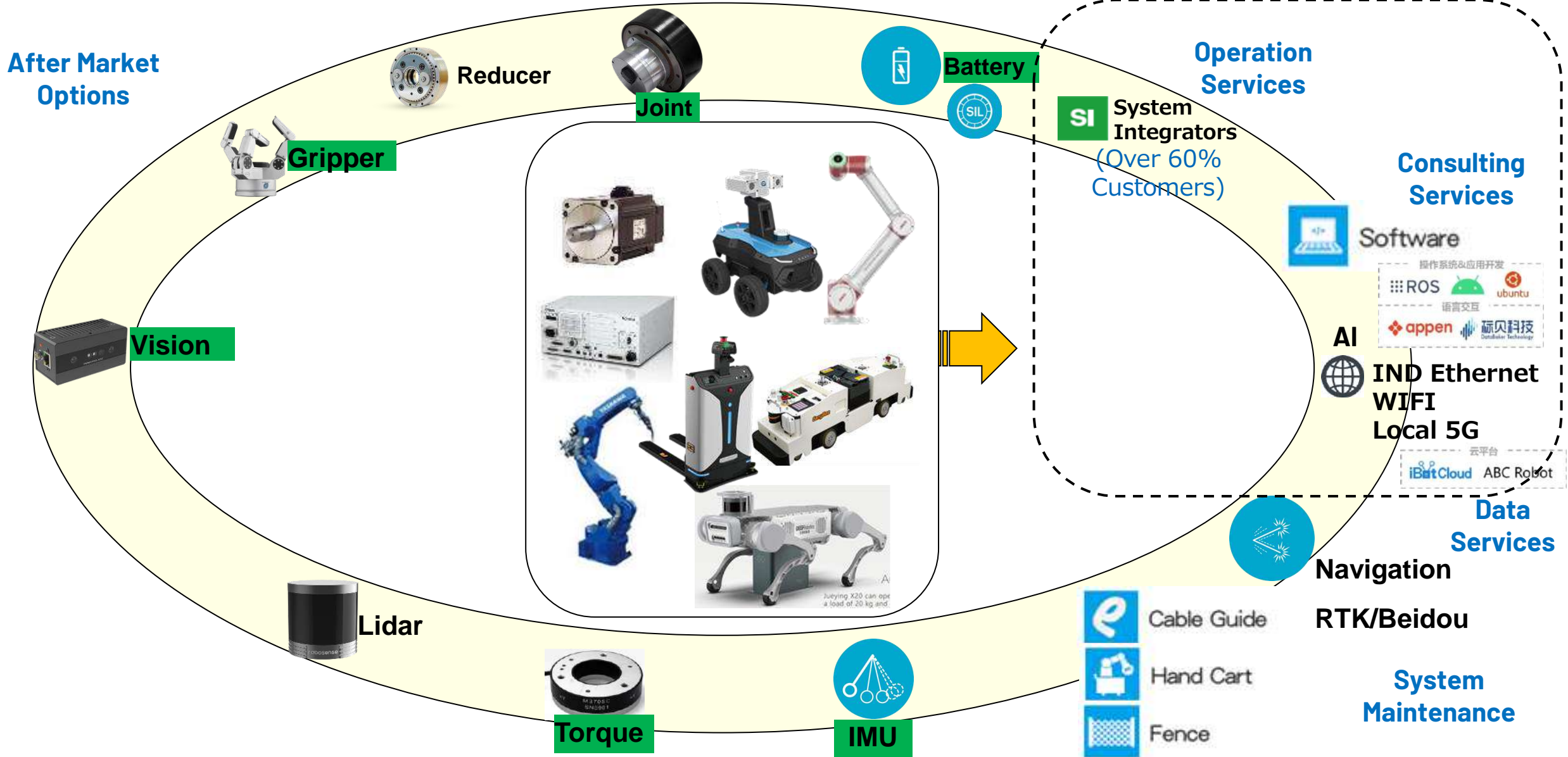
Autonomous Mobile Robots



Key Challenges

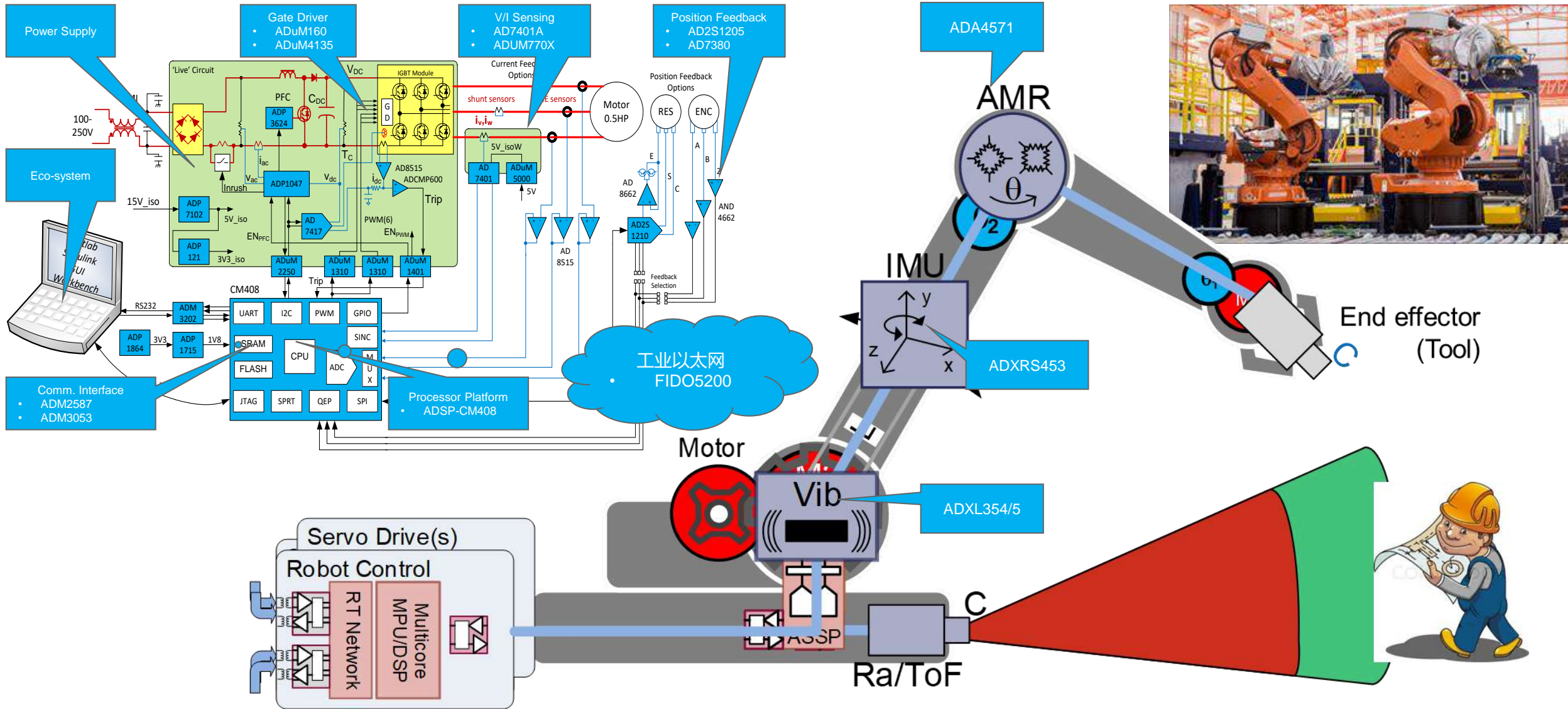
- ▶ Navigation
- ▶ Stabilisation
- ▶ Efficient Power Conversion
- ▶ Battery Management
- ▶ Wireless Comms
- ▶ Functional Safety

