

恩智浦N-AFE模拟前端产品在工业自动化中的应用

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NXP FAE
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SECURE CONNECTIONS
FOR A SMARTER WORLD

PUBLIC

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OVERVIEW

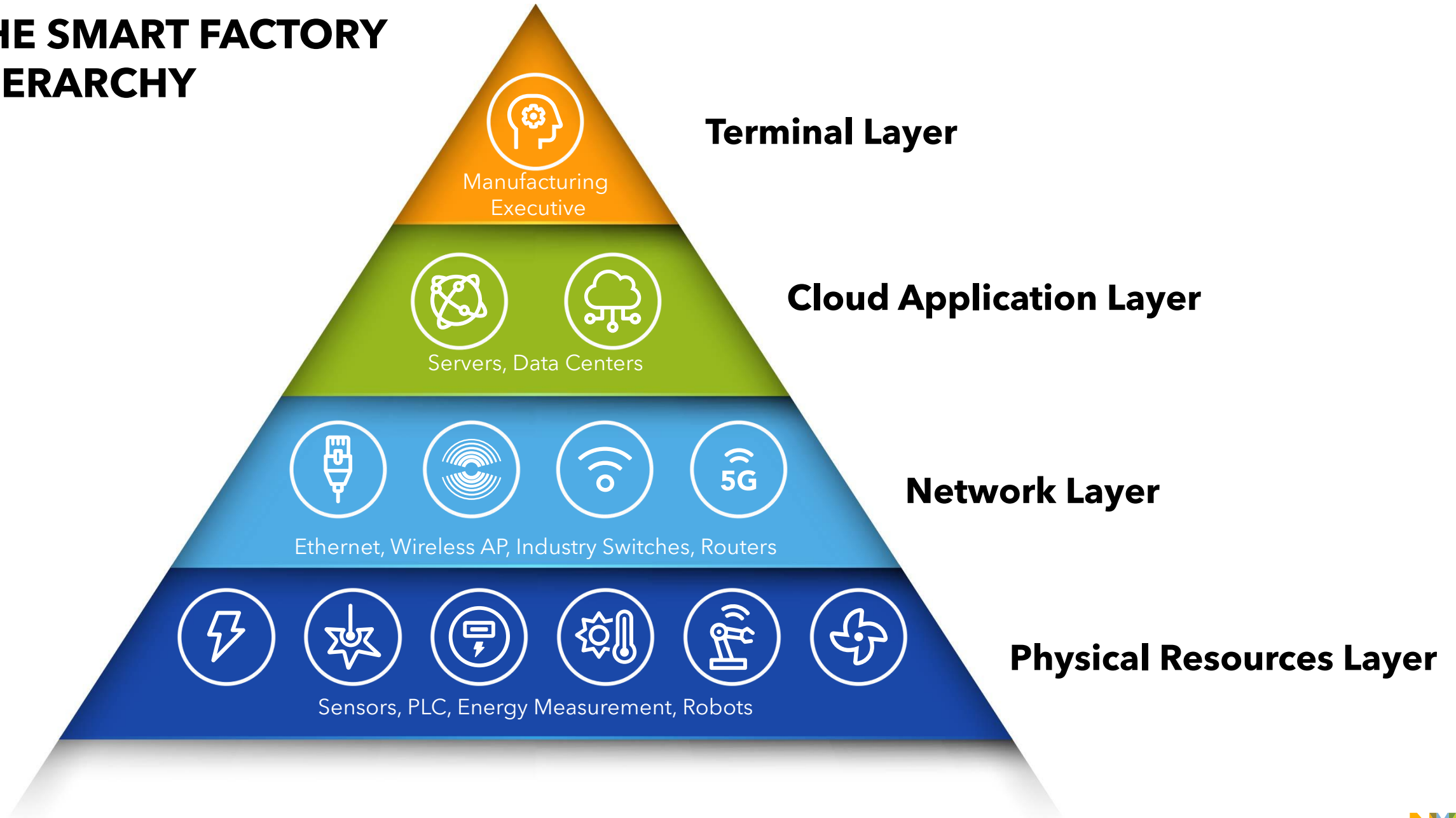
Smart factory and the need of a software-defined factory

