ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

Architecting Industrial Robots for Global Challenges

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Agenda

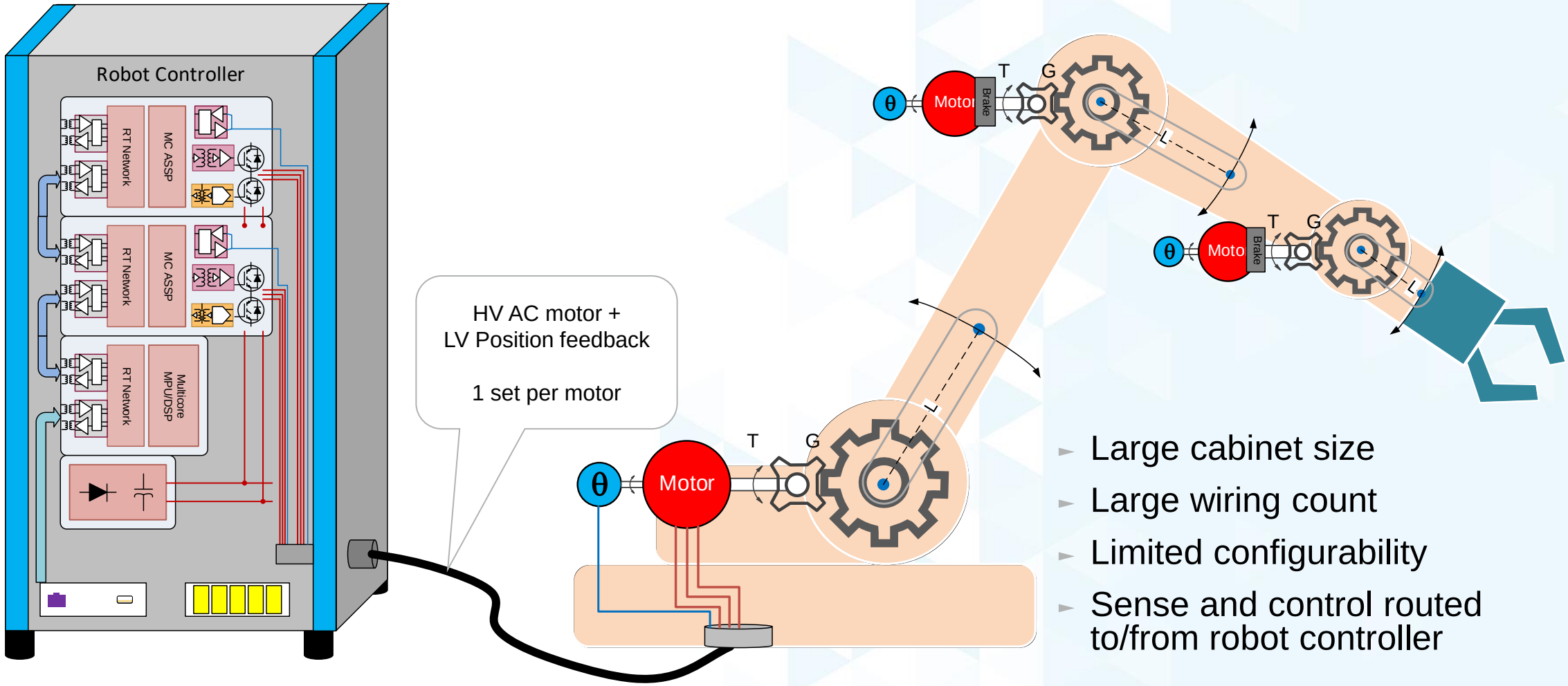
- Recent Trends in Robotics Adoption
- Robot Architecture
- Robot Communications
- Encoders in the Robot Architecture
- Force Sensing in Robotics

Global Challenges Accelerating Robotic Adoption

- Globalisation driving adoption of automation and robots
- Negative media headlines on impact
- Global pandemic accelerating adoption

- Pivoting manufacturing lines to essential products
- Worker Distancing in manufacturing, logistics, workplaces
- Cleaning and Disinfection in Hospitals, Airports, etc.
- Movement of items in labs, hospitals, warehouses
- Picking and packing of goods in distribution centres

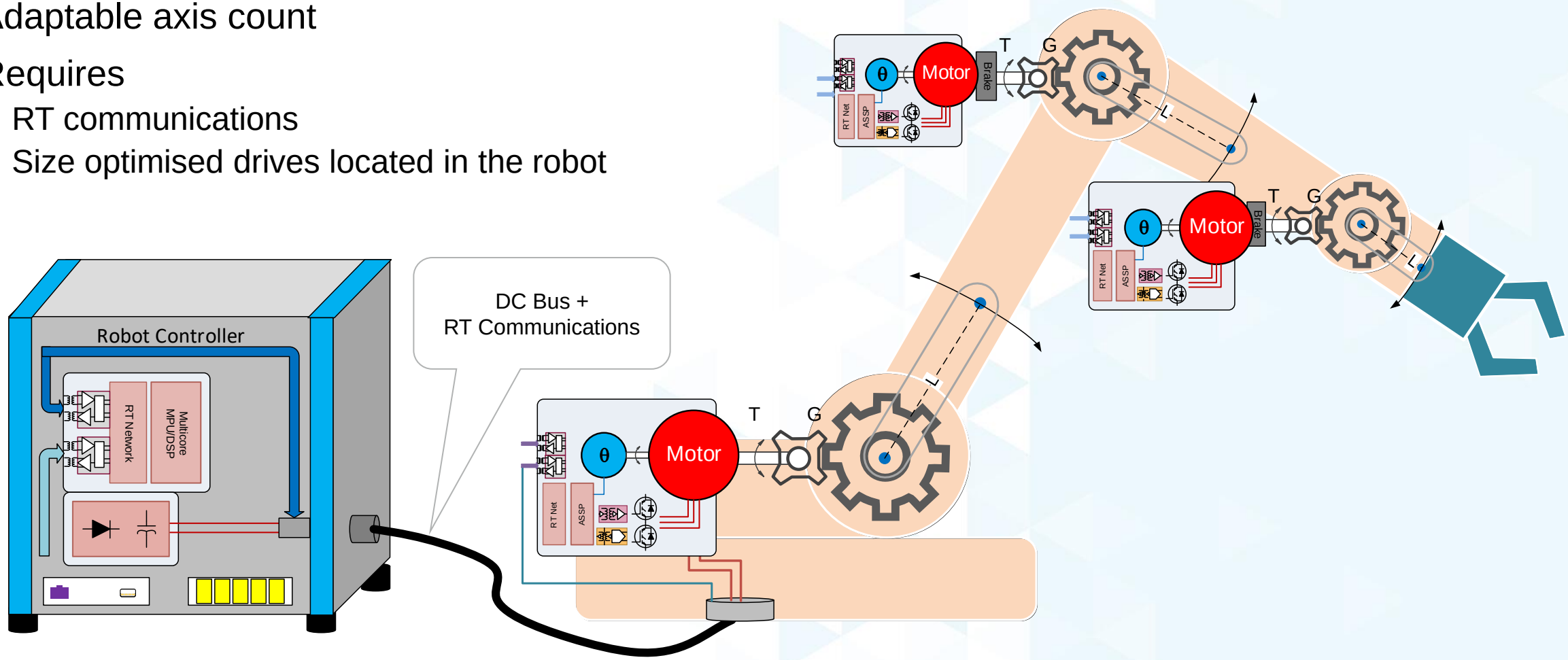
Traditional Robot Architecture



- Large cabinet size
- Large wiring count
- Limited configurability
- Sense and control routed to/from robot controller