Industry Robotic Players

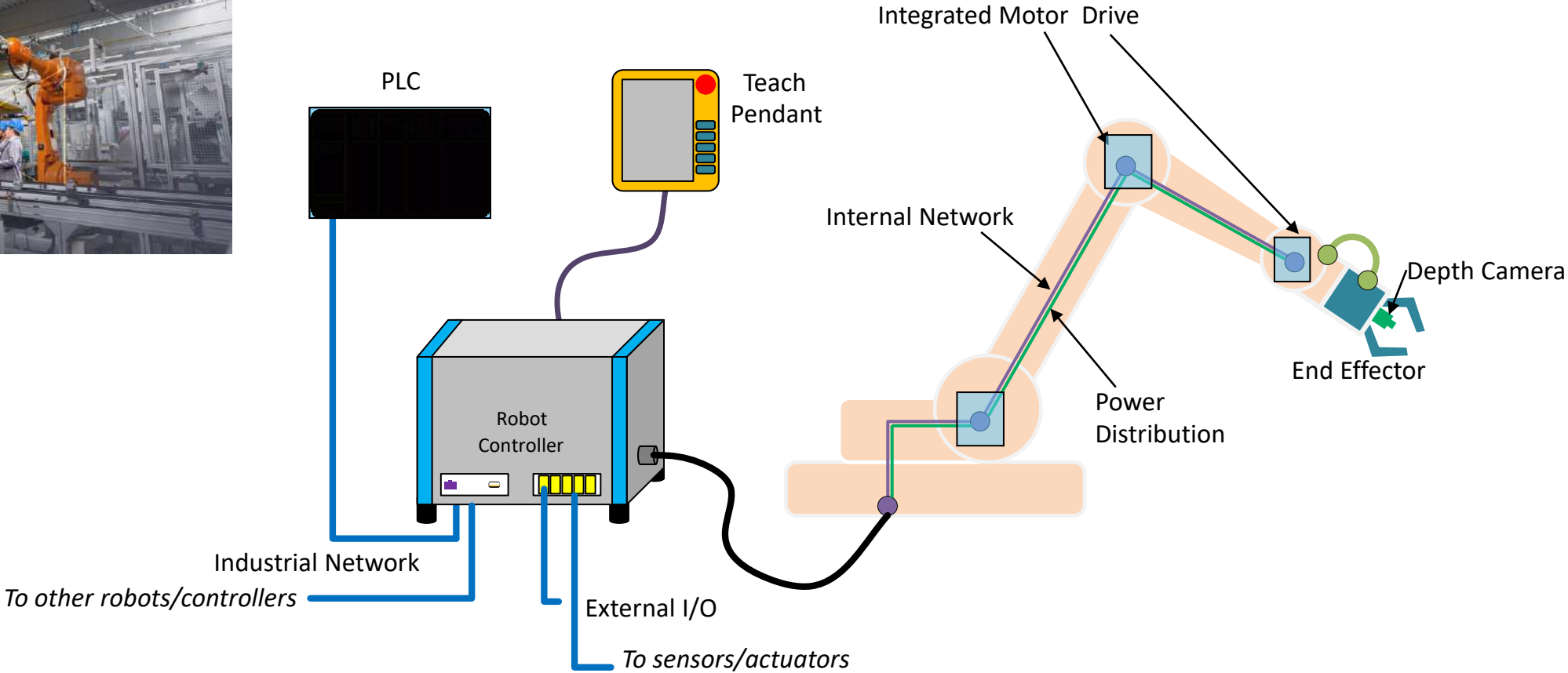


ADI Solutions Offer

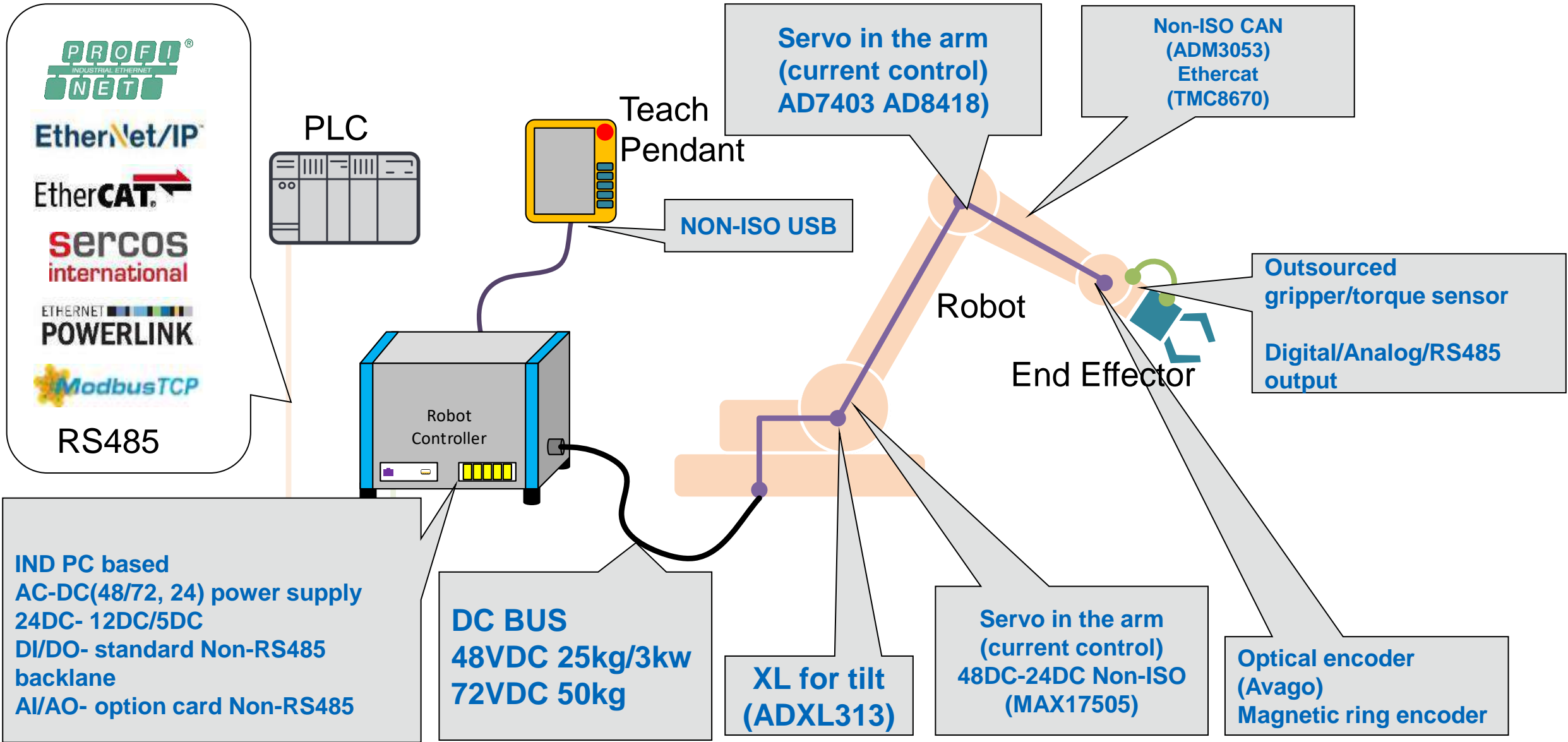
Traditional Robot Diagram



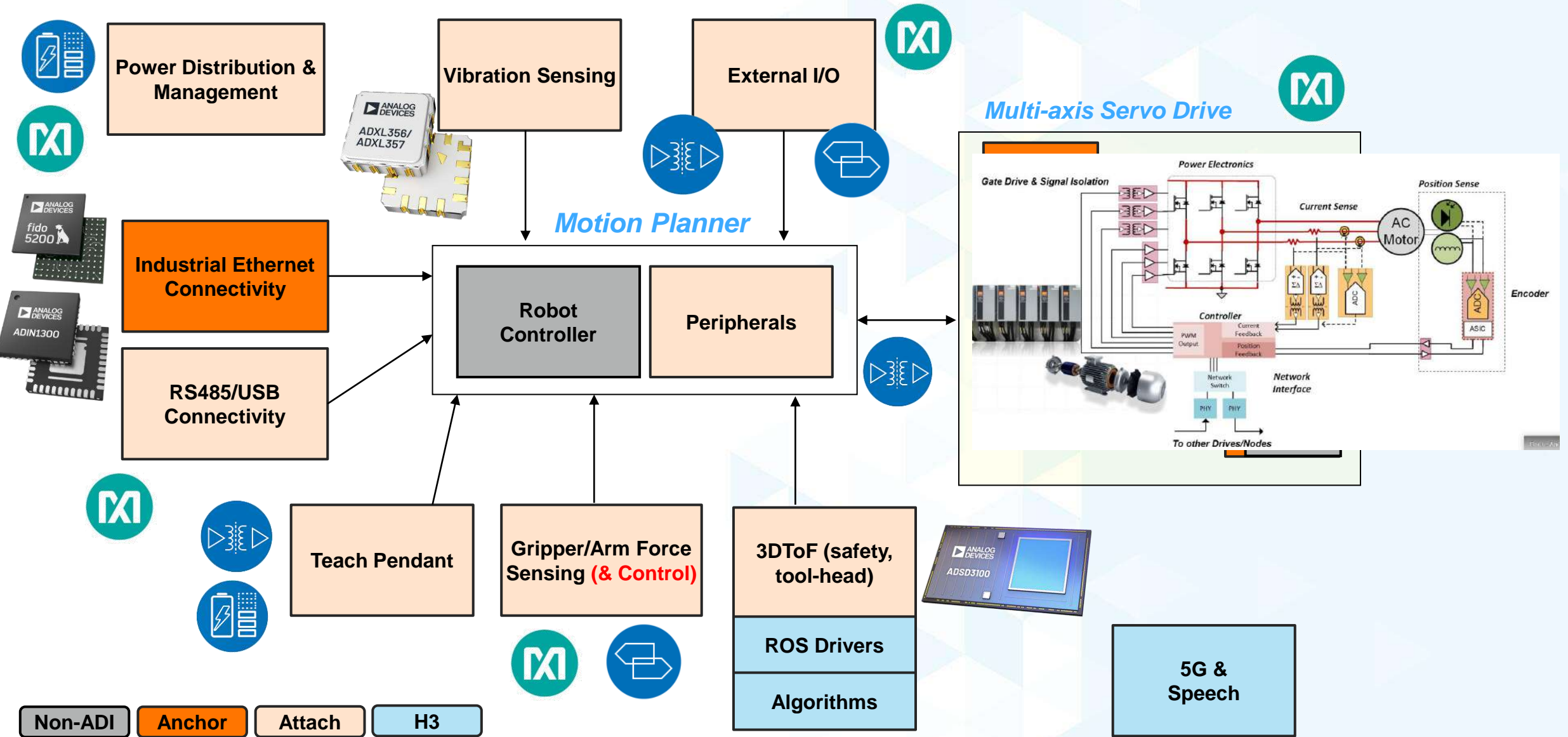
Cobot Diagram



Cobot Diagram

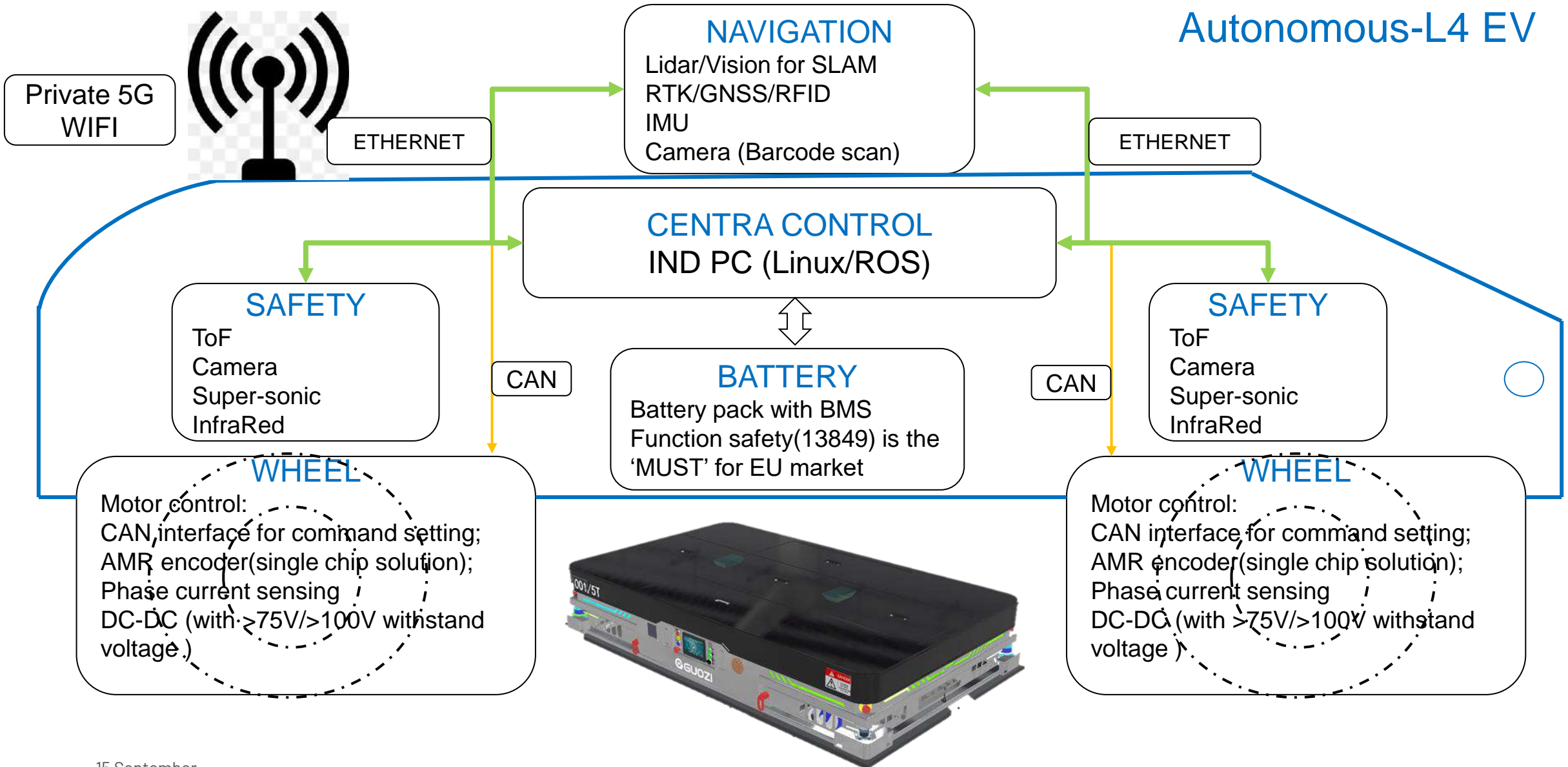


Robots/Cobots – Technology Block Diagram

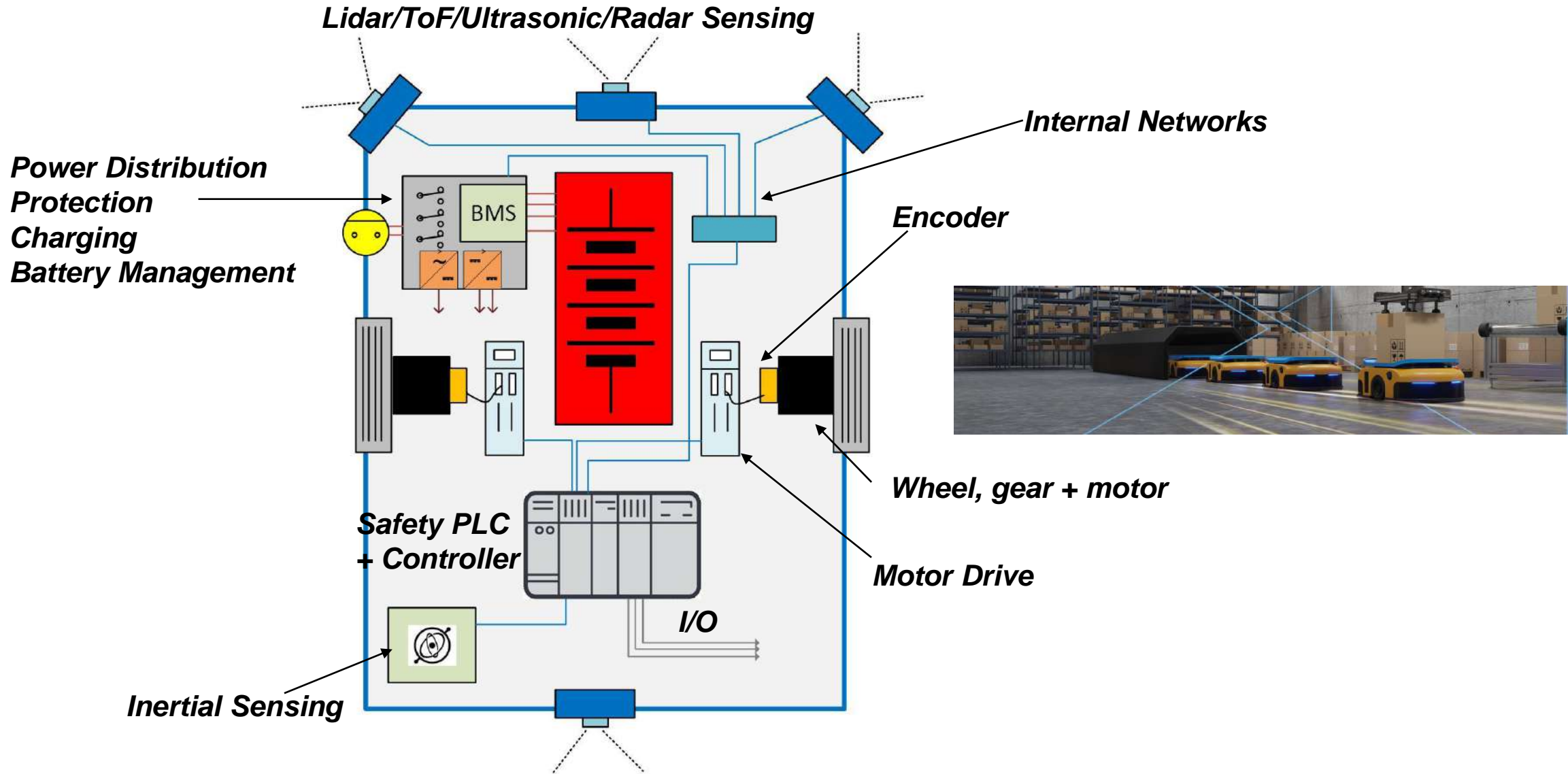


AGV/AMR Diagram

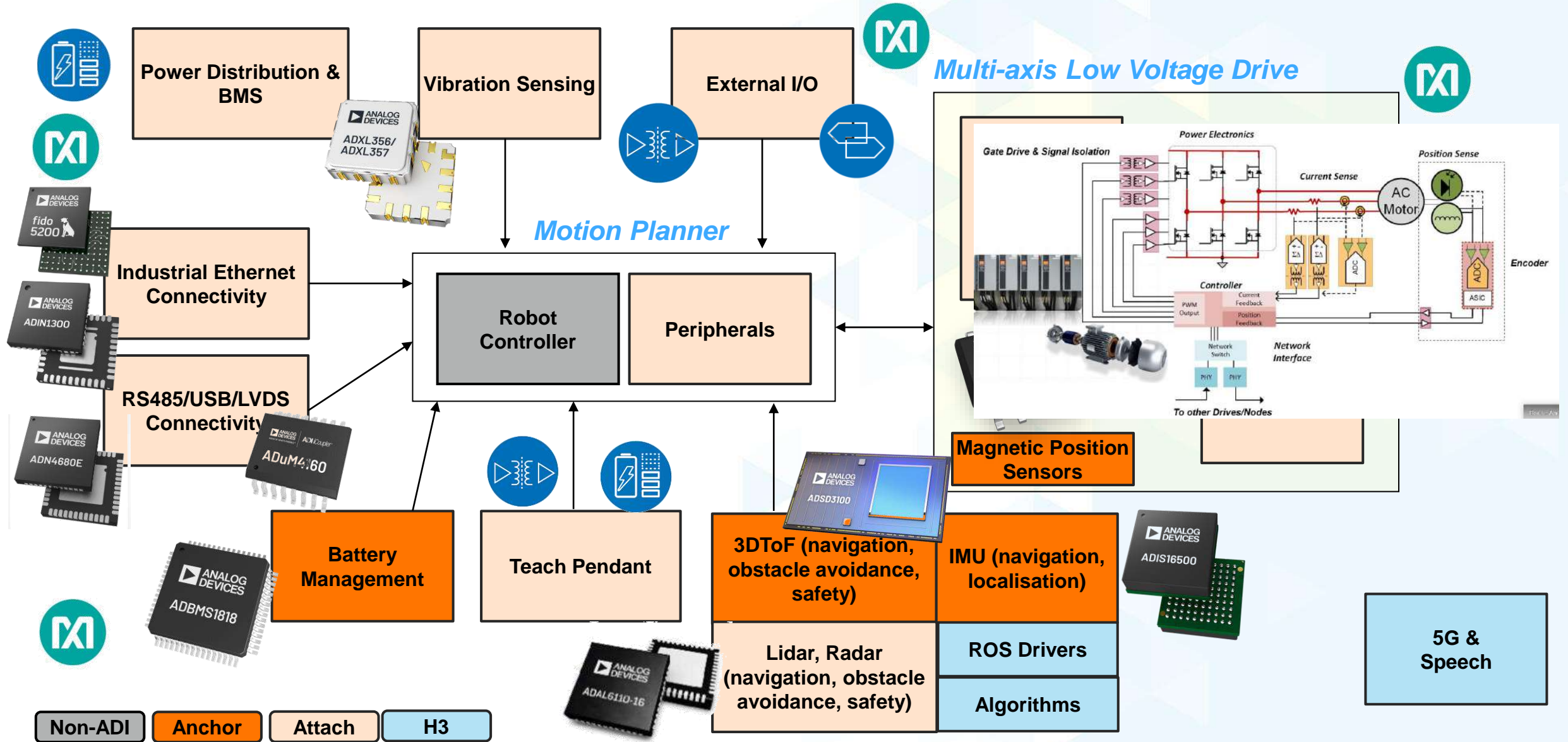
Autonomous-L4 EV



Mobile Robots – System Diagram

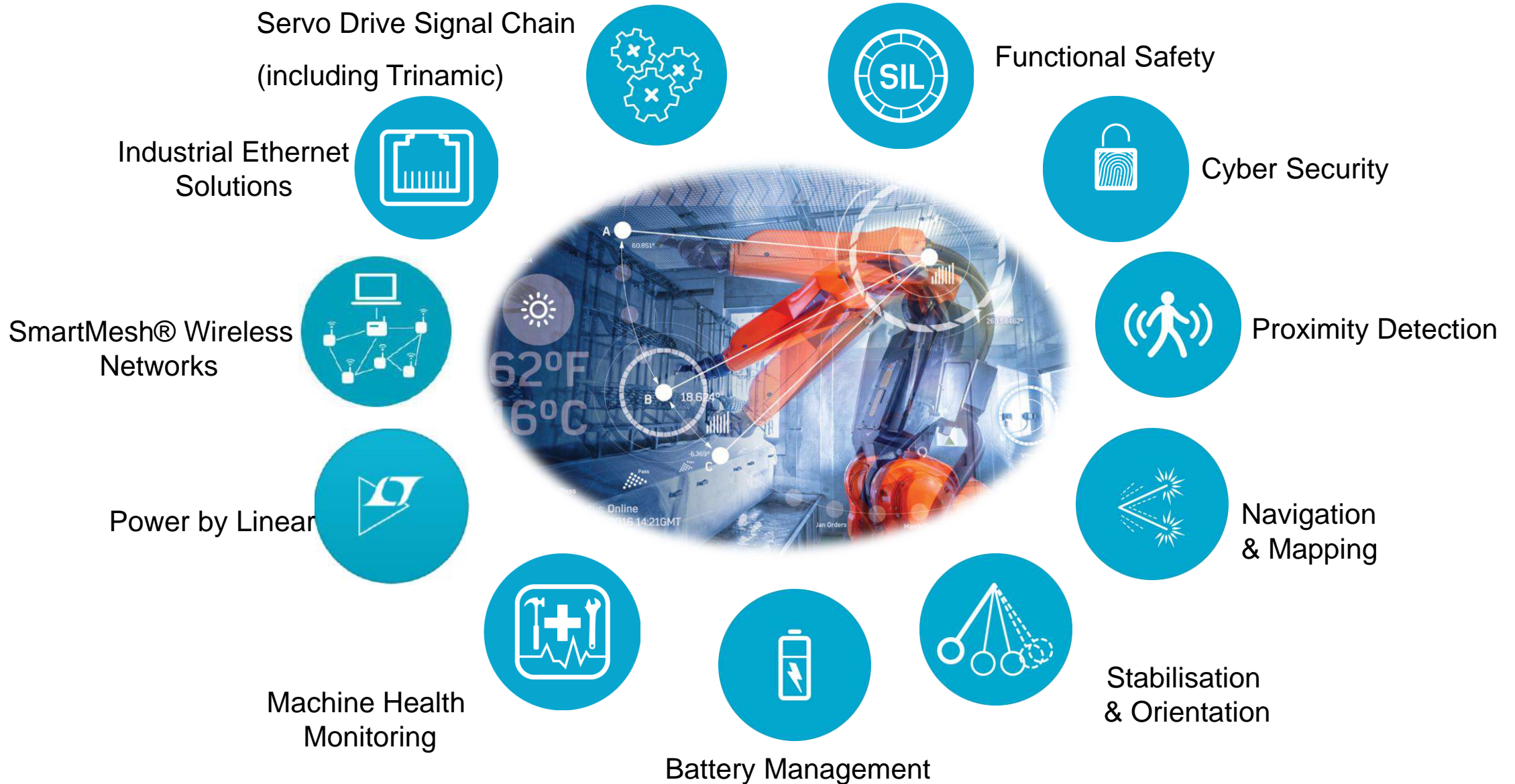


Mobile Robot – Technology Block Diagram



Non-ADI | Anchor | Attach | H3

ADI Technologies Advancing Robotics



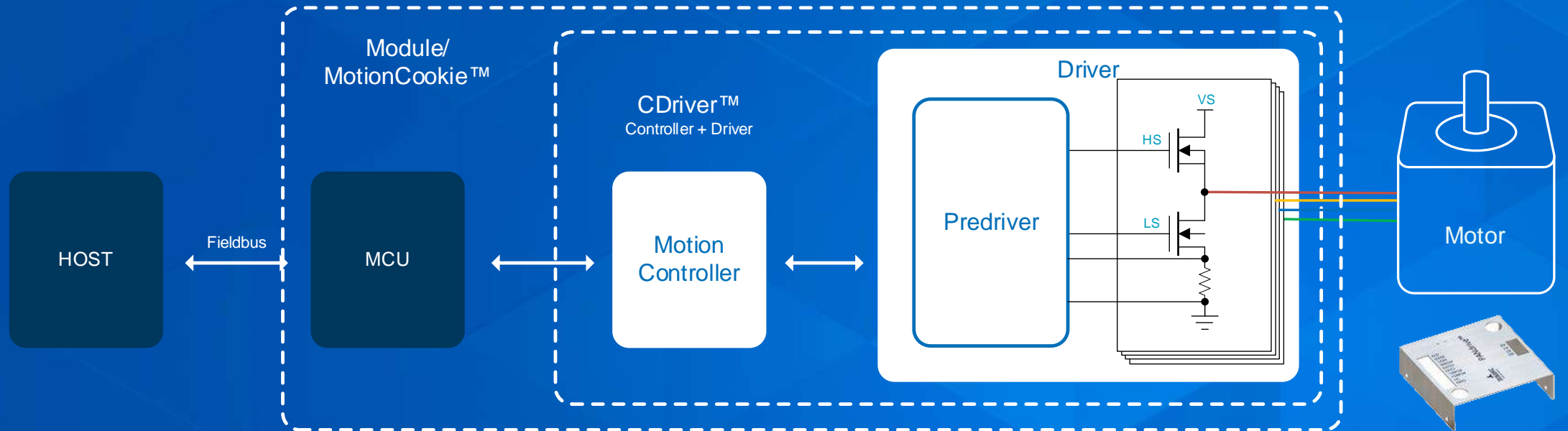
ADI Trinamic


```
1101000011100010101001  
0011101000011100010101  
0100100100011101000011  
0101000100100100100011
```

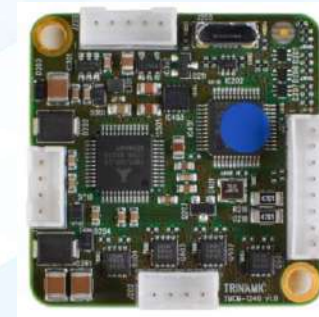


We Transform **Digital** Information Into **Physical Motion**

Motor & Motion Control



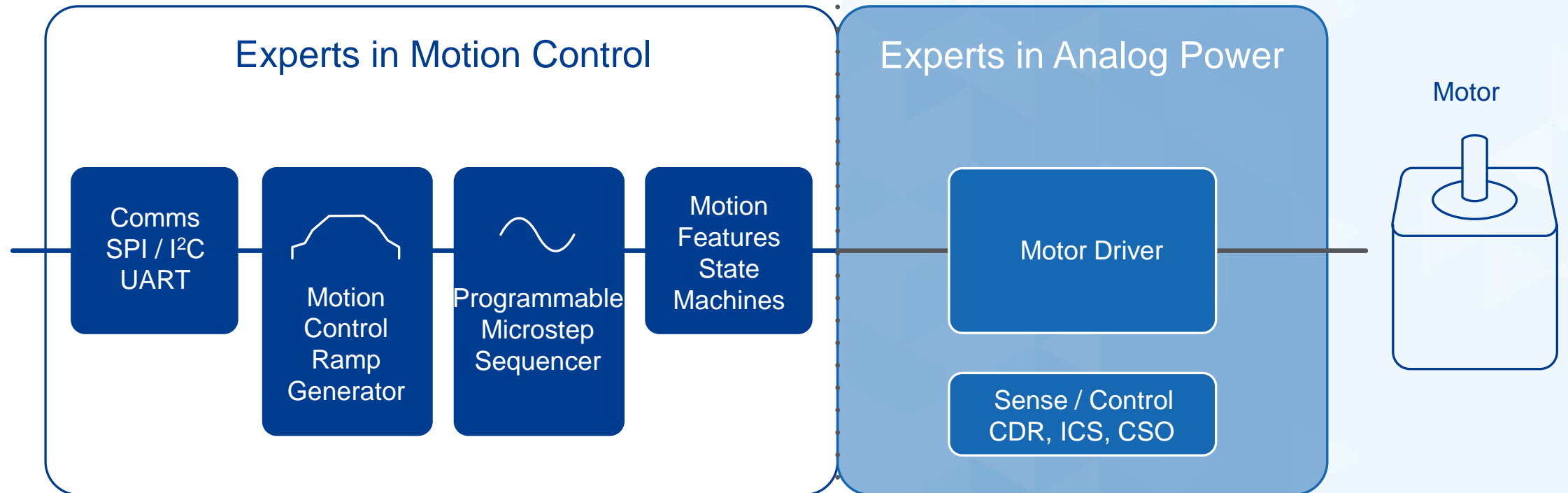
- ▶ Motor Types: Stepper, BLDC
- ▶ Motor Sizes: mW ... kW
- ▶ Voltage Range: 1.8...80V



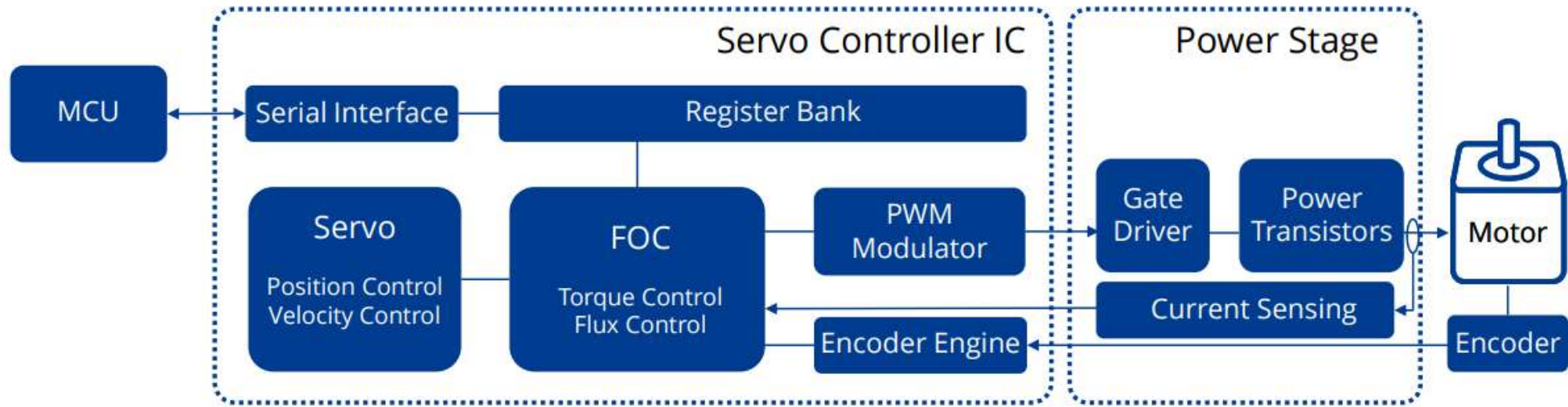
Problem Solving Differentiators

Energy consumption / heat and power dissipation Current control based on sensorless StallGuard™ values	CoolStep™
Pulsation in movement / vibrations High-resolution microstepping	SpreadCycle™
Audible noise / mechanical resonances Advanced current control	StealthChop™
Dynamic load changes / overload and pot. position loss Sensorless load monitoring	StallGuard2™
Jerky motion / position overshoot Advanced multi-segment / jerk-limiting acceleration ramps	SixPoint™

Analog Devices + Trinamic:



ServoControl System





TRINAMIC

MOTION CONTROL

► Camera Gimbal

...winning with **efficiency**
and **integration**

thanks to hardware FOC



► Respiration

...winning with **precision**
and **fast time to market**

thanks to closed-loop
reference designs



► AGVs

...winning with **efficiency** and
code-free building blocks

thanks to hardware FOC

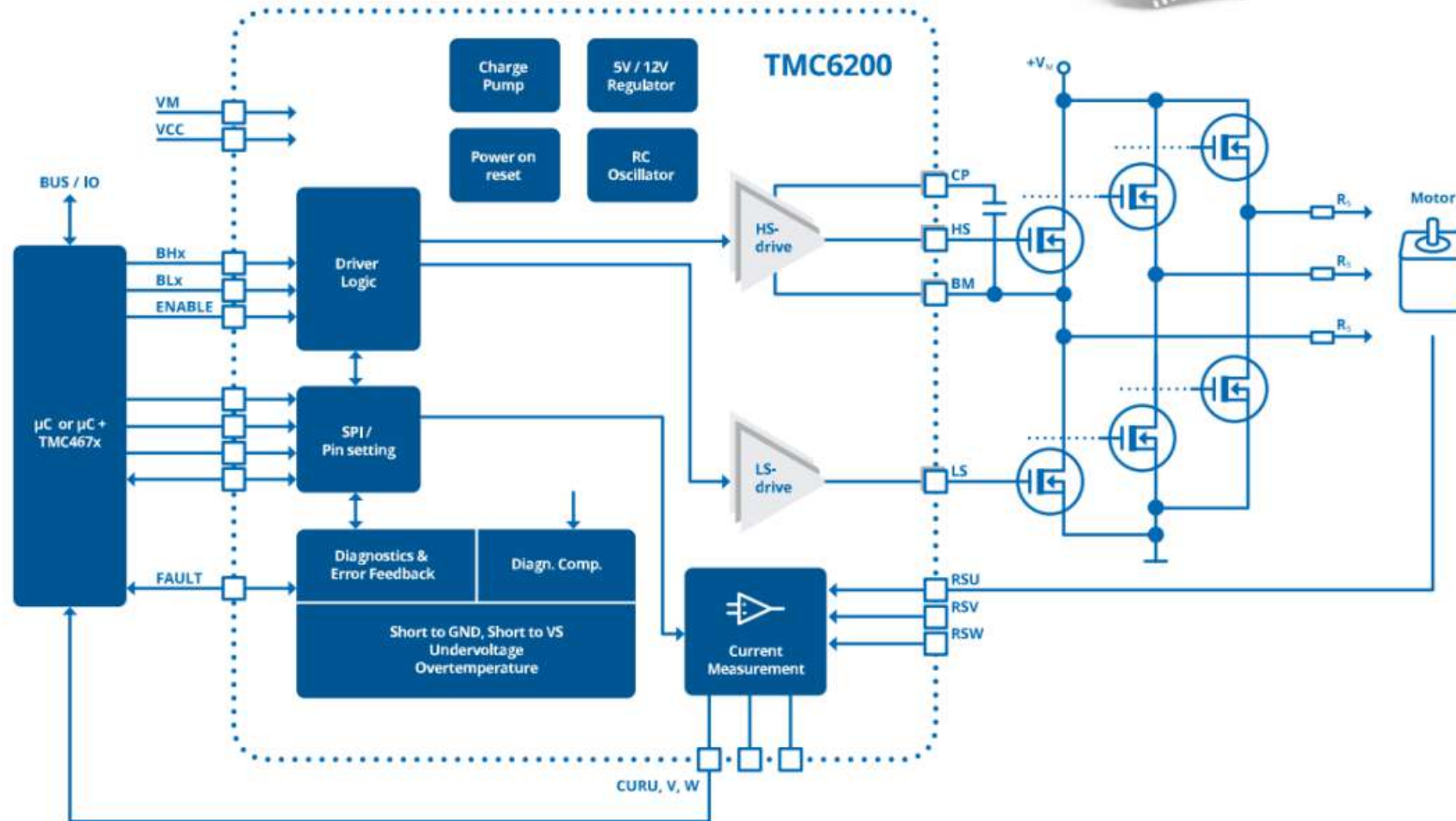


Gate Driver

Gate driver



BLOCK DIAGRAM



Gate Driver

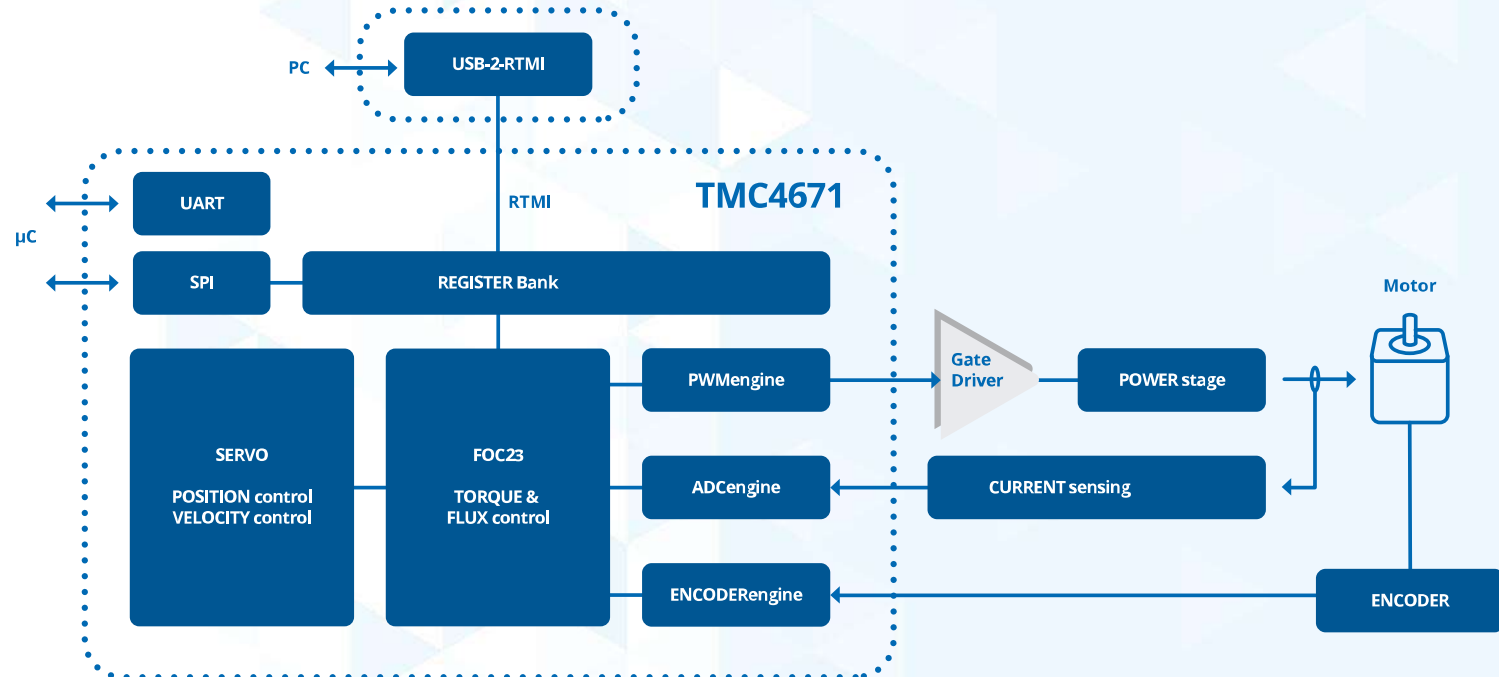


PRODUCT	TMC6100-LA	TMC6140-LA	TMC6200-TA	TMC6300-LA
Number of axes	1	1	1	1
Motor type	3-Phase BLDC, PMSM	3-Phase BLDC, PMSM	3-Phase BLDC, PMSM	3-Phase BLDC, PMSM
Gate current	0.5A / 1A / 1.5A	0.5A / 1A	0.5A / 1A / 1.5A	-
Motor supply voltage	8V...60V	6V...30V	8V...60V	2V (1.8V)...11V
Controller interface	3/6 line HS & LS, SPI	6 line HS & LS, UART-TxD	3/6 line HS & LS, SPI	6 line HS & LS
Shunt amplifier	-	triple	triple	-
Short to GND protection	✓	✓	✓	✓
Switching regulator	-	3.3 V, 500 mA	-	-
Linear regulator	5V, 12V	5V, 10V	5V, 12V	1.8V
Low side charge pump	-	✓	-	-
Break before make logic	✓	✓	✓	✓
Slope control	✓	✓	✓	-
MOSFET type	N	N	N	N
Package	QFN37 (7x7)	QFN36 (5x6)	eTQFP48 (7x7)	QFN20 (3x3)

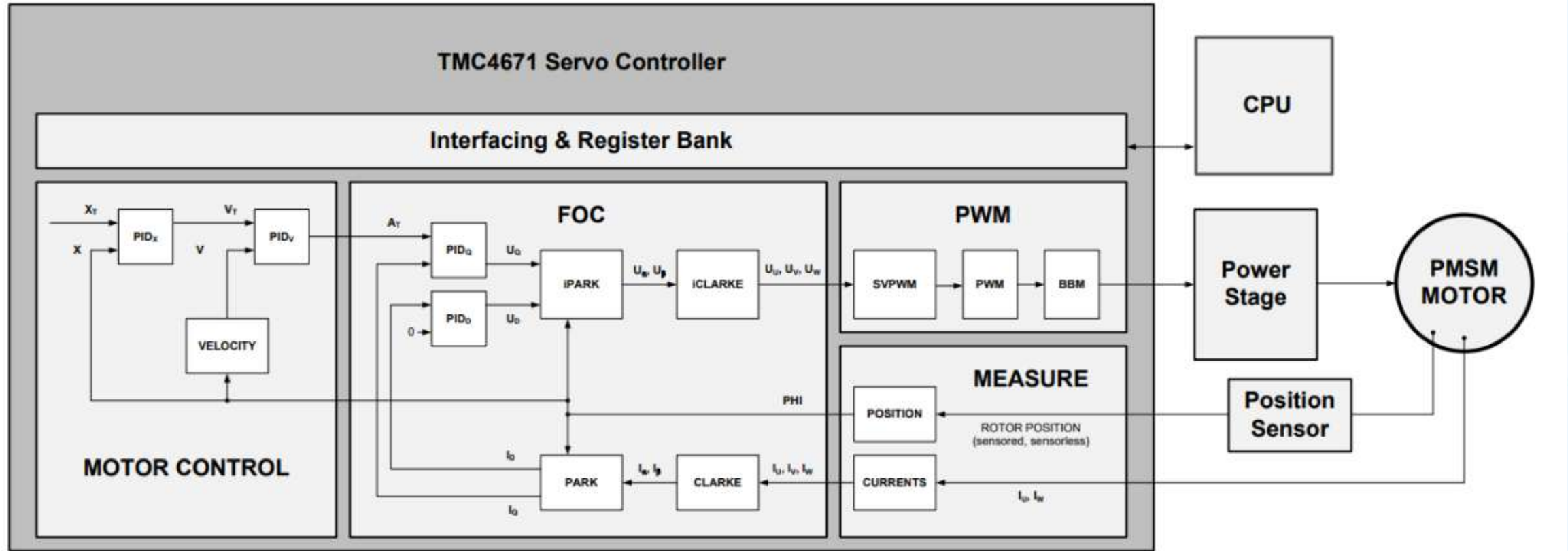
TMC4671-LA -- FOC in Hardware

Features:

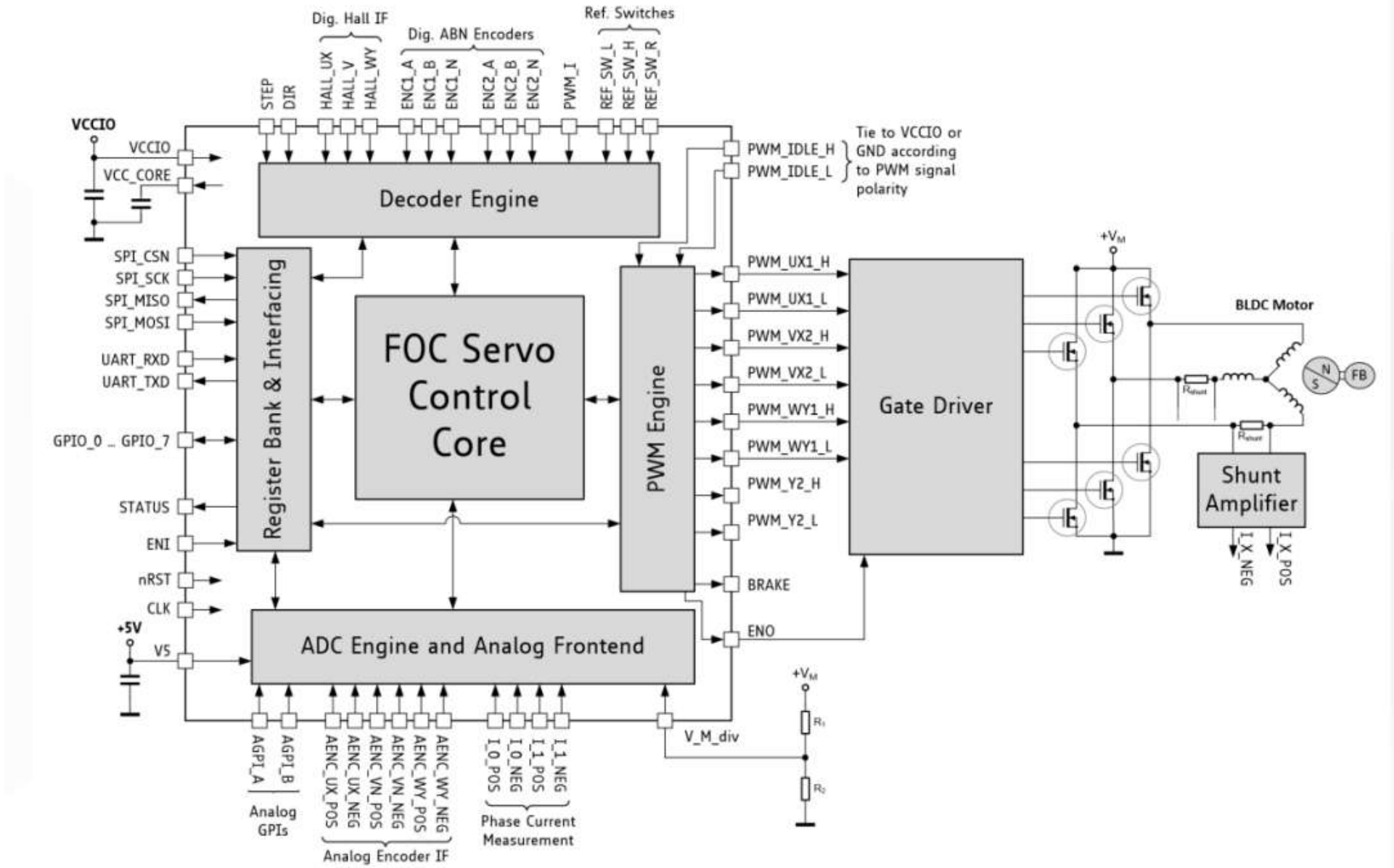
- ▶ Servo Controller w/ Field Oriented Control (FOC) • Torque Control (FOC), Velocity Control, Position Control
- ▶ Integrated ADCs, $\Delta\Sigma$ -ADC Frontend
- ▶ Encoder Engine: Hall analog/digital, Encoder analog/digital
- ▶ Supports 3-Phase PMSM/BLDC, 2-Phase Stepper Motors, and 1-Phase DC Motors •
- ▶ Fast PWM Engine (25kHz ... 100kHz)
- ▶ Application SPI + Debug (UART, SPI)
- ▶ Step-Direction Interface (S/D)
- ▶ QFN76 (10.5x6.5) package



TMC4671-LA -- FOC in Hardware

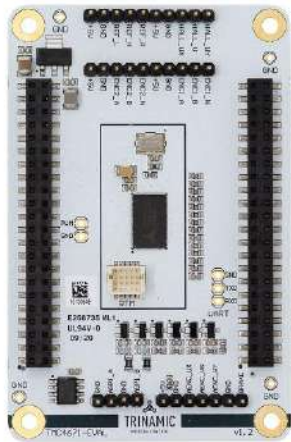


TMC4671 pin function for BLDC/PMSM

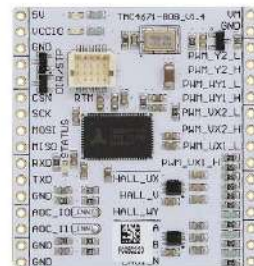


TMC4671 – Get Started

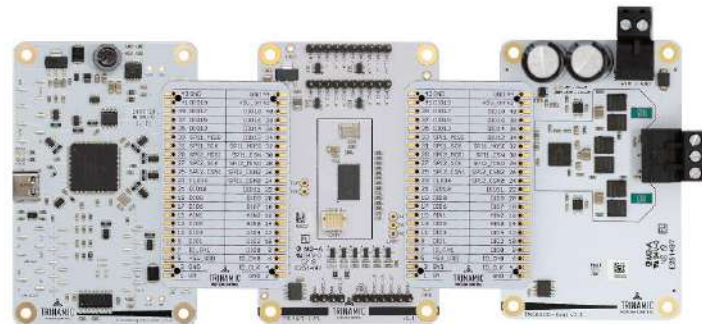
- ▶ Start your design easily using Trinamic's evaluation boards and kits
 - Open source: access to all registers using Trinamic's own software, allowing you to develop your own firmware
- ▶ Open-source breakout boards for rapid prototyping
 - Can be used on a breadboard or with flying wires
 - All sensitive signals are routed on the BOB itself



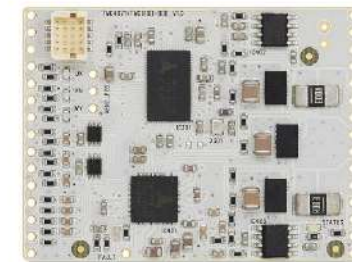
TMC4671-
EVAL



TMC4671-BOB



TMC6100+TMC4671-EVAL-KIT



TMC4671+
TMC100-BOB

TMCL-IDE

- ▶ Connect & get Started
- ▶ Parametrize & Program
- ▶ Analyze & Debug
- ▶ Intuitive

It's free to download & use!