New NXP analog front-end enables the software-defined factory

N-AFE enhanced diagnostics enable predictive maintenance

NXP system solutions for smart factory

THE SMART FACTORY HIERARCHY





World population to grow
2 billion by 2050



Smart factories needed to
meet the market demands

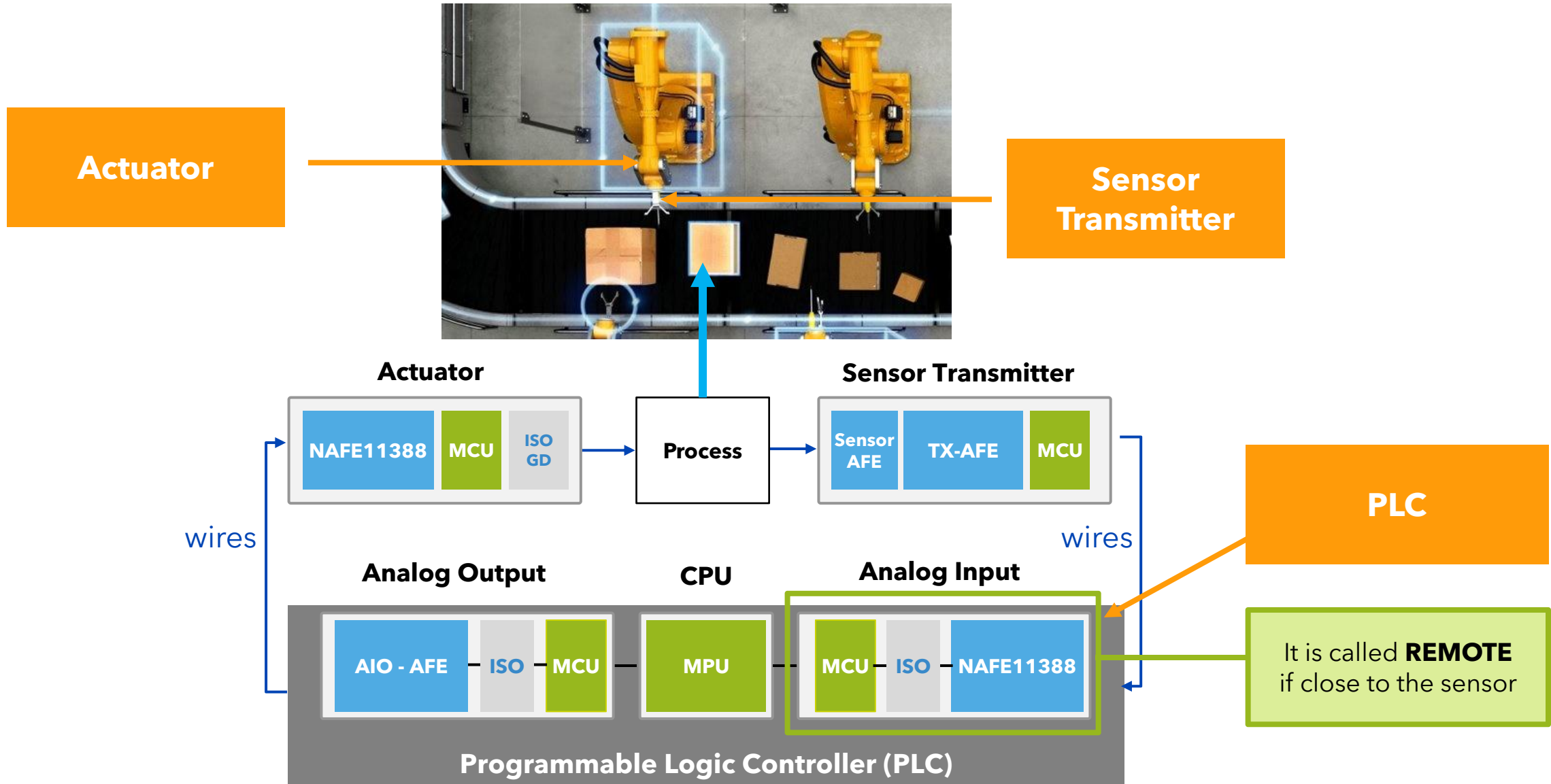


Smart factories estimated to grow
US\$214.2 billion by 2026

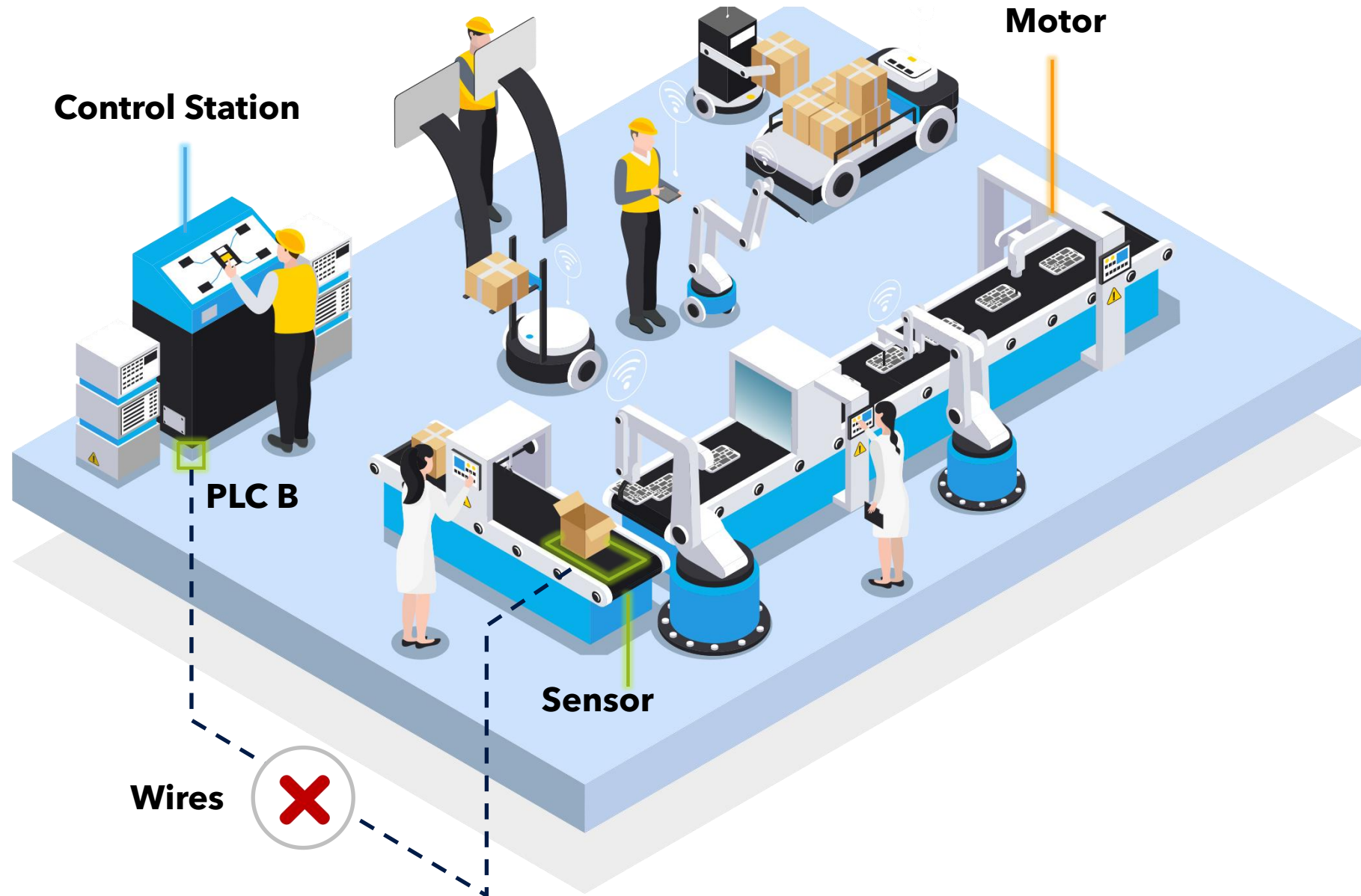


Flexible automation
offers manufacturers much-needed resilience in an ever-changing environment

AFE AND EP ENABLE THE SMART FACTORY



EXAMPLE OF SMART FACTORY





BUILD UNIQUE AFE FOR DIFFERENTIATED CUSTOMERS' SYSTEMS

Most flexible AFE architecture

Enables software-configurable universal input in a small package

High integration

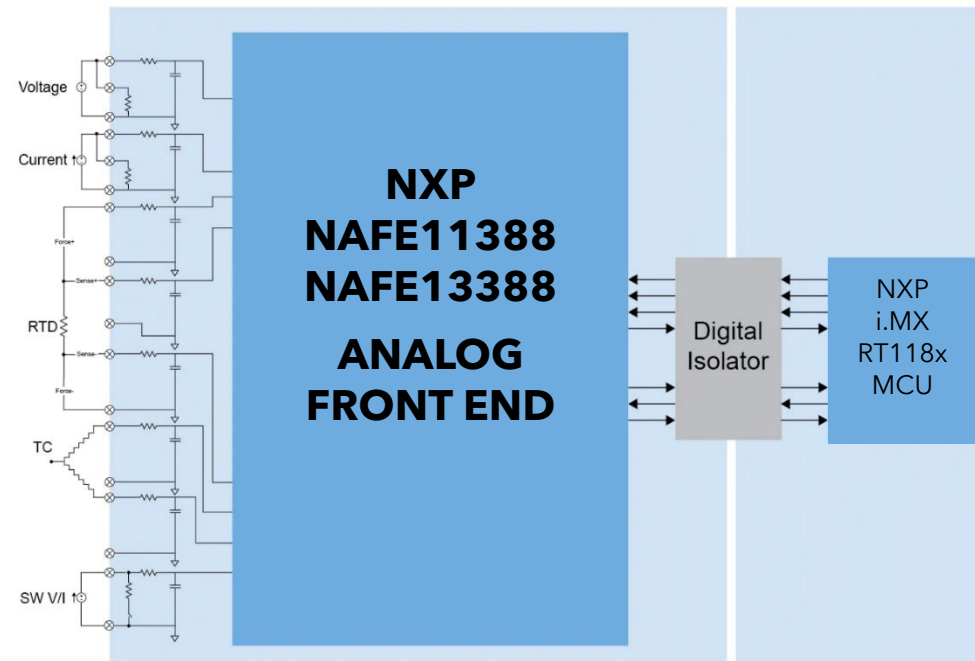
Reduces system cost

Superior accuracy, precision, and speed

Provides superior measurements performance

Unique and advanced diagnostic circuitry

Enables FuSa, anomaly detection and failure prediction



MOST FLEXIBLE AFE ARCHITECTURE



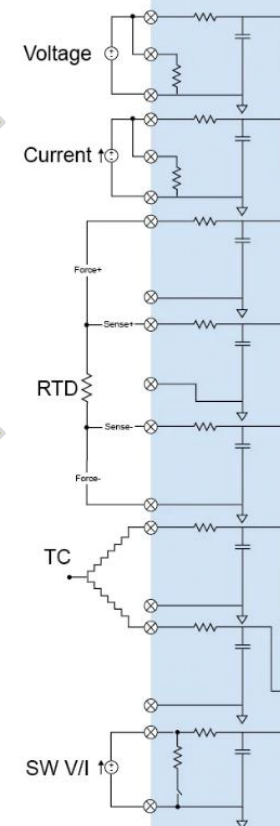
Analog input modules

Several versions according to the sensors type

0.15 V to 12.5V
Input Range

Channels configured
via SPI

8 kV HBM ESD IEC61000-
4-5 2 kV Surge protection

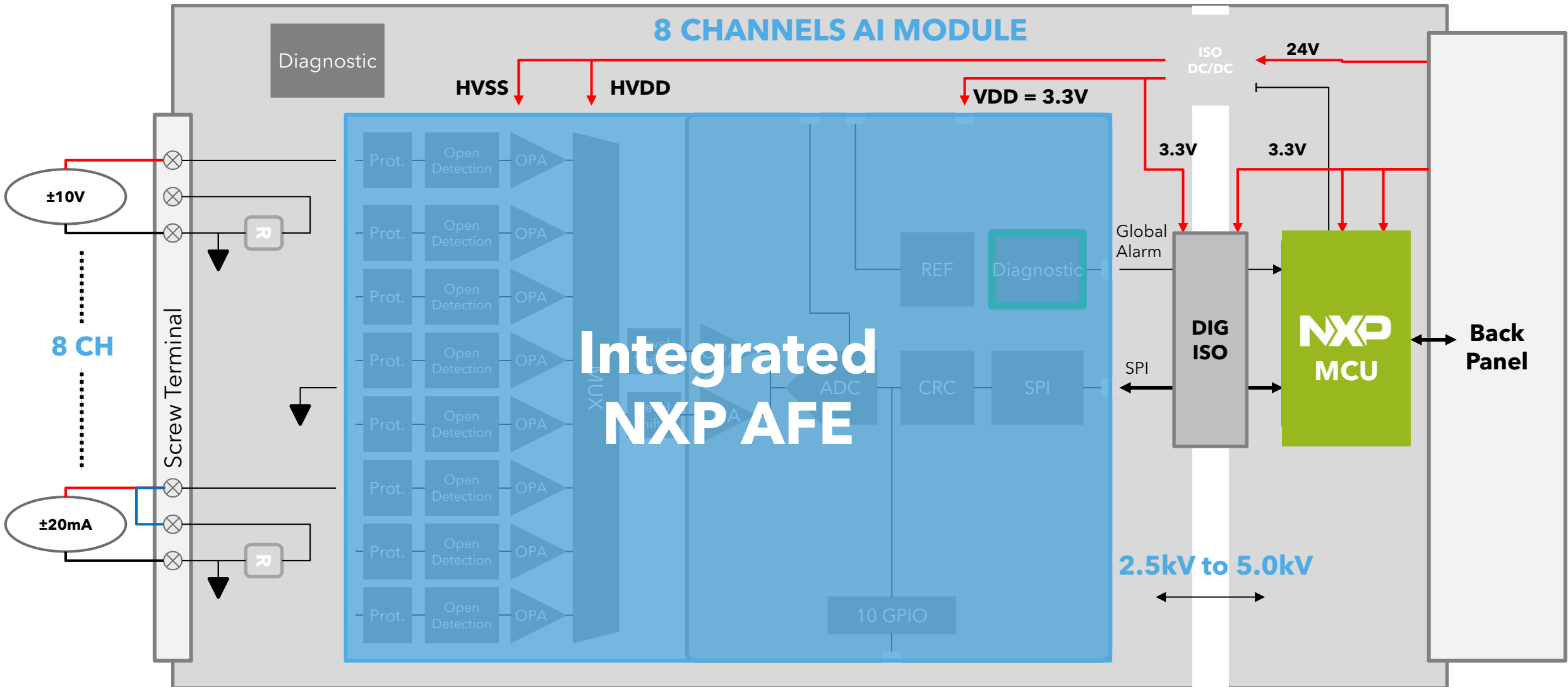


NXP
NAFE1138
ANALOG
FRONT END

Universal input AFE

Each of the 8 channels is compatible with all sensors

AI MODULE - NXP OFFERINGS (AFE + MCU)