Emerging Robot Architecture

- Reduction in robot controller size
- Reduced wiring configuration
- Adaptable axis count
- Requires
  - RT communications
  - Size optimised drives located in the robot



Robot Communications

PROFINET INDUSTRIAL ETHERNET

EtherNet/IP

EtherCAT

sercos international

ETHERNET POWERLINK

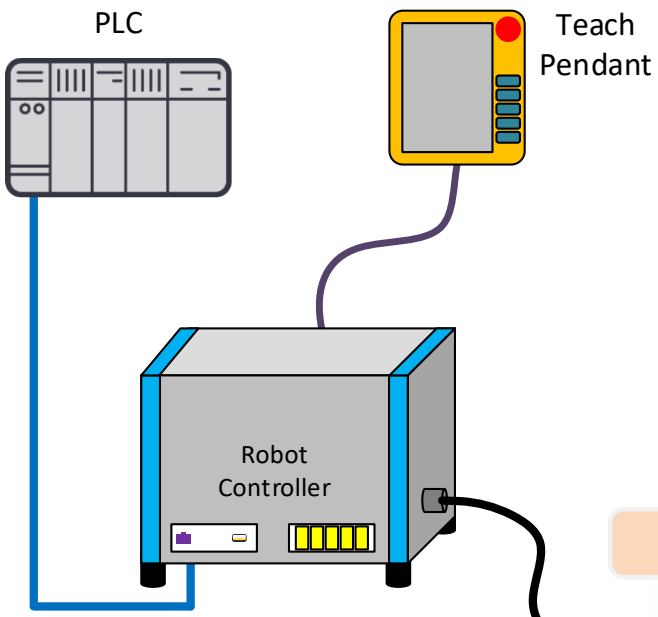
ModbusTCP

TSN with:

OPC UA

DDS

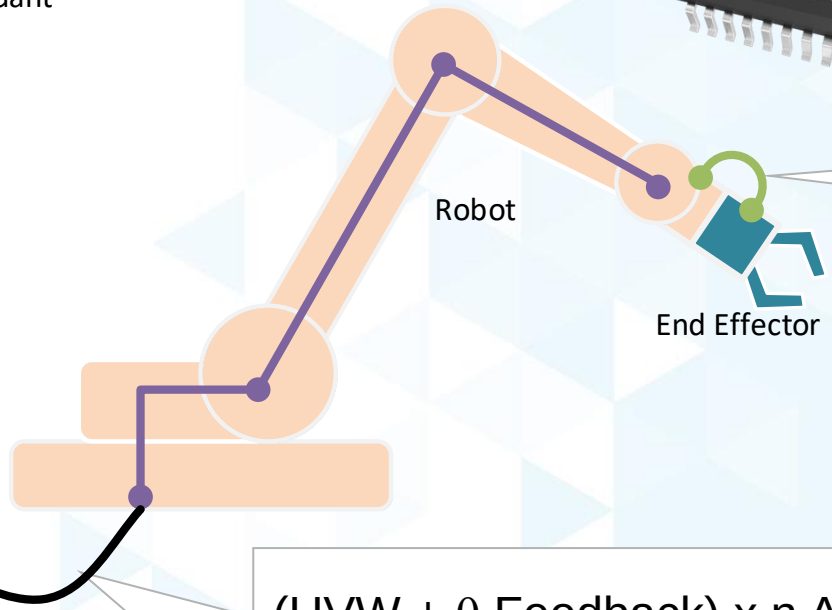
61850, *etc.*



Gbit LVDS

CANBus

EtherCAT



RS-485
Analog
Digital

ESD Protected
Isolated RS-485/422

(UVW + θ Feedback) x n Axis

EtherNet/IP

EtherCAT

Gbit LVDS

Market Leading Industrial Ethernet Solutions

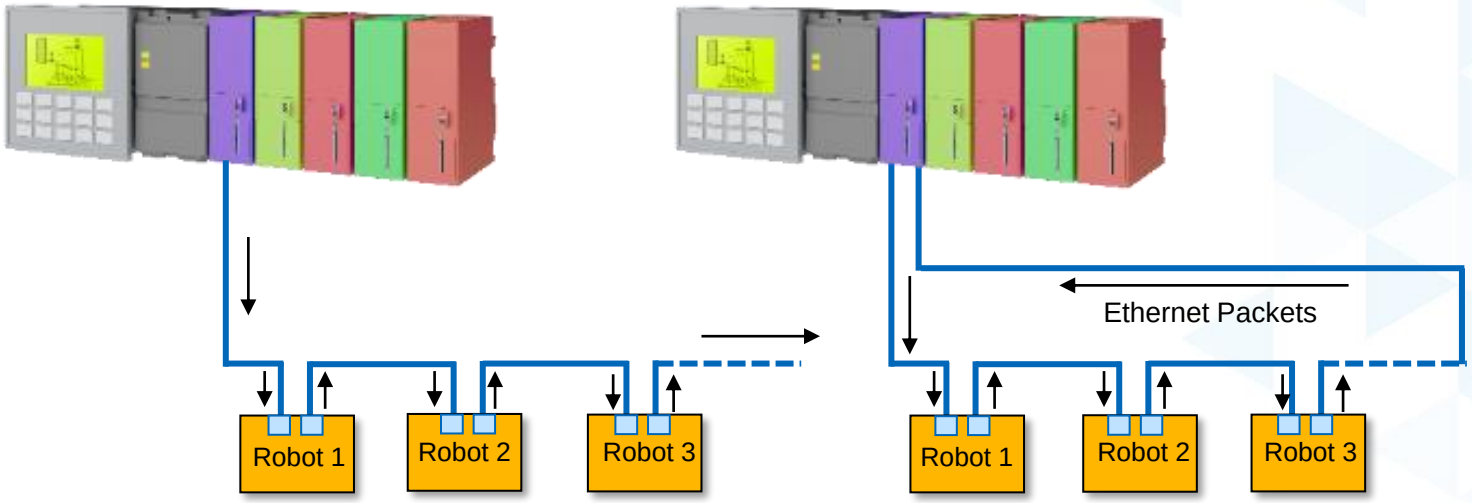
1. Physical Layer Transceivers (Phy)
2. Embedded Ethernet Switch's
3. Platform Solutions with Protocol Stacks