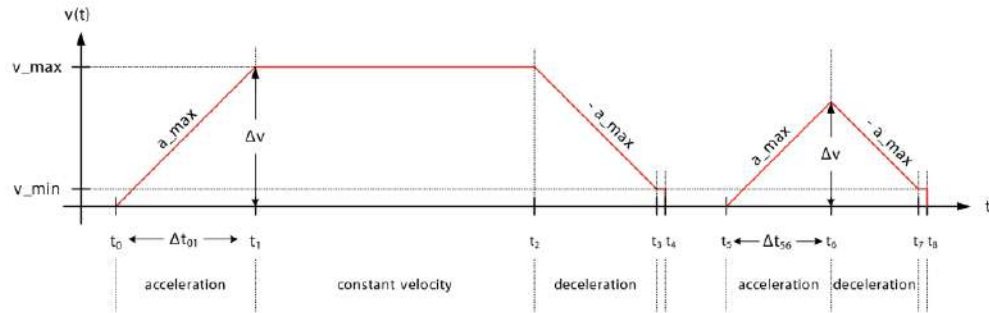
[TMCL-IDE page](#)

The screenshot displays the TMCL-IDE 3.0 software interface. On the left, a tree view under 'Connected devices' shows a USB port connected to a TCMC-3110 motor. The 'TMCL creator' option is selected. The main window shows a code editor with a TMC program for moving a motor left and right in a loop. Below the code is a 'Position graph' showing the motor's position over time, with the position remaining at 0.0 from 20s to 23s.

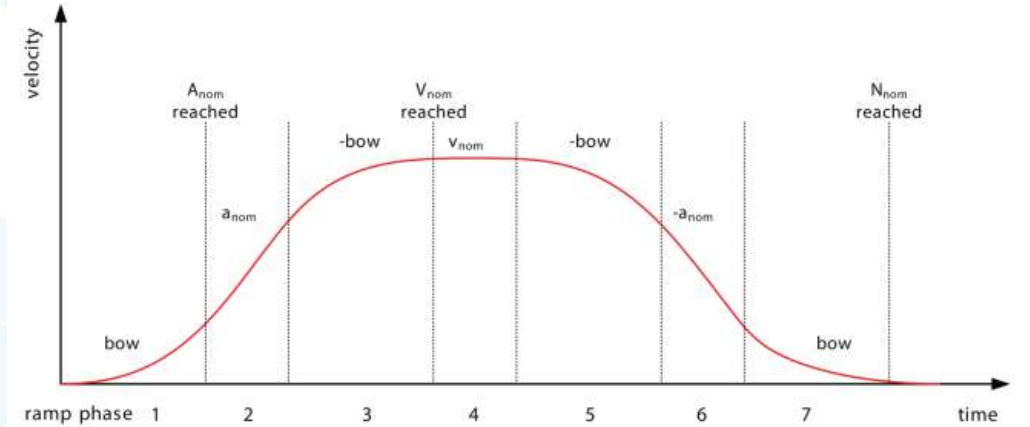
```
// move repeatedly left and right
loop:
  MVP 1.0,100000 // move 100000 ticks right
  WAIT POS,0,0 // wait to arrive
  MVP 1.0,-100000 // move 100000 ticks left
  WAIT POS,0,0 // wait to arrive
  JA loop
```

Position graph @TMCM-3110 [Aa] <1st motor of 3> : COM3-

Time (s)	Position
20.0	0.0
20.5	0.0
21.0	0.0
21.5	0.0
22.0	0.0
22.5	0.0
23.0	0.0

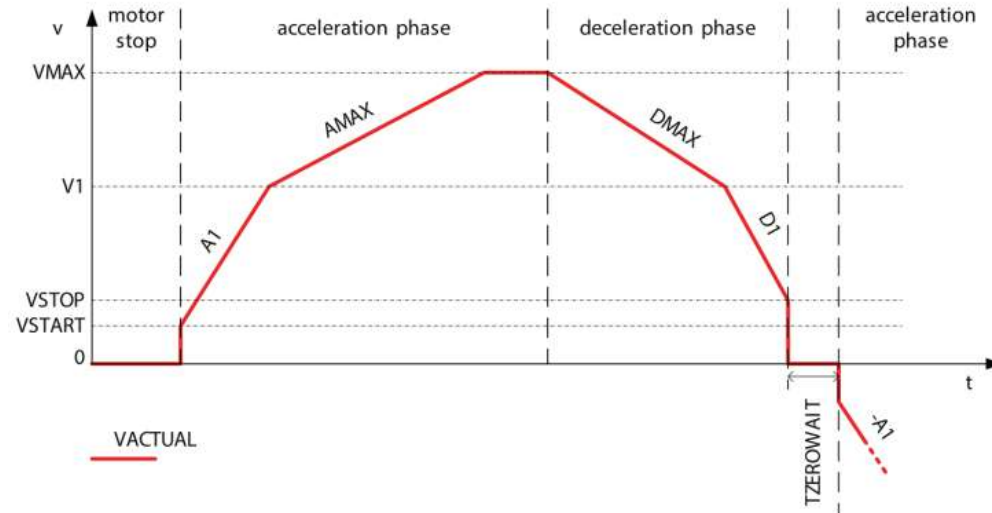


Linear ramping



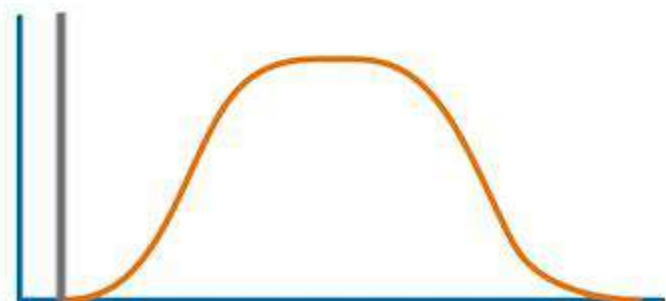
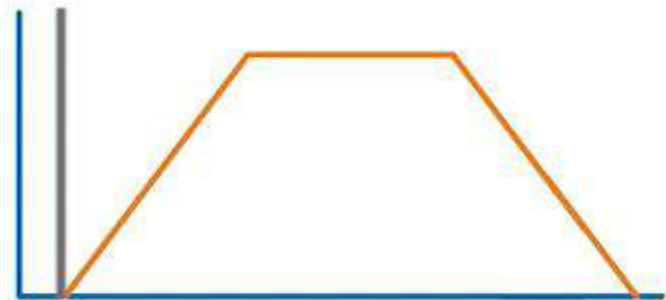
N_{nom} : number of steps
 V_{nom} : maximum velocity
 A_{nom} : maximum acceleration
 B : increase of acceleration (bow)

S-Shaped ramping



sixPoint™ ramping

ALL IN
HARDWARE!

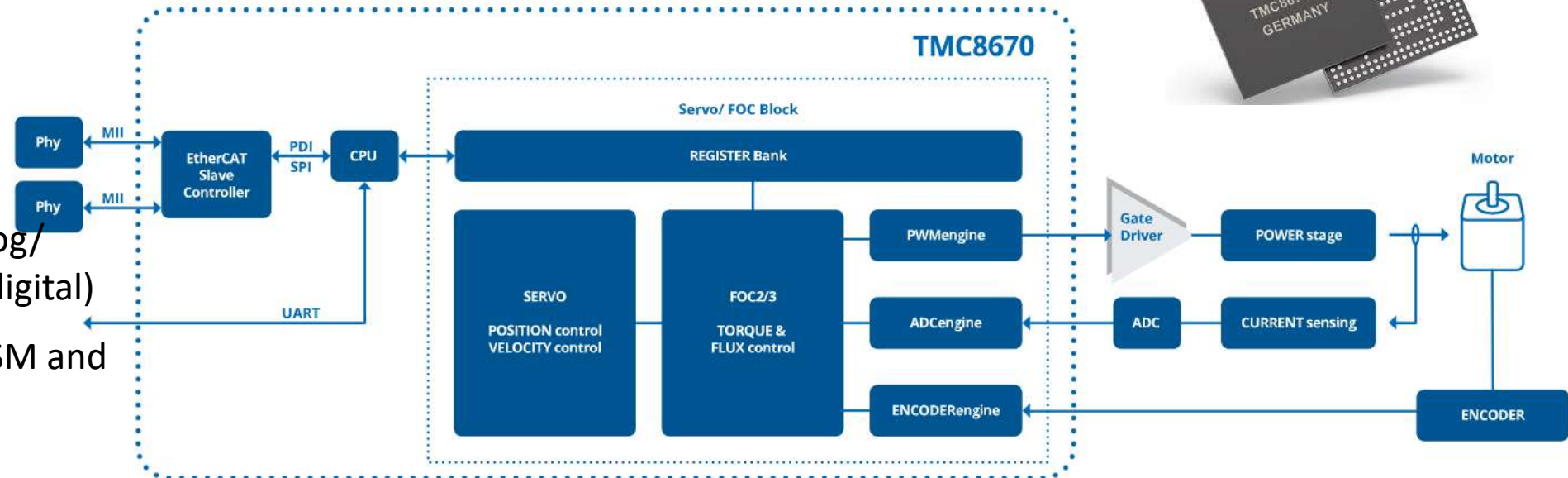


TMC8670 --- Most Integrated Part

Features

- ▶ Field Oriented Control (FOC) Servo Controller
 - Torque Control (FOC)
 - Velocity Control
 - Position Control
- ▶ Sensor Engine (Hall analog/digital, Encoder analog/digital)
- ▶ Support for 3-Phase PMSM and 2-Phase Stepper Motors
- ▶ PWM Engine including SVPWM
- ▶ Integrated EtherCAT Slave Controller, CoE protocol CiA 402 drive profile
- ▶ UART interface

Block Diagram (TMC8670-BI)

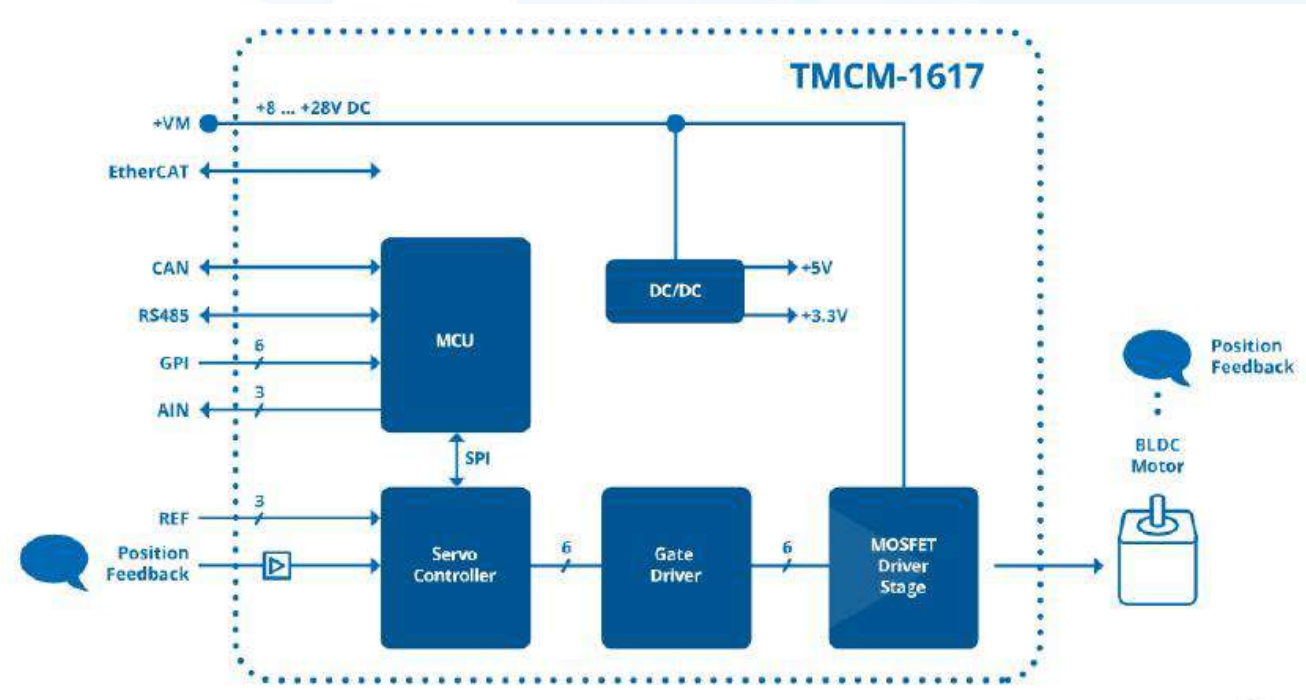
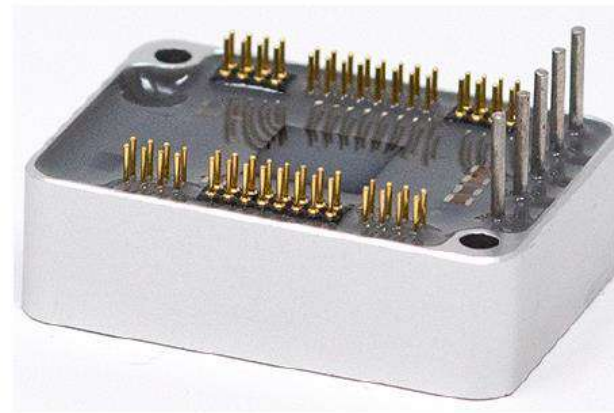


- Two MII interfaces to external Ethernet PHYs plus management interface
- Four Fieldbus Memory Management Units (FMMU)
- Four Sync Managers (SM)
- 4 Kbyte of Process Data RAM (PDRAM)
- 64-bit Distributed Clocks support
- IIC interface for an external SII-EEPROM for ESC configuration

TMCM1617 --- Custom Module Offer

Features

- ▶ • Servo drive for BLDC motors
- ▶ • +8...28V DC supply voltage
- ▶ • Up to 18A RMS max. motor current
- ▶ • RS485, CAN&EtherCAT® interfaces
- ▶ • Incremental encoder feedback
- ▶ • Digital HALL sensor feedback
- ▶ • Reference switch inputs
- ▶ • Cooling via aluminum housing
- ▶ • L/W/H: 36.8mm x 26.8mm x 11.1mm
- ▶ • Weight: ca. 24g
- ▶ • Customization options



TMCM-1617-GRIP-REF

► Features

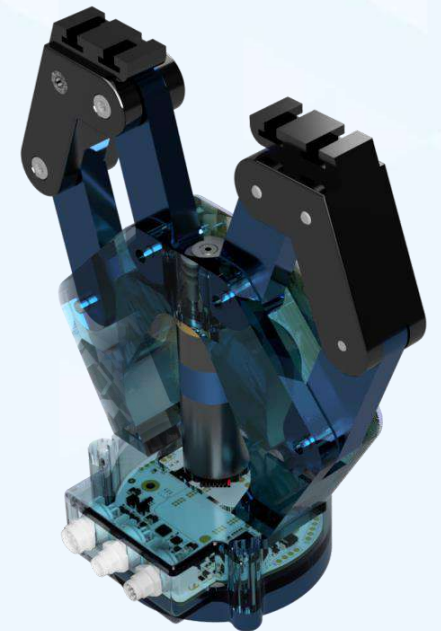
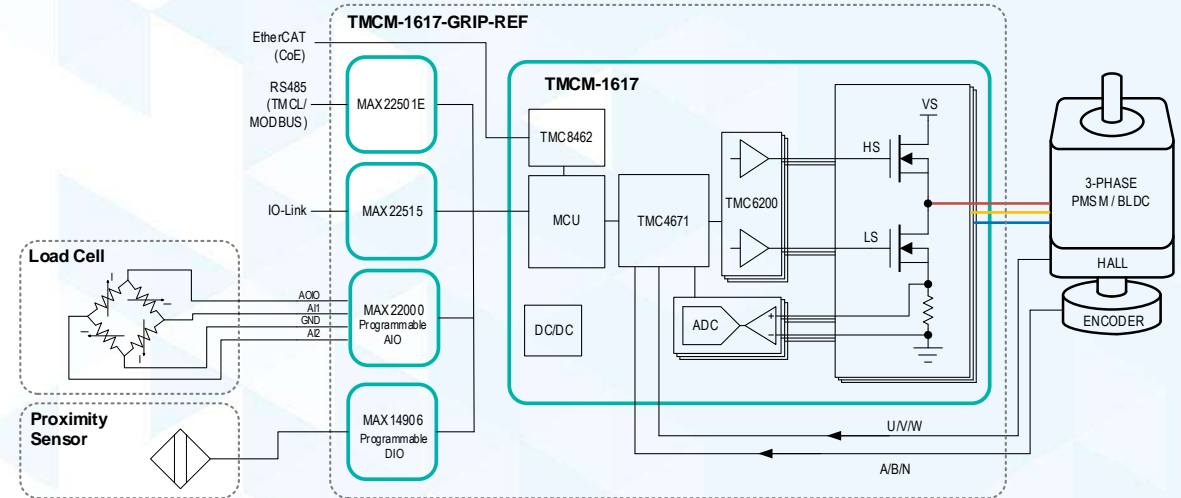
- Supply Voltage: 8...28V
- Phase Current: Up to 2.5A
- Interfaces: RS485, EtherCAT, IO-Link
- Fast, deterministic & High performance Motor Control
- Advanced Diagnostics
- 1x Precise configurable analog Output
- 1x Precise configurable analog Input (MAX22000)
- 4x configurable digital I/Os (MAX14906)
- Efficient Cooling

► Benefits

- No Software development required.
- Easy deployment using TMCL-IDE
- Small Formfactor (to be mounted in a ISO 9409-1-50-4-M6 Flange)

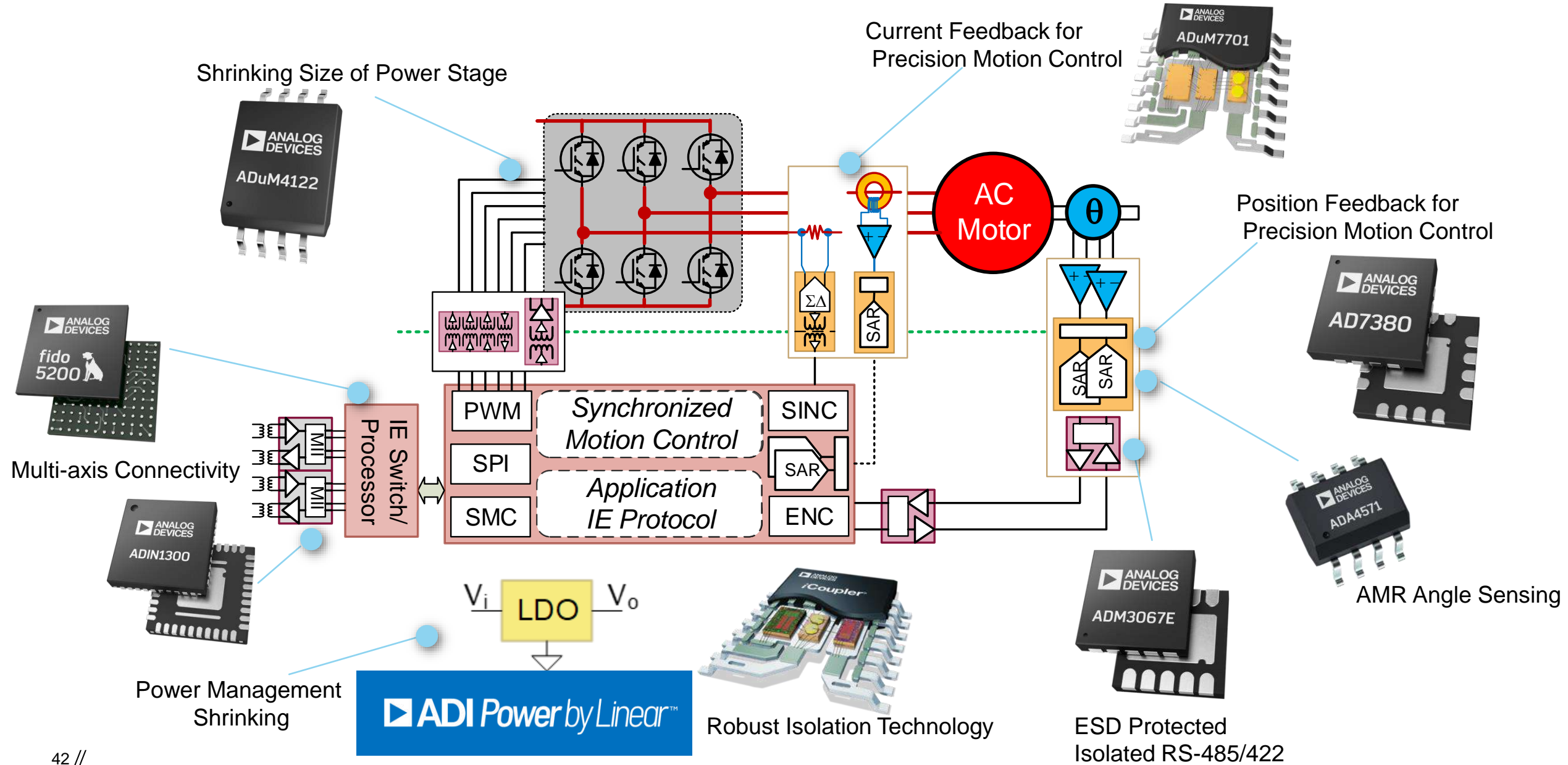
► Applications

- End of Arm tooling (EoAT)



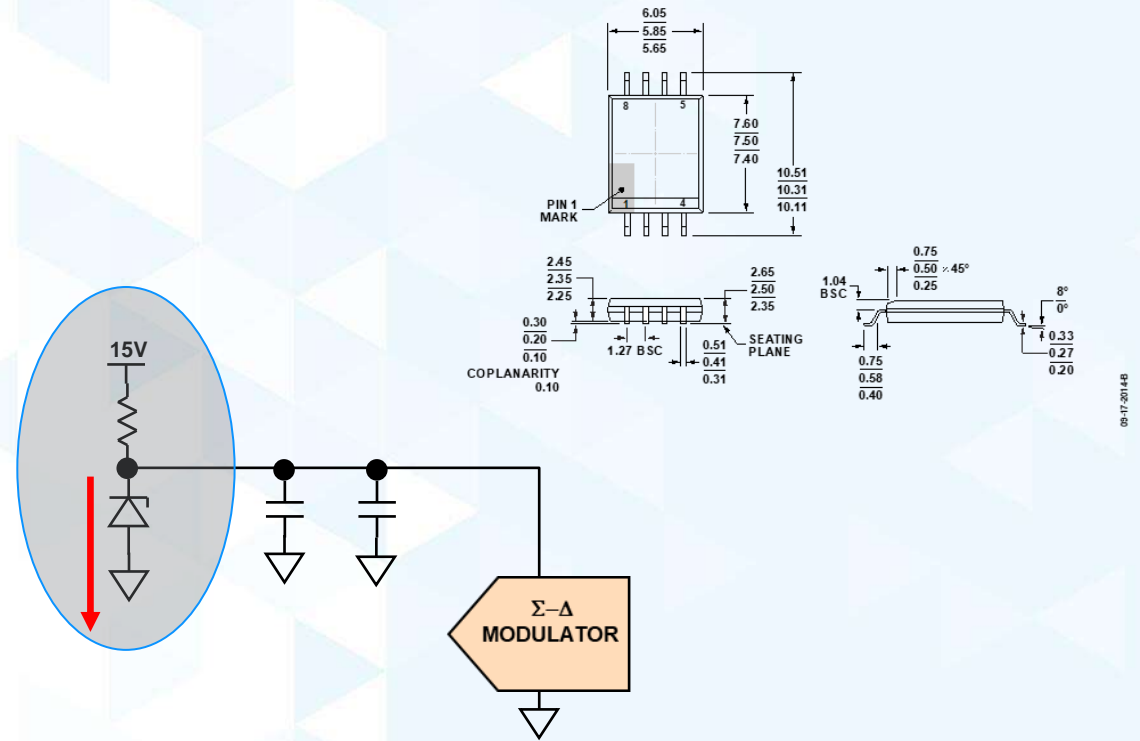
Current/Voltage Sensing

Mid to High Performance Servo Drive Signal Chain



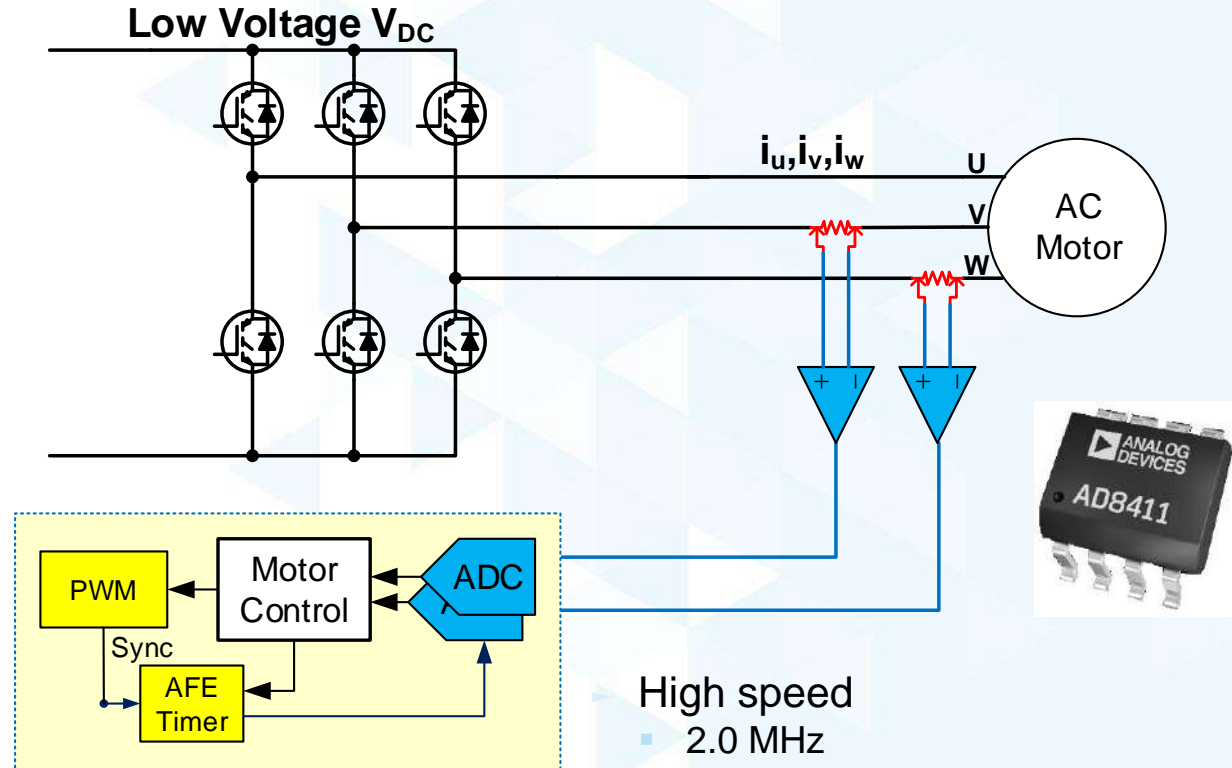
ADuM7703, Integrated LDO

- ▶ Space saving package RI-8, 8-lead wide body SOIC
- ▶ ADuM7703/04-8 only devices with integrated LDO in 8-lead package
- ▶ No external LDO or bootstrapping required
 - Delivering board area savings, fewer components
 - Bootstrap zener diode breakdown voltage varies vs. temperature adding additional offset error
 - Current loss through Zener
- ▶ **ADuM770x reduces system size, weight and cost compared to competition**