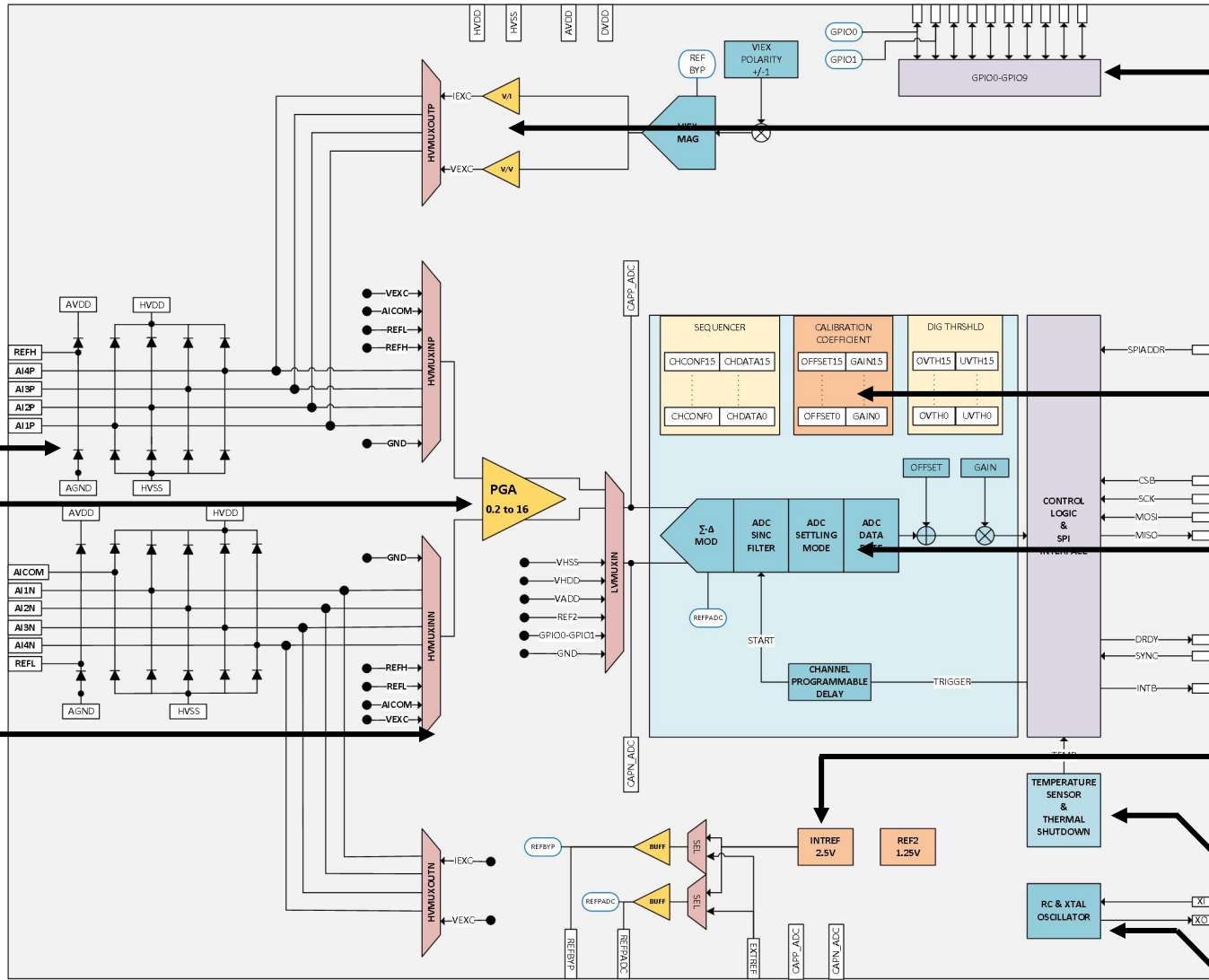


NAFE SERIES: WHAT'S INSIDE

8 high voltage Protected inputs and software configurable

0.2x to 16x low noise PGA

Two HV, low leakage MUX with diagnostic signals inputs



10 GPIOs

Voltage/current excitation with positive and negative polarity

Calibration registers with factory calibration option

24 bits $\Sigma\Delta$ ADC with digital filters

Internal voltage reference with 2 voltage sources for self calibration

Independent digitized temperature sensor

Oscillator with low power and high speed option

NAFE IN NUMBERS

Distinctive features

- 8 configurable HV inputs
 - Single ended or differential, with ranges up to +/-25 V
 - Configurable for voltage, current, resistance, RTD, Thermocouples
 - Over-voltage protected up to +/-36 V
- Fast Data Rate
 - **NAFE11388: 7.5 SPS to 288 kSPS**
 - **NAFE71388: 15SPS to 576 kSPS**
 - Simultaneous 50Hz/60 Hz line rejection
- Excitation Source
 - **NAFE13388 / NAFE73388**
- High Accuracy
 - ±0.01 % accuracy at room
 - ±0.05 % accuracy over temperature
 - ENOB:
 - **NAFE11388: 17-bit at 72 kSPS / 24-bit at 30 SPS**
 - **NAFE71388: 17-bit at 144 kSPS / 24-bit at 50 SPS**
- System Calibration
 - End-to-end calibration with integrated precise voltage sources
 - Accurate digitally calibrated products are available

- Full readout +/-3 °C accurate temperature sensor
- 0.2 % accuracy for internal oscillator
- Diagnostic system for faults detection and prediction
- CRC error detection
- 10 GPIOs
- 30 MHz SPI Interface
- 8 kV HBM ESD and IEC61000-4-5 2 kV Surge protection
- Power supply: HV: ±7 V to ±24 V, LV: 3.3 V
- Operating temperature range TA: -40 °C to 125 °C
- Package: 64 pin, 9 mm x 9 mm x 0.85 mm VQFN



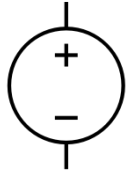
Product **Longevity**

Product Longevity |
NXP Semiconductors

THE GOAL OF NXP'S PRODUCT LONGEVITY PROGRAM:

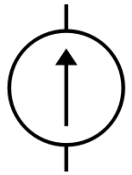
TO ENSURE A STABLE SUPPLY
OF PRODUCTS FOR YOUR
EMBEDDED DESIGNS

UNIVERSAL INPUT CONFIGURATION CHALLENGES



VOLTAGE
0-10 V

requires high input voltage range up to 12.5 V



Current
0-20 mA

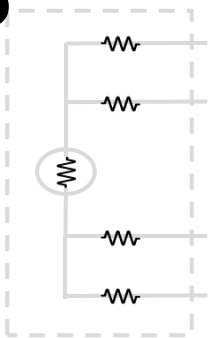
Requires reading currents from 0 to 20 mA with 0.2 % accuracy FS. $R_{sense} = 50 \Omega$
Minimum voltage level 2mV
12 bits resolution is enough

TC



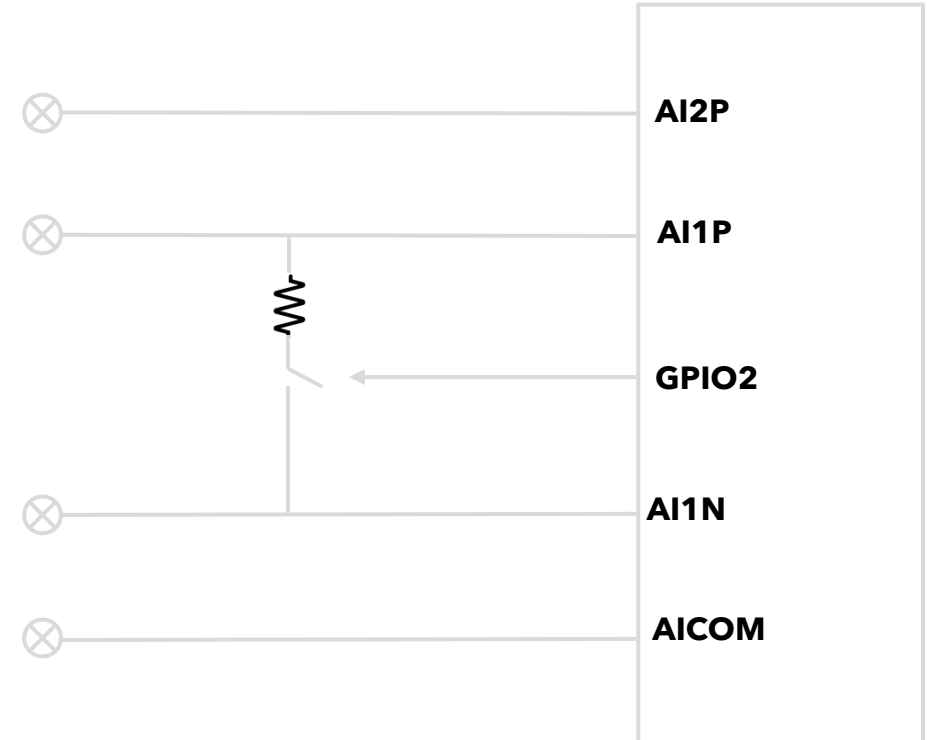
Example: K-Type
-270 to 1370 °C
16 bits resolution is enough
1 °C Accuracy Needs Noise < 2µVRMS

RTD



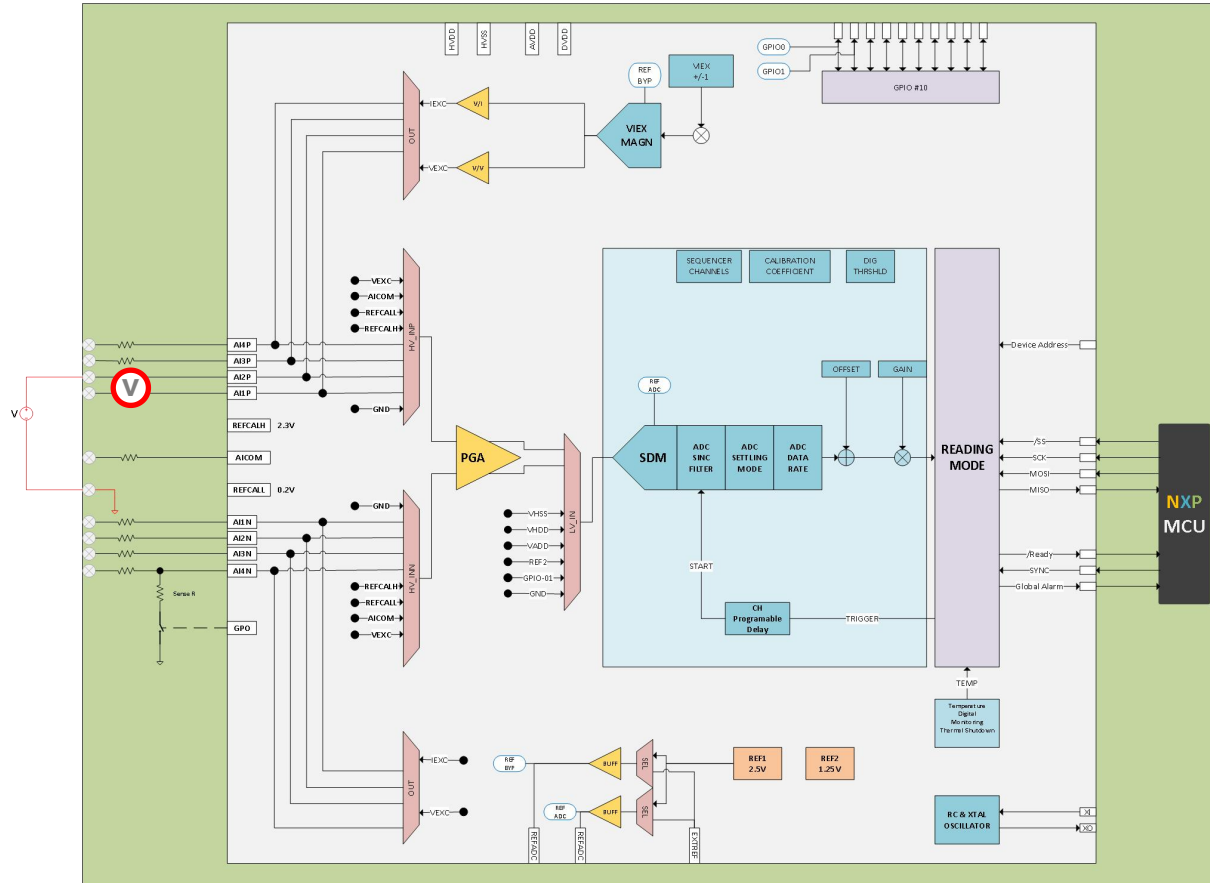
Pt100: -200 to 800 °C
100 µA excitation current
0.5 °C accuracy requires 11 bits but Noise < 22 µVrms
0.1 °C accuracy requires 13 bits but Noise < 4 µVrms