Consumer Gb PHY vs. Industrial Gb PHY

PHY Key Features	Consumer Ethernet PHY	Industrial Ethernet PHY	Benefit
Ambient Temperature Operation	0°C to 70°C	-40°C to 105°C	Robust Operation in Harsh Industrial Applications
Gb PHY Latency (RGMII)	400ns	294ns	Reduced Network Cycle Time
Gb PHY Power	500mW	330mW	IP66/67 product without fans or heat sinks.
EMC/ESD Robustness	Not required	Surge, EFT, ESD, Radiated Immunity, Conducted Immunity, Radiated Emission, Conducted Emissions.	Reduced product development and certification time and cost. Robust product
Package Size	48-Lead, 7mm x 7mm	40-Lead, 6mm x 6mm	Smaller form factor products
Product Lifetime	Short	20-25 years	Long Product Availability

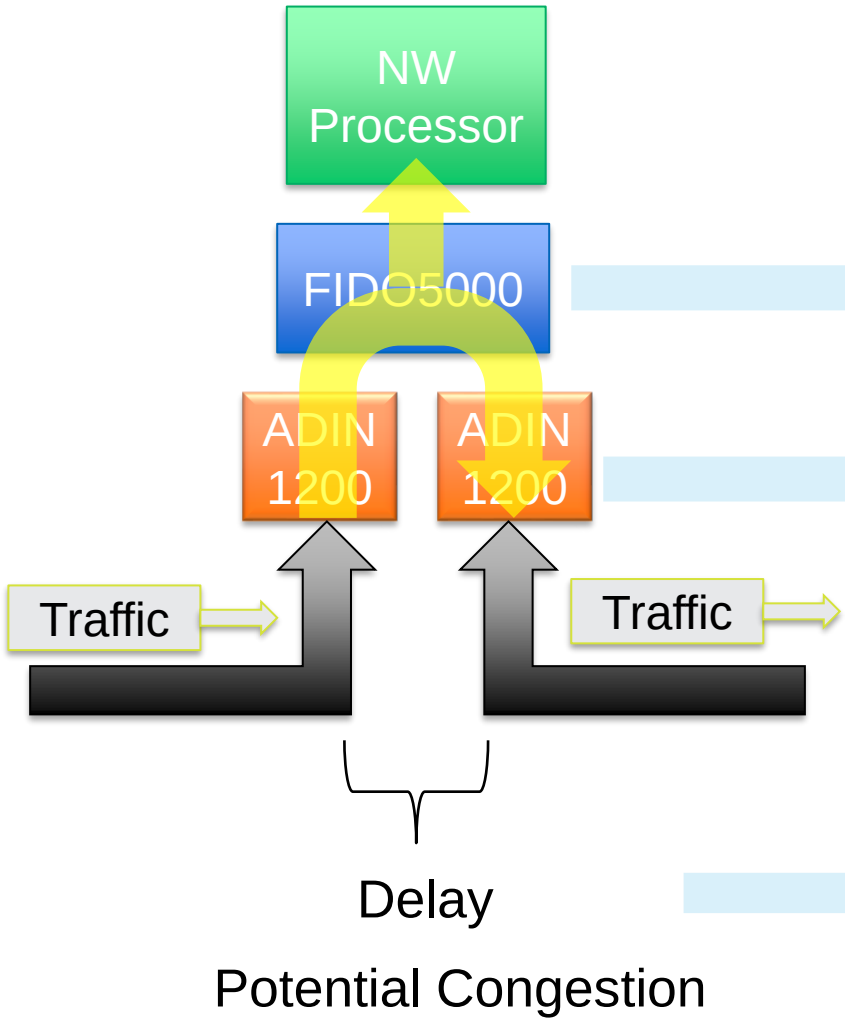
Why does PHY Latency Matter – Network Cycle Time

- Industrial Ethernet Network topologies are typically LINE and RING



- Low PHY Latency / Network Cycle Time
  - The network cycle time is the communication time required by the controller to both collect and update the data of all devices.
  - Lower network cycle time allows for higher application performance in time critical communications.
  - A low latency Ethernet PHY helps achieve a minimum network cycle time and allow more devices to be connected to the network.

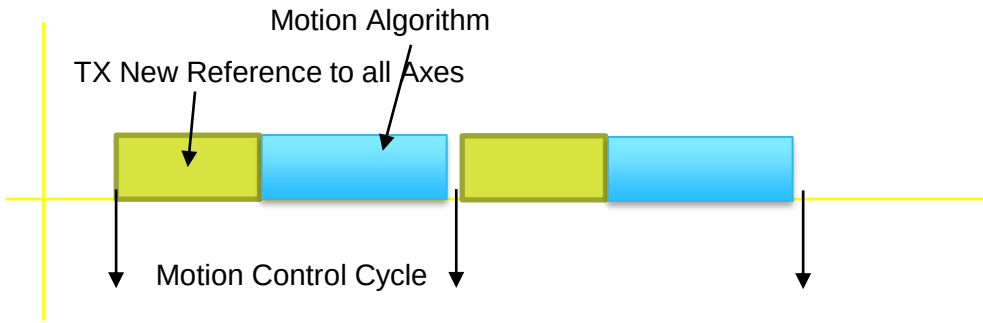
ADI Chronous Motion System Impact



- Increasing axes per drive
- Shorter Cycle times

Fido 5000 manages congestion via traffic prioritisation, and time sensitive protocol capabilities

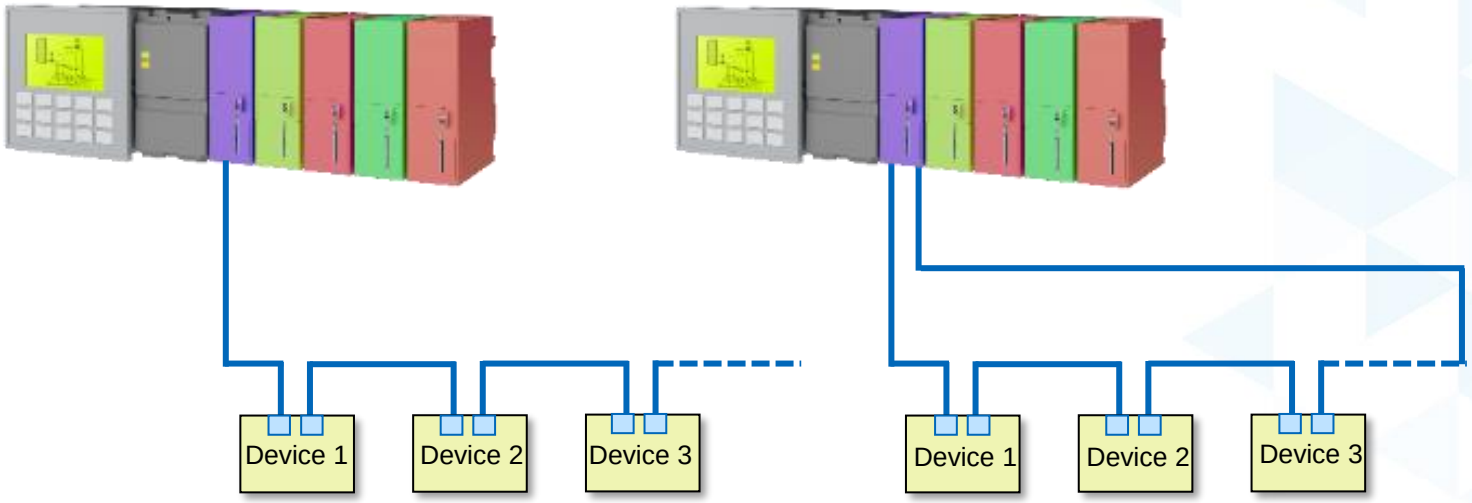
ADIN1200/1300 industry leading latency minimises traffic frame delay through each axis node