Low Voltage Current Sensing

- ▶ Low voltage DC bus option in cobots and light payload robots
 - Controller Box space saving
 - Wiring reduction
- ▶ Drives integrated into robot arms, joints
- ▶ Typically 48V – No isolation requirement
 - Shunt + High common mode amplifiers
- ▶ Isolated signal chain may still be used in LV systems for noise reduction



High speed

- 2.0 MHz
- 9 V/ μ s slew rate

High input common-mode voltage

- -2V to +70V Continuous Operation

Small packages for integration in robot joints

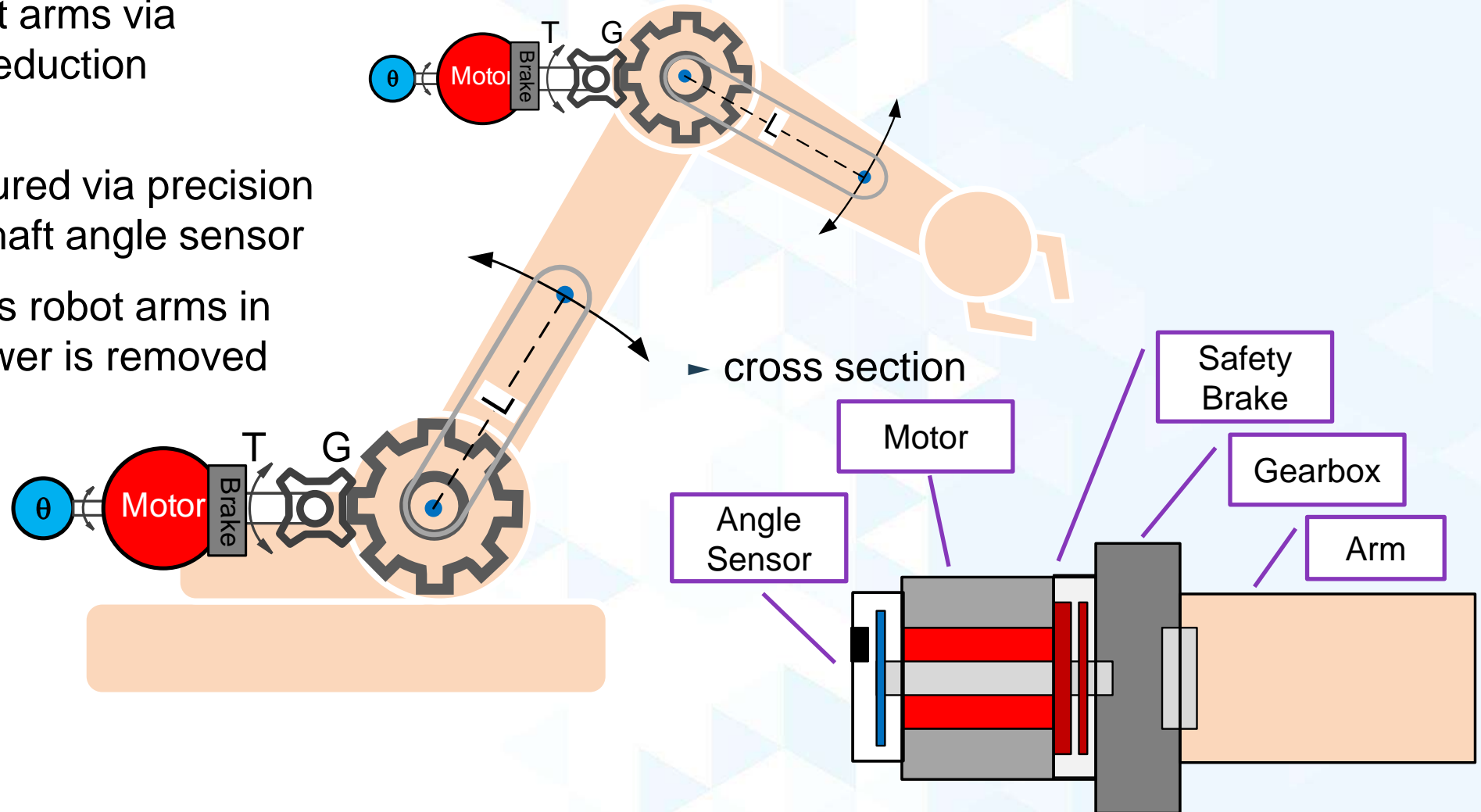
- 8-lead SOIC_N
- 8-lead MSOP

Low drift: 1.0 μ V/ $^{\circ}$ C max

Positioning

Robot Electromechanical System

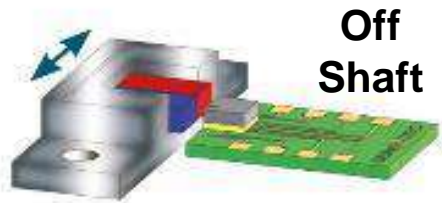
- ▶ Motors drive robot arms via precision speed reduction gearboxes
- ▶ Joint angle measured via precision motor mounted shaft angle sensor
- ▶ Safety brake holds robot arms in position when power is removed



xMR - Measurement arrangements



End of Shaft

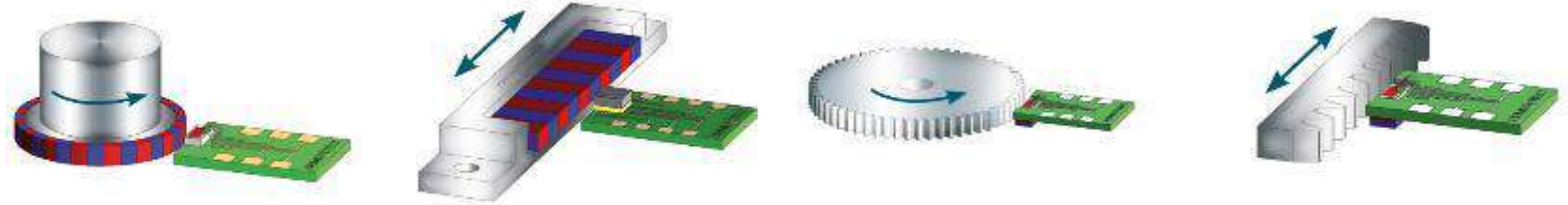


Off Shaft

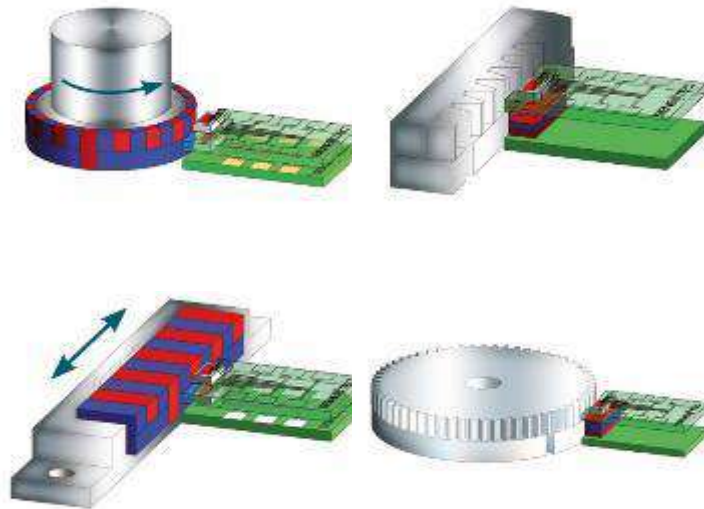
1

Absolute Position

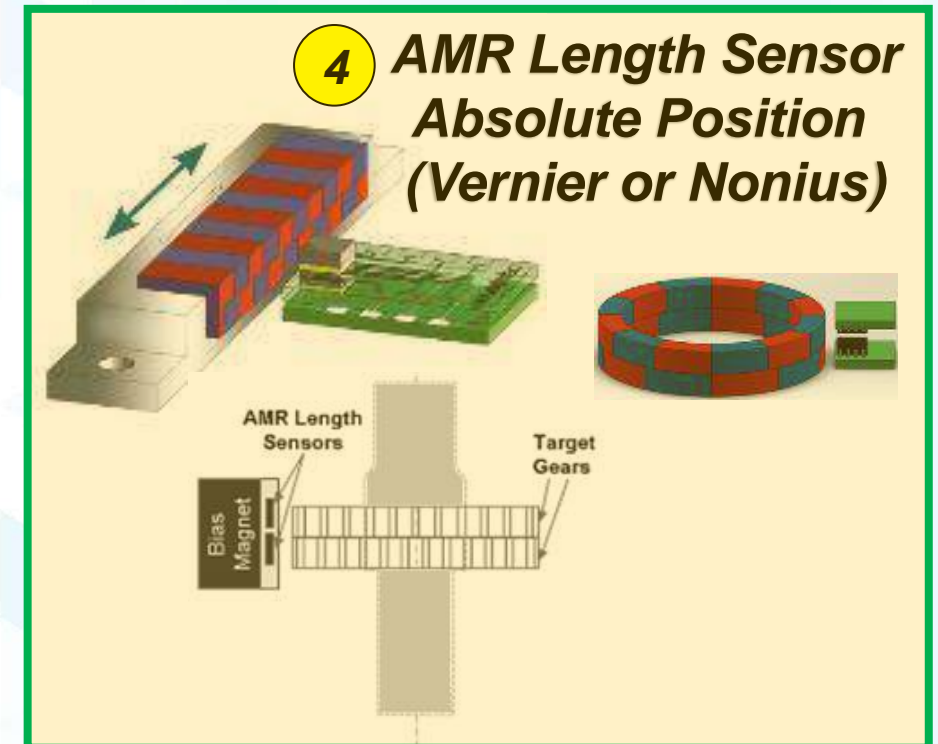
2 **Incremental**



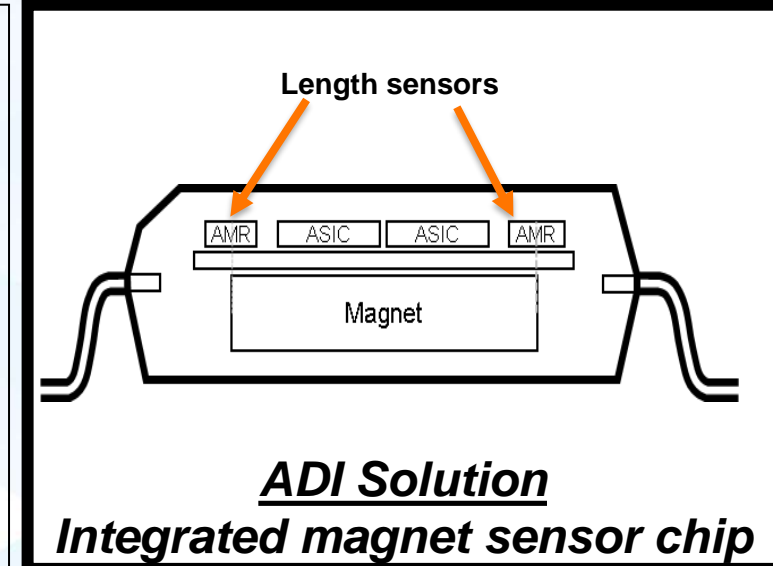
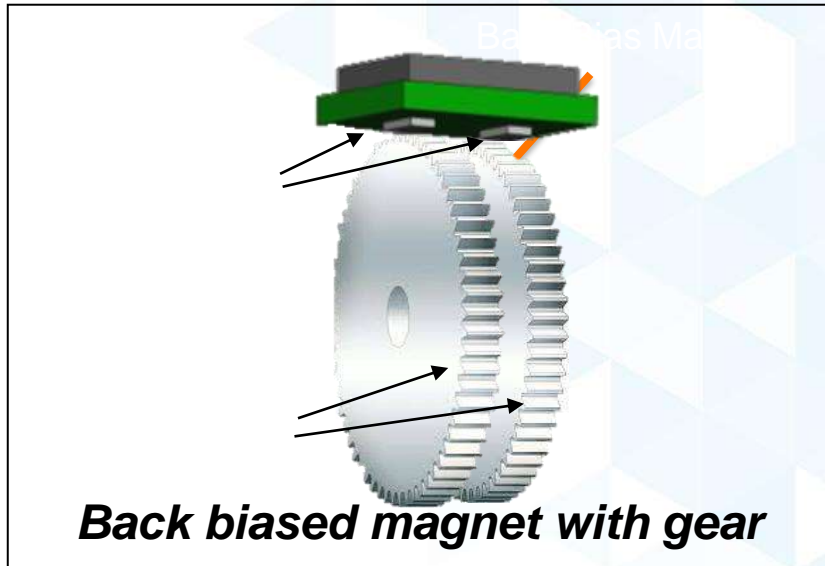
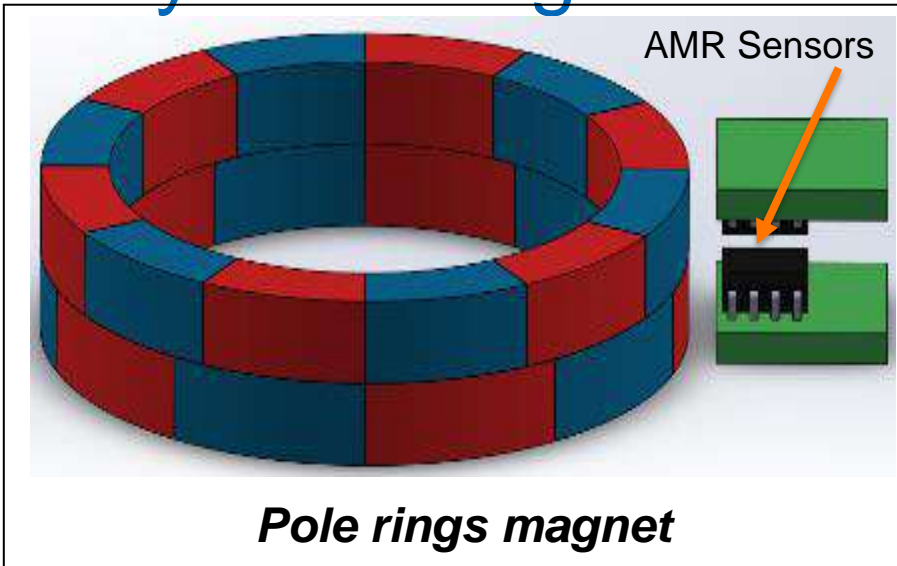
3 **Incremental + Index**



4 **AMR Length Sensor Absolute Position (Vernier or Nonius)**



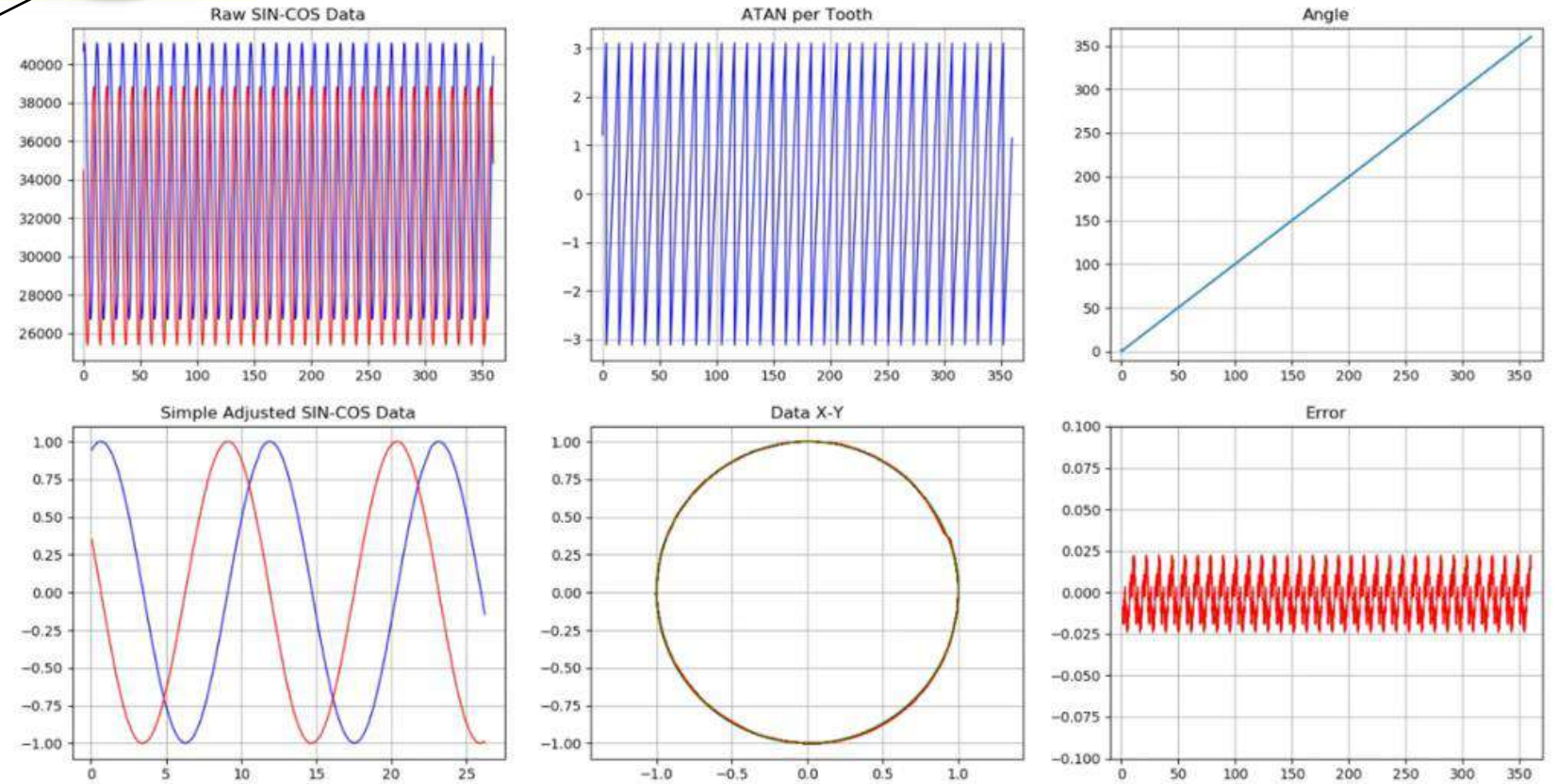
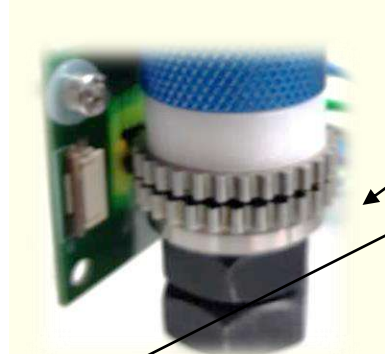
Off Shaft Sensing - Practical Implementations & Key Advantages



- Low sensitivity to external(stray) fields due to differential angle/field measurement
- Less sensitive to operation distance (sensor – magnetic scale) than angle sensor
- Higher precision with magnetic scales or gears than angle sensors
- The resolution of the sensor can be tuned by changing the number of teeth on the gear(s) fitted around a given shaft

Length Sensor Measurement Setup & Performance

Un-Calibrated



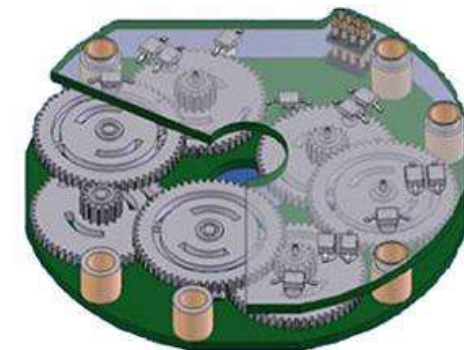
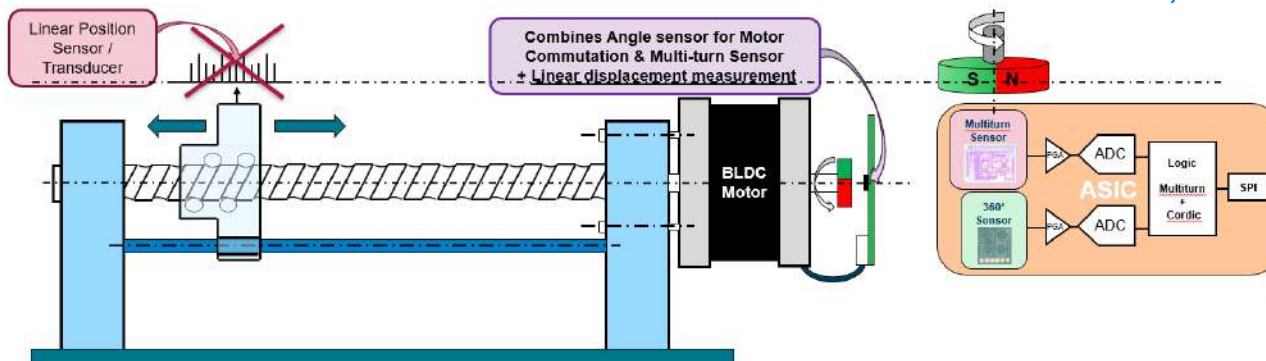
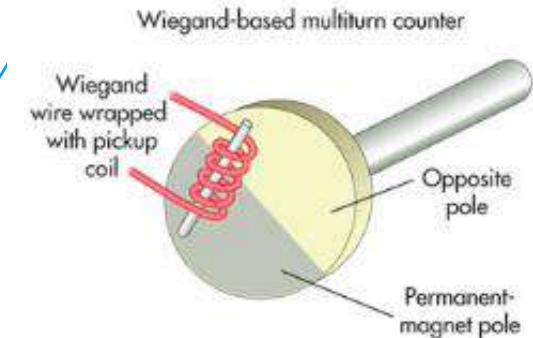
xMR- Position Sensing

ADI xMR Multiturn can be the disruptive technology to replace existing solutions

- +Zero power, battery-less
- +Small formfactor
- +Can be combined with angular position sensors
- +Cost effective


Multi-Turn:


- 40T today
- Machine Tool Applications
- Short Range Linear Motion or Tracks
- ~~Closed Loop multi-turn still several years out~~


























Power Conversion

Gate Driver Companions

 Automotive Qualified

 Automotive Capable

				Basic				Protecting			Programmable		
													
				ADuM4120	ADuM4121	ADuM4122	ADuM4221	ADuM4135	ADuM4136	ADuM4146*	ADuM4137	ADuM4138	ADuM4177*
1200V XM3 Module		400A, 425A, 450A	XM3 					C, E, T*	C		C	C	C, E*
1200V HM2 Module		325A	HM2 					C	C		C	C	C
1200V BM2 Module		120A, 300A	BM2 					C, E	C		C	C	C
1700V BM2 Module		300A	BM2 							V, E*			
1200V CM2 Module		20A, 50A	CM2 	C	C	C	H						
650V C3M MOSFET		15mΩ, 60mΩ	D, K, J 	C	C, E*	C	H, R	P	P	F	P	P	P, R*
900V C3M MOSFET		30mΩ, 65mΩ, 120mΩ, 280mΩ	D, K, J 	C	C	C	H	P	P	F	P	P	P
900V E3M MOSFET		65mΩ, 120mΩ, 280mΩ	D 	C	C	C	H	P	P	F	P	P	P
1000V C3M MOSFET		65mΩ, 120mΩ	J, K 	C	C	C	H	P	P	F	P	P	P
1200V C3M MOSFET		16mΩ, 21mΩ, 25mΩ, 32mΩ, 40mΩ, 49mΩ, 75mΩ, 80mΩ, 160mΩ, 280mΩ	D, J, K 	C	C	C	H	P	P	F	P	P	P
1700V C2M MOSFET		45mΩ, 80mΩ, 1000mΩ	D, P 							V			

* - In development

E - Evaluation Board Exists

T - Test Report Exists

R - Reference Design Exists

C - General companion recommendation

H - Preferred for Half Bridge Configurations

F - Preferred for High Frequency Applications

V - Preferred for High Voltage Applications

P - Preferred when paralleling switches

CGD12HBXMP

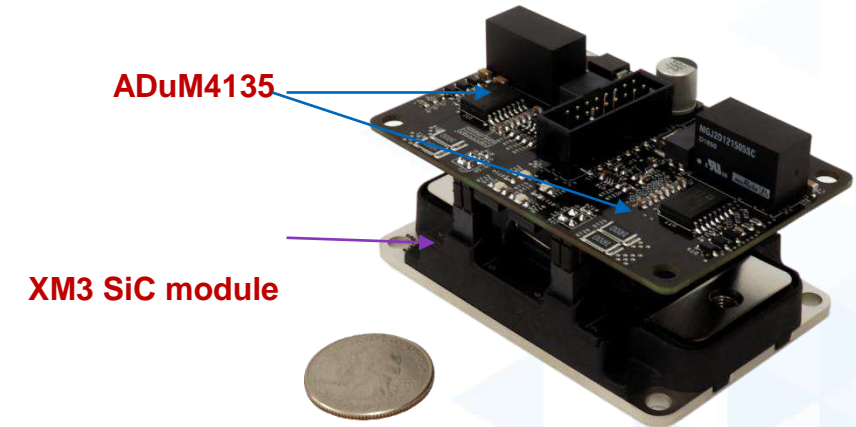
Evaluation Gate Driver Tool Optimized for the XM3 Module Platform

Specifications

- 2-Channel , Single Half Bridge
- Isolation Voltage of 1000 V
- 16-Pin Interface
- 10A Peak Gate Drive Current
- Direct low inductance mounting
- Dv/Dt capability of 100 kV/μs
- Maximum Switching Frequency of 80 kHz

Features:

- Optimized for Wolfspeed's XM3 SiC half bridge power module
- 2W isolated supplies support 80kHz switching frequency
- User configurable turn-on & turn-off gate resistors
- Overcurrent, shoot-through and reverse polarity protections
- Differential inputs for increased noise immunity
- Very low isolation capacitance (<5pF) and 100 kV/μs common mode transient immunity (CMTI)
- Fault and power LEDs



Wolfspeed Products	ADI Products
CAB450M12XM3 CAB450M12XM3 CAB450M12XM3 1200 V, Silicon Carbide Conduction-Loss Optimized XM3 Half-Bridge Modules	ADUM4135BRWZ 4A Gate Driver Magnetic Coupling 5000Vrms 1 Channel
	LT3015 50mA, 3V to 80V Low Dropout Micropower Linear Regulator

Application Note 

Schematic 

BOM 

Gerbers 

Force Torque Sensing

Force Sensing in Robotics

- ▶ Collaborative robot applications require force limiting by law
 - Contact with the robot should not cause pain

- ▶ Application level motivators
 - Precision assembly
 - Quality improvements in polishing & grinding
 - Tool damage prevention
 - Increase productivity

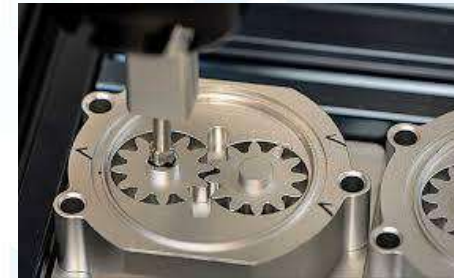
- ▶ Human safety, 65N limit
- ▶ **Precision applications, 0.1N resolution**



ISO/TS 15066:2016(E)

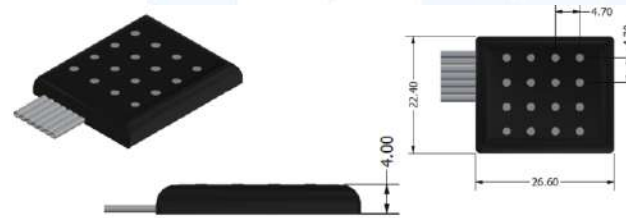
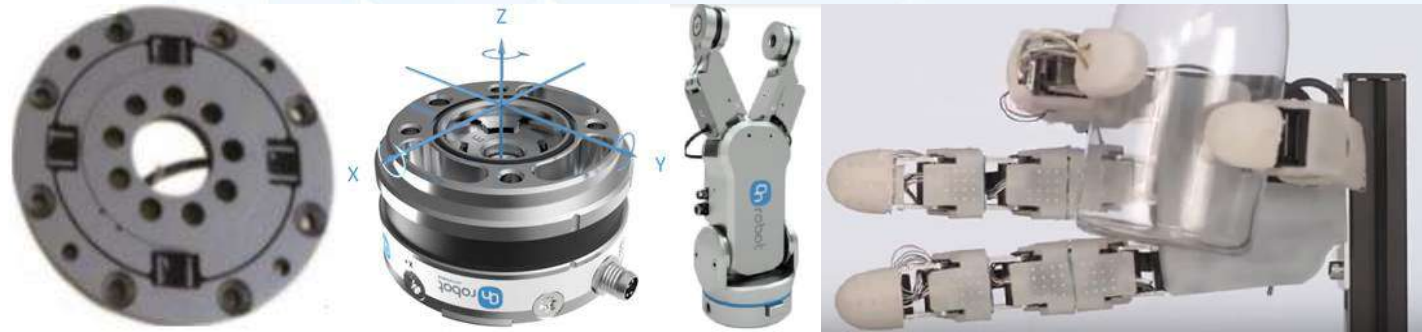
Table A.2 — Biomechanical limits

