Industrial Sensors: A Practical Guide to Improve Your System

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Introduction

The term “Industrial Market” sounds very general, multi-disciplinary, and maybe even overwhelming. But it actually is. It includes a wide range of branches of industry, such as manufacturing, energy, construction, transport, agriculture, and many more. It is a fundamental component of the global economy and plays a key role in the production of goods and providing the necessary infrastructure for modern society.

Advanced electronic devices are essential in the modern industrial market because they enable businesses to automate processes, ensure product quality and safety, collect valuable data, and remain competitive in a constantly evolving landscape. The quick enhancement of the technology establishes new fields that require specialized devices to perform very narrowly defined tasks. When we talk about such specialized devices, sensors play a crucial role. They gather data from various processes and equipment. The Global Industrial Sensor Market is advancing rapidly every year. The market size and forecast from 2020 to 2025 are shown below.

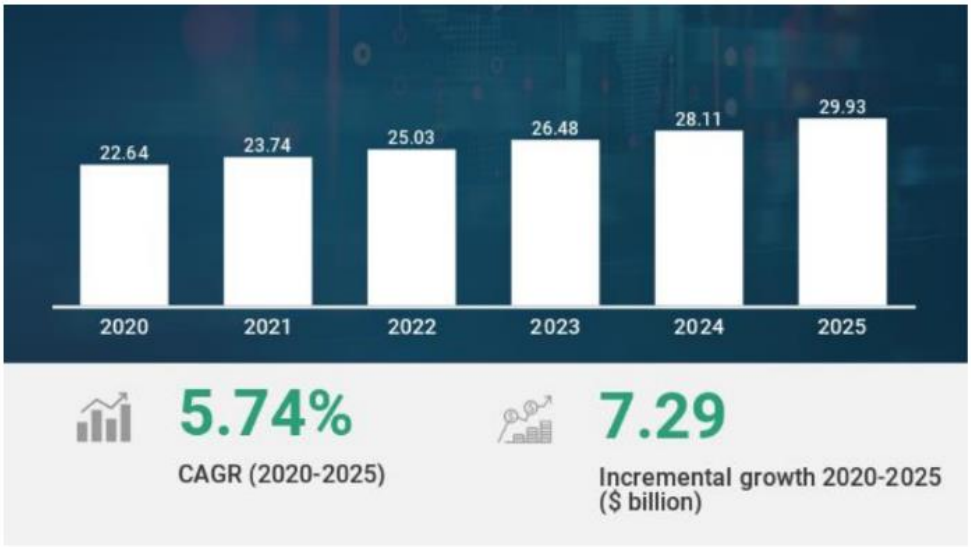


Figure 1: Market Size and Forecast 2020-2025. Source: Technavio. 2020. Global Industrial Automation Market 2021-2025

The next figure shows the year-to-year growth 2020-2025 in percentage.

Figure 2: Market Year-to-Year Growth 2020-2025. Source: Technavio. 2020. Global Industrial Automation Market 2021-2025

Here is an overview of the types of sensors and their functionality:

- **Temperature Sensors** monitor and control the temperature of industrial equipment, processes, and environments. They are vital for ensuring safe and efficient operation in chemical processing, HVAC, and food production applications.
- **Pressure Sensors** measure pressure in industrial systems, such as hydraulic systems, pipelines, and pneumatic equipment. They help maintain optimal pressure levels and detect leaks or anomalies.
- **Flow Sensors** measure the rate of fluid or gas flow in pipelines, ensuring accurate distribution and preventing blockages or overflows in industries like water treatment, oil and gas, and manufacturing.
- **Level Sensors** monitor the levels of liquids or solids in tanks and containers. These sensors are used in industries like agriculture, chemical processing, and wastewater treatment.
- **Position Sensors** detect the position or movement of machinery components, enabling precise control in applications such as robotics, conveyor systems, and industrial automation.
- **Proximity Sensors** detect the presence or absence of objects without physical contact. They are used in industrial safety systems, object detection, and automated material handling.

All of these types of sensors require electronics for signal conditioning, conversion, power efficiency, and reliability to ensure accurate and consistent performance in demanding industrial environments. Technology is improved all the time and new solutions appear.

AnalogPAK Benefits for Industrial Applications

Renesas provides a broad portfolio of analog products including AnalogPAK™ which is an innovative product originating from the GreenPAK family of programmable mixed-signal circuits. AnalogPAK SLG47004 adds more advanced analog functionality with its built-in Op Amps with programmable bandwidth, 10-bit digital rheostats, analog switches, analog comparators, and more mixed-signal blocks.