CHALLENGE: 10 V and 2 µVRMS Noise need to be supported by the signal chain

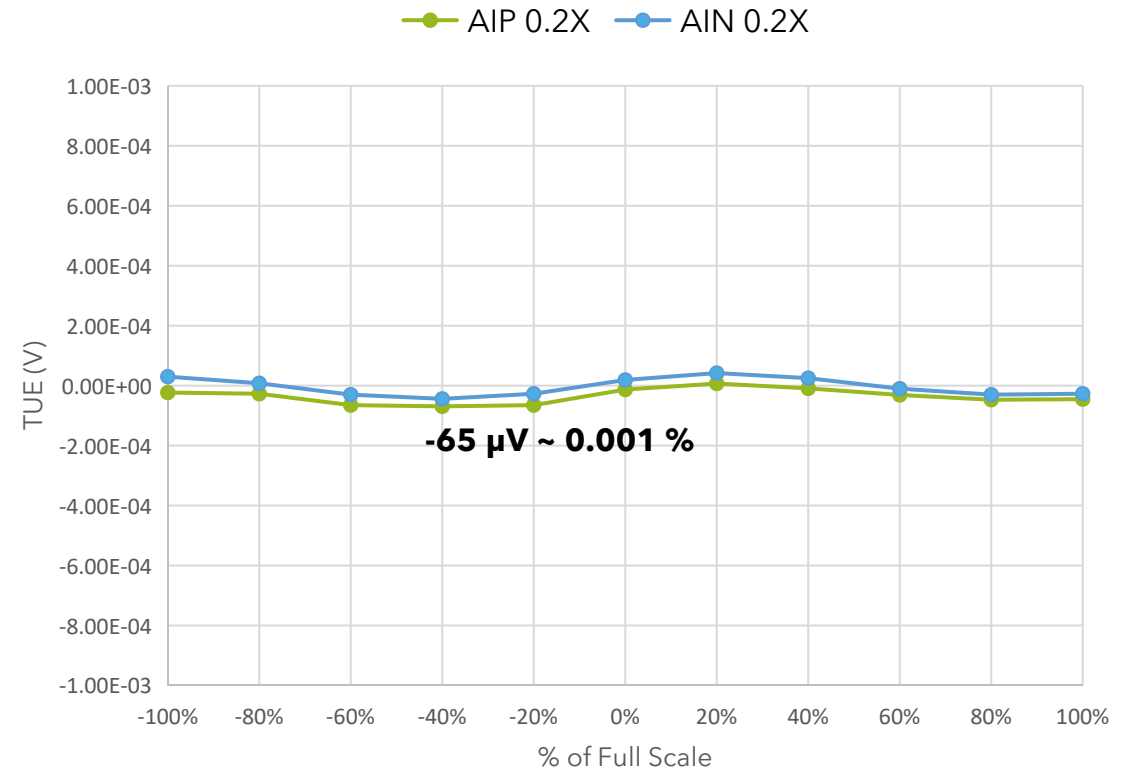


180 db
Dynamic Range

TUE AND INL @ ±10 V RANGE ROOM TEMPERATURE

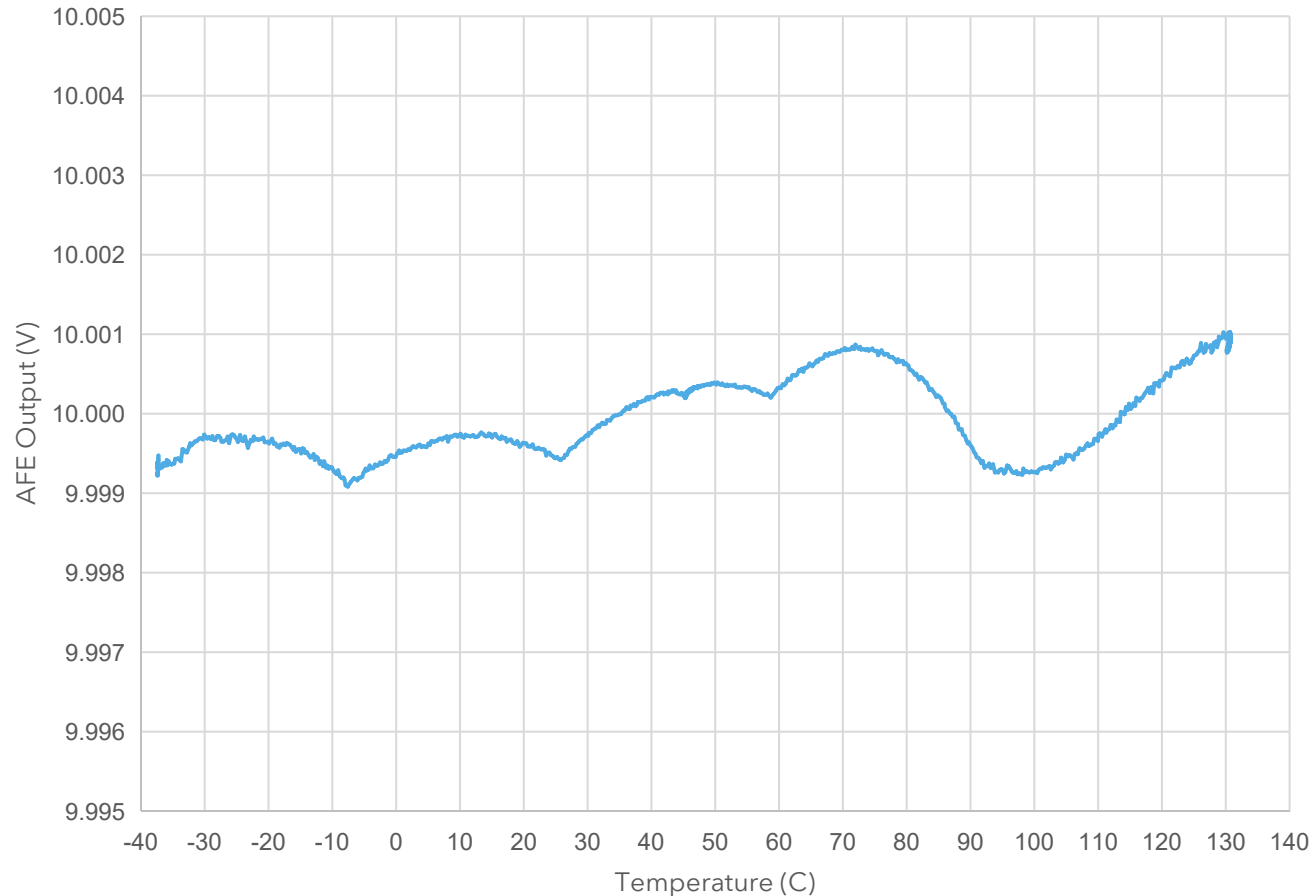


Total Unadjusted Error @ ±10 V Range



TEMPERATURE COEFFICIENT CORRECTION TCC IMPROVES GAIN DRIFT OVER TEMPERATURE

TEMPERATURE DRIFT TEST
Temperature Coefficient Compensation (TCC) Enabled



End to End Accuracy

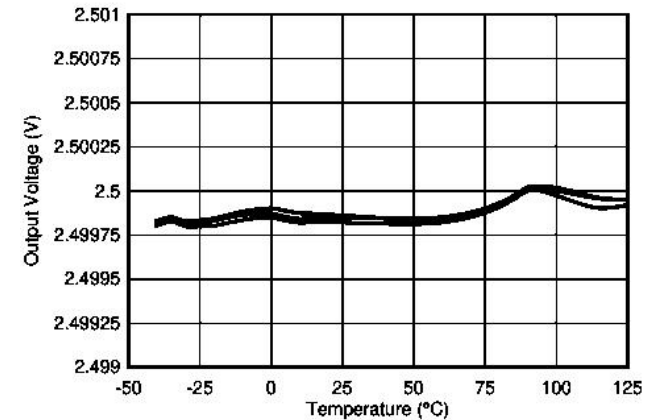
Voltage Error = +/-1 mV @ 10 V

TUE = 0.01 % over 165 °C

Temp Coefficient = 0.6 ppm/C

Internal Voltage Reference Included

High Precision Standalone VREF



VOLTAGE AND CURRENT EXCITATION

Excitation Enables:

- resistance measurement
- biasing of RTD
- Ratiometric measurement
- built-in self-test (BIST)
- self-monitoring channel readback

Open Detection:

The excitation block includes a dedicated **65 nA** current source, for open detection on the selected AI channel. The open detection allow detect a **missing or broken wire** in the sensor connection

VIEX CHOP:

The source polarity is inverted automatically. The Common mode voltage of the sensing circuitry is removed by averaging the difference of two ADC conversions

Voltage Excitation
 $\pm 6 \text{ mV to } \pm 12 \text{ V}$
Current Excitation
 $\pm 1 \text{ } \mu\text{A to } \pm 2 \text{ mA}$

