AN14106

Adding value to a PLC or Remote I/O applications with the NAFE family

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Document information

Information	Content
Keywords	NAFE, analog input module, Calibration, diagnostics
Abstract	This application note provides the overview of NAFE features, which add value to the PLC/ Remote I/O systems. NAFE enables the efficient design and enhanced reliability for these PLC or remote I/O applications. At the same time, the accurate NAFE measurements help the manufacturers to save on calibration capital expenses.

Revision history

Revision history

Rev	Date	Description
1.0	20231027	Initial release

1 Introduction

Programmable logic controllers (PLCs) have been around for nearly 50 years. Yet, these devices are still the essential part of industry 4.0 as they control various electromechanical processes in factories. Over the years, PLCs have continued to evolve with respect to technology. Now, industry requires PLCs that are compact, have faster processing power, have reduced downtime, are cost-optimized, and are extremely reliable.

In this application note, we will explore how to enable the efficient design and enhanced reliability for PLC analog input designs. We will also explore how manufacturers can reduce the capital expenses toward PLC development that essentially helps cost-optimization of the design. Each of these requirements helps to realize the industry 4.0 requirements-ready analog I/O design for PLC analog input designs.

2 Efficient design

A PLC usually consists of a main microcontroller, analog I/O cards, digital I/O cards, and communication cards. If the production line must be modified, the I/Os must also be changed. Figure 1 shows an example of I/O cards used in traditional PLC design.

There are similar cards for each type of input and output required by the production line. If there is a change to the production process, for example, to meet new customer requirements, then either the entire PLC has to be replaced, or at a minimum, the various I/O cards have to be replaced to meet the new configuration. This requires time, effort, and poses the challenge of having the right PLC or I/O cards available in time, which is not compatible with the rapid changes required by today's Industry 4.0.

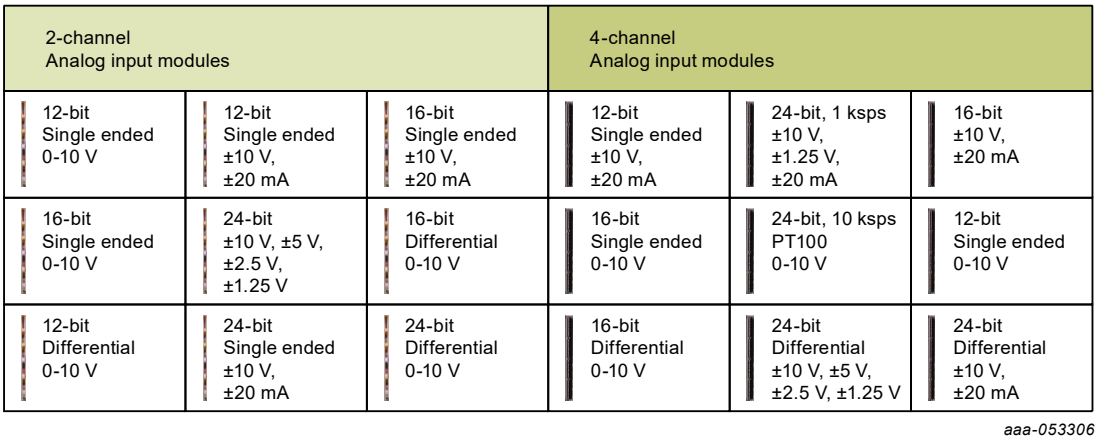

Figure 1. Traditional input card used in PLC

An Industry 4.0 PLC must be so flexible that its inputs and outputs can be digitally configured by software without manual intervention. This flexibility allows for quick changes, increased efficiency, and reduced cost. With the latest semiconductor innovations, the I/O's software configurability is now accomplished with the use of fully configurable analog input and output front-end ICs. These ICs allow the dynamic configuration of inputs and outputs at any point in time, from design to after the deployment of the PLC on the factory floor, allowing the various flavors of analog input and output modules to be replaced with a single universal i/o module with software configurable capabilities.