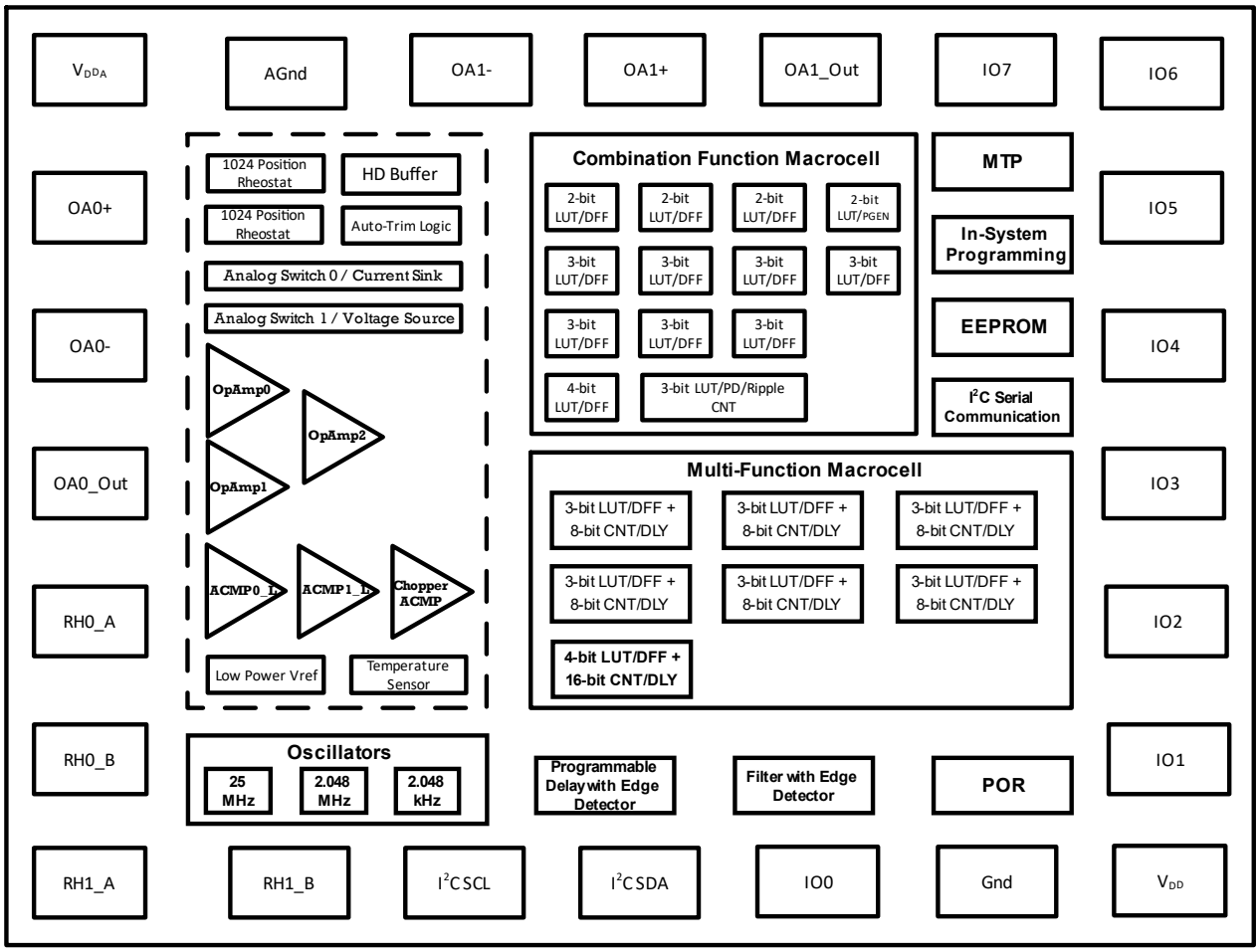


Figure 3: AnalogPAK SLG47004 Block Diagram

Here are the main benefits of AnalogPAK for industrial applications:

- **Analog Signal Processing**: SLG47004 provides precise analog signal conditioning, amplification, and filtering to ensure accurate and reliable measurements. SLG47004 builds upon the flexibility of the GreenPAK's traditional mixed-signal solution by integrating a mix of advanced analog features including op amps with programmable bandwidth, two analog switches, three analog comparators, three oscillators, and additional digital logic.
- **Signal Conditionin**g: SLG47004 includes two configurable OpAmps and one internal OpAmp. All three OpAmps within the IC are used to create an instrumentation amplifier. It also includes 10-bit digital rheostats, analog switches, analog temperature sensor, and a chopper analog comparator. The unique Auto-Trim feature highlights the ability of this GreenPAK device to periodically tune its rheostat value to either compensate for system error sources or reconfigure circuit parameters.
- **Low Power Consumption**: SLG47004 is energy-efficient to prolong battery life or reduce power costs, which is important for remote or battery-powered sensor applications. It provides dynamic Power-Down control for all analog and digital blocks to optimize power consumption performance.
- **Communication Interfaces**: SLG47004 includes an I2C serial communication interface to transmit sensor data to control systems or data loggers.
- **Environmental Considerations**: Industrial environments can be harsh, so SLG47004 is designed to withstand wide temperature ranges from -40 to 125 °C.

- **Safety and Reliability**: thirteen combination function and seven multi-function macrocells allow the addition of built-in diagnostics for fault detection, hence SLG47004 will adhere to safety standards in safety-critical applications.

AnalogPAK as an Analog Front-End for pH Probe

Below is an example of using the AnalogPAK as an Analog Front-End for pH Probe.

Figure 4: pH Electrode General View

The pH Probe (pH electrode) – the main component of any pH meter. A pH electrode assesses the activity of hydrogen ions (H+) and generates an electrical potential. The pH electrode yields an output that fluctuates both above and below the reference point, it generates a voltage output that exhibits a linear correlation with the pH level of the solution under examination. The pH electrode's source impedance is very high due to the substantial resistance of the thin glass bulb, 250 MΩ in this case. As a rule, operational amplifiers with a small offset current (about tens of femtoamperes or even less) are used as buffer amplifiers for such sensors. However, such precise amplifiers come at a high price. The unique Auto-Trim feature of the SLG47004 allows for the elimination of offset error caused by bias current at a reasonable cost.

The SLG47004 Analog PAK from Renesas can perfectly cope with pH probe key interfacing challenges such as high impedance of the electrode, a bipolar pH electrode output, and temperature sensitivity. Figure 3 shows a general schematic of the analog front end for the pH probe based on the SLG47004.

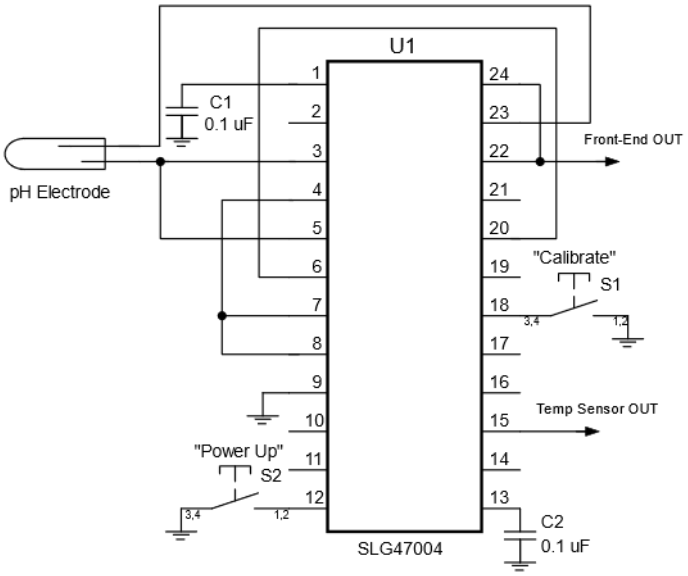


Figure 5: General Schematic of Analog Front-End for pH Probe Based on SLG47004

Figure 5 shows an internal design of the analog front-end for the pH electrode in our free GUI-based GreenPAK Go Configure™ Software Hub. It consists of two main parts which are described below: pH Probe Interfacing and Auto-Trim.