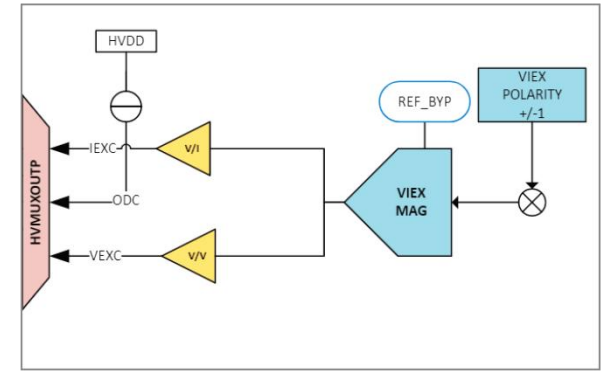


Table 15. Programmable excitation V/I source: DAC code, magnitude, and polarity

Polarity bit = 0			Polarity bit = 1		
DAC code	VEXC Magnitude (V)	IEXC Magnitude (A)	DAC code	VEXC Magnitude (V)	IEXC Magnitude (A)
0	0.000	000.0E+0	0	0.000	000.0E+0
1	0.006	977.0E-9	1	-0.006	-977.0E-9
2	0.012	2.0E-6	2	-0.012	-2.0E-6
3	0.023	3.9E-6	3	-0.023	-3.9E-6
4	0.047	7.8E-6	4	-0.047	-7.8E-6
5	0.094	15.6E-6	5	-0.094	-15.6E-6
6	0.188	31.3E-6	6	-0.188	-31.3E-6
7	0.375	62.5E-6	7	-0.375	-62.5E-6
8	0.750	125.0E-6	8	-0.750	-125.0E-6
9	1.500	250.0E-6	9	-1.500	-250.0E-6
10	2.250	375.0E-6	10	-2.250	-375.0E-6
11	3.000	500.0E-6	11	-3.000	-500.0E-6
12	4.500	750.0E-6	12	-4.500	-750.0E-6
13	6.000	1.0E-3	13	-6.000	-1.0E-3
14	9.000	1.5E-3	14	-9.000	-1.5E-3
15	12.000	2.0E-3	15	-12.000	-2.0E-3

DIAGNOSTIC FUNCTIONS

REFH / REFL



- Drift during PCB assembly process
- Component and board aging
- Predictive maintenance

2nd Independent Reference



- REF_Coarse allows checking VREF drift, not detectable because same reference of the ADC

Oscillator



- Quartz damage
- External sync frequency missing

Power Supply Check



- Anomalies after PCB assembly
- Bad soldering of the part
- Power supply failures

Voltage / Current Excitation



- Open / short detection at the inputs
- Check mounting and cable degradation

Temperature Monitoring



- Overtemperature warning at 145 °C
- User programmable temperature threshold

Input Signal Check



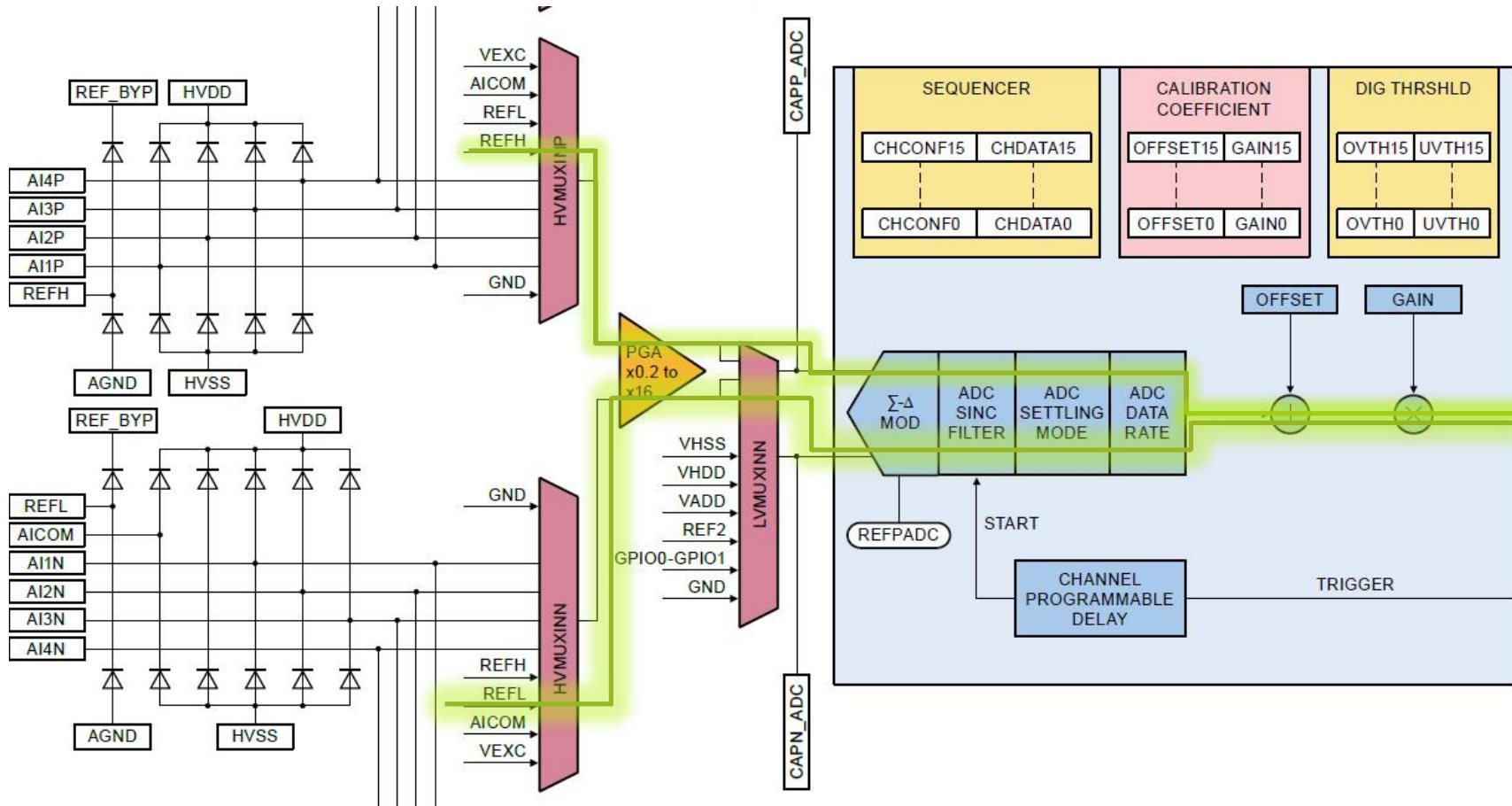
- Measurement out of user selectable range
- Input channel overload

SELF CALIBRATION FOR GAIN AND OFFSET

Table 12. Optional calibration registers

CAL REGISTER	NVM stored parameter	Nominal value
OPT_COEF0[23:0]	VREFP_ADC	2.496 V
OPT_COEF1[23:0]	REFH - GND	2.29632 V
OPT_COEF2[23:0]	REFL - GND	0.19968 V

±0.01% accuracy



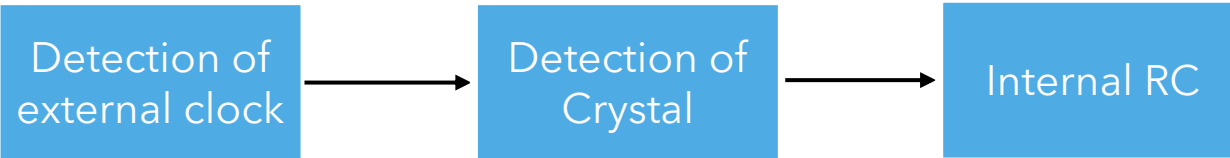
Accurate REFH / REFL dual function:

1. Self Calibration
2. Diagnostic by comparing the factory cal values with the measured ones

OSCILLATOR

The internal oscillator nominal frequency is 18.432 MHz.

Auto-selection upon power on

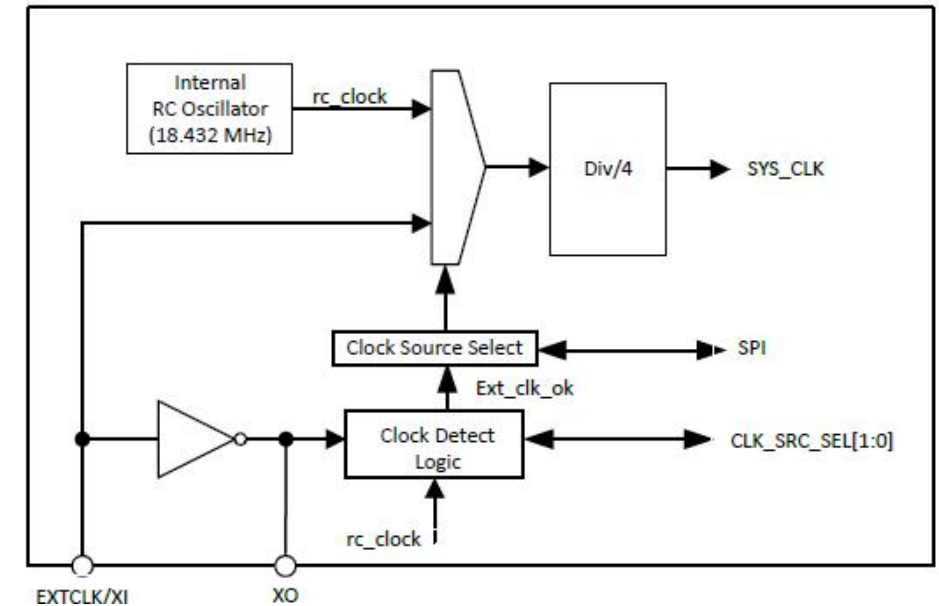


Clock Period Drift Detection

The clock running average on 128 ms (external or Crystal) is compared with the internal oscillator.

If there is a 20 % difference the Clock Alarm is issued.

NAFE Oscillator Architecture



MISWIRING PROTECTION

24 V Supply Applied to the inputs by mistake

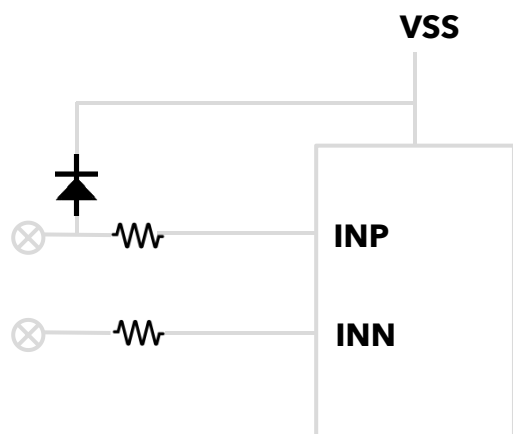
How to protect?