One important design consideration when converting to a universal I/O system is evaluating whether such a system compromises on performance. NXP's NAFE family provides dynamic configurability for many types of inputs, such as current, voltage, RTD, and thermocouple, while improving the overall system-level performance.

The NAFE family is a highly configurable industrial-grade multichannel universal input and output analog front-end (AFE) that meets high-precision measurement requirements. The device integrates low-leakage, high-voltage (HV) fast multiplexers, low-offset and low-drift programmable gain amplifier (PGA) and buffers,

high data-rate, 24-bit delta-sigma analog-to-digital converter (ADC), precise voltage and current excitation source, and low-drift voltage reference. The NAFE family is equipped with various diagnostic tools and supplies supervisory circuitry for condition monitoring and anomaly detection. Two precise calibration voltage sources are made available for ease of end-to-end system self-calibration and predictive maintenance.

Another important feature that NXP's NAFE family enables is a compact design thanks to the high level of integration. PLC analog inputs are exposed to various signals. Ensuring the reliability of the I/O modules is critical to maintaining a safe and efficient industrial environment. Analog inputs are quite susceptible to surge events. The traditional method of adding large resistors to limit current or adding TVS diodes is neither effective nor space efficient and worsens the measurement accuracy due to leakage currents.

In contrast, NXP's NAFE family integrates protection diodes connected to HVDD and HVSS, as shown in Figure 2. It is recommended that an external series 2.5 kΩ resistor with a 1 nF or 10 nF capacitor to AGND is installed for each high voltage input pin for limiting the current through internal diode reliability. The integrated clamping circuits, shown in Figure 2, protect the NAFE inputs from possible surge voltage caused by lightings when the system is installed in the field and from ESD events occurring during the manufacturing process and during printed-circuit board (PCB) assembly.

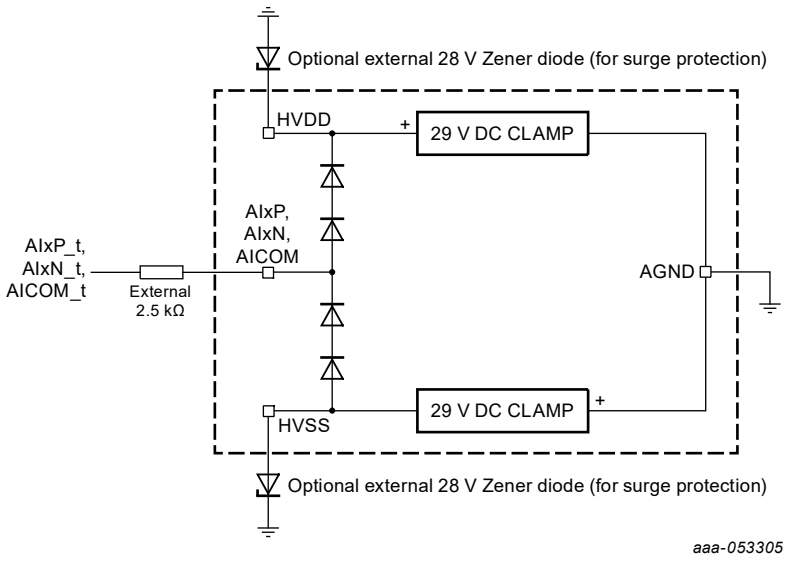

Figure 2. Internal protection diodes in the NAFE family

Having these internal protection diodes helps save valuable real estate on each board, enabling a compact design.

Another important system consideration is calibration support. Calibration support for analog I/O modules helps the manufacturer to reduce the capital expenses towards the development of PLC analog input designs.

Calibration support: Whenever a sensor is connected to an input of an AFE, it is imperative that the AFE does not introduce any gain nor any offset anomalies that affect the accuracy of the sensor reading. Toward that end, the sensor to ADC signal path will need to zero any offset and gain mismatches by performing a system calibration. Calibrating a PLC requires expensive test equipment and lengthens the production test time.