Body region	Specific body area	Quasi-static contact		Transient contact	
		Maximum permissible pressure ^a P_s N/cm ²	Maximum permissible force ^b F_T N	Maximum permissible pressure multiplier ^c P_T	Maximum permissible force multiplier ^c F_T
Skull and forehead ^d	1 Middle of forehead	130	130	not applicable	not applicable
	2 Temple	110		not applicable	
Face ^d	3 Masticatory muscle	110	65	not applicable	not applicable
	4 Neck muscle	140	150	2	2
Neck	5 Seventh neck muscle	210		2	
	Back and shoulders	6 Shoulder joint	160	210	2
7 Fifth lumbar vertebra		210	2		2
Chest	8 Sternum	120	140	2	2
	9 Pectoral muscle	170		2	
Abdomen	10 Abdominal muscle	140	110	2	2
	11 Pelvic bone	210		180	2
Upper arms and elbow joints	12 Deltoid muscle	190	150	2	2
	13 Humerus	220		2	
Lower arms and wrist joints	14 Radial bone	190	160	2	2
	15 Forearm muscle	180		2	
	16 Arm nerve	180		2	

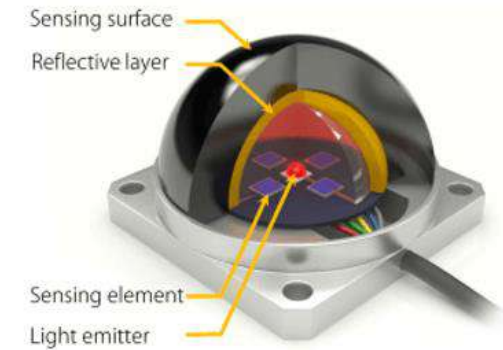


Force, Torque, Tactile Sensors

- ▶ Sensors can be placed in
 - Joints
 - Intermediate end effectors (wrist)
 - End effectors (grippers/tools)
- ▶ Multiple sensor types
 - Tactile
 - Mems
 - Resistive
 - Force & Torque
 - Current
 - Capacitive
 - Piezo
 - Optical
 - Strain gauge

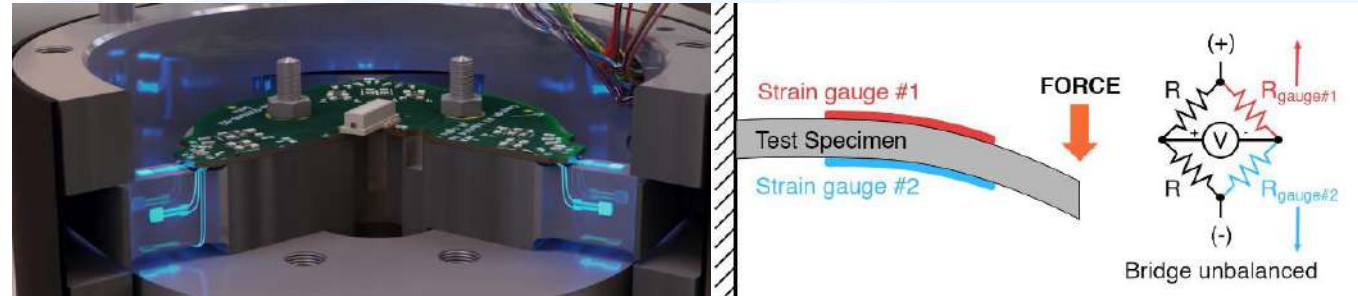


3D Force Sensor (OMD)



Force Sensing Solutions

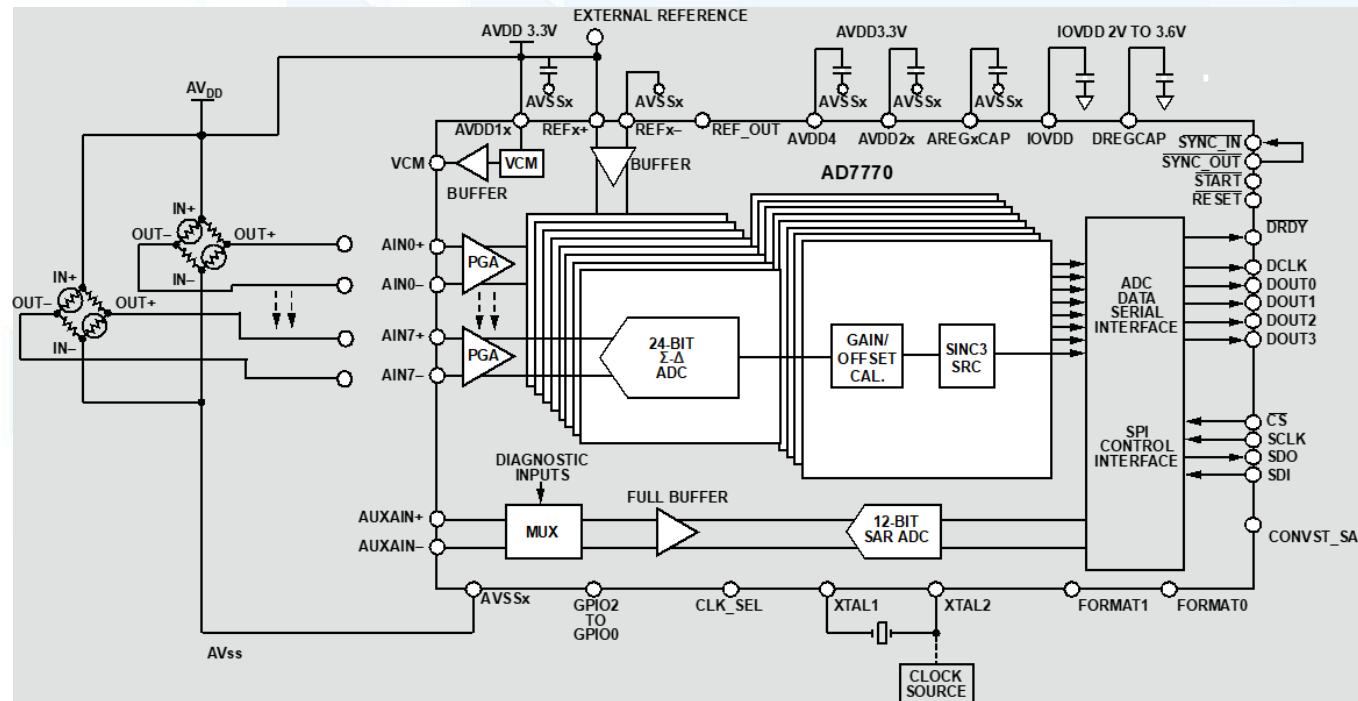
- ▶ Typical wrist force and torque sensor
 - 3 stress beams
 - 4 strain gauges per beam
 - Typically 4mV/V to 80mV/V sensors
 - 6x simultaneous sampling half bridge channels
 - Sub 10kHz sampling



- ▶ Ideally suited to $\Sigma\Delta$ signal chain

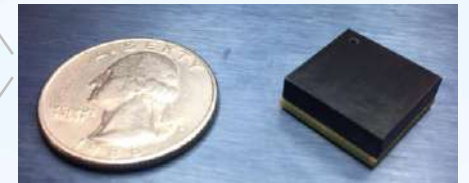
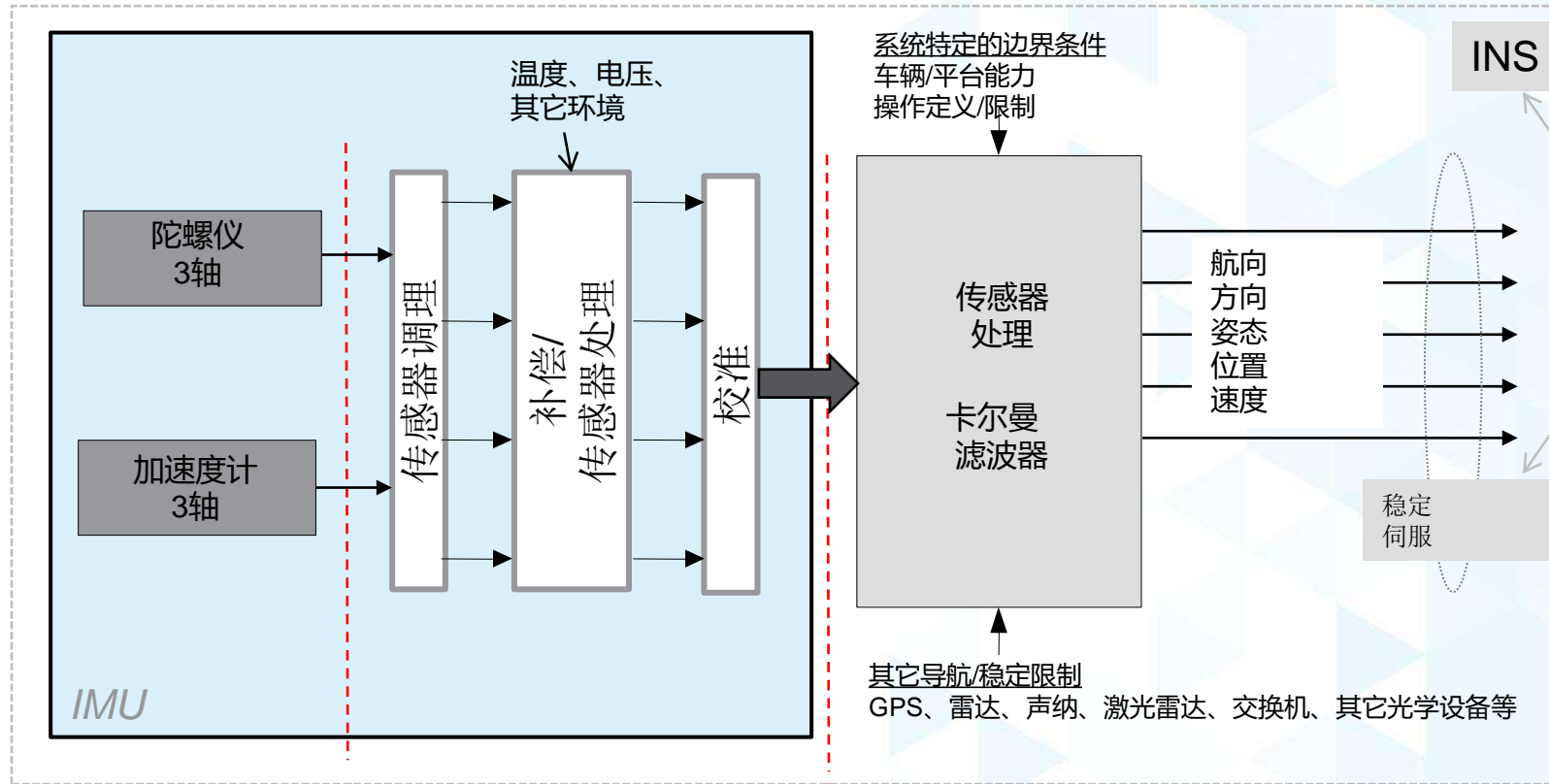
▶ AD777x

- 8x sim sampling
- Integrated PGAs, 1x, 2x, 4x, 8x
- Configurable filters



Stability and Navigation

What IMU Looks Like?



ADIS16500/ADIS16505/
ADIS16507 IMU
2019.11量产

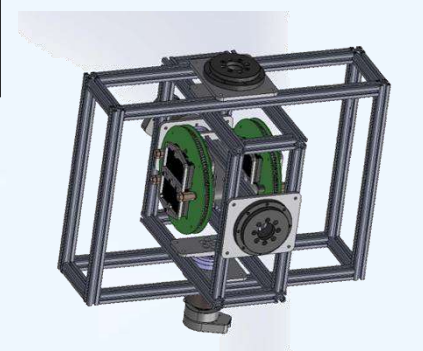
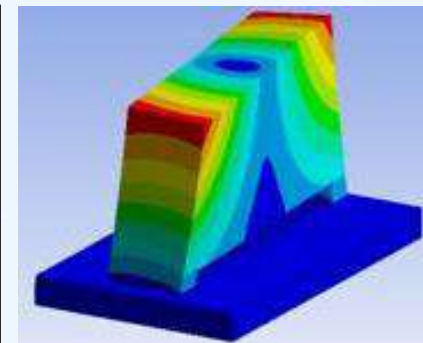
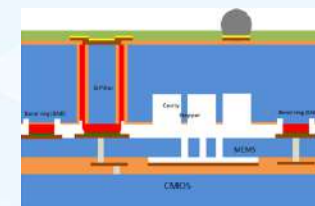
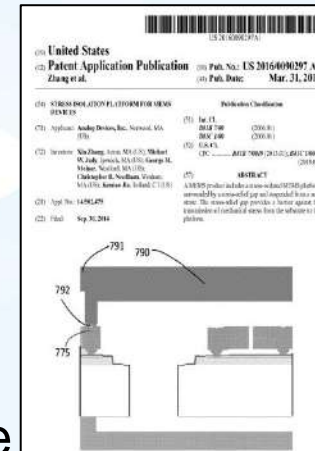
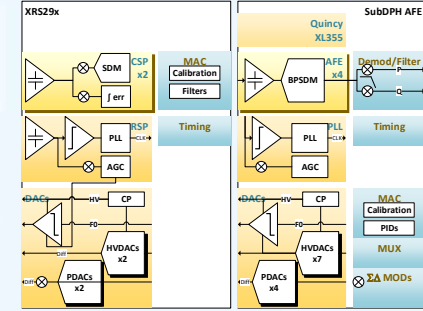
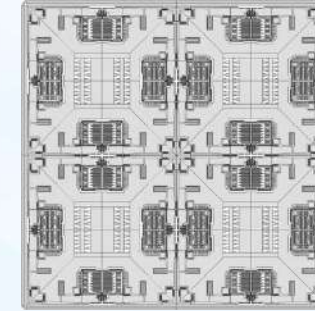


“传感器”与“导航引擎”的分际，代表：

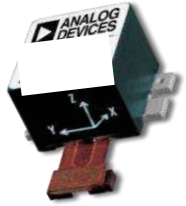
- 开发周期衡量单位： 人-年
- 性能改进衡量单位： 数量级
- 测试设备衡量单位： 10万美元数
- 单台设备生产测试时间衡量单位： 小时
- 传感器处理衡量单位： 技术先进程度

High-Performance MEMS IMUs – Key Advancements

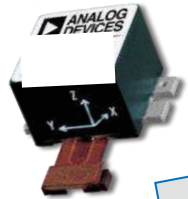
- Specific focus on “all condition” stability in the gyroscopes
- Thicker MEMS process for core gyroscopes
4 μm (ADIS16135) -> 16 μm (ADIS16545)
- Gyroscope architecture
Dual-mass structure (ADIS16135)
-> Quad-mass structure (ADIS16136/48x)
-> Synchronous quad mass (ADIS1654x, ADIS1655X)
- Ceramic packaging for the core MEMS and supporting ASIC.
- IMU package that provides precision features, which can mate to system features -> 0.25° misalignment error (package to sensors)
- Significant functional integration advances in the ASIC, which manage key control (resonant drive) and signal processing (modulation, ADC, filtering...) requirements, for operating the new gyroscope architectures.
- Calibration equipment, fixturing and techniques



Performance-Driven MEMS IMUs/Gyros – Brief History



ADIS1635x
ADI First to Market with Industrial Targeted IMUs
2007



ADIS1636X
2x Performance Increase; Interface/Footprint Compatible
2009



ADIS1644x
50% Size Reduction; Interface Compatible; 10 DoF
2012



ADIS1646x
% Size Reduction ; Noise, Stability, and Cost Improvements
2016



ADIS1647x
70% Size Reduction; Smallest/Best-in-Class IMU
2017



ADIS1650x
40% Size Reduction; High Performance Component-Level IMU
2019



ADIS16135
4x Performance Increase
Tactical Grade Gyro
2010



ADIS16136/7, ADIS1648x
2x Performance Increase
Tactical Grade Gyro/IMU Family
2011



ADIS1649x
2-4x Performance Increase
Tactical Grade IMU Family
2016



ADIS1654x
6-10x Performance Increase
Tactical Grade IMU Family
2020

Compact Strategy

High-Performance Strategy

Understanding the Influence of Critical Specifications to Minimize Threats to Performance, at the Application Level

- ▶ Stability/repeatability (long-term drift; scale and bias)
- ▶ Noise (angle random walk)
- ▶ Vibration rectification
- ▶ Hysteresis

→ **Inherent to sensor performance (limited opportunity to calibrate)**

- ▶ Nonlinearity
- ▶ *g*-effect error (linear acceleration)

→ **Theoretically capable of being corrected through test and calibration, to limits of resolution and stability**

- ▶ Offset/bias
- ▶ Scale/gain error
- ▶ Tempcos
- ▶ Cross-axis sensitivity

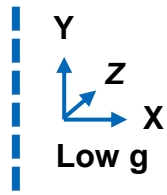
→ **Correctable through test and calibration, to the limits of resolution and stability**

ADI Designed-In Performance at MEMS Sensor Level

ADI System-Level Calibration Focus

- ▶ Architected to reject performance limiting errors
- ▶ Sensor conditioning and filtering optimized for reliable precision at application level
- ▶ Subsystem test and calibration ensure out-of-box best precision and reliability
- ▶ Packaging minimizes stress; avoids long-term drift (that is, from overmold/moisture)
- ▶ Fully, conservatively specified

ADIS16505 ADIS16507



Yaw/Roll/Pitch
xyz

Compact Performance
SMT IMU



✓ Compact Performance

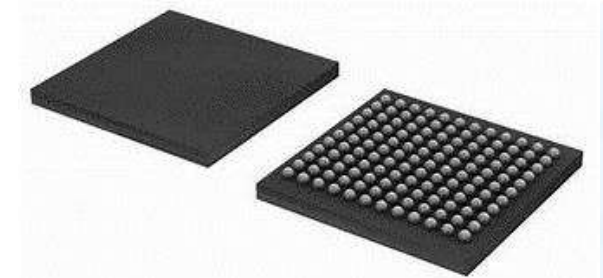
- In-run bias stability of $2.5^\circ/\text{hr}$ and $3.6\mu\text{g}$ (industry leading)
- Lowest angular random walk ($0.15^\circ/\sqrt{\text{hr}}$) and velocity random walk ($0.012 \text{ m/sec}/\sqrt{\text{hr}}$)
- Gyro range: $500^\circ/\text{s}$, Accelerometer: 8g
- Achieved via extended factory calibration

✓ Industry-Leading Compact Footprint

- Much smaller than Fiber Optic Gyros (FOG) used in prototype vehicles today

✓ Robust performance in automotive testing environments

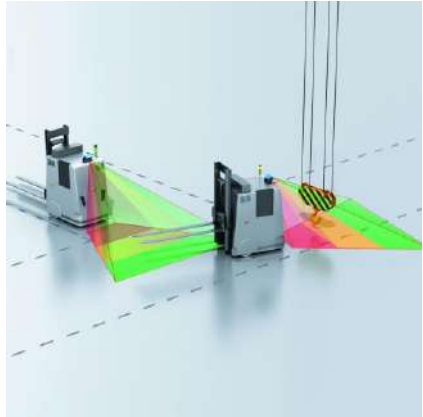
- High level of immunity to vibration ($0.01^\circ/\text{s/g}$) and shock (2,000g) over -40 to 105C temperature range
- ADI's iSensor portfolio is already on the road in Autonomous Driving prototype systems



6-DoF IMU available
in planar BGA
(in development, not to scale)

Environmental Awareness Sensing

Application Examples of Environmental Sensing



Obstacle Avoidance

- AGV moves around an obstacle or another AGV
- Robot avoids a companion workpiece

Safety

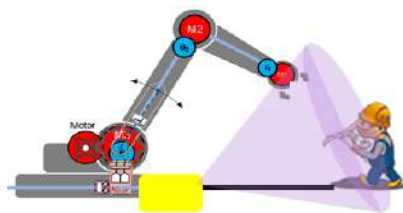
- AGV slows or stops near humans
- Robot slows or stops with human in vicinity

SLAM

- AGV uses sensors to map dynamic environment

Object ID

- Production system identifies different items by dimensions
- Robot picks randomly sorted objects



Raw Material – to – Consumer Automation

Factory



Warehouse



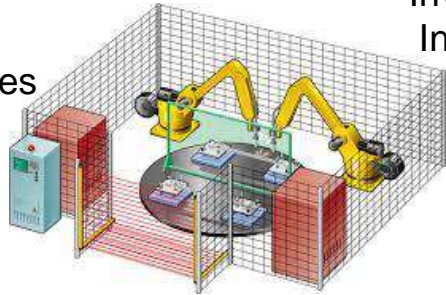
Delivery



Robot Perception
Higher Diversity of Use Cases



Inventory Management
Increased Automation



Safety / Proximity Sensing
Faster speed. Higher throughput



Autonomously Moving Robots
360° Perception. Higher Speed
Object identification. Obstacle avoidance. Path planning

Sorting
Speed. Object overlap



Dimensioning
Market efficiency. Cost optimization



Object identification / manipulation
Rapidly complete delicate tasks



Palletization / Measurement
Size and throughput

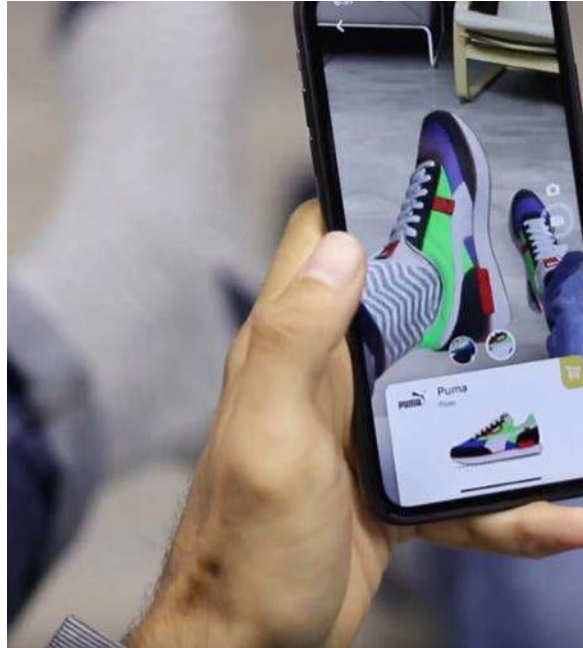


Pallet dimensioning
Transport efficiency

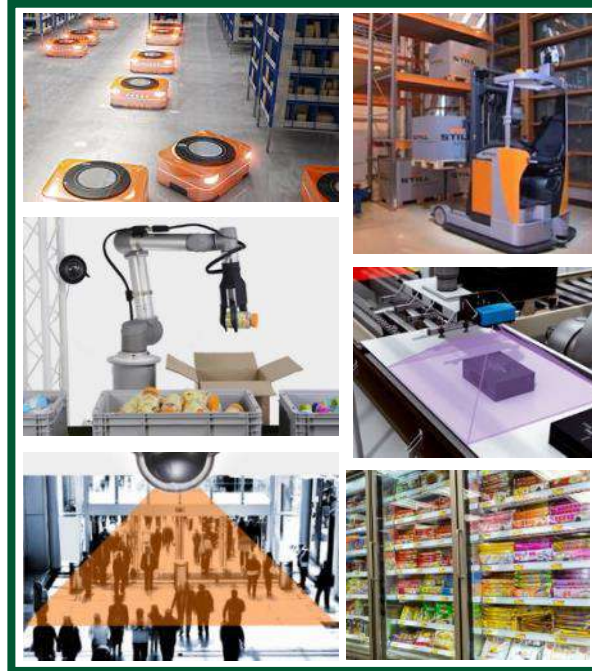
Value proposition for ToF

	Time-of-Flight (high resolution)	2D Vision, Stereo Camera, Structured Light
Box Dimensioning	Accuracy & computational efficiency	Cannot reach required accuracy for small boxes. Stereo is too big for portable applications
Object manipulation	Accuracy & computational efficiency	Too much image processing for efficient control loops
Safety curtains	Higher coverage. Safer	Can make mistakes
AMR/AGV	Higher angular resolution. True depth	Lower resolution. Limited object identification/ML
Inventory management	Range. Better fidelity. Works in the dark	Cheaper
Object sorting	True depth. Overlapping objects	Mistake prone. Computation time limits speed.

Benefits of ADIs ToF Solutions for Multi-Markets



Consumer



Industrial



Automotive

Key benefits include...