Option 1

Diode **before** the Resistance

Pro: no leakage on the input

Cons: no current limitation. VSS can go above the high level potentially destroying active components

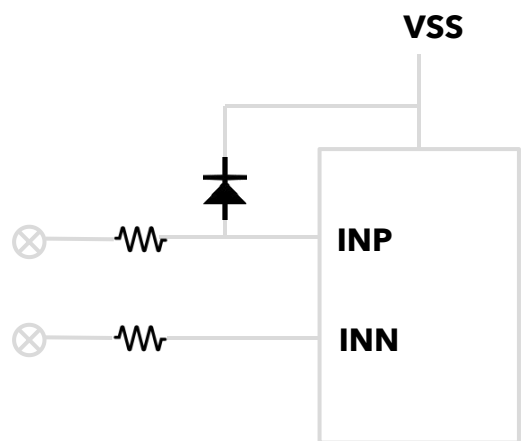


Option 2

Diode **after** the Resistance

Pro: current limited by the resistance

Cons: diode leakage affects the measurement

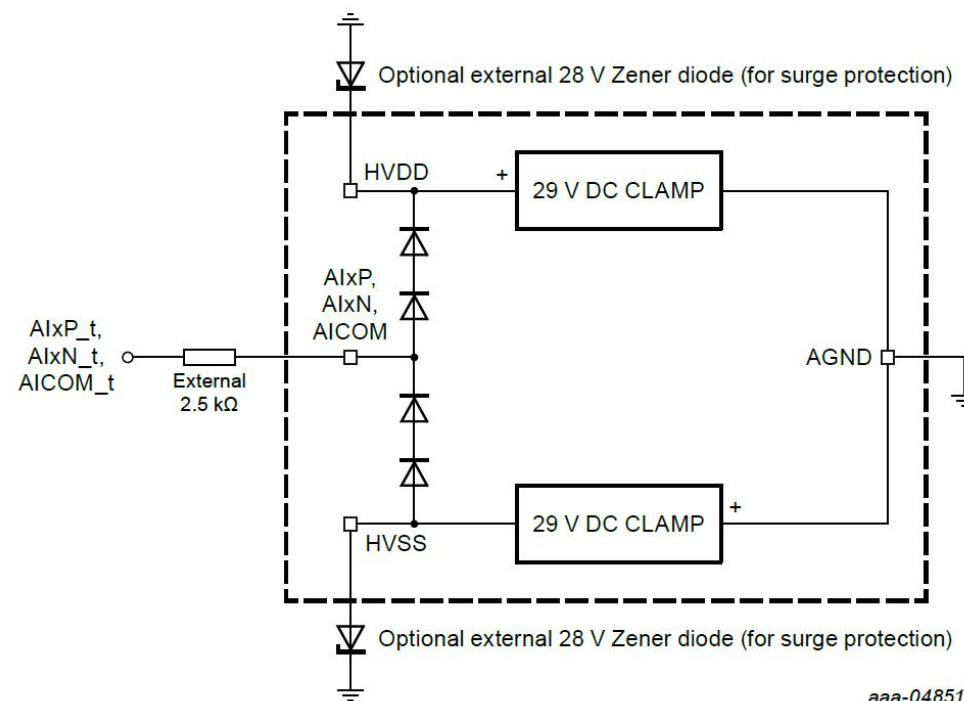


NAFE Option

Diode **after** the Resistance

Pro: current limited by the resistance

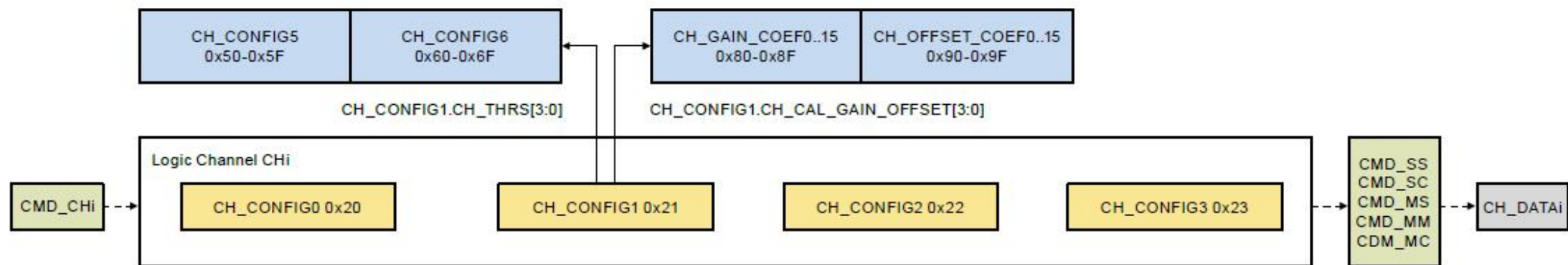
Pro: with a 1 nA at 105 °C leakage current of the integrated diodes, the measurement accuracy is preserved



8kV HBM ESD

and IEC61000-4-5 2kV Surge protection

16 VIRTUAL CHANNELS



Select logical channel (i)

Select high voltage input
Select channel gain
Select high or low voltage
Select low voltage input
Enable TCC

Select 1 of 16 pair of gain and offset coefficients
Select 1 of 16 over and under threshold
Select 1 of 29 data rates for ADC conversion
Select 1 of 4 SINC filters

Select the conversion channel delay
Select ADC settling (single/normal)
Select filter reset
Enable ADC high precision mode

Select excitation source: V/I
Select V/I polarity
Select V/I source magnitude 4-bit
Enable VEXC voltage output
Enable excitation 100 nA source
Enable two conversions with polarity chopping
Select excitation source to A1xP, A1xN inputs

aaa-049072

Select one of the 16 Logic Channels

Apply Channel Configuration

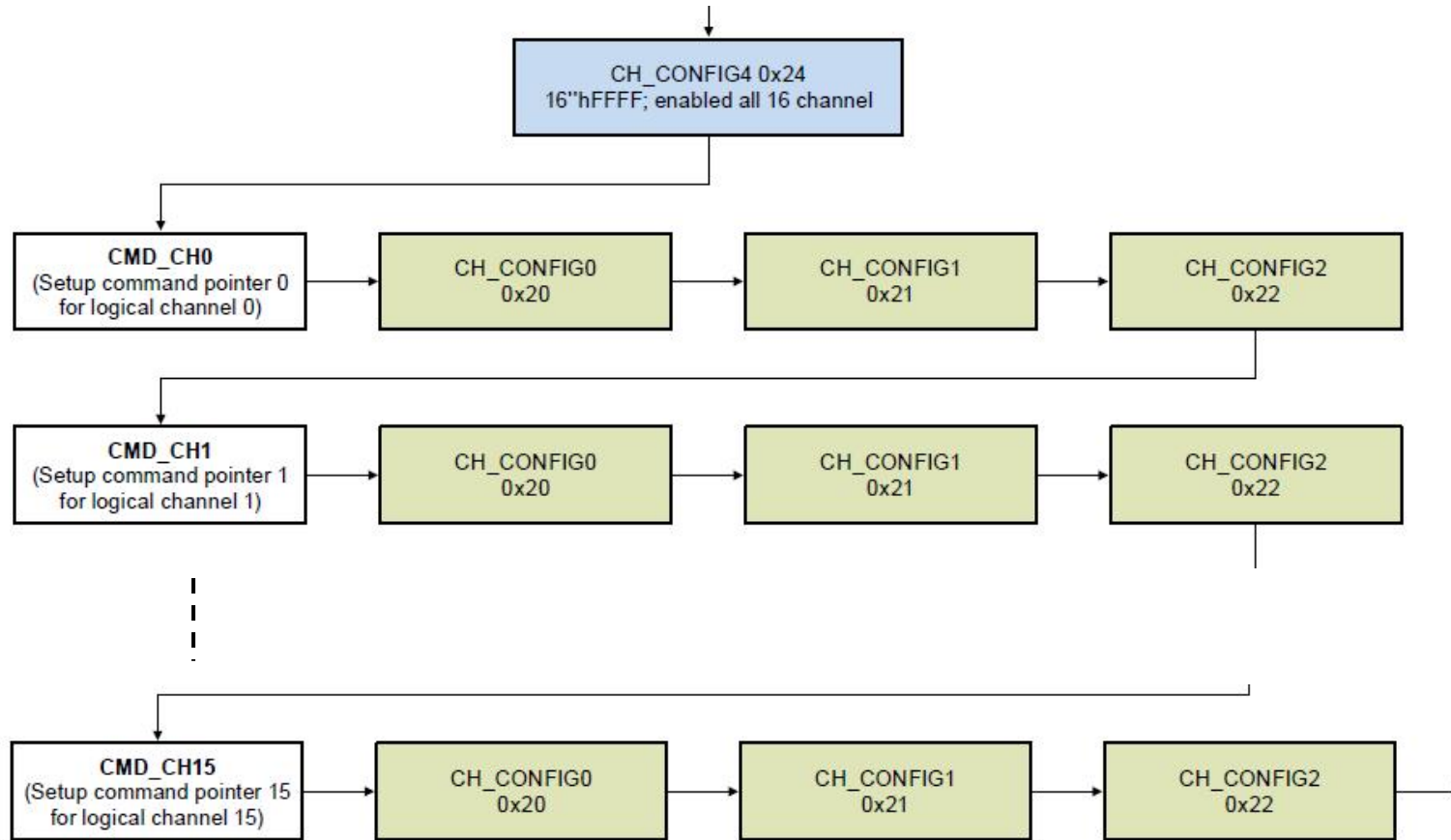
Select the reading mode

ADC Conversion is done applying the selected configuration

DATA is available in CH_DATA register

Once configured at startup, the channel configuration is stored in NAFE registers. The MCU does not need to write them at each conversion

SEQUENCER



CH_CONFIG4 register allows selecting the active logic channels

The sequencer loads the corresponding configuration for the selected channel before performing the conversion

The sequencer allows saving SPI transitions reducing MCU workload and avoids SPI speed issues.