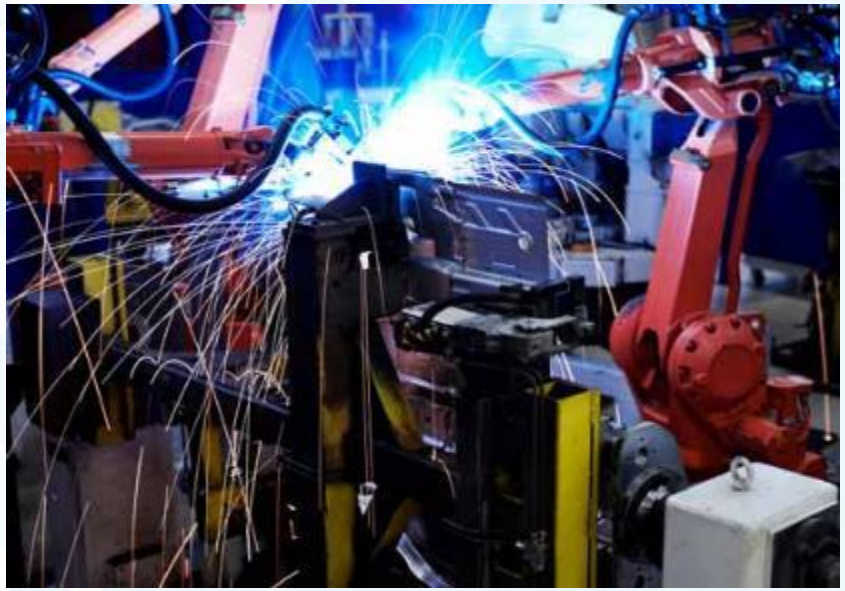


Example: Robot application – 7 axes, 100Mbit, 16us

Why does PHY Power Matter – Industrial Environment

Industrial Ethernet Network topologies are typically LINE and RING





- Reduced thermal conduction capability of sealed IP66/67 enclosures
- Ethernet PHY power dissipation becomes more critical in these use cases, as there are two PHYs per connected device.
- A Gb PHY with low power consumption allows more of the available power budget for the FPGA/Processor and Ethernet Switch in the device.
- 105C ambient temperature operation is often a requirement.

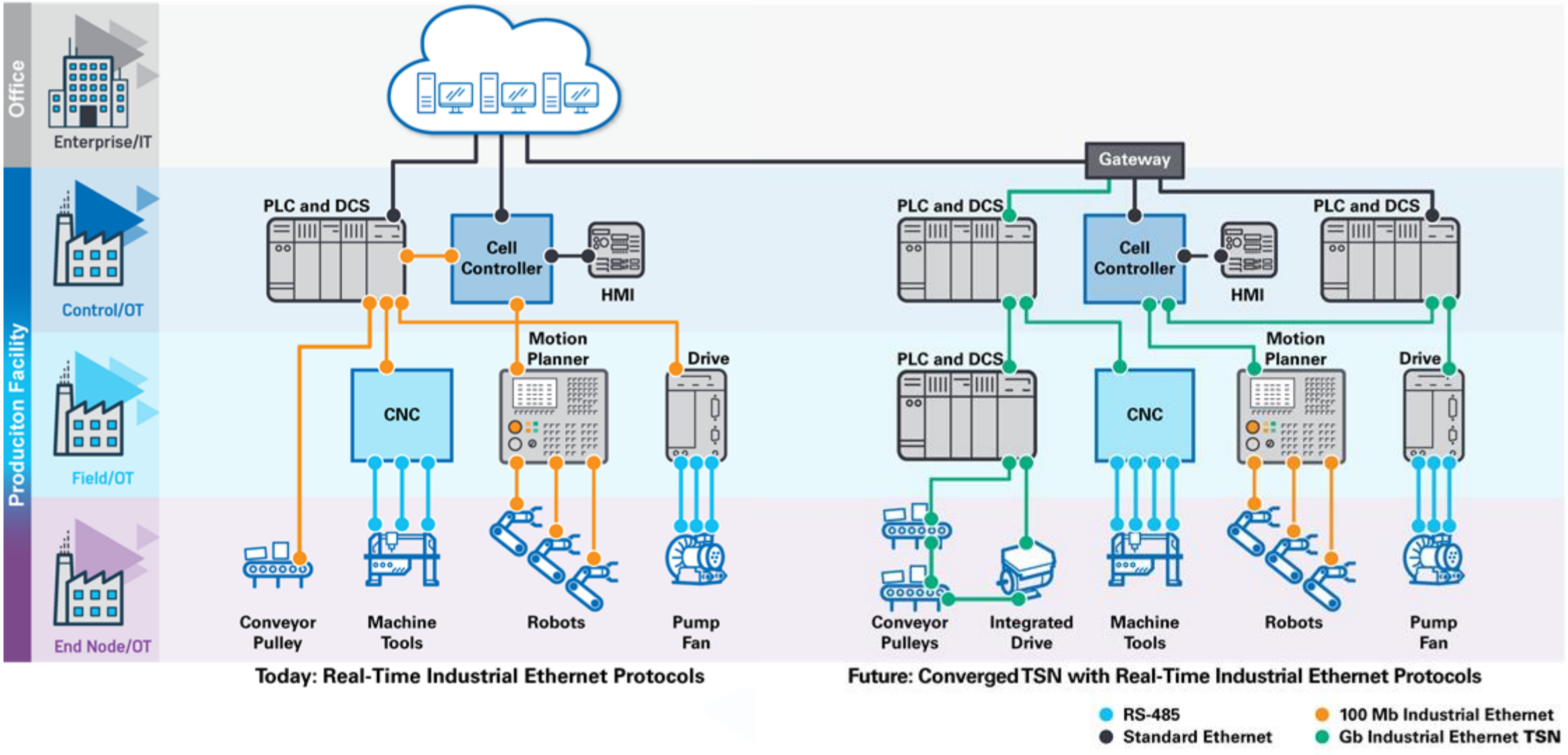
ADIN1200 / ADIN1300 Robust, Industrial, Low Latency, Low Power Ethernet PHY