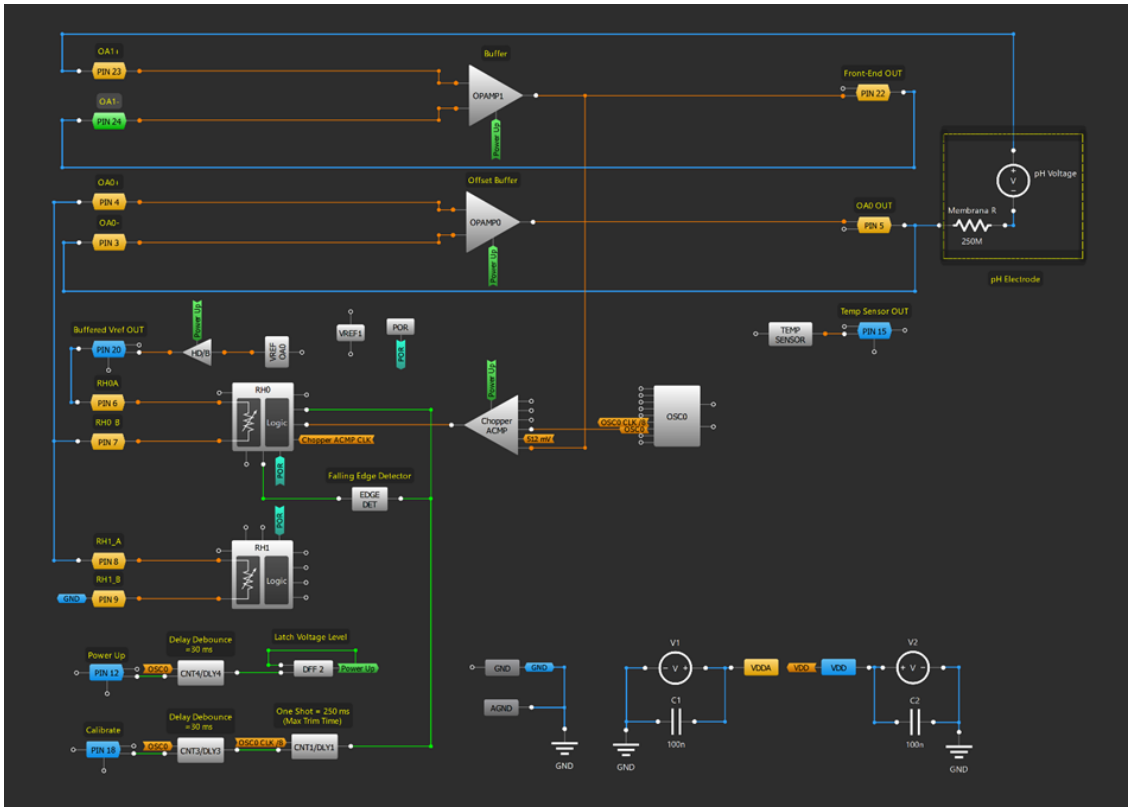


Figure 6: GreenPAK Designer Schematic of Analog Front-End for pH Probe

pH Probe Interfacing. The first OpAmp0 amplifier circuit transforms the bipolar pH-electrode signal into a unipolar signal suitable for use in a single-supply system.

The second amplifier, OpAmp1, is configured with a unity-gain setup, serving as a high-input impedance buffer between the pH electrode and the measurement device ensuring the circuit's compatibility with a wide range of measurement instruments, including those with lower input impedance.

In most scenarios, the voltage output from the pH electrode is sufficiently high for direct use, eliminating the need for extra amplification. However, if amplification becomes necessary, this circuit can be readily adjusted by introducing gain resistors to OpAmp1.

The SLG47004 has a built-in temperature sensor to measure the temperature of the solution so that adjustments are made for the sensitivity variations due to temperature.

Auto-Trim. When using a pH meter for the first time, it is necessary to calibrate it. In addition, it is recommended to perform periodic calibrations, once a week if the pH meter operates continuously. During calibration, the pH electrode should be immersed in a buffer solution with a neutral pH level. There is a special calibration button that initiates this process.

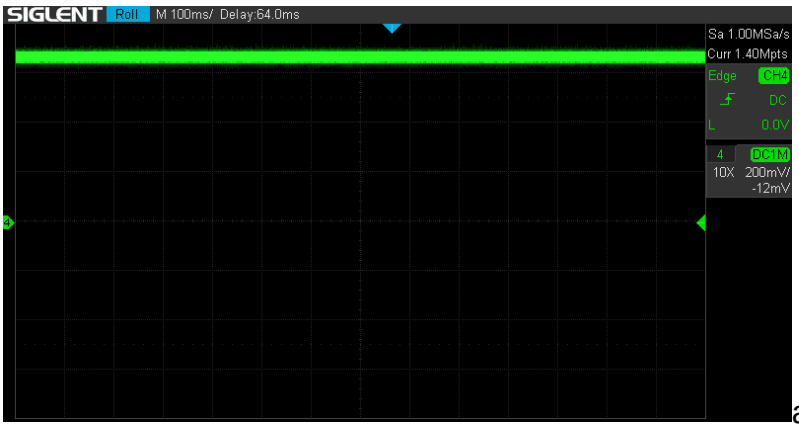
For calibration, the SLG47004 has a unique function called the Auto-Trim. The key macrocell responsible for the Auto-Trim is the Chopper Analog Comparator. The Chopper ACMP uses OpAmp1's output signal as voltage feedback and compares it with the desired voltage level (512 mV in this case). If these two voltages do not match, the Chopper Comparator adjusts the rheostat's RH0 resistance and at the end of the Auto-Trim, the voltage at OpAmp1's output will be the desired 512 mV.