NAFE PART NUMBER VARIANTS

NAFE**a****b****c****d****e**B40BS

a	b	c	d	e
<u>Power / Speed</u>	<u>V. Excitation</u>	<u>Factory Calibration</u>	<u>Resolution</u>	<u>Channels</u>
1= low power 7= high speed	1= no 3= yes	1= no 3= yes	4= 16 bit 8= 24 bit	4= 4 inputs 8= 8 inputs

Released Parts

NAFE11388: Low Power - No VIEX - Cal - 24 bits - 8 ch

NAFE71388: High Speed - No VIEX - Cal - 24 bits - 8 ch

NAFE13388: Low Power - VIEX - Cal - 24 bits - 8 ch

NAFE73388: High Speed - VIEX - Cal - 24 bits - 8 ch



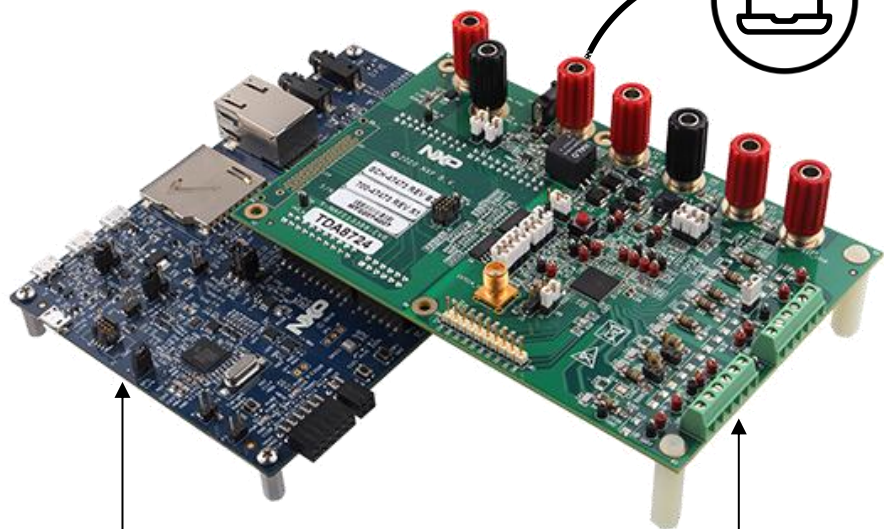
SYSTEM SOLUTIONS OVERVIEW

N-AFE SYSTEM EVALUATION KIT

KITNAFE11388-EVB

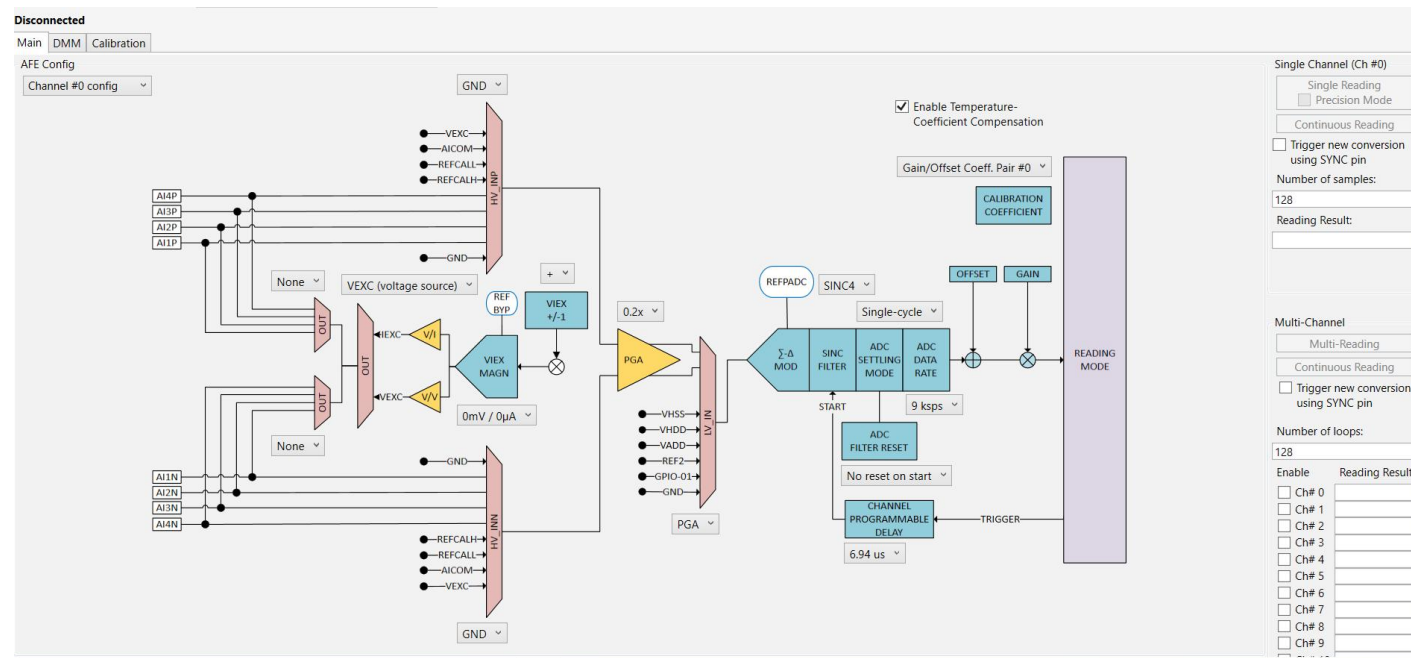
- NAFE1x388 / NAFE7x388 + LPC54
- AFE software drivers

Computer



LPC54

N-AFE

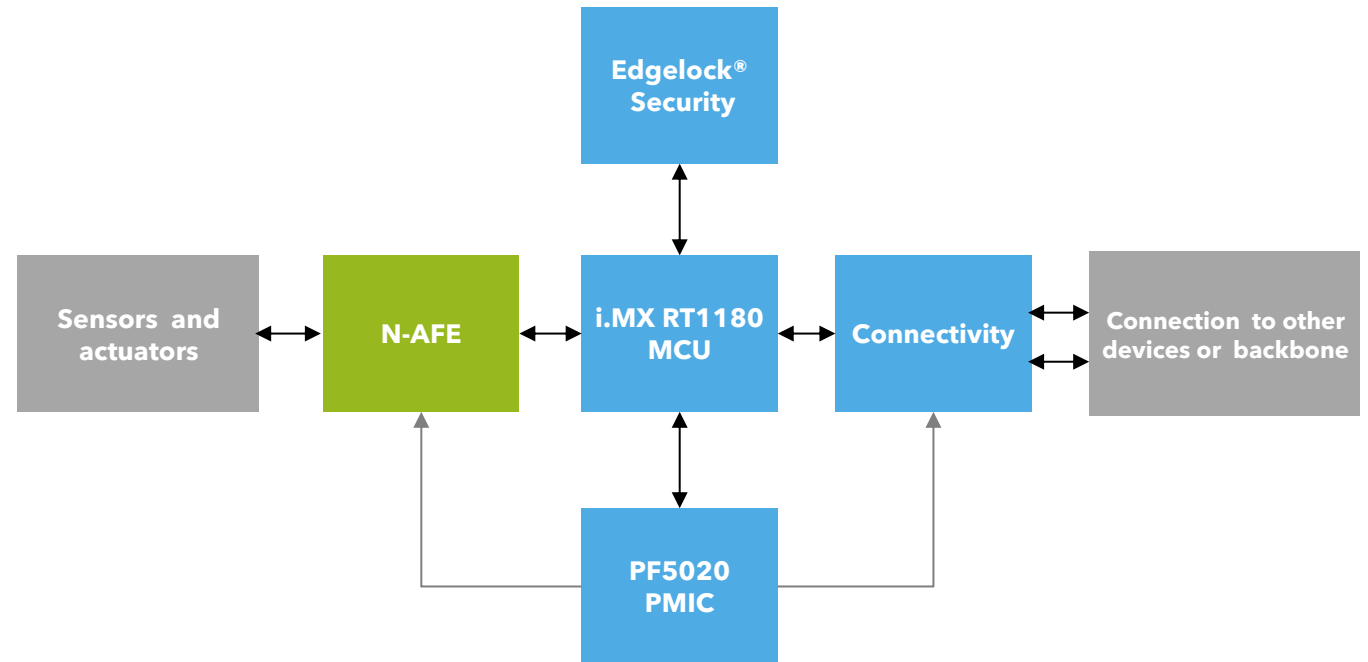


NAFE11388-EVB

(NAFE Board + USB cable + wall power adaptor)



INDUSTRIAL PLATFORM OPTIMIZED FOR THE SMART FACTORY



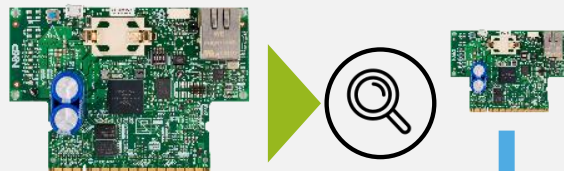
INDUSTRY 4.0 Factory Automation Controller

NAFE PERFORMANCES ENABLE PREDICTIVE MAINTENANCE IN MOTOR DRIVE

i.MX RT Industrial Drive Development Platform

Daughter card (ISI-QMC-DGC02)

Control board, which integrates MCU chip, debugging interface and Ethernet TSN port.



Digital Board (ISI-QMC-DB02)

Expansion board for Daughter Card, integrates multiple peripherals for communication, security and display.