- ADIN1300 10/100/1000 Gigabit PHY
  - Robust Temperature Range: -40 to 105C
  - Robust EMI / EMC / ESD performance
  - Small Footprint: 6x6mm 40-LFCSP
  - Low Power: 330mW
  - 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 : 139mW
  - Low Latency : 300ns Tx & Rx (MII)

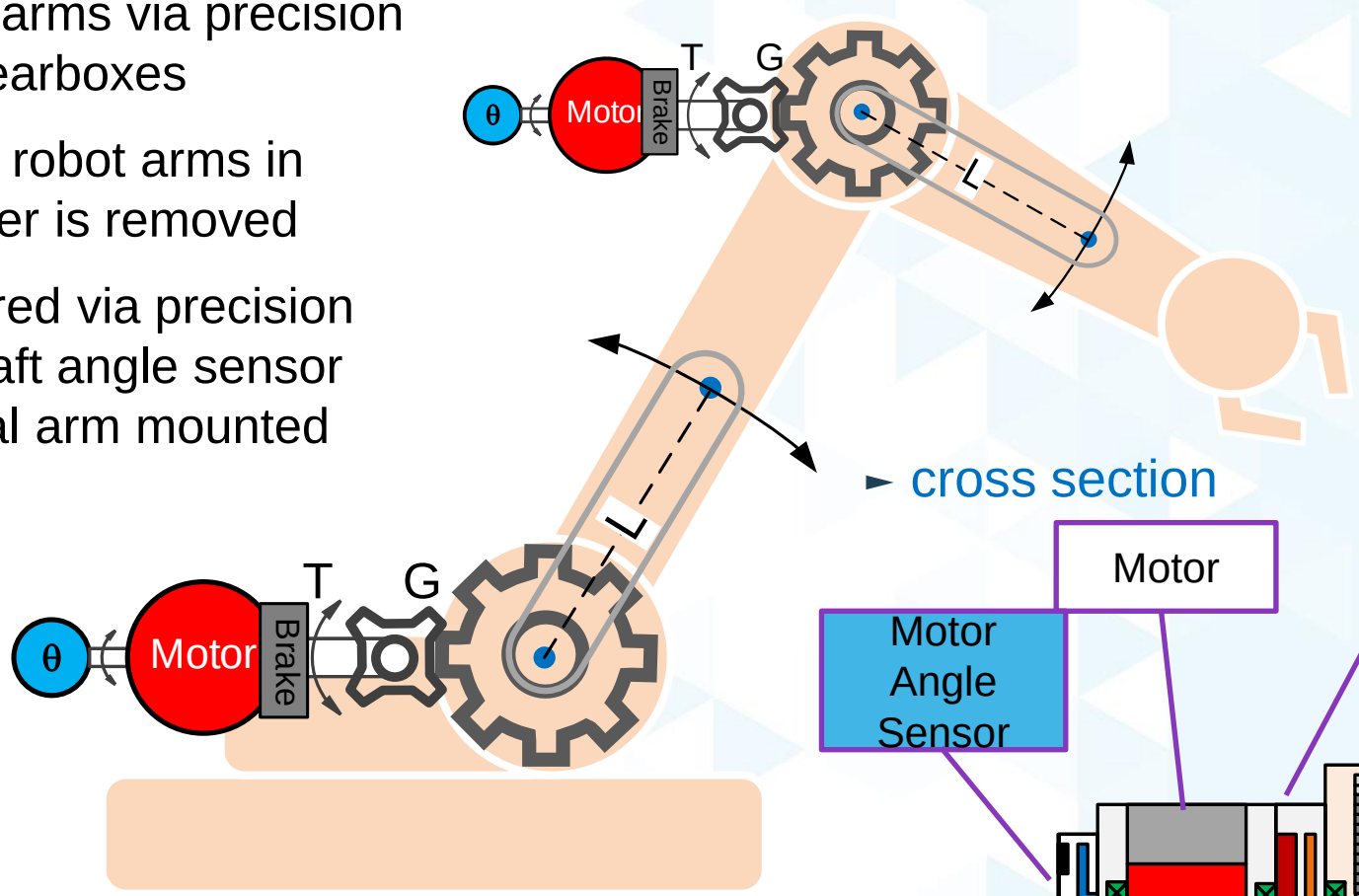
Generic	Package	Temp Range
ADIN1300 Gb PHY with RGMII	40 Lead LFCSP	-40C to 105C
	40 Lead LFCSP	-40C to 85C
ADIN1200 100M PHY	32 Lead LFCSP	-40C to 105C
	32 Lead LFCSP	-40C to 85C