To start the calibration, the "Calibrate" button is used. The Delay macrocell DLY3 functions as a debounce filter to eliminate switch bouncing. The internal counter stores the current value of the rheostat. The SLG47004's ability to program and store rheostat value is very useful in this situation because it allows for the use of the stored rheostat value each time the pH meter is turned on, without the need to perform the Auto-Trim every time.

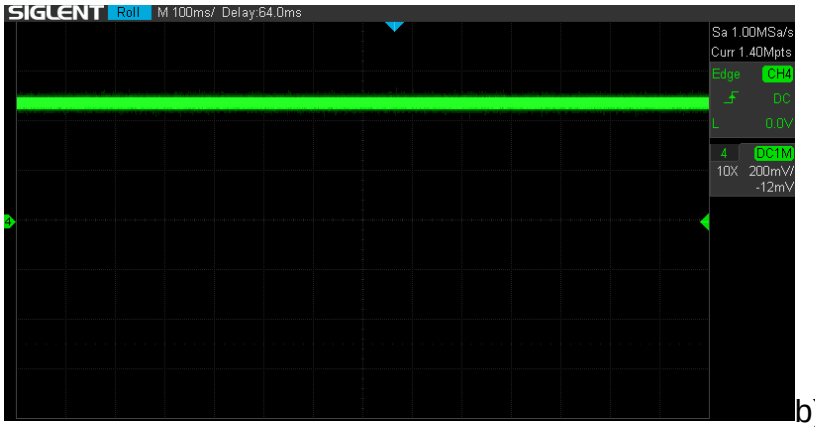
Test Results

The system was initially calibrated using the Auto-Trim function with a buffer liquid of pH 7 (neutral), which resulted in a 512 mV output. To test the meter readings, a buffer liquid with a pH value of 4 was used, resulting in a measured voltage of 676 mV. Therefore, 676 – 512 = 164 mV is the voltage attributed to the pH electrode. Because the electrode's sensitivity at 25°C is 59.16 mV, then 164/59.16 = 2.77. As neutral liquid has a pH level of 7, the measured liquid's pH is 7 - 2.77 = 4.23 pH.

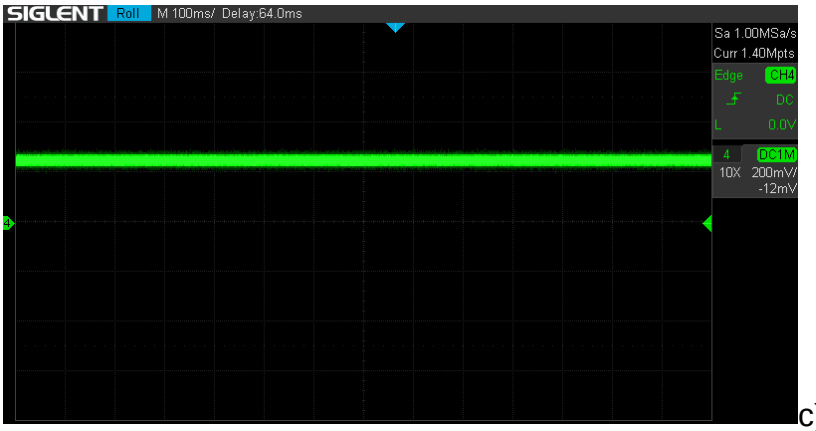
Test results for distilled water (pH = 7), diluted water with acid (pH = 4), and diluted water with base (pH = 11) are shown in figures below.



a) pH = 4



b) pH = 7



c) pH = 11

Figure 7. Front-End Output Waveforms for Different pH Values

Although the buffer fluid may have some error (often indicated on the solution bottle), the electrode has its offset error, and no temperature compensation was applied, the results are accurate and informative.

Summarizing all of the above, the SLG47004 is the right choice for a variety of applications in industrial sensors. With its help, it is easy and cheap to create high-quality products and services in the industrial sector, ensuring measurement accuracy, process stability, and compliance with safety standards.

View our Application Notes for ready solutions and visit AnalogPAK from Renesas to get more information.

Revision History

Revision	Date	Description
1.00	Feb 26, 2024	Initial release.