Table 1. Standard I/O module

I/O module ambient temperature = 0 °C to +55 °C					
IC ambient temperature = 0 °C to 85 °C					
Ranges	**TUE factory calibrated**	**TUE mV**	**Rsense Ω**	**Rsense ppm**	**Rsense ppm/C**
±10 V	0.10%	20.00	—	—	—
0 to 10 V	0.20%	20.00	—	—	—
±5 V	0.10%	10.00	—	—	—
±20 mA	0.30%	30.00	125	200	10

Table 2. High features I/O module

I/O module ambient temperature = –25 °C to +70 °C					
IC ambient temperature = –25 °C to +100 °C					
Ranges	**TUE factory calibrated**	**TUE mV**	**Rsense Ω**	**Rsense ppm**	**Rsense ppm/C**
±10 V	0.10%	20.00	—	—	—
0 to 10 V	0.20%	20.00	—	—	—
±5 V	0.10%	10.00	—	—	—
±20 mA	0.20%	20.00	125	100	5
4 to 20 mA	0.30%	12.00	125	100	5

NXP's NAFE offers excellent accuracy over voltages and temperatures. NXP factory-calibrated devices increase initial system accuracy while reducing the capital expenditure for expensive test instruments and reducing the production test time. The NAFE family has best-in-class TUE (0.005 % at room and 0.1 % across temperature) to support the high accuracy calibration requirements. The NAFE stores factory-calibrated coefficients based on two points self-calibration to reduce the gain and offset error. It also includes two voltage sources to perform built-in or dynamic end-to-end self-calibrations. The NAFE also offers an automatic offset reduction circuit that is software configurable.

Overall, all these calibration features help to design an accurate PLC system without the need of external equipment.

Let us discuss another important topic for PLC design, functional safety to enhance the reliability of the system. IEC61508 functional safety requirements aim to reduce the probability of harm to humans. Functional safety for PLC touches many parameters, such as hardware design, software design, communication environment, etc. From a hardware point of view, having internal diagnostics helps to meet the hardware safety requirements in terms of fault tolerance.

3 Internal diagnostics

NXP's NAFE family supports a variety of internal diagnostics to enhance the hardware fault tolerance. The following are features that the IEC61508 requires from the I/O module point of view and how NXP's NAFE family can help to achieve these features.

1. **Ability to apply and measure a known voltage:** NAFE includes a diagnostics mux that can route known signals, such as VHDD, VHSS, etc., output to be read by the internal ADC to confirm proper operation.

2. **Temperature sensing:** The NAFE family includes an integrated temperature sensor with ±3 °C accuracy to monitor the system temperature and ensure reliable operation.
3. **CRC over data:** Detecting corrupted data over the bus plays a pivotal role in meeting the functional safety bus reliability requirements. It helps to identify the errors in the data and information transmitted over the network. NXP's NAFE family provides an optional CRC code for improved SPI data integrity.
4. **Known condition for floating inputs:** Floating inputs are susceptible to random voltages and thus pose a safety risk to PLCs. NXP's NAFE family supports this detection of floating inputs or more commonly referred to as an *open detection feature*. The excitation block in NAFE has a setting that injects a very small (65 nA) current to detect the open fault, in case of floating inputs.
5. **Stuck-at-fault detection:** In this scenario, one of the PLC inputs is assumed to be stuck at a fixed logic value, either GND0 or VDD1, regardless of the supplied voltage. This situation, if undetected, needs the complete reset of the PLC. NXP's NAFE can handle this with its integrated excitation sources, VIEXC. It measures the analog value through the external pins and through the MUX. If the result is different from an expected result, then it helps to identify the input stuck-at-fault.
6. **Incorrect clock or drift diagnostics:** Incorrect clock frequency could generate errors in the PLC measurement. If undetected, it could take a longer time to understand the underlying root cause of the issue. NXP's NAFE identifies this fault by checking whether the mismatch between the internal RC clock and external clock is greater than 20 %.

4 Conclusion

In conclusion, having a software-configurable compact design, with inherent calibration support, and diagnostic capabilities enables the most efficient PLC designs. NXP's NAFE family plays a key role in developing this type of industry 4.0 PLC.

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