Seamless, Edge-to-Cloud Connectivity Solutions
Connected Motion

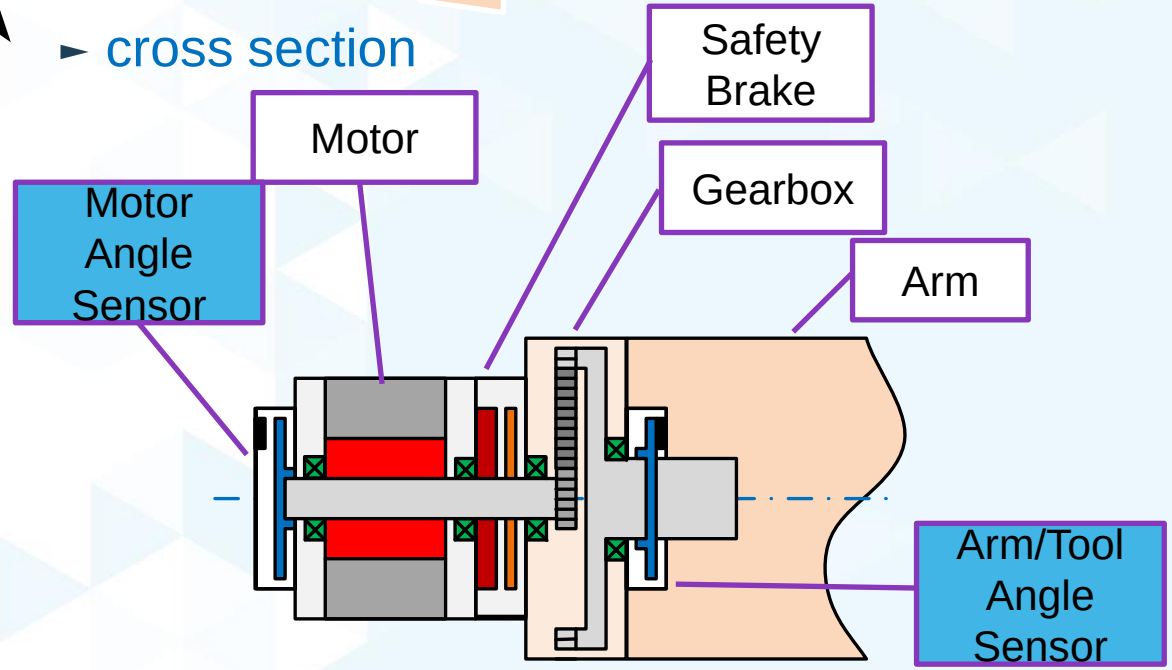


Encoders in the Robot Architecture

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

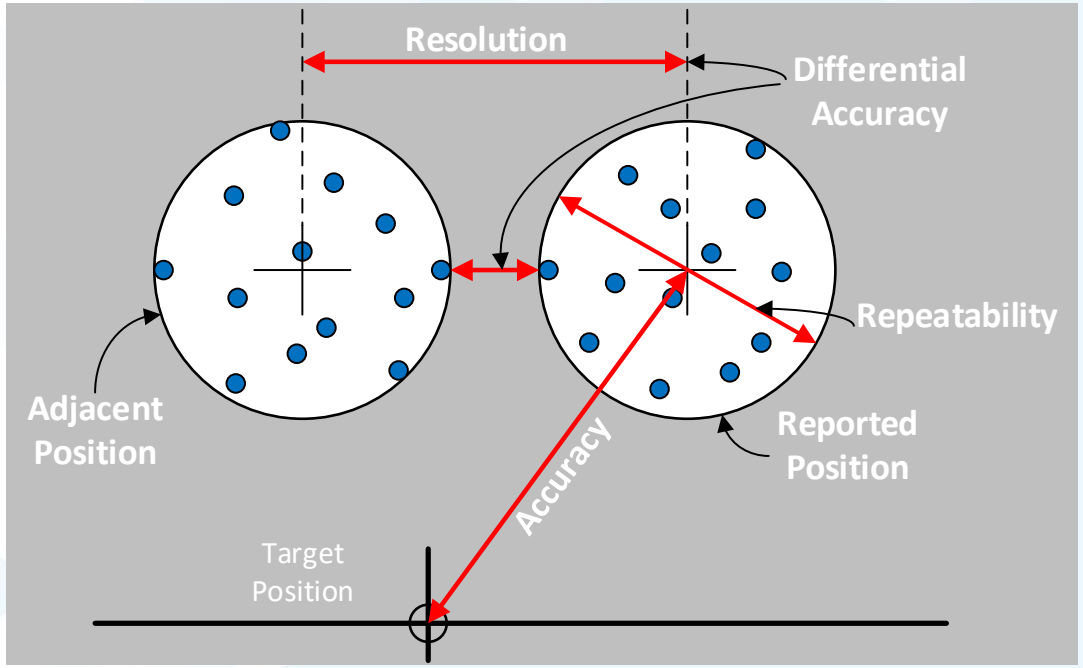


- cross section



Encoder Performance

- **Resolution**: The number of different positions (n) an encoder can distinguish per revolution.
- **Absolute accuracy**: The difference between the actual position and the reported position through 1 rotation (Like INL)
- **Differential accuracy**: The difference between the reported distance between two neighbored positions and the ideal distance between positions (Like DNL)
- **Repeatability**: How consistently the encoder returns to the same commanded position
- What is the most important?
  - **Resolution** is high in the decision process to select an encoder but it can be just a number.
    - Trend is higher resolution, higher accuracy but don't assume
  - Speed control applications dependent on **differential accuracy**
  - Absolute accuracy for positional control
  - Repeatability for repetitive tasks such as in robotics
  - With high repeatability, systems can be calibrated for high absolute accuracy

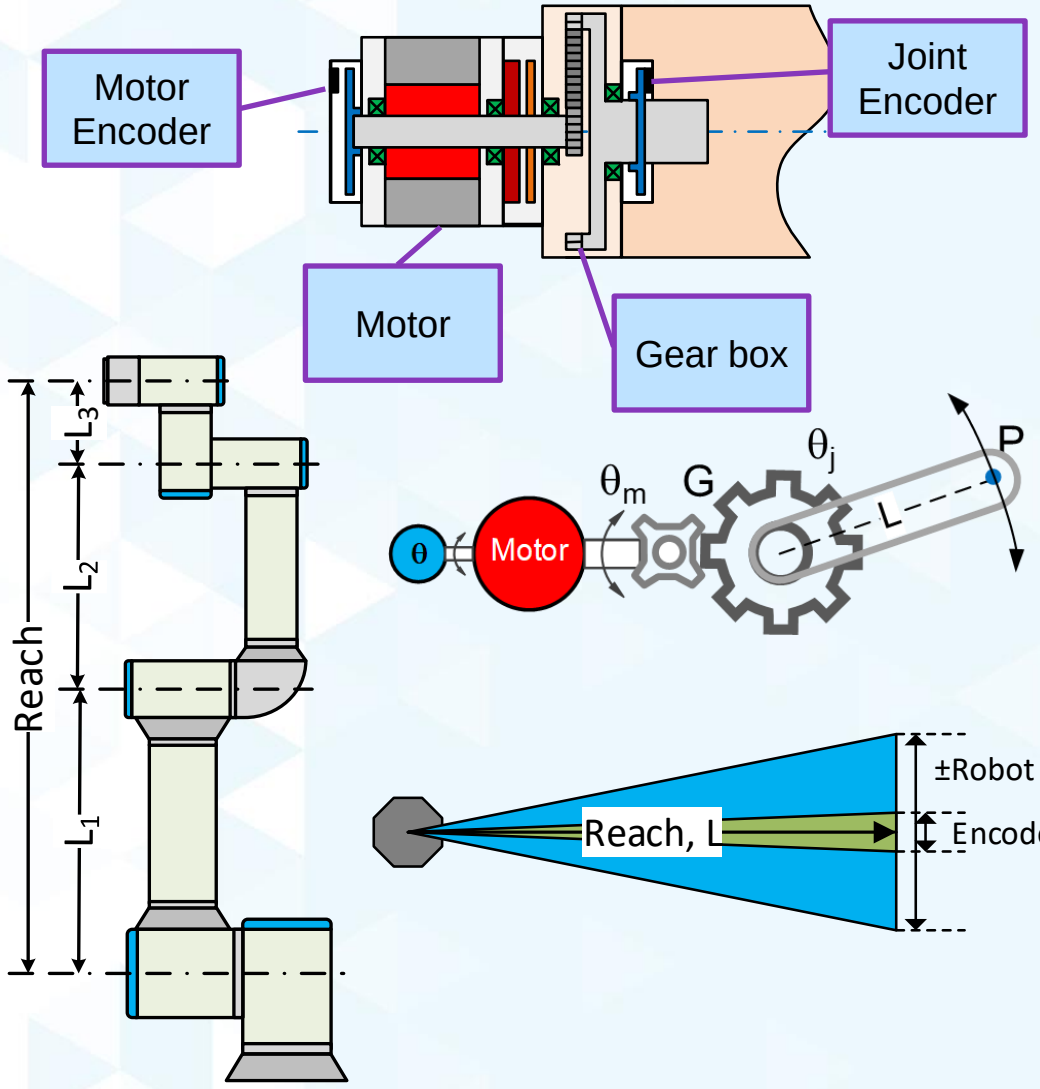


What Drives Accuracy and Repeatability?