Digital Board front view

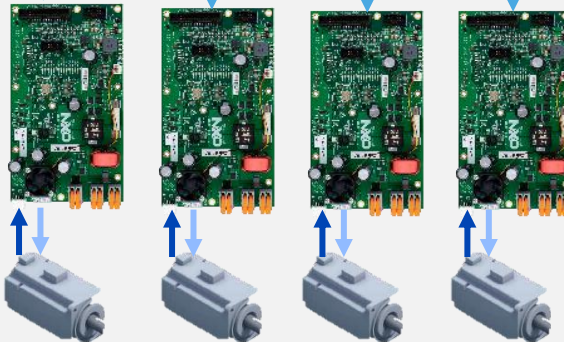


Digital Board rear view



Power Stage Board (ISI-QMC-PSB02)

Transforms the control commands into power signals to drive servo motor (200W up to 450W)



Motors are not included

DETECT

Sense small anomaly in presence of large signal with wide dynamic range AFE

Enable easy implementation

PREDICT

Predict failure with powerful EP + Algorithms

Avoid unexpected downtime and plan maintenance

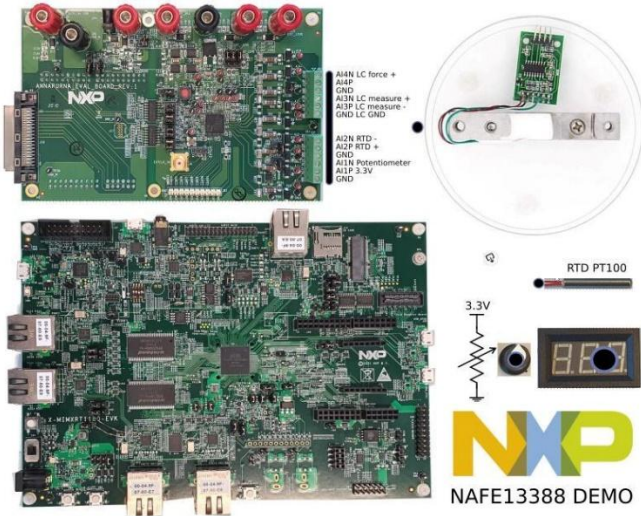
PREVENT

Reduce the anomaly and prevent failure

Increase system life-time



UNIVERSAL INPUT REMOTE I/O SYSTEM SOLUTION



i.MX RT1180 Crossover MCU

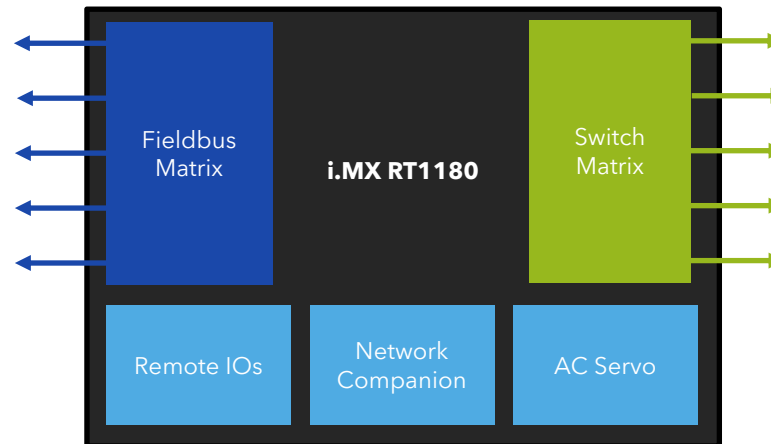
- Dual core with ARM Cortex M7 at up to 800MHz and ARM Cortex M33 at up to 240MHz
- Enabling IEC 62443 system-level compliance, and IEC 60802 industrial profile support
- Enhanced Drive capability
- Secure , Compact and Low power



NAFE measures all types of sensors
Provide diagnostics to the MCU

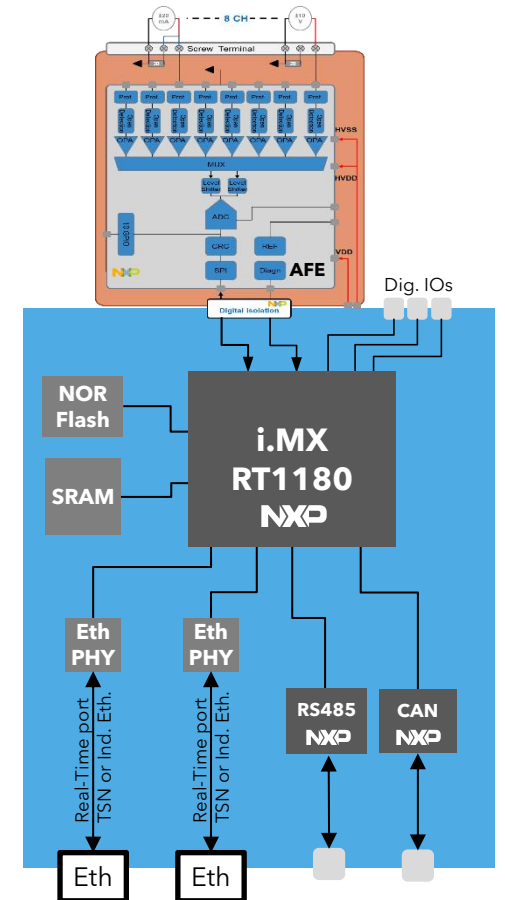
RT1180 elaborates the digitized information
Change the AFE configuration by software through SPI

Communicate to the network layer with TSN capability



Remote I/O

System solution with **NXP's AFE**





SOFTWARE-DEFINED FACTORY

ENABLED BY N-AFE NXP ANALOG FRONT END

Most flexible analog front-end with software-configurable analog inputs



RECONFIGURABILITY

Reconfigure a smart factory and **adjust settings** based on shifting market needs



ACCURACY AND PRECISION

Improved **product quality** thanks to enhanced **accuracy and precision**



PREDICTIVE MAINTENANCE

Diagnostics and anomaly detection to **identify issues** before they occur

“The N-AFE family enables flexibility in our designs to allow our customers to quickly respond to market trends, but more importantly, it also helps to reduce unplanned downtime, enabling a more productive factory overall.”

Ralf Nuebert, VP, R&D

Schneider
Electric



TECHNOLOGY SHOWROOM

JOURNEYS BY DESIRED ENGAGEMENT

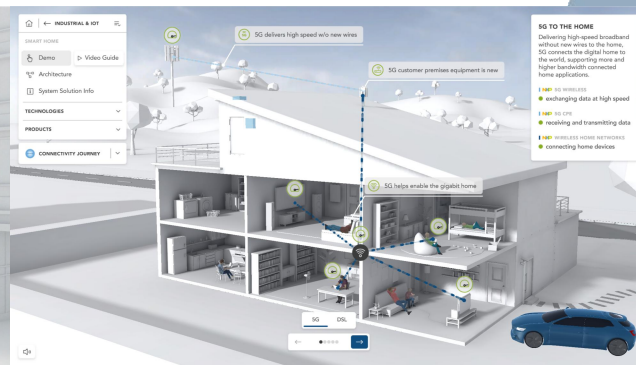
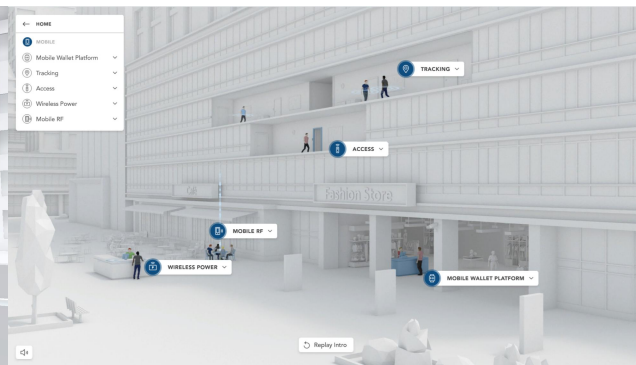
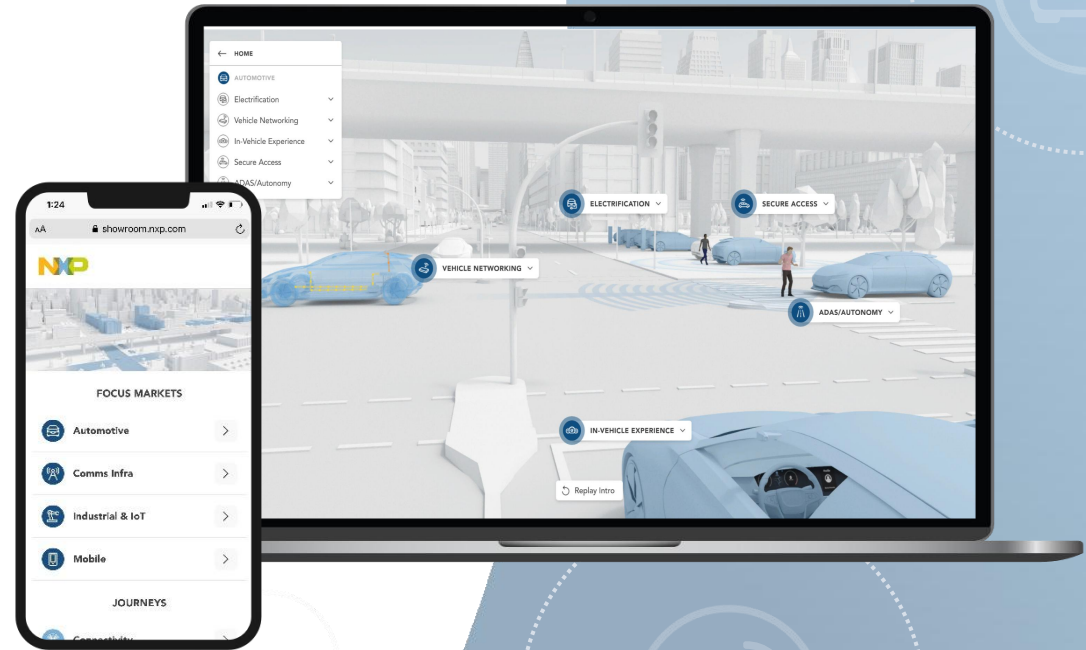
- Self-guided tour
- Live-streaming at set times
- Guided tours

60+ VIRTUAL DEMOS

- Focus on system solutions
- Set up along NXP verticals

JOURNEYS BY DESIRED FOCUS

- Low Power Innovations
- Advanced Analog
- Connectivity
- Edge & AI/ML
- Safety & Security



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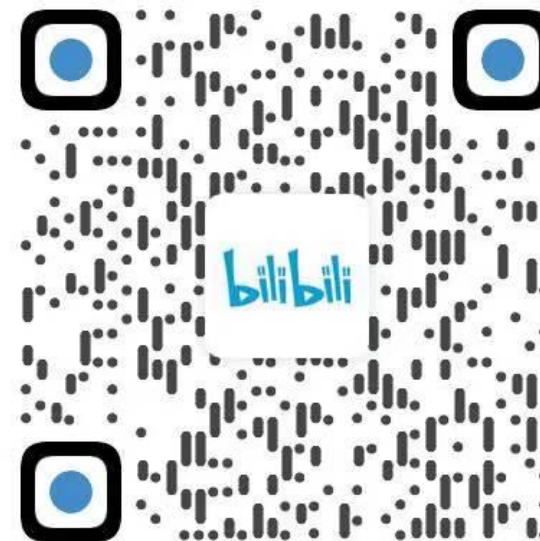
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FOR A SMARTER WORLD



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QUESTIONERS?

WHO? HOW? WHERE? WHEN? WHAT? WHERE? WHO? WHEN? WHAT? WHERE? HOW? WHEN? Where?

When? WHERE? Why? WHEN? When? WHAT? where? WHAT? When? HOW? What? WHEN? Why? WHERE? When? HOW? When? Why? What? What? When? When?