Highest resolution
















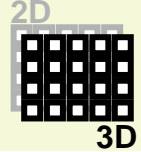










Highest dynamic range



Millimeter depth precision

ADI ToF Key Enablers

ADI next-gen system feature	Application enabler	Component facilitator
 High depth resolution	<ul style="list-style-type: none"> High modulation frequency (320 MHz) High raw frame rate (500 FPS) Innovative modulation schemes 	 
 High dynamic range	<ul style="list-style-type: none"> Low readout noise (3e-) High raw frame rate 	  
 Ease of use	<ul style="list-style-type: none"> Innovative modulation schemes (ease of calibration) Temperature compensation & eye-safety monitoring 	  
 Outdoor operation	<ul style="list-style-type: none"> High sensitivity at 940nm (27% QE) Efficient illumination 	  
 Flexible depth & 2D	<ul style="list-style-type: none"> Small pixel (3.5 x 3.5 μm^2) Depth & 2D IR binned and ROI modes up to 1 mega-pixel 	 
 Multi-system operation	<ul style="list-style-type: none"> In-pixel cancellation of interfering light Camera synchronization 	 

 = laser driver
 = image sensor
 = algorithms

ADTF3175 – Crosby ToF Module

► Specs

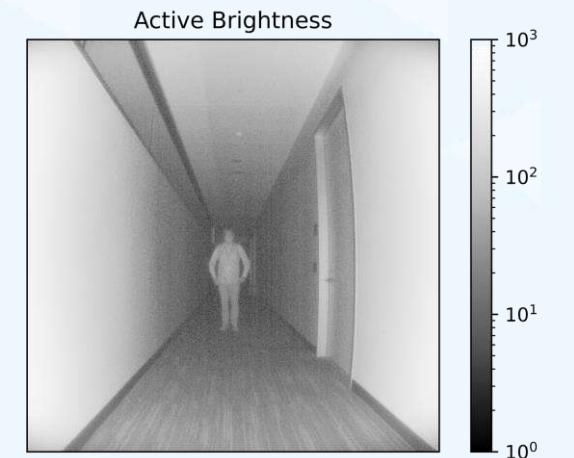
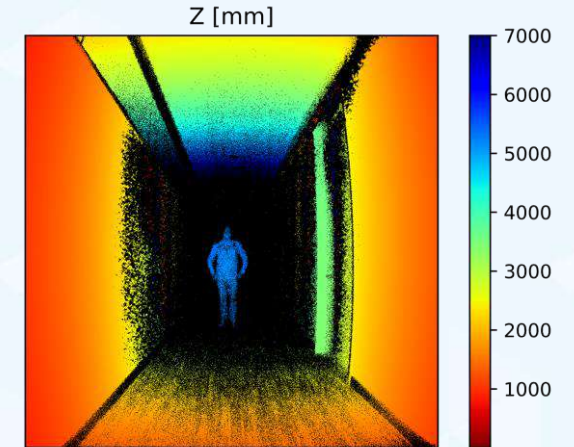
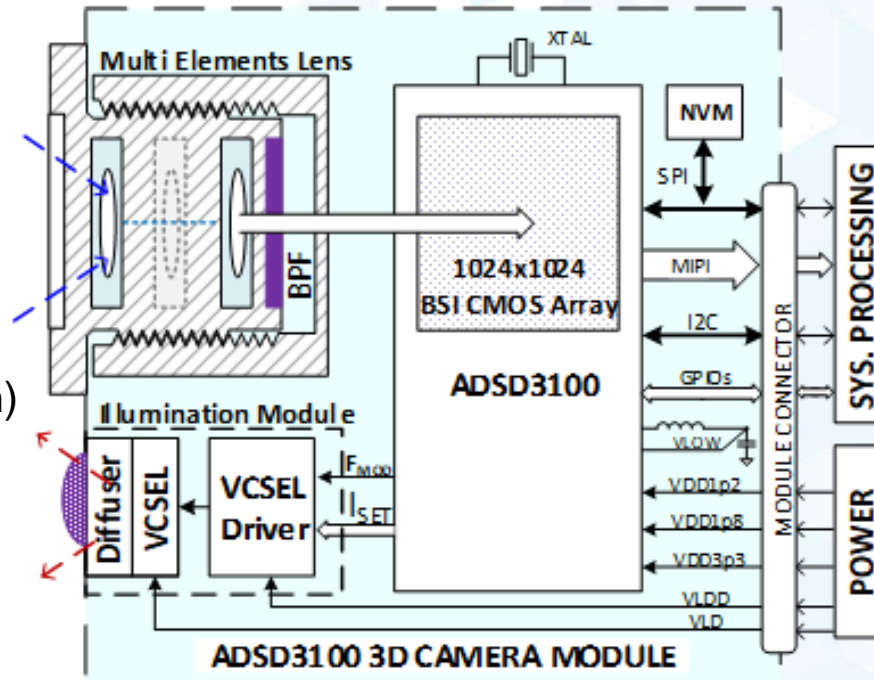
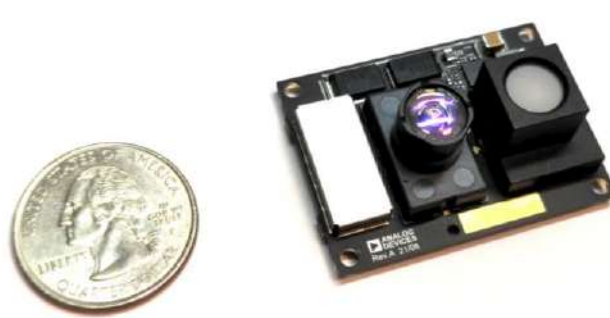
- Field of view (FOV): 75° x 75° @ 1024 x 1024
- 43mm x 31mm x 15.1mm

► Modes of operation

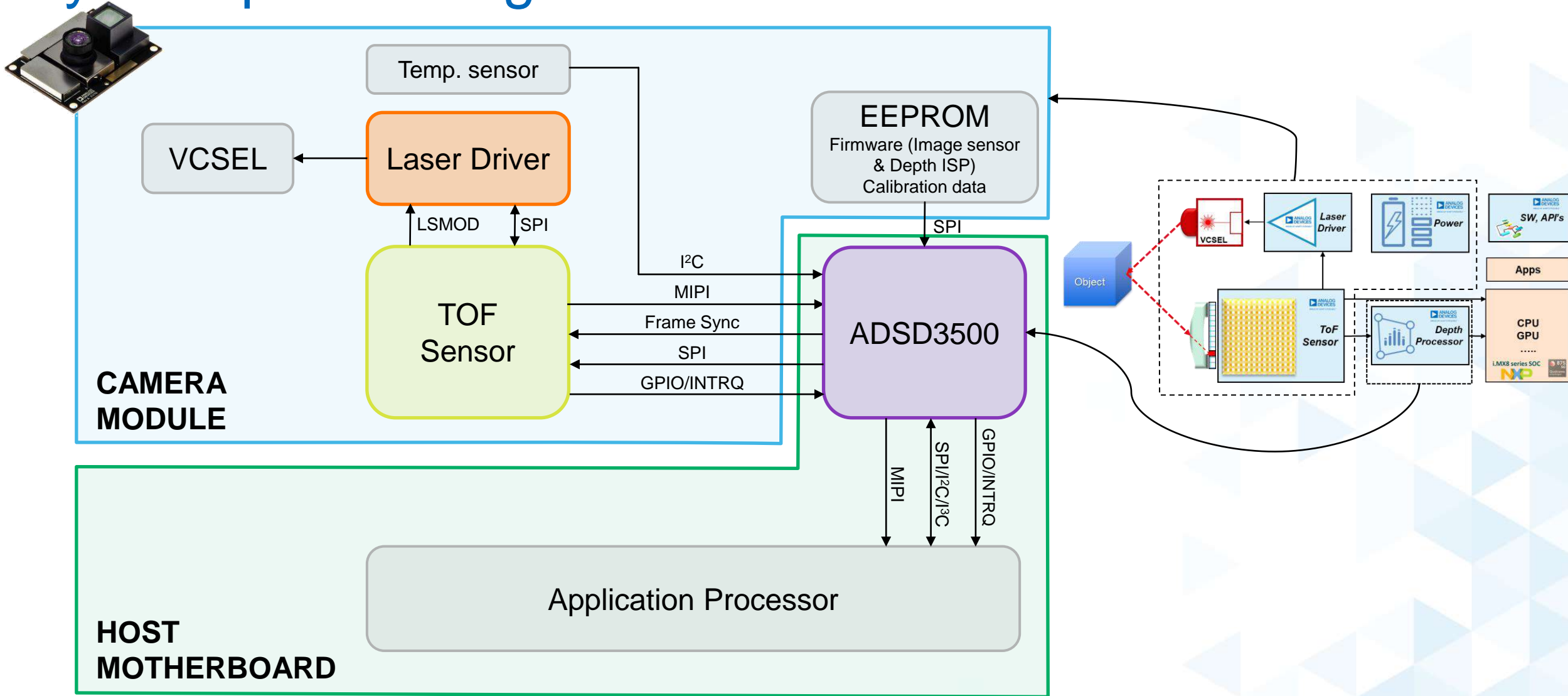
- QMP (512 x 512 binned)
 - short range (~0.1m - 1m)
 - long range (~ 0.4 - 5m)
- 1MP (1024 x 1024)
 - short range (~0.1m - 1m)
 - long range (~ 0.4 - 4m)

► Operating conditions

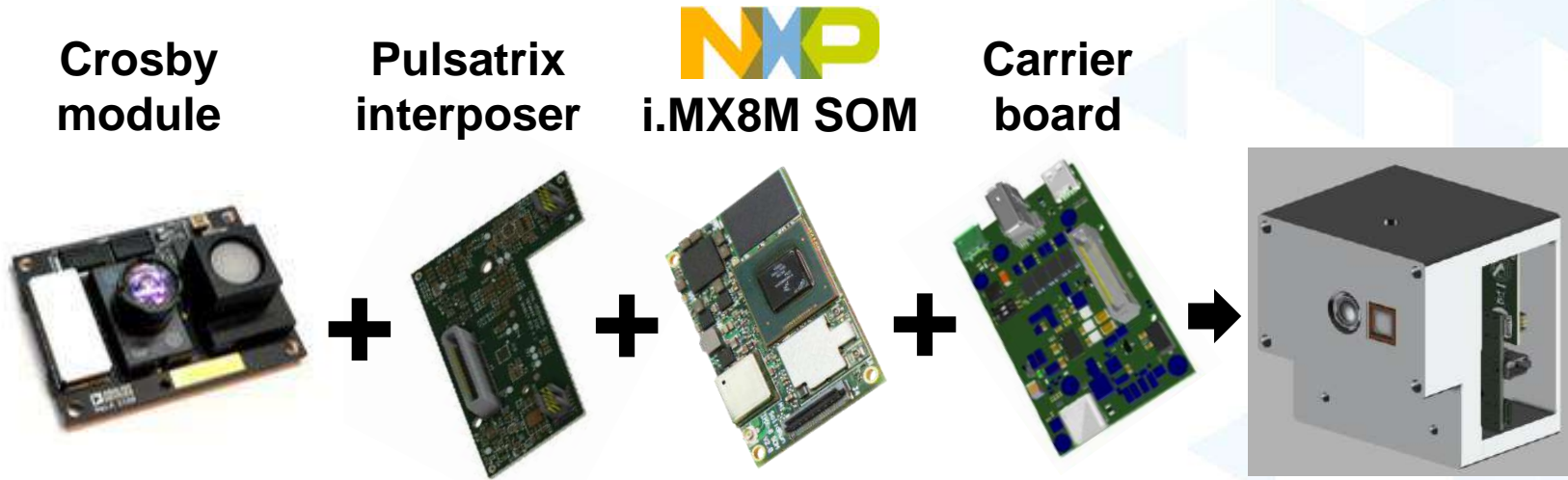
- Reflectance range: 15% - 90% (Lambertian)
- Ambient temperature -20°C to 65°C
- Ambient light < 5,000 lux
(~1 W/m² @ 940 nm +/- 25nm)



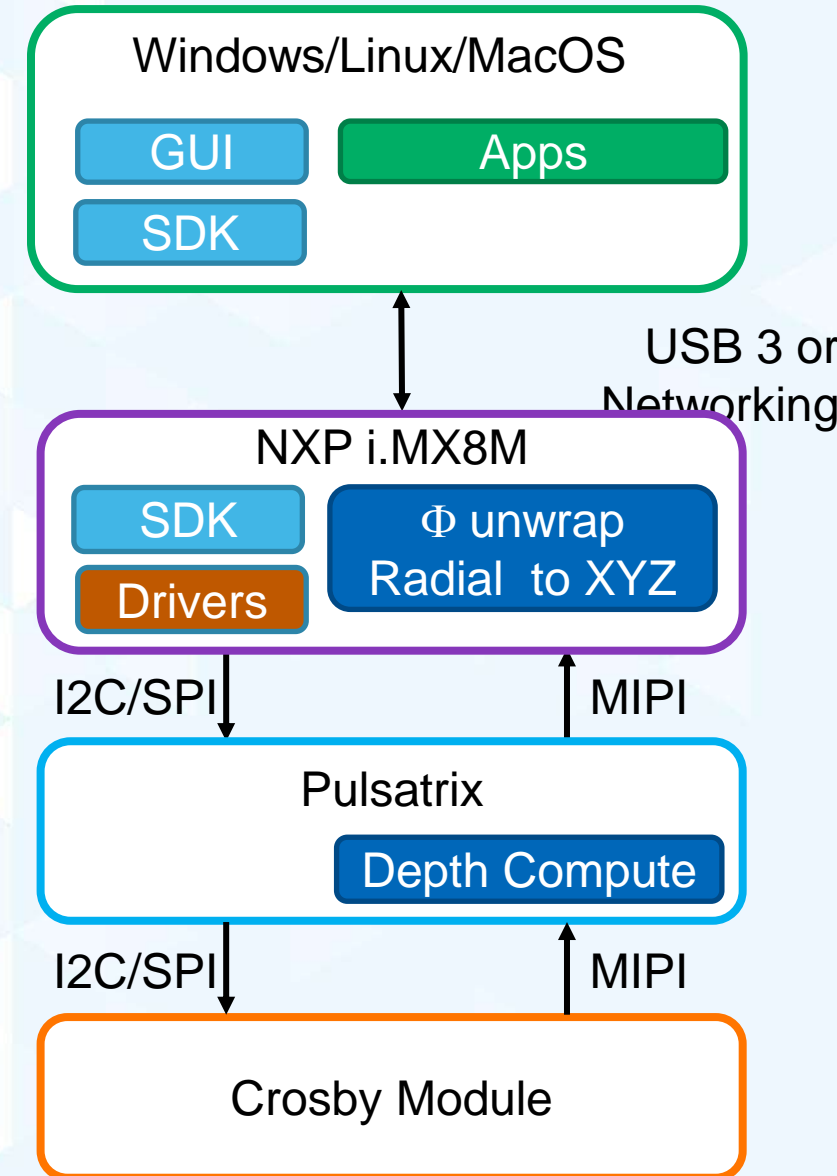
System partitioning – ISP on motherboard



1MP ToF Eval/Dev Platform: Condor



- ▶ Crosby 1MP ToF module
- ▶ Pulsatrix interposer: HW depth engine, module power support
- ▶ Reference Linux MIPI drivers
- ▶ SDK for both embedded and PC
- ▶ Enables customer product development
 - Crosby: ADI production module (RTS Aug '22)
 - Pulsatrix, Power, Host AP: Reference design collateral for 3rd party customization
- ▶ Shipping now in limited quantity (w/o Pulsatrix)
- ▶ Wider availability w/ Pulsatrix: June 2022



ROS Hardware/Software

ROS: A widely accepted robot system middleware that enables inter-operability between robotic subsystem components

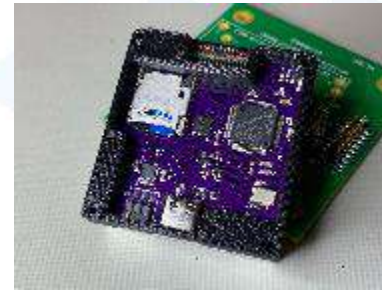
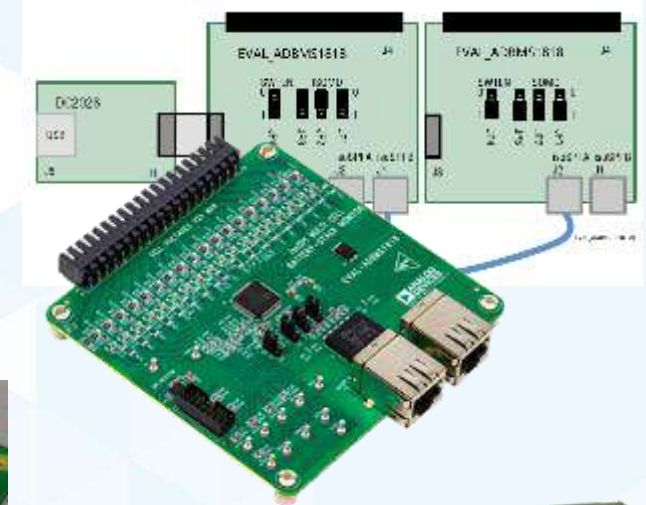
ADI Goal: Provide ROS drivers, standard HW interfaces (USB/Ethernet) and Gazebo plugins to relevant components and subsystems

▶ *In progress*

- IMU iSensor Buffer Board
- 3D ToF (Swan)
- ADI Github – Dec 2021
- Official ROS release – Jan 2022

▶ *Other Options*

- BMS
 - ADBMS1818 18-Cell Battery Stack Monitor
- Motor control
 - Maxim Trinamic Motor Control for LV Brushless motors

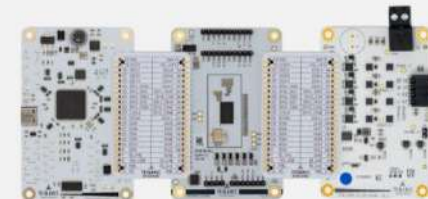


TRINAMIC BLOG

We transform digital information into physical motion.

[NEWSLETTER](#) | [BLOG ETHICS](#) | [LEGAL/IMPRESSUM](#) | [MAIN WEBSITE](#)

CONTROLLING BRUSHLESS MOTORS WITH ROS



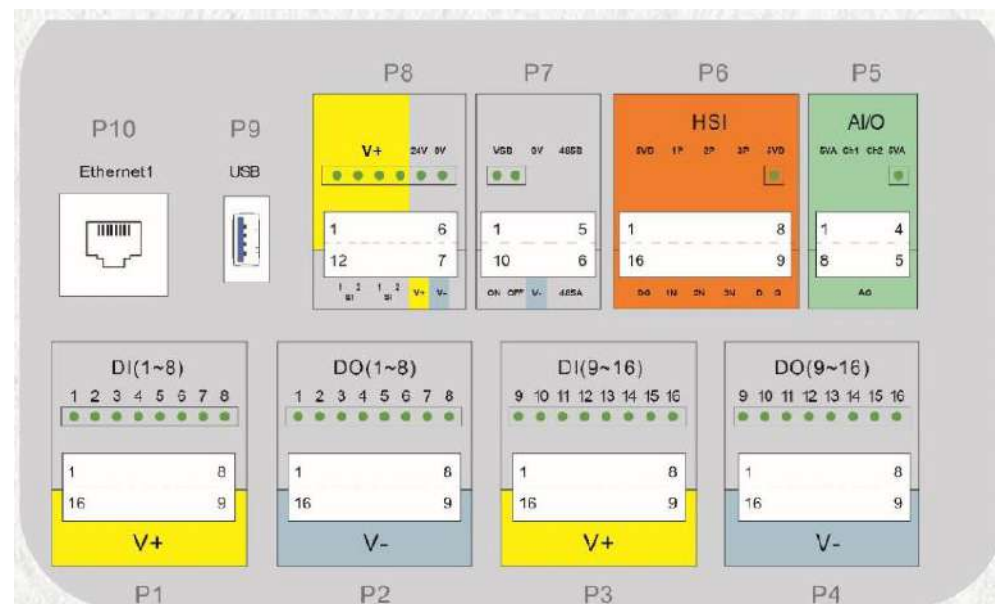
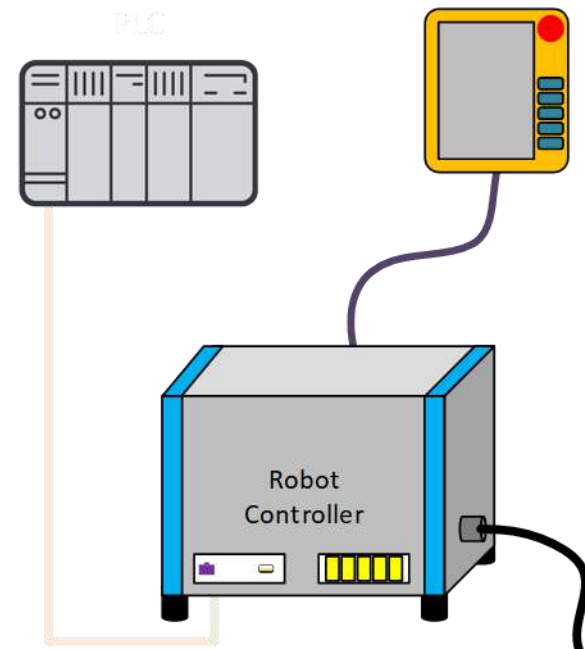
GAZEBO

Robot simulation made easy.

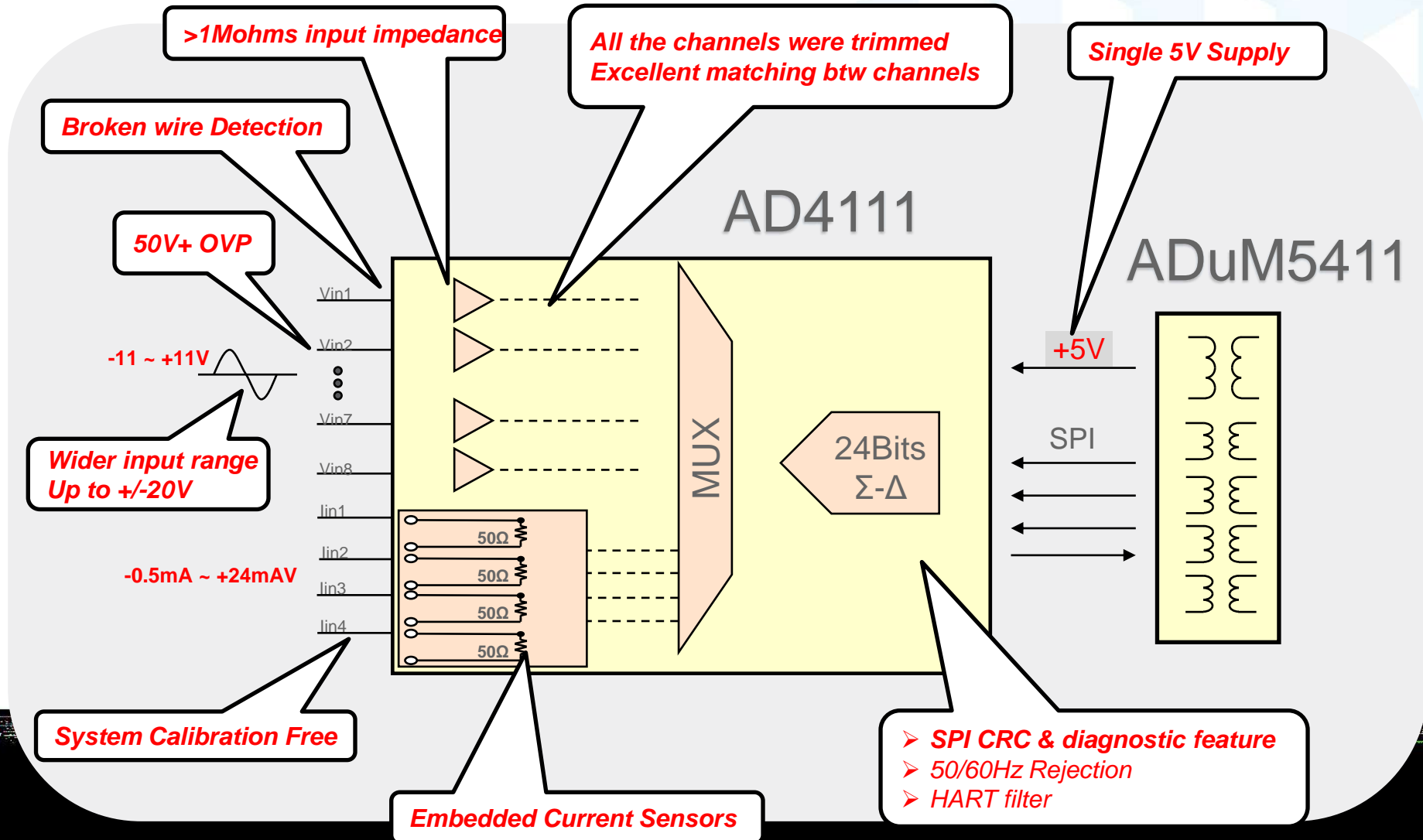
Interface and Networking

Signal Option Card

最大负载	7 kg	关节角度限制	Max. ± 220° (依据配置)	
臂展	最大臂展 850 mm	重量	29 kg	
	最大臂展 1000 mm (5 kg 负载时)			
视觉	集成2D视觉以及2个高功率LED光源	防护等级	IP 54 (本体和控制柜)	
		电源电压	200–253 VAC, 47–63 Hz	
灵敏度	集成力矩传感器在每个关节	平均功耗	250 W	
机器学习及AI	集成神经处理单元 (NPU)	最大电流	8 A @ 230 VAC	
重复定位精度	0.05 mm	环境条件	温度: 5–40 °C	
TCP常规速度	1.2 m/s		湿度: 80 % RH (非冷凝)	
TCP最大速度	2.0 m/s	用户界面	基于浏览器的图形化机器人用户界面 集成 Python-API, 包括图形化用户界面编辑器 集成三个可自定义功能按钮的腕部工具接口	
最大关节速度	关节 1: 141°/s			
	关节 2: 141°/s			
	关节 3: 169°/s			
	关节 4: 180°/s			
	关节 5: 180°/s			
关节 6: 180°/s				
安全功能符合 EN ISO 10218-1 EN ISO 13849-1 PL d, Cat. 3	ES: 紧急停止包括 STO, SBC			
	ED: 使能装置			
	OM: 操作模式			
	SLDS: 安全限制的驱动速度			
	SLDP: 安全限制的驱动位置			
	SLDT: 安全限制的驱动力矩			
	SLRP: 安全限制的机器人功率			
	SLCP: 安全限制的笛卡尔坐标系位置			
	SLCO: 安全限制的笛卡尔坐标系方向			
	SLCS: 安全限制的笛卡尔坐标系速度			
	SLCF: 安全限制的笛卡尔坐标系力			
	PS: 保护性停止			
	可定制的安全多个I/O接口			
	通讯协议 机器人控制	支持16 DI, 16 DO, 4 AI, 4 AO, 支持Ethernet通讯		
		支持8 SafeDI, 4 SafeDO (safe Ins- and Outs)		
基于OPC UA的网关通讯 (SPS, Cloud等)				
通讯协议 末端执行器	最大电源供给: 2 A & 24 V			
	M8接口(8 Pin): 2 DI, 1 DO, 2 AI/ModbusRTU, 1DI/O/IOLink			
	弹性探针插头 (无需硬线链接): 2 DI, 3 DO, 2 AI/ Modbus RTU, 1DI/O/IO Link, 支持Modbus and IO Link			
	M8接口(6 Pin): 总线接口、支持以太网通信			
手控器	紧急停止			
	使能按钮			
	操作模式切换			
	开机/关机 按钮			

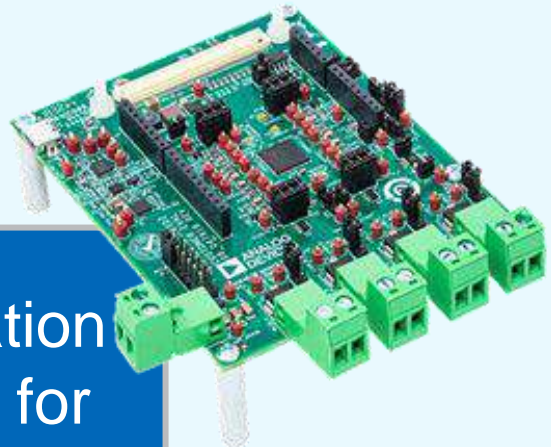
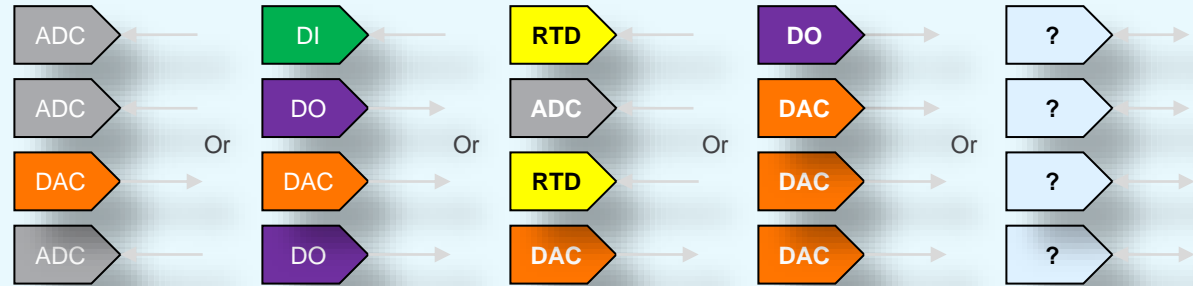
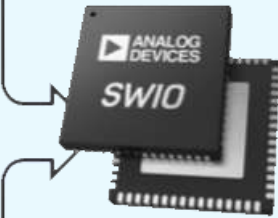
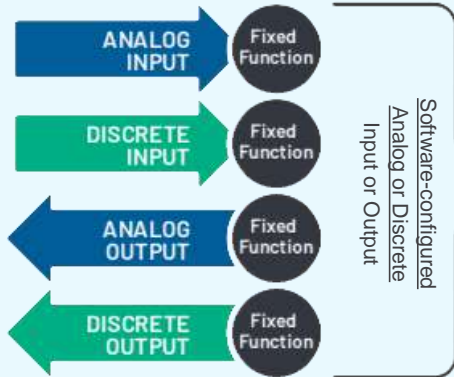


AD4111/2 Simplify AI Design

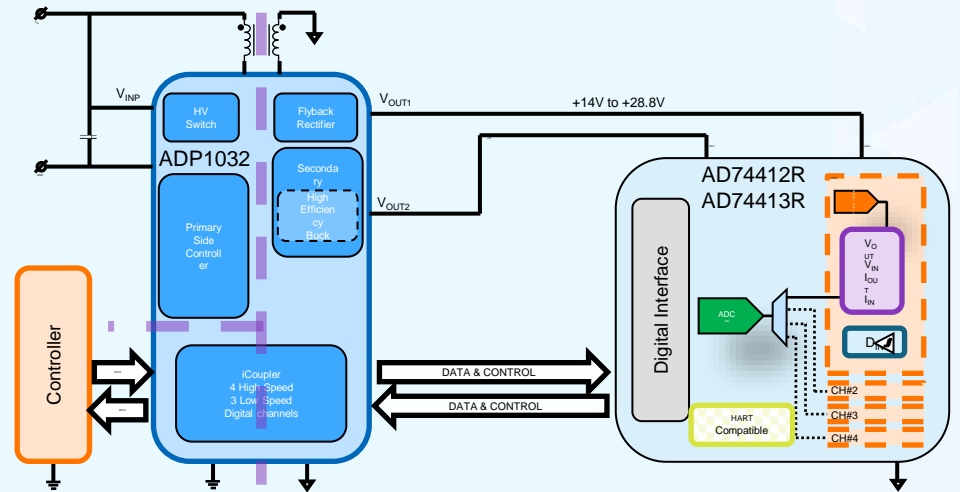


- ▶ **AD4111**
 - 4-dif/8-se channels
 - 6.25kHz CH switching
 - 1Mohms impedance
 - w/ OWD feature
 - 4-se Current channel
- ▶ **AD4112**
 - 4-dif/8-se channels
 - 6.25kHz CH switching
 - 1Mohms impedance
 - w/o OWD feature
 - 4-se Current channel