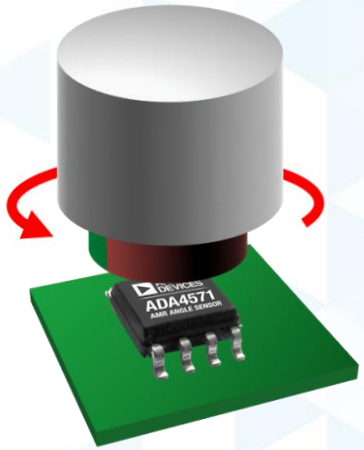
- Encoder requirements driven by robot repeatability spec
- Encoders on motor and joint
- Joints driven by motor using a gearbox
  - Typical gearbox ratios, G = 80 to 140
  - $\theta = \tan^{-1}\left(\frac{Repeatability}{Reach}\right)$
  - $\theta_j = \theta / n$
  - $\theta_m = \theta_j \times G$
  - Typical gearbox accuracy is 0.017°, prohibits motor encoder to achieve robot repeatability spec

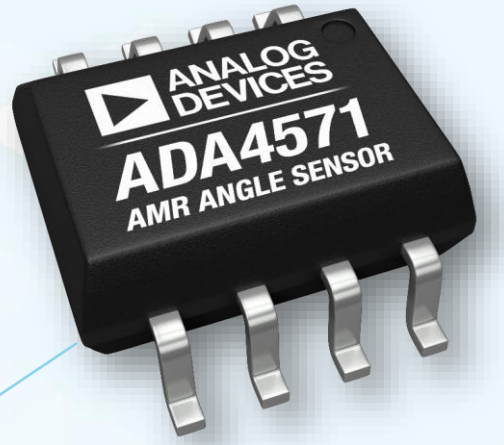
Robot System		Robot 1	Robot 2
Assumed Gear Ratio		100	
Repeatability Spec		±0.05mm	±0.01mm
Reach		1.30m	1.10m
Encoder Repeatability Spec	θ	0.0022°	0.0005°
	θ_j/10 *	0.00022° (~20-bit)	0.00005° (~22-bit)
	θ_m	0.02° (~14-bit)	0.005° (~16-bit)

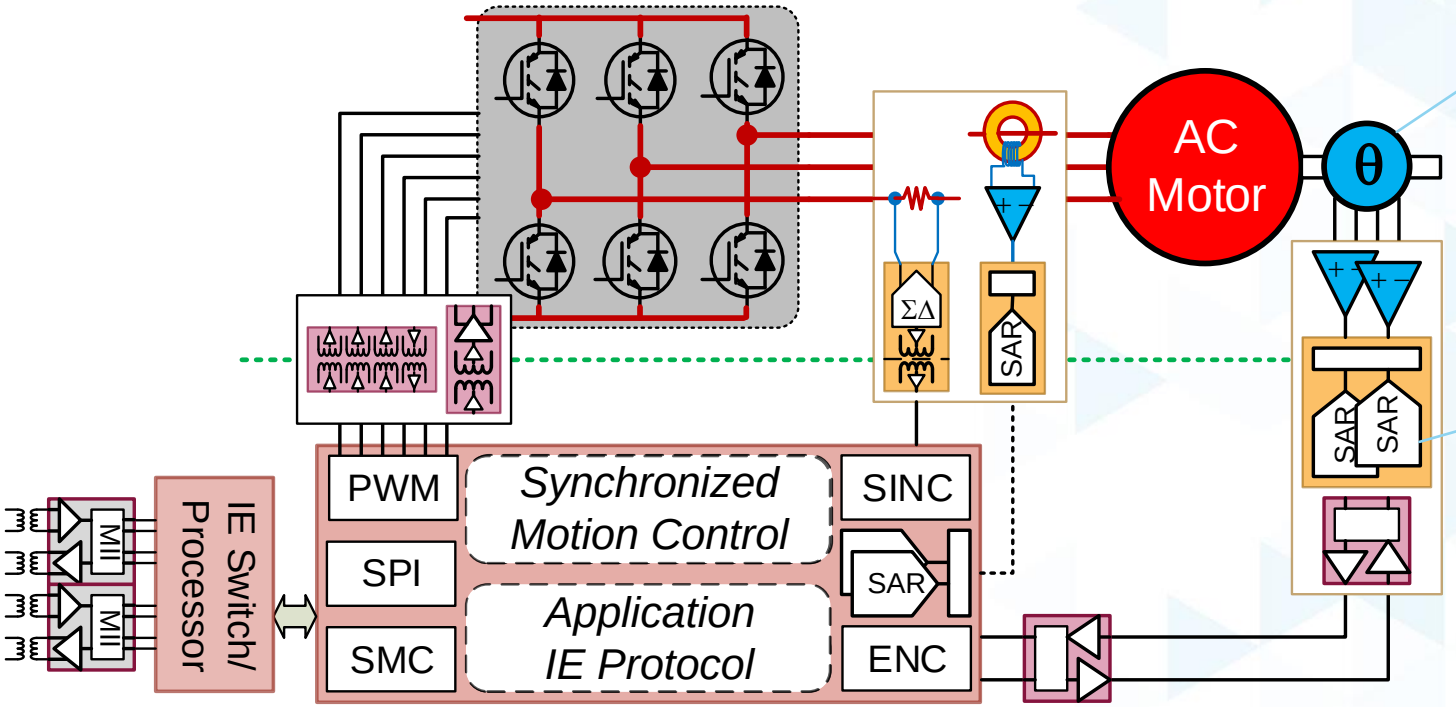
* individual encoder must be higher accuracy to achieve overall system accuracy as multiple joints



Optical and Magnetic Encoder Solutions







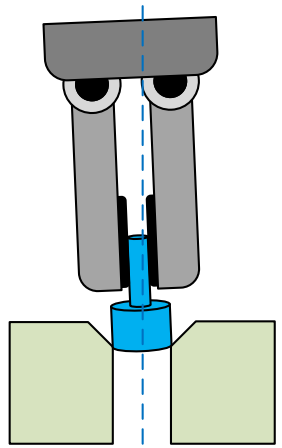
IEC 61800-5-3

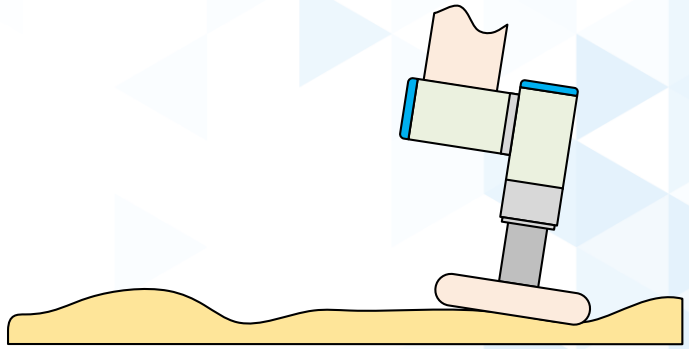
Robotics Force Sensing

- Legally collaborative robots require power and force limiting (PFL)
  - Force limits outline in ISO/TS 15066
  - Limits dependent on
    - Contact type, Quasi-static or Transient
    - Region on body

