Smart Sensor of Liquid Analyzers

Hideo Doi [*1] *Takeshi Nakajima* [*2]
Teunis Both [*3] *Ralph de Leede* [*3]

In recent years, the share of liquid analyzers with smart sensors has been expanding especially in Europe. Unlike conventional analog sensors with no active components, smart sensors containing an electrical circuit can complete the measurement by itself and output the measured values as digital data. This digitization is expected to improve maintenance efficiency from calibration to data management and enable an integrated measurement management system to be constructed. Yokogawa named its smart sensors SENCOM® (SENsor and COMmunication) and released them in September 2013. This paper introduces the features and upcoming trend of smart sensors, and Yokogawa's efforts in developing this technology.

INTRODUCTION

In 1971, Yokogawa released the P/H Cell two-wired liquid analyzer as the first liquid analyzer for process application. Since then, a number of improvements have been implemented, such as the adoption of a modular structure in the current model, modular 2-wire liquid analyzer FLXA21 [(1)], for improving system flexibility and extensibility. Generally, a liquid analyzer for process application is composed of a sensor and a converter. The sensor does not have an active element and the analog signal of the sensor output is converted into the measurement value by the electronic circuit in the converter. Such an analog sensor is calibrated in a pair with a converter, and the calibration values are stored in the converter. This means that calibration must be carried out in the field. Another issue of an analog sensor is the restriction on the length of the cable connecting it with a converter, because the weak signals of a sensor transmitted through the cable are susceptible to external noise. An efficient way to resolve these issues is such that a sensor has an electric circuit in its body, completes measurements within itself, and transmits the measured values to a main body of an analyzer in the form of digital data. Sensors with such intelligence are called smart sensors, which are recently offered by various vendors and accepted by the market.

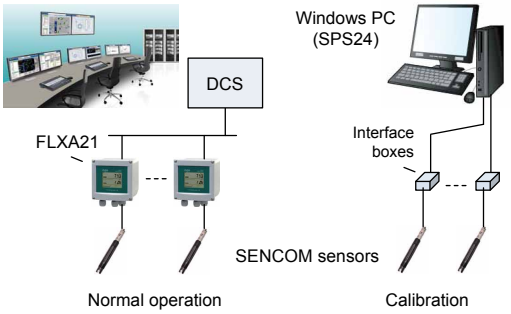


Figure 1 System configuration examples using SENCOM series products

Yokogawa calls its smart sensors and related peripheral devices SENCOM® (SENsor with COMmunication). In this paper, newly developed SENCOM series products are introduced. The products include a pH/ORP SENCOM sensor for pH and oxidation-reduction potential (ORP) measurement, SENCOM module that is installed in FLXA21 to connect with a SENCOM sensor, management software SPS24 running on Windows PCs, and an interface box to connect SENCOM sensors to PCs. Figure 1 shows system configuration examples for normal operation and calibration using SPS24 in a laboratory or other environments.

MAKING SENSORS SMARTER

Figure 2 shows structure elements when using an analog sensor and those using a smart sensor.

*1 Analytical Products Dept., Product Business Center, IA Platform Business Headquarters
*2 Software D&E Dept., Global Development Center, IA Platform Business Headquarters
*3 Yokogawa Process Analyzers Europe B.V.

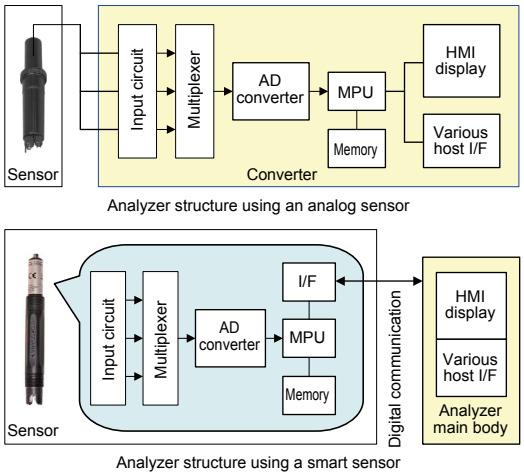


Figure 2 Difference in structure elements when using an analog sensor and a smart sensor

The converter for a usual liquid analyzer is composed of a signal converter section, a display for HMI and various host interfaces such as for 4-20mA signal output. In the signal converter section, signals from a sensor are transmitted to the input circuit and to the multiplexer, and then the AD converter converts them into digital data. The MPU performs various calculations on them and shows the results representing physical quantities such as pH on the display unit. At the same time, the results are transmitted through an interface such as for 4-20mA signal output. In a conventional analyzer using an analog sensor, all the required electric circuits are included in the converter and calibration data for the sensor are stored in the memory of the converter. In a smart sensor, in contrast, the signal converter section including the MPU is implemented in the sensor itself. The sensor-specific data such as calibration data are also kept in the sensor. The compensated measured values such as pH are output to the main body of the analyzer in digital data. Thus, smart sensors provide features of better maintainability and following when compared with conventional sensors.

- Calibration can be conducted collectively in a laboratory or similar environments using dedicated software, while the conventional sensors must be calibrated in the field.
- Each sensor has its own ID and sensor-specific data are stored in the sensor itself, enabling collective management of sensor information including calibration data on a PC.
- Applying a general digital communication interface enables a smart sensor to connect to devices other than dedicated devices for an analyzer, including a PC.
- Less susceptibility of digital communication against external disturbances such as electrical noise and fluctuation in a magnetic field reduces restriction on the communication cable length.
- The main body of an analyzer connected with a smart sensor can be simpler in structure and thus can be standardized among various analyzers.

SENCOM (SENsor with COMmunication) PRODUCTS

Besides the general features of a smart sensor described above, SENCOM products have the following product-specific features.

- Adoption of Modbus
  The digital communication between a SENCOM sensor and a main body of an analyzer, that is FLXA21, uses RS485 for its physical layer and Modbus for its protocol. This enables a SENCOM sensor to connect to Yokogawa's wireless modules, data recording devices and others.
- Detector diagnosis functions
  A SENCOM module has a sterilization detection function in addition to the existing detector diagnosis functions of the analog sensor module, such as predictive maintenance and sensor wellness diagnosis.
- PC software for calibration and data management
  SENCOM PC software SPS24 can simultaneously calibrate up to 4 smart sensors and perform collective management of sensor information including calibration values.
- Configuring a field wireless system
  A field wireless system can be configured by connecting a SENCOM sensor to the field wireless multi-protocol module FN310 [(2)] reported in Vol. 57, No. 1 of Yokogawa Technical Report English Edition.

pH/ORP SENCOM Sensor

Since the pH/ORP SENCOM sensor FU20F, the first SENCOM sensor, was released in September 2013, new products have been released to expand the sensor lineup for various applications. The new products include the FU24F, which is less affected by pressure fluctuation, and the SC25F, which has a sensor diameter of 12 mm. These are smart sensor versions corresponding to analog sensors that are highly evaluated in the market. In these smart sensors, the signal converter section is integrated on a small printed circuit board (hereafter sensor chip) and installed in the top of the sensor bodies. Figure 3 shows the external views of FU20F and of the sensor chip, and Figure 4 shows the block diagram of the sensor chip.

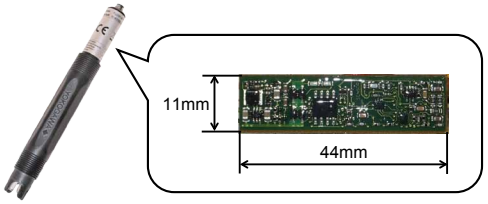


Figure 3 External view of FU20F and sensor chip