Software Configurable I/O - SWIO



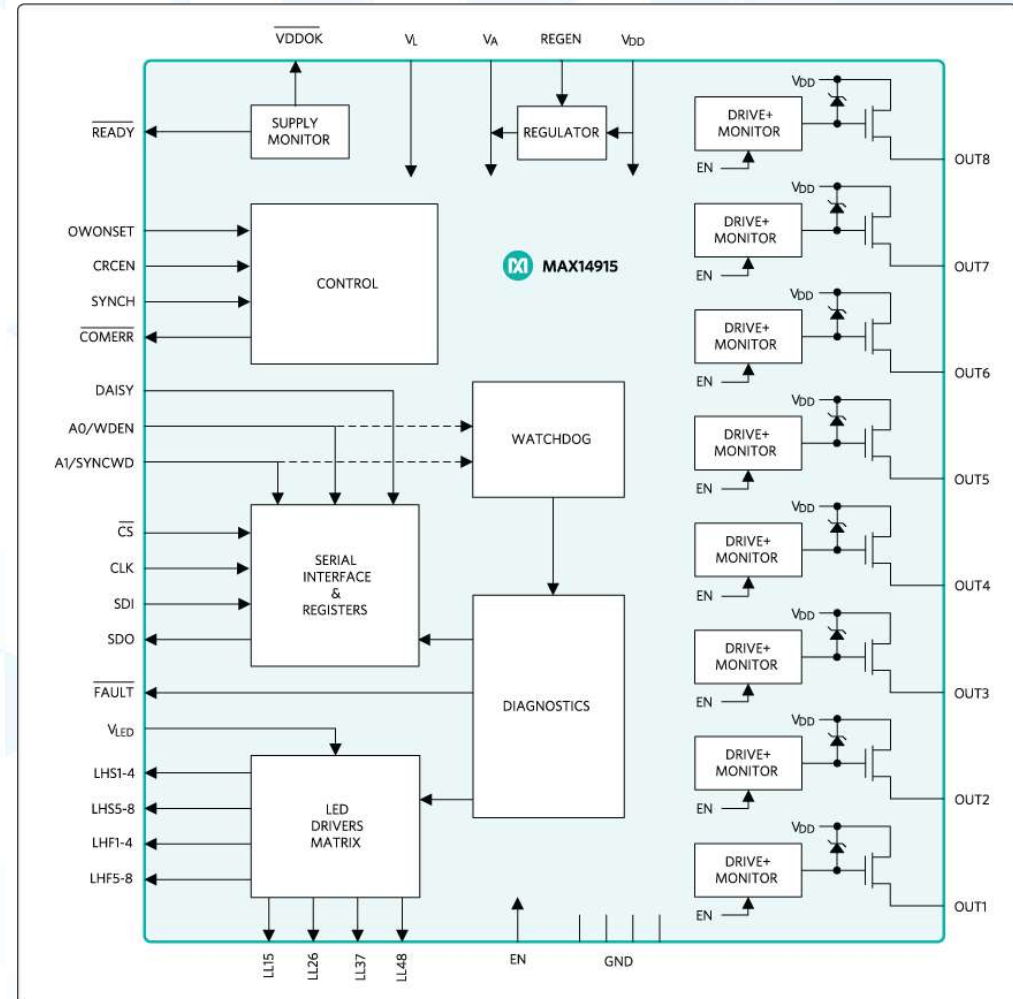
Any function, any combination on any pin, no restrictions for ultimate flexibility
Industrial IO on Demand



MAX14915, MAX14916, MAX14917

Industrial Octal High-Side Switch with Diagnostics

- ▶ **Robustness**
 - 65V ABS MAX Supply Range
 - Fast Demag for Inductive Load
 - Integrated 1kV surge protection per IEC 61000-4-5
- ▶ **Outputs**
 - Accurate Output Current Limiting (0.7A, min)
 - 250mΩ (max) On-Resistance at 125°C
- ▶ **Diagnostics**
 - Open Wire/Load Detection, with Switches On and Off
 - Overload and Current Limiting Detection
 - Over and Undervoltage Detection on VDD
 - Thermal Shutdown Protection
 - Loss of VDD or GND Protection
- ▶ **Interface/Control**
 - Addressable SPI allowing multiple MAX14915 sharing a common Chip Select
 - CRC Error Checking on SPI Interface
- ▶ **Compact 6mm x 6mm QFN package**



MAX14915, MAX14916, MAX14917

Industrial Octal High-Side Switch with Diagnostics

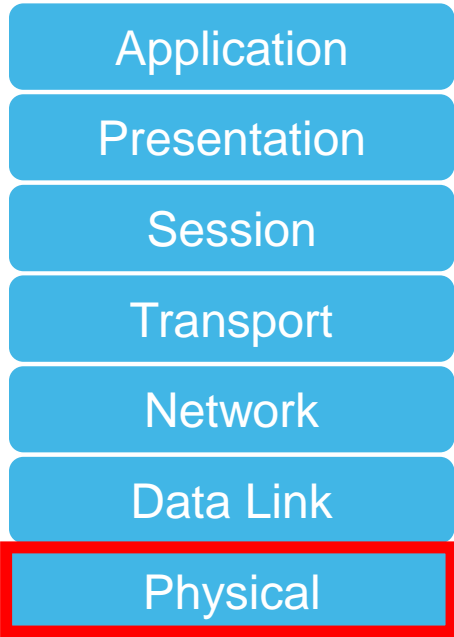
- ▶ **Robustness**
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 - Loss of VDD or GND Protection
- ▶ **Interface/Control**
 - Addressable SPI allowing multiple MAX14915 sharing a common Chip Select
 - CRC Error Checking on SPI Interface
- ▶ **Compact 6mm x 6mm QFN package**

	MAX14915	MAX14916	MAX14917
Octal Output Current Limit (A) (min)	0.7	1.1	0.7
Quad Output Current Limit (A) (min)	1.4	2.4	1.4
Addressable SPI	Yes	Yes	No
Enhanced Diagnostic	Yes	Yes	No
Daisy Chained SPI (limited diagnostic)	Yes	Yes	Yes
Budgetary Price @1k volume	\$4.18	\$4.53	\$3.88

* MAX14917 is pin compatible with the MAX14915 only in daisy chain configuration. It is a limited features, low-cost part for low-end application.

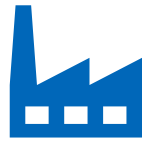
RS-485 in Industrial Connectivity

RS-485 (and RS-422)
are flexible
physical layer



OSI Model

Applications



Industrial Processing
PROFIBUS, Interbus

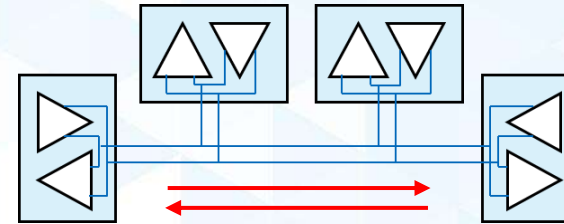


Motor Control
Hiperface DSL

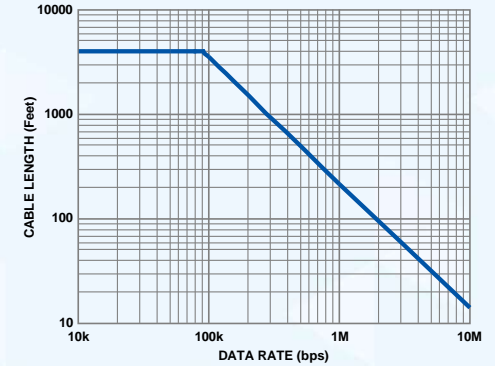


Building Automation
Modbus RTU, BACNet

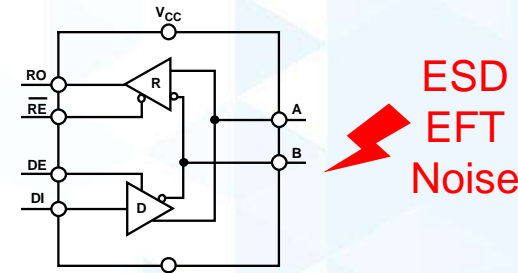
Multipoint



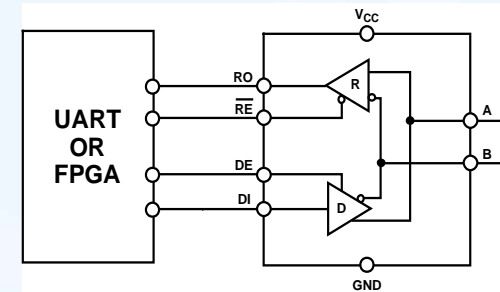
Reach (≥1km)



Robustness



Simplicity



ADM286xE/ADM256xE Family

3kV / 5.7kV Signal & Power Isolated RS-485

▶ Transceiver

- Half or Full duplex transceiver
- 500 kbps or 25 Mbps data rate over 192 nodes
- Level 4 IEC61000-4-2 ESD robustness on bus pins
- Smart cable invert feature

▶ Isolated DC to DC

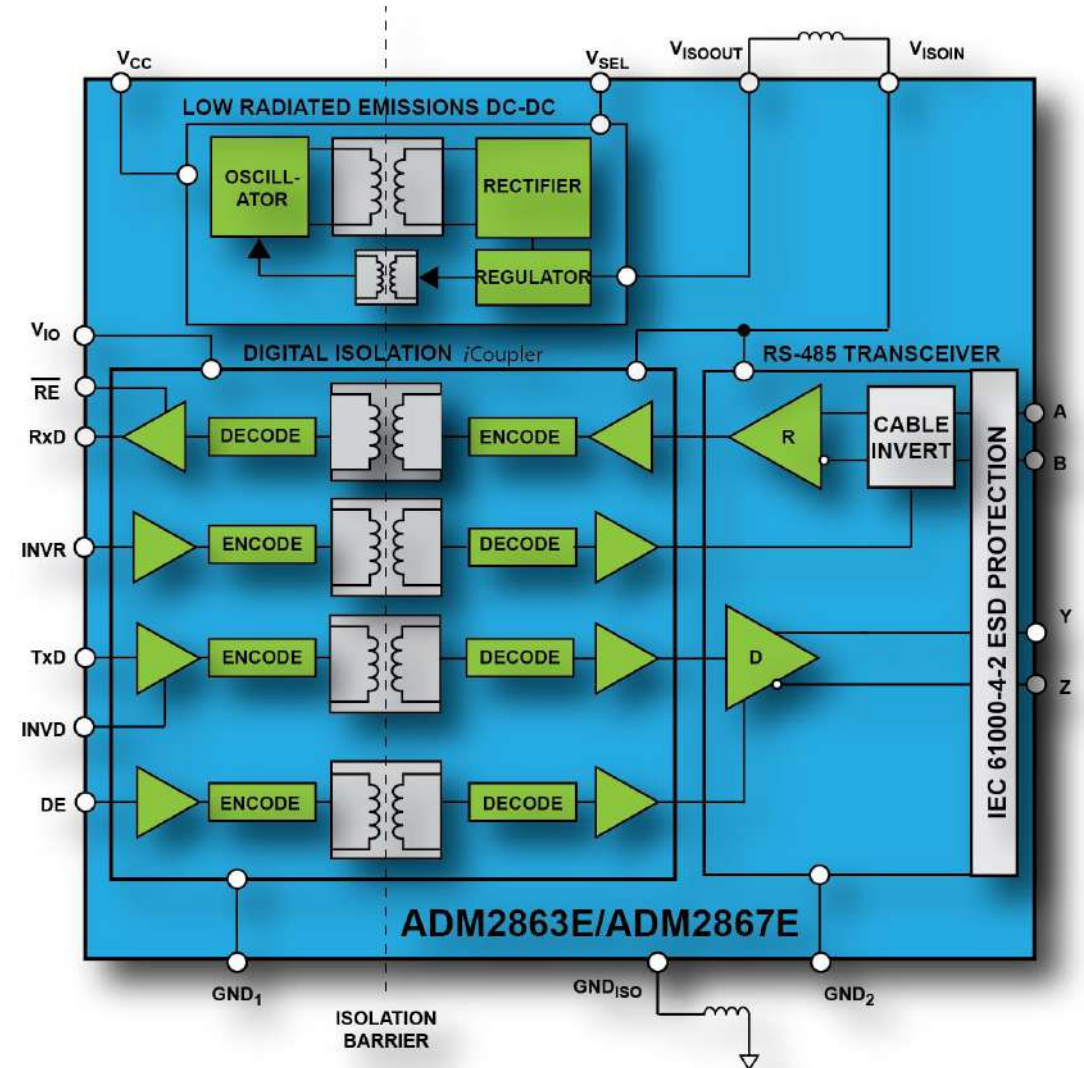
- Wide 3V to 5.5V input, 3.3V or 5V output
- 5V output for PROFIBUS DP
- Meet Class B Radiated Emissions on 2-layer PCB

▶ Isolator

- Supports I/O from 1.7V – 5.5V
- 225kV/us common-mode transient immunity.

▶ Isolation / Package

- Smallest form isoRS485 on 16L SOICW body size
- 5.7 kV, 8mm creepage, MG I for reinforced insulation



M-LVDS : Optimised Backplane Communication

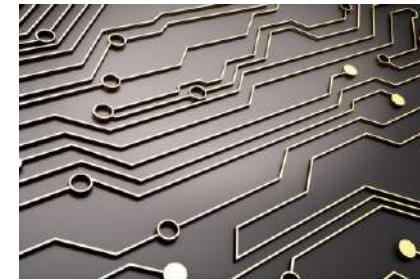
RS-485



Long cables

Multipoint
High power
Slow

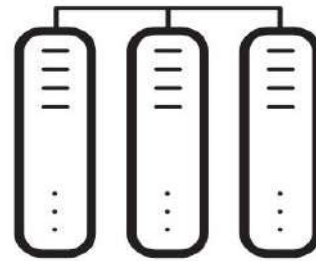
LVDS



P2P Backplane

High Speed
Low Power
Point to point

M-LVDS



Multipoint
Backplane

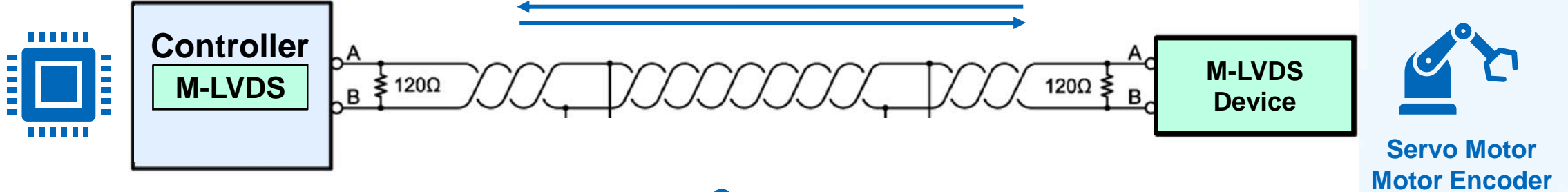
Multipoint
High Speed
Low Power


M-LVDS Key Features

- Multipoint across 32+ nodes
- Up to 250 Mbps per lane
- Wide common mode range
- Low power consumption

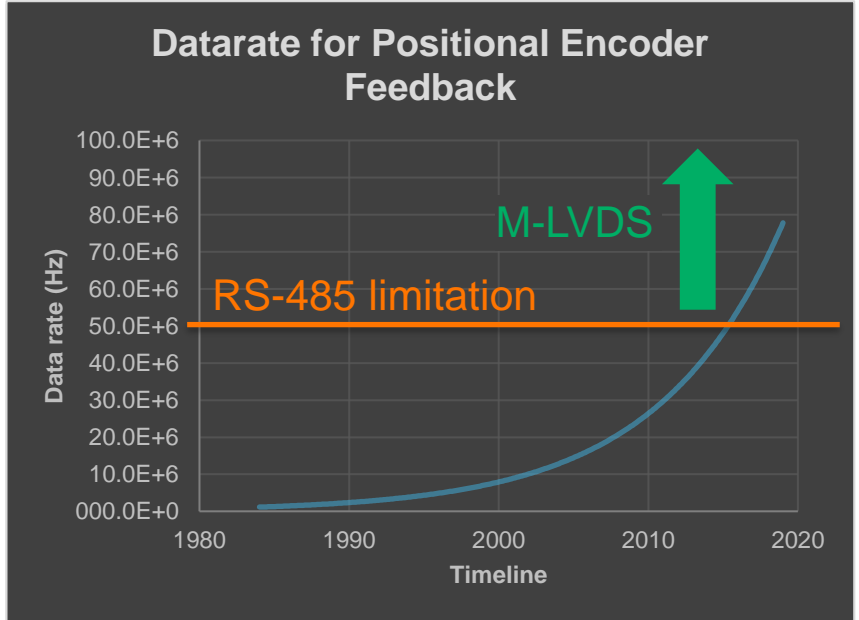
Why M-LVDS for Motor Control

Bi-directional at 200 Mbps over 30m+
Bi-directional at 20 Mbps over 100m+




Temp
Sensor


Vision
Sensor



	RS-485 / RS-422	M-LVDS
Topology	Differential, Multipoint	Differential, Multipoint
Maximum Data Rate	50 Mbps	250 Mbps
Power Consumption	High, 165mW – 425mW	Low, ~ 60mW
Min Output Voltage	1.5 V	0.48V
# of Devices, Distance	Up to 256 over 1km+	Up to 32 over 30m+

High Density M-LVDS Transceivers

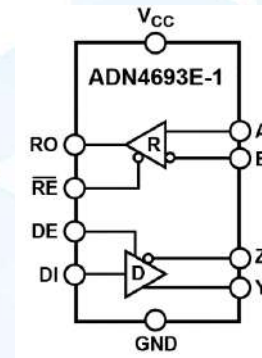
Value proposition

- ▶ Low power solution in a compact packages
- ▶ Low latency, skew and jitter performance for optimum SI
- ▶ Hot-swap and system level ESD for robust end systems

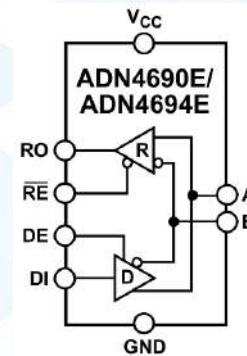
Key benefits

- ▶ Extended industrial temperature ranges
- ▶ Reduced dynamic power consumption
- ▶ Skew less than 5% of unit interval at 200 Mbps
- ▶ Level 4 IEC 61000-4-2 ESD on M-LVDS I/O

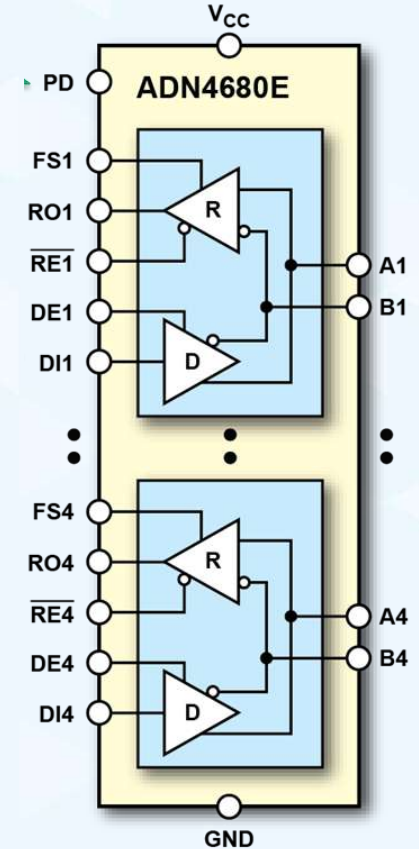
Full duplex



Half duplex



Quad half duplex



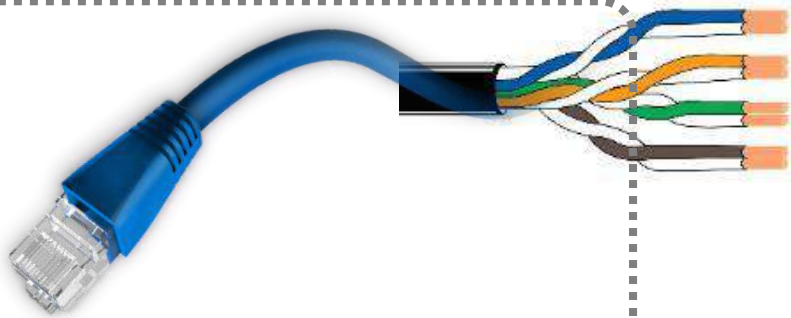
10BASE-T1L

Ethernet Physical Layer, IEEE 802.3cg-2019

Robust Physical Layer








- ▶ 1000BASE-T
- ▶ 100BASE-TX
- ▶ 10BASE-T



- ▶ 10BASE-T1L



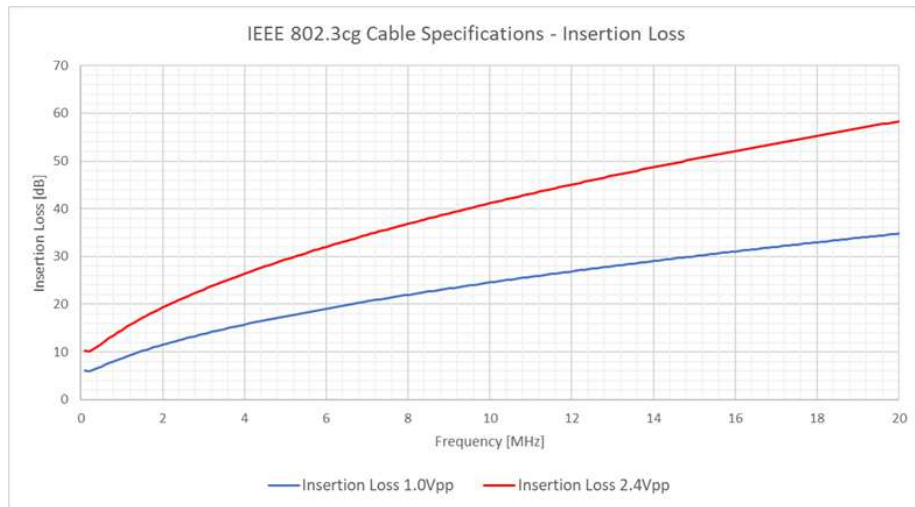
PHY Key Features	10/100/1000 BASE-TX	10BASE-T1L
Cabling	 2 or 4 pair Ethernet	 Single Pair Ethernet
Distance	100m	Up to 1km
Speed	10Mb, 100Mb, Gb	10Mb
Connector	RJ45	Two Pin Connector
Intrinsic Safety Compatibility 	No	Yes 
Power	PoE	PoDL or Engineered Power 

**Photo is from internet

Cable Types and Diagnostics

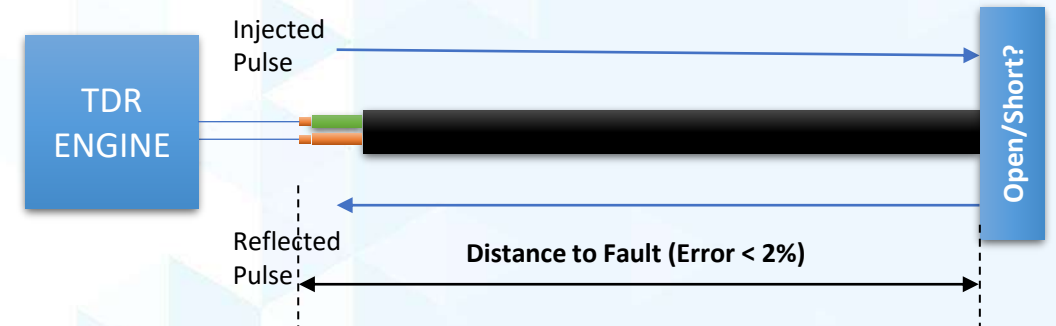
IEEE cable characteristics

- ▶ 100 Ohm impedance
- ▶ Insertion loss limit
- ▶ Return loss limit
- ▶ Maximum link delay
- ▶ Conversion mode
- ▶ Up to 10 inline connectors



ADI's 10BASE-T1L diagnostic capabilities

- ▶ Transmitter PMA test modes
- ▶ Signal quality monitoring through MSE
- ▶ Loopback modes
- ▶ Frame generator & frame checker
- ▶ On-chip Time Domain Reflectometry engine

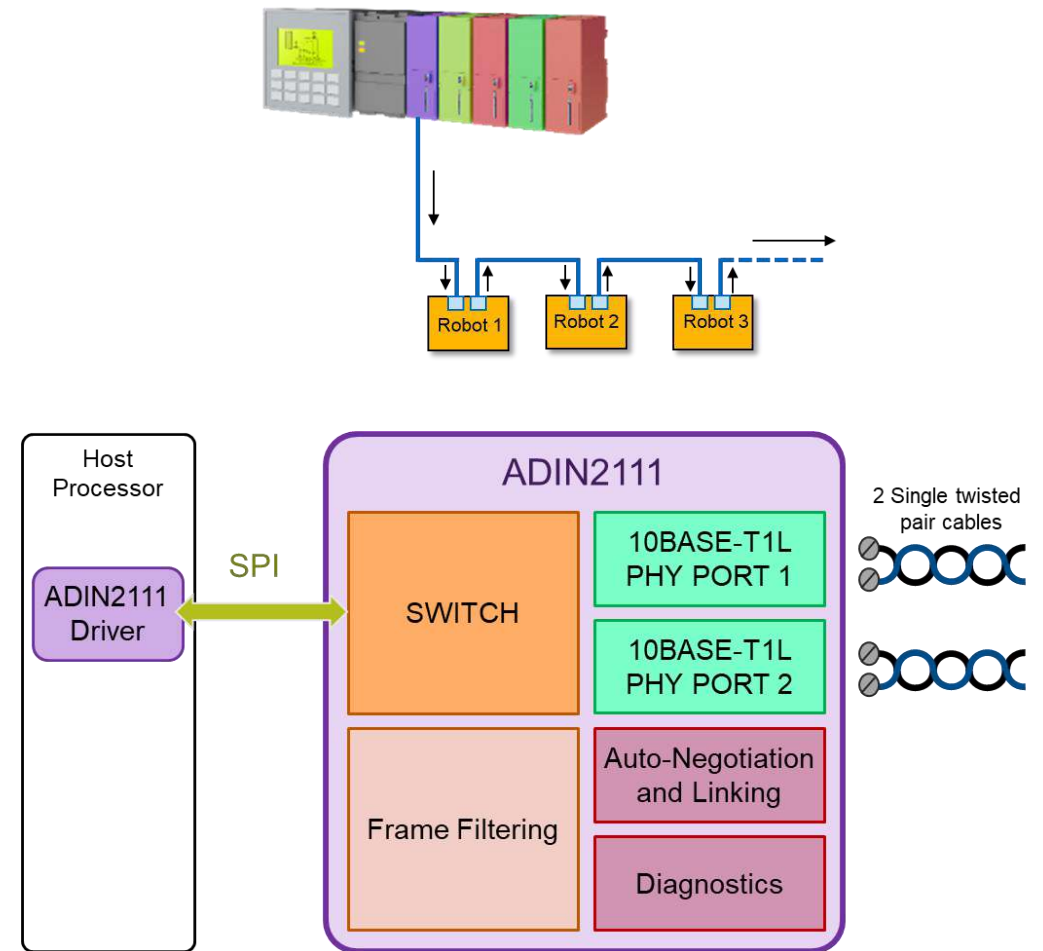


**Photo is from internet

10BASE-T1L 2-Port Low Complexity Switch

ADIN2111

- ▶ Low complexity ethernet switch
 - Cut-through or store & forward operation
- ▶ SPI host interface
 - 10Mb/sec full duplex
 - Generic/Open Alliance SPI
- ▶ Low power: 118 mw typ. (Dual supply, 1V p-p)
- ▶ Small package 48-lead (7 x 7 mm) LFCSP
- ▶ 2x 10BASE-T1L PHYs
 - Features as on ADIN1100



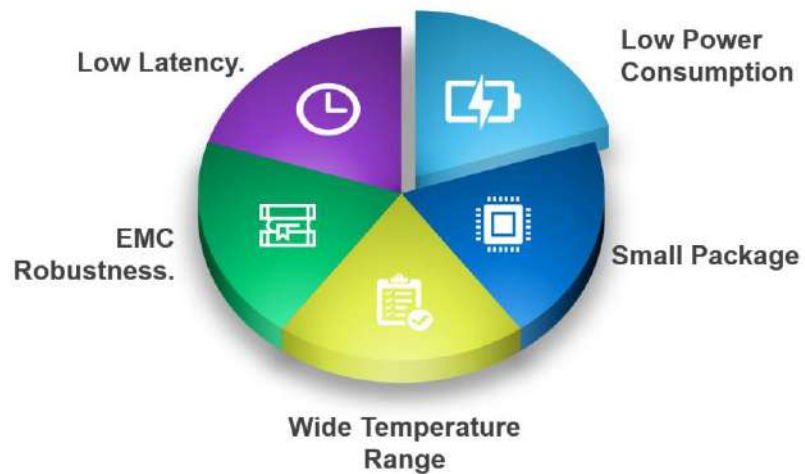
ADIN1300: 10/100/1000 Robust Industrial Ethernet PHY

ADIN1300 10/100/1000 gigabit PHY

- ▶ Small footprint: 6 x 6mm 40-LFCSP
- ▶ Low power: 330mW
- ▶ Low latency: 290ns Tx & Rx (RGMII)

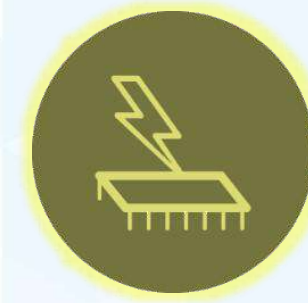
ADIN1200 10/100 fast ethernet PHY

- ▶ Small footprint: 5 x 5mm 32-LFCSP
- ▶ Low power: 139mW
- ▶ Low latency: 300ns Tx & Rx (MII)



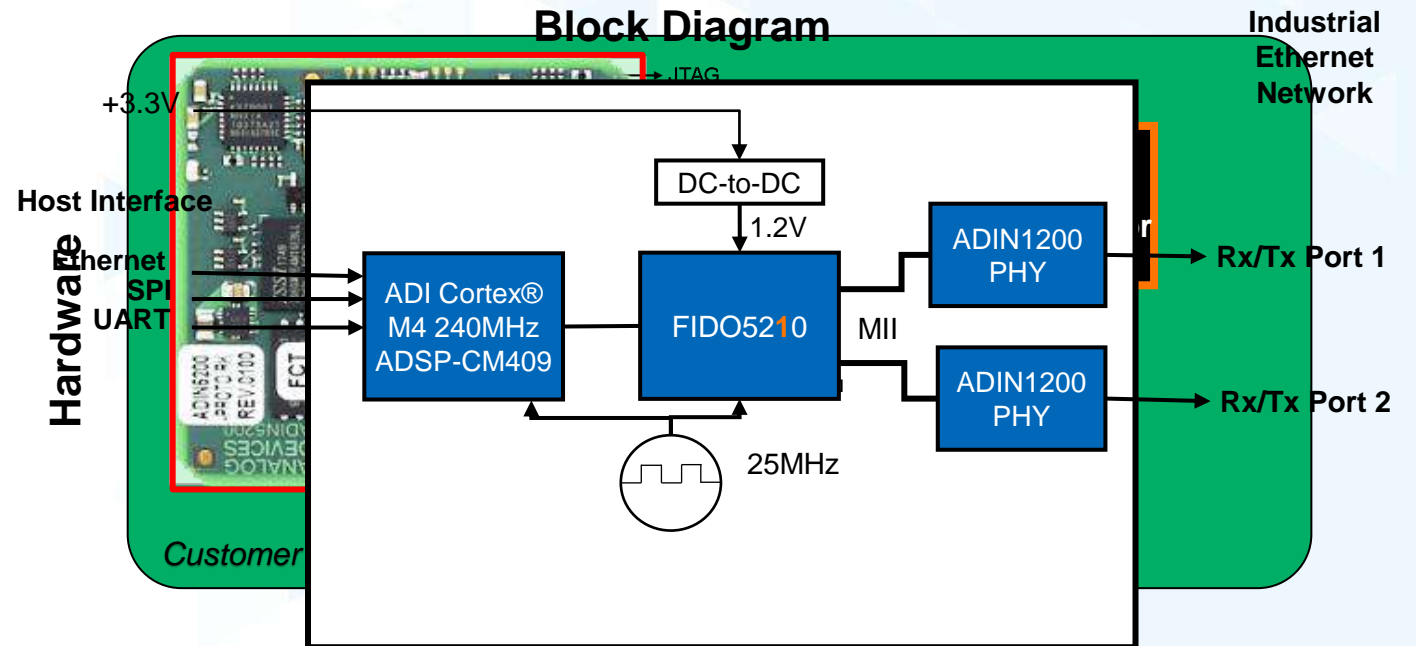
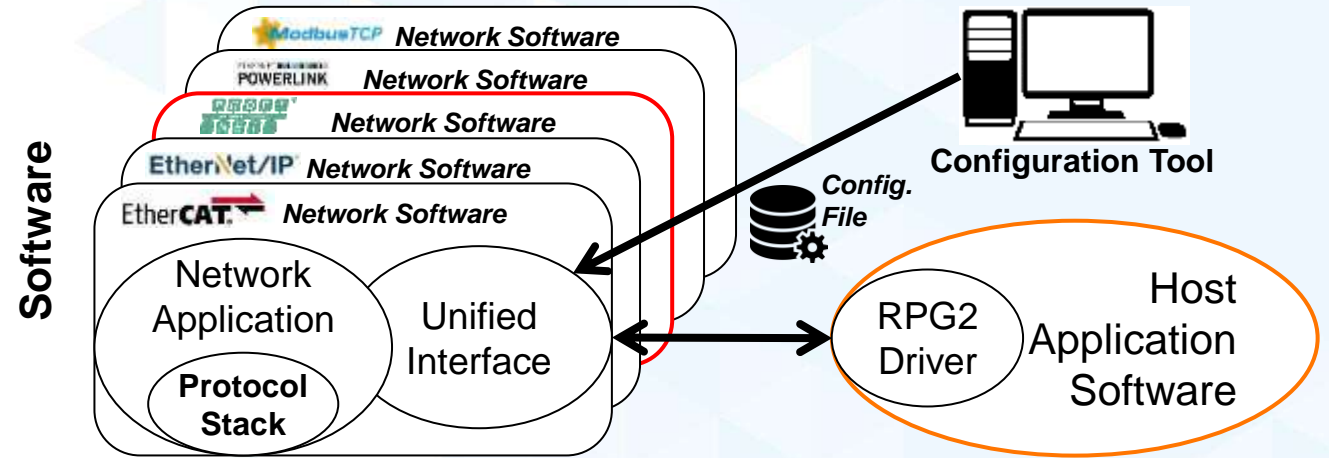
Extensive EMC/ robustness testing

- ▶ IEC 61000-4-5 surge (± 4 kV)
- ▶ IEC 61000-4-4 electrical fast transient (EFT) (± 4 kV)
- ▶ IEC 61000-4-2 ESD (± 6 kV contact discharge)
- ▶ IEC 61000-4-6 conducted immunity (10 V)
- ▶ EN55032 radiated emissions (Class A)
- ▶ EN55032 conducted emissions (Class A)



RapID Platform Generation 2 (RPG2) - 100BASE-Tx

- ▶ 2-Port multiprotocol platform
- ▶ Network software for each protocol
 - A module comes pre-installed with network software (PROFINET is shown here in RED)
- ▶ Driver provided for the host-side software to communicate with the network software
- ▶ Unified interface in the network software
 - Host application software does not have to change when the protocol changes



Network Interface Solutions: Two Options

- ▶ Pre-certified hardware with multiprotocol software
- ▶ Reduces development effort
- ▶ Speeds time to market

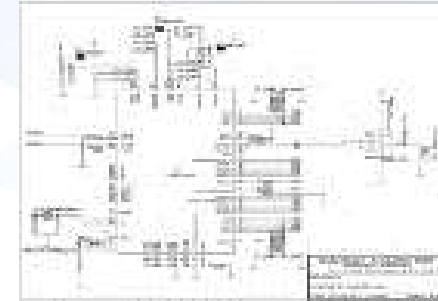
Module



ADIN2299

Complete off-the-shelf,
ready-to-use solution
Fully tested reducing
development risk

Embedded reference design



Pre-certified

Enables optimisation
of board design
Cost effective solution for
high volume applications

Isolated USB in Industrial Systems

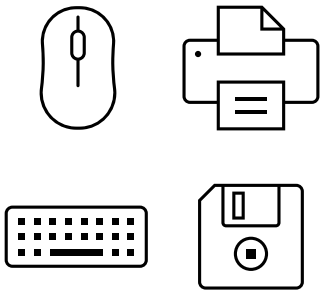


- ▶ Debug Ports (RS-232 Replacement)
- ▶ Noise Immunity
- ▶ Electrical Safety for Operators

**Photo is from internet

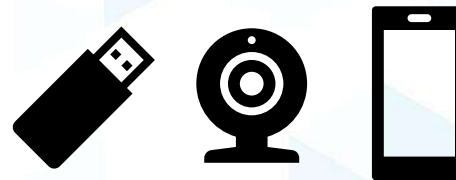
Gen 1 Isolator (USB 1.X)

Low Speed (0.5 Mbps)
Full Speed (12 Mbps)



Gen 2 Isolator (USB 2.0)

Low & Full Speed
High Speed (480 Mbps)

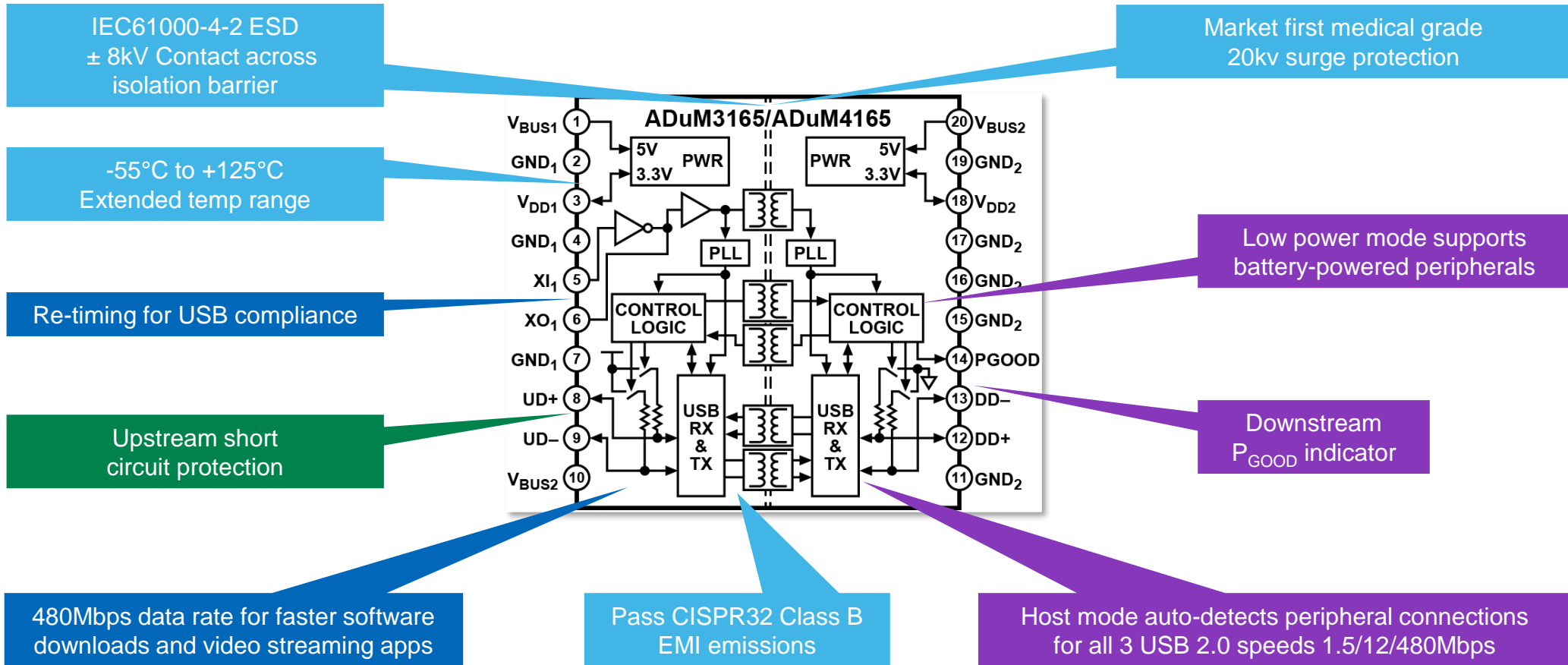


ADI 2nd Gen Isolated USB

- Faster Firmware Updates
- Supports video streams
- More flexible systems
- Enhanced robustness

Isolated USB Gen 2 Product Highlights

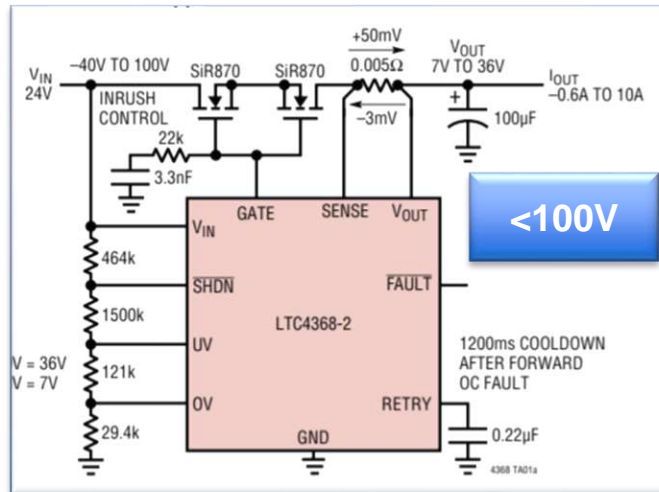
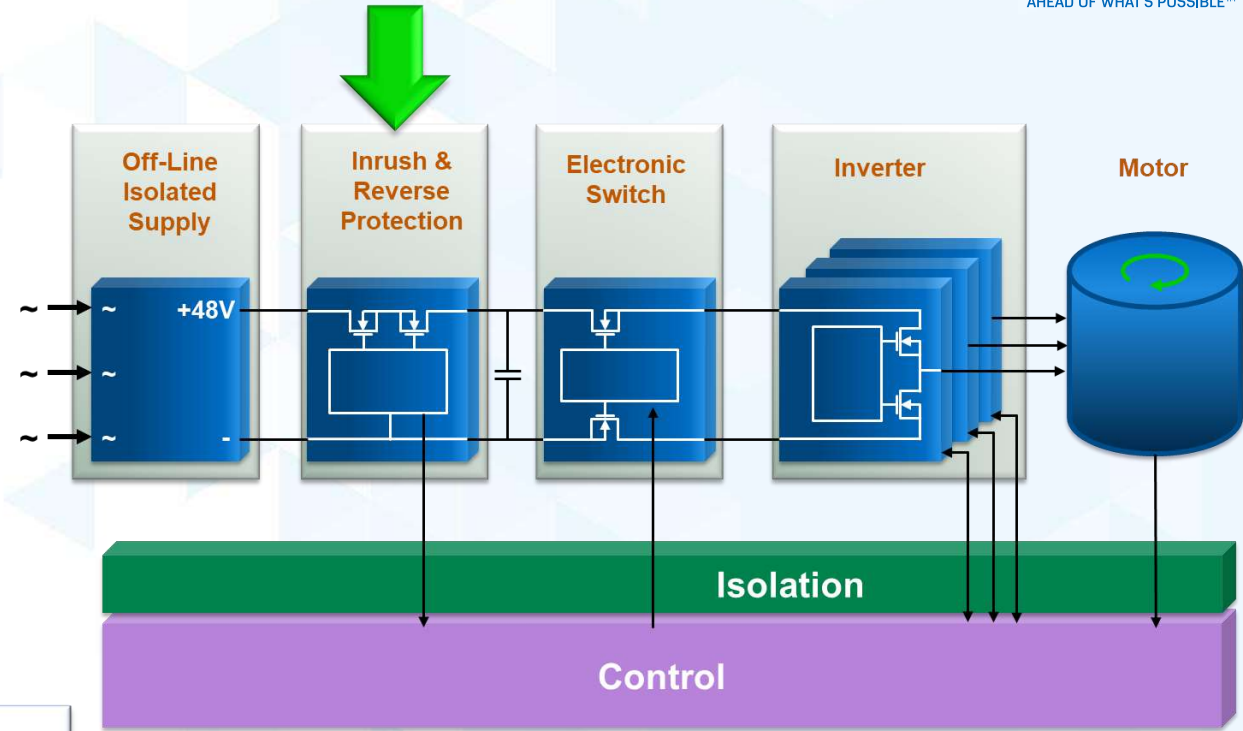
ADuM3165/ADuM3166/ADuM4165/ADuM4166



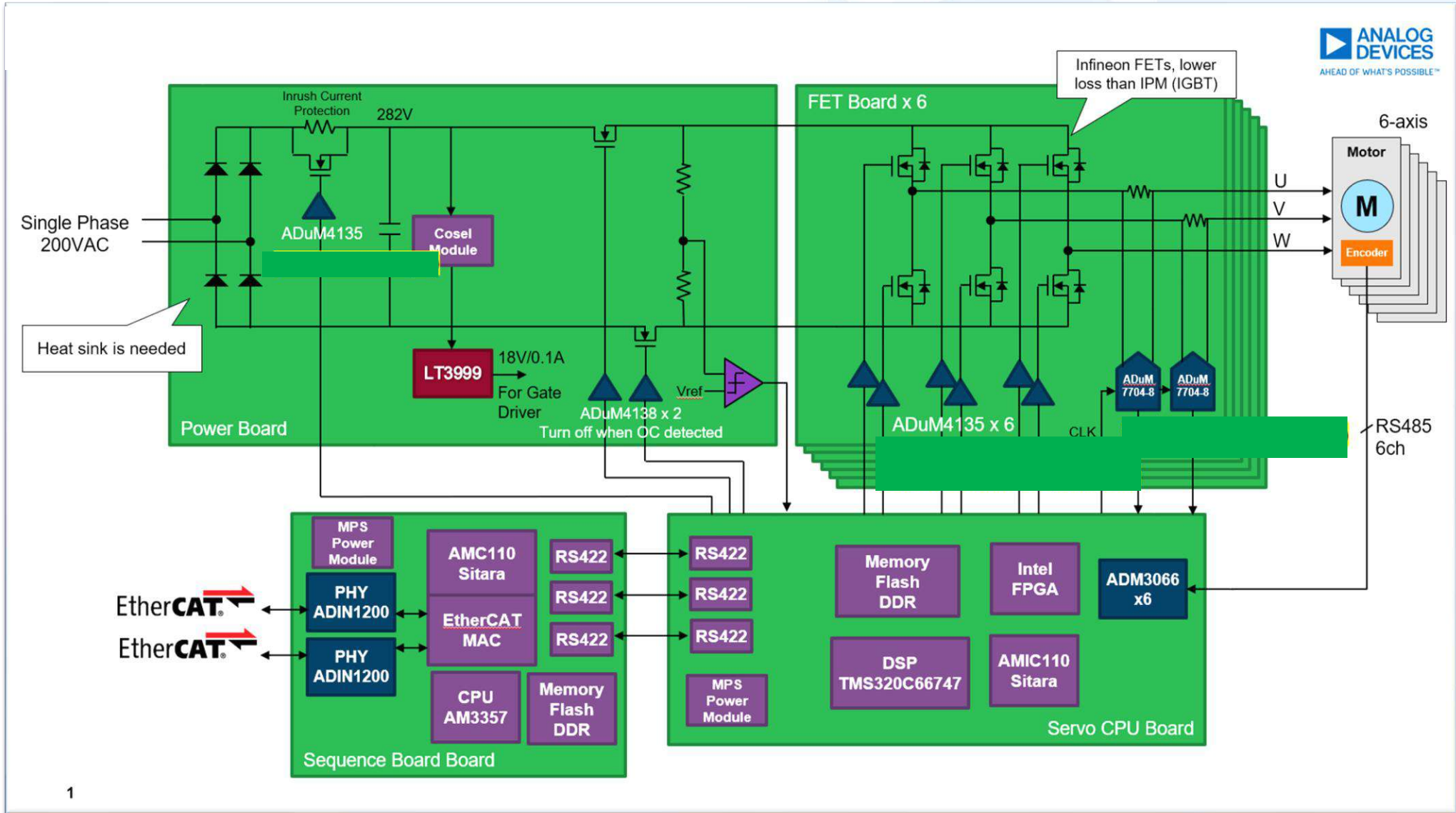
Power

Inrush Hot Swap

- ▶ Currently using wire wound cement resistors to inrush very large bulk capacitor
 - Relay or MOSFET switch closes after inrush
 - Input shorts can blow up Hot Swap relay or MOSFET
 - Solution size is too big and can get very hot during inrush
- ▶ ADI Solutions – Very small, very low heat and protects against input shorts
 - <100V
 - LTC4368 – Now
 - LTC4267 – Soon

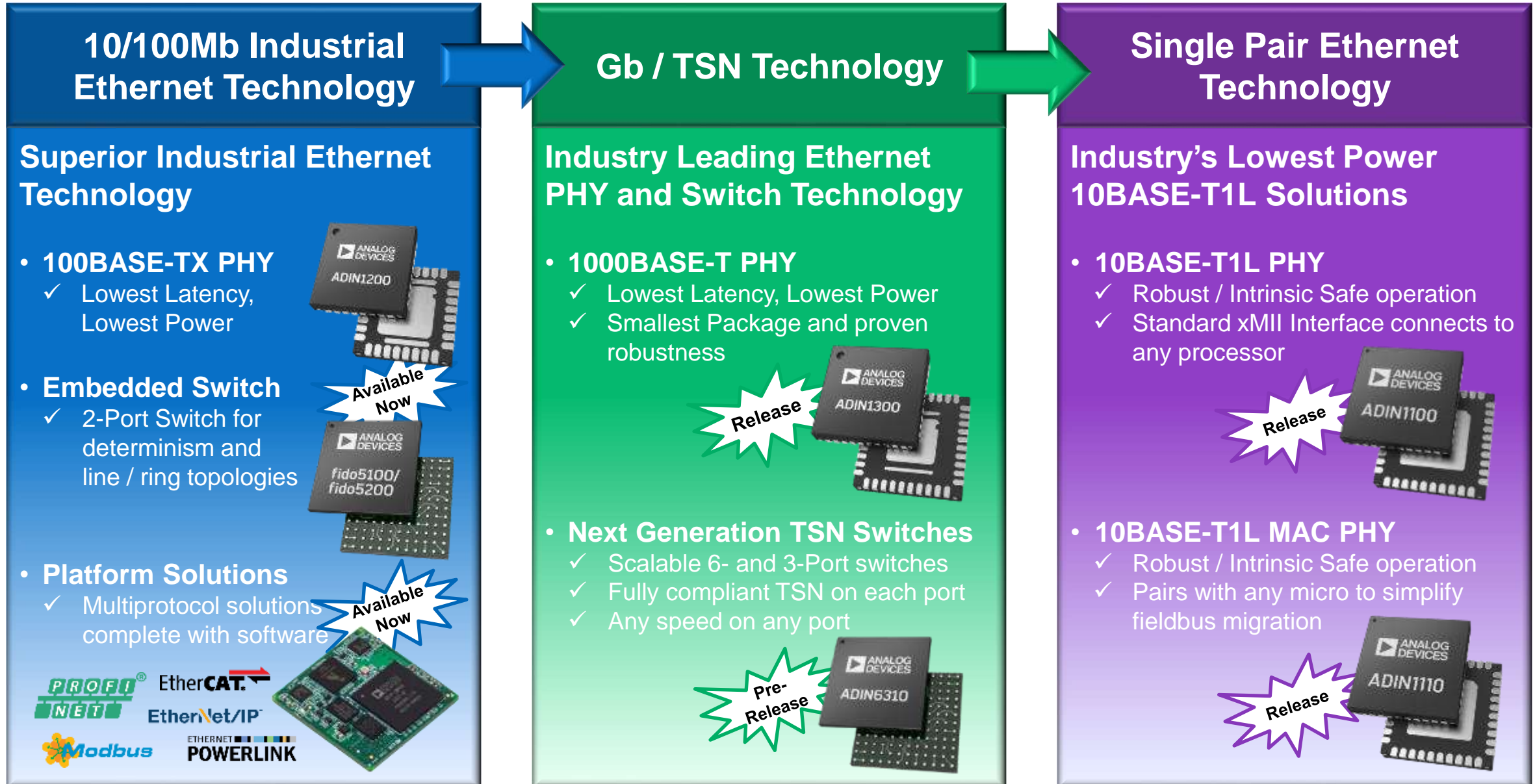


Current ADI Content – Over 100V



1

Scalable Ethernet Solutions for Deterministic Applications



Industrial BMS System Application and Requirement

► **Market will move to Li-ion battery**



- ▶ LFP(LiFePO4) battery is required.
- ▶ Module voltage: 48V (stack)
- ▶ Rack voltage, 720V to higher (1500V)
- ▶ Strongly need safety (industrial FuSa)
- ▶ 3mV/cell voltage accuracy

Stack

- ▶ Move from Lead to LFP.
- ▶ 48V system is base
- ▶ Application suitable for using EV-Car retired battery
- ▶ More protection and safety design
- ▶ Oversea market need industry FuSa
- ▶ UV/OV/OT wake up

Stand-Alone

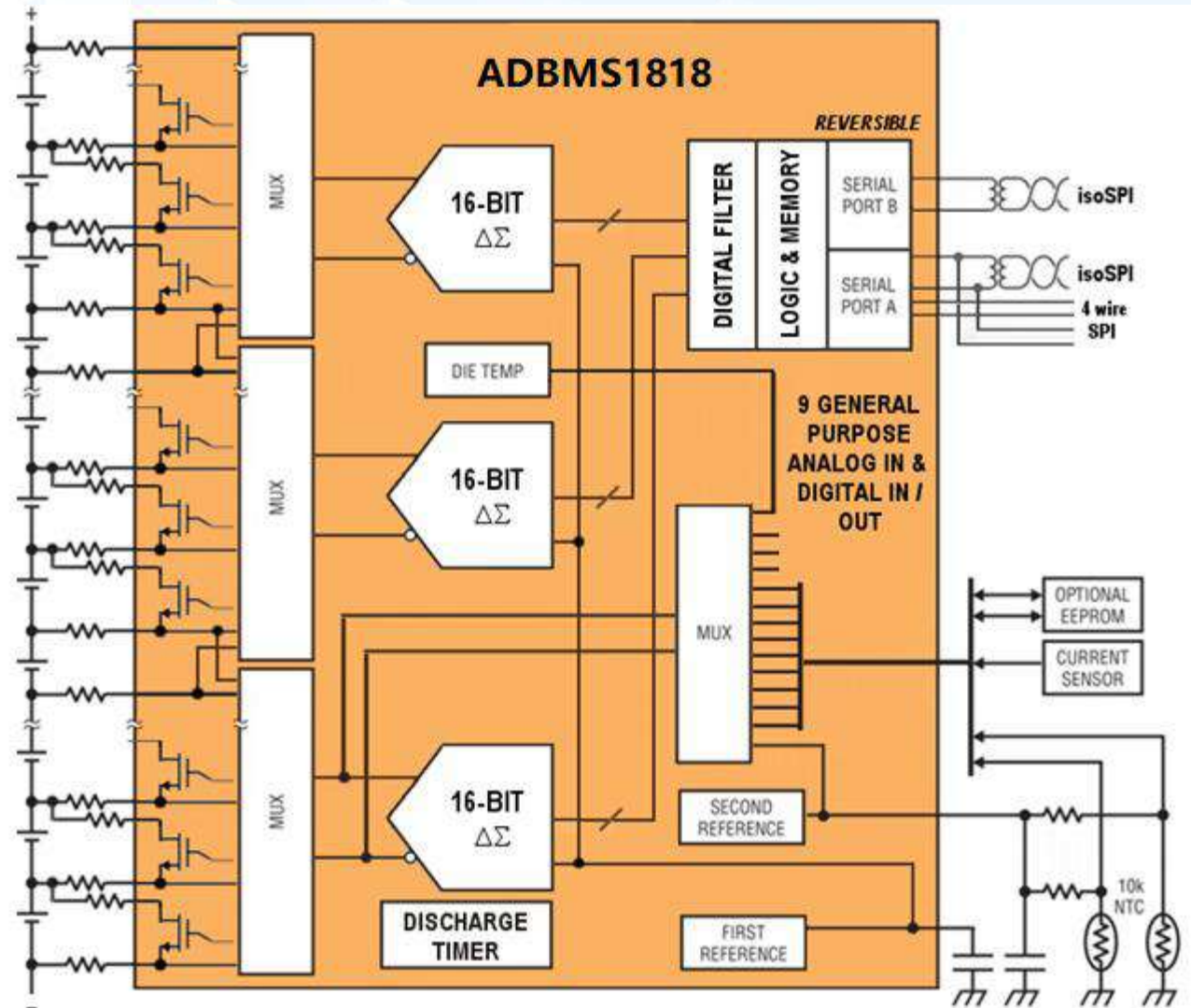
- ▶ GB standard: 48V, E-Motor, 60V, 72V
- ▶ Move from Lead to LFP battery.
- ▶ Small size (44 pin) and low cost
- ▶ UV/OV/OT wake up

#	Requirement	Target Performance (min/max)
1	Functional Safety	SIL2 – SIL3
2	Voltage Channels	16-(48V), 18-(stack voltage)
3	Voltage Accuracy	3.2mV (full temp & Life cycle)
5	More temperature sensing node	8x (in 16ch) & 9x (in 18ch)
7	Passive balancing	>200mA
8	Smart during sleep	Balancing in low power mode
9	Robust communication	isoSPI
10	Low Power Consumption	<10uA
11	Temperature Range	-40~85
12	High EMC	
13	Good Hot Plug Capability	

ADBMS1818 Industrial BMS Product Concept

Product Highlights

- ▶ Measures 18 Series Connected Battery Cells
- ▶ Industry Leading Accuracy:
 - 3.2mV Total Measurement Error
- ▶ 16-Bit Delta Sigma - Programmable Noise Filter
- ▶ Advanced Reversible isoSPI™ Interface
- ▶ 200mA Passive Cell Balancing Capability
- ▶ 9 General Use Digital I/O or Analog Inputs
- ▶ Synchronized Voltage and GPIO Measurements
- ▶ LQFP 64pin package



Q&A