- At the application level, force sensing increases efficiency, improves quality & control
  - Improve process quality
  - Reduce cycle time
  - Improves precision
  - Increase life of process tools

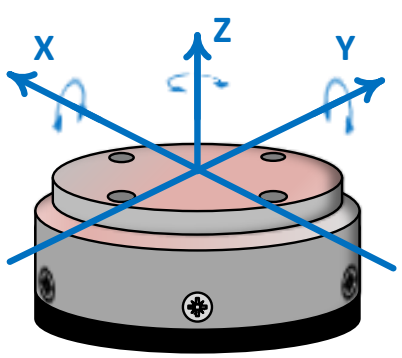
Body Region	Specific area	Maximum Permissible Force	
		Quasi-static contact	Transient contact
Skull and forehead	Middle of forehead	130	260
	Temple	130	260
Face	Masticatory muscle	65	130
Back and shoulders	Shoulder joint	210	420
	Fifth lumber vertebra	210	420
…	…	…	…

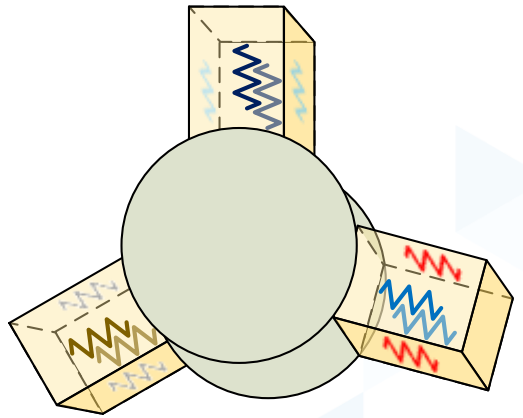


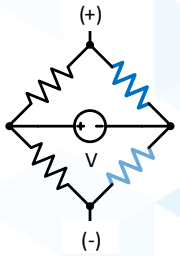


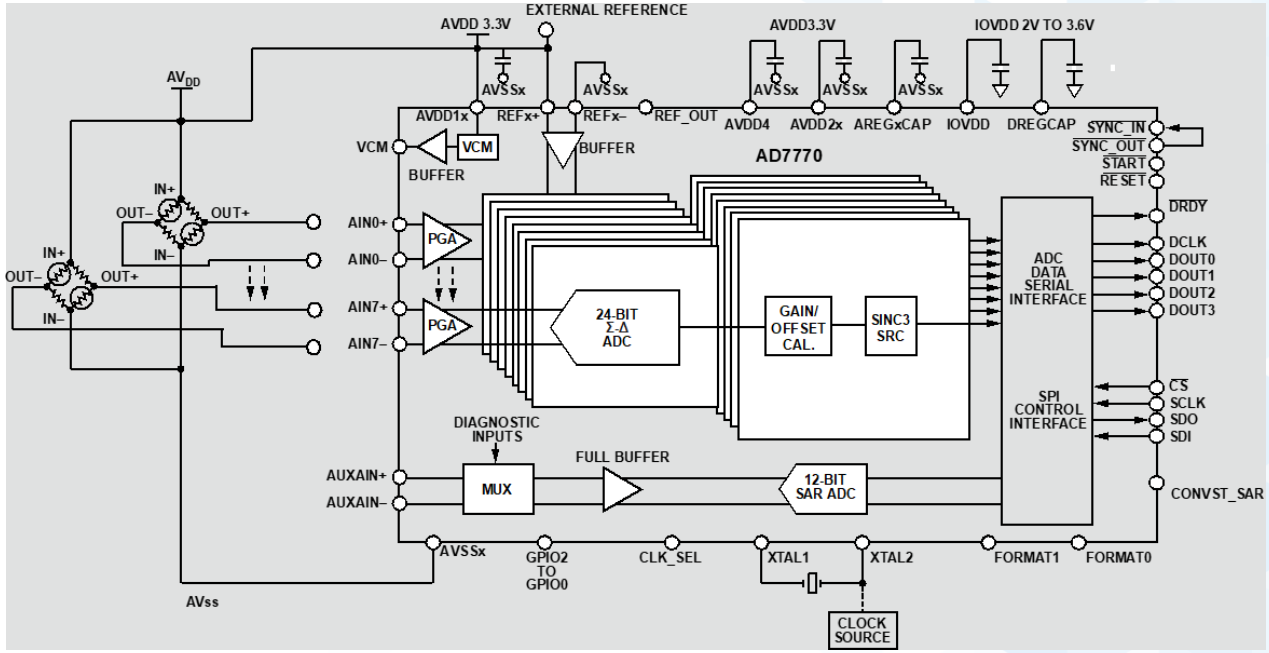
6 Axis Force Torque Sensor

- Strain gauge 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
  - Low kHz sampling
- AD777x
  - 8x sim sampling
  - Integrated PGAs, 1x, 2x, 4x, 8x
  - Configurable filters









Technologies Fueling Robotics Revolution

Further Information

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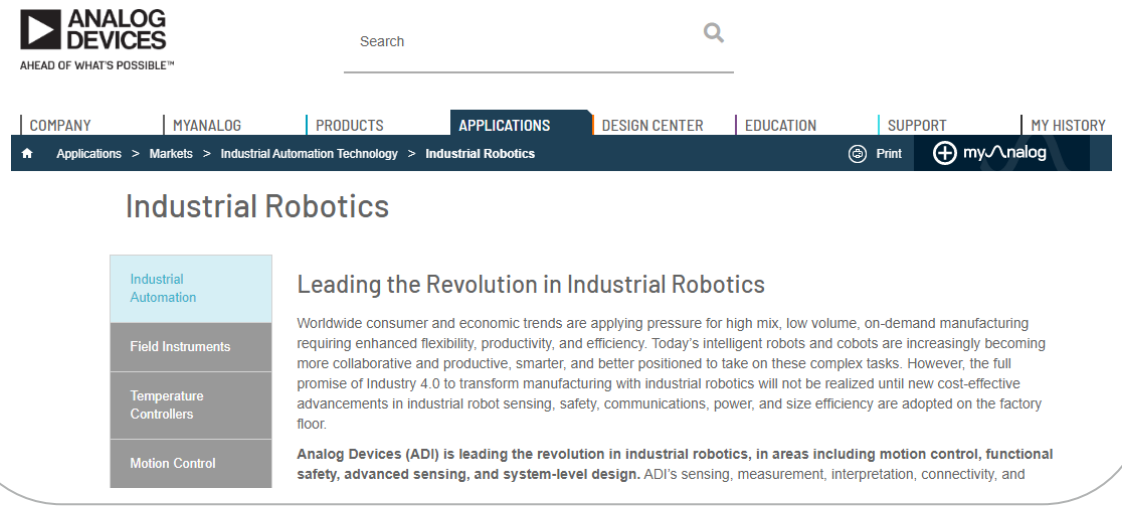

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Thank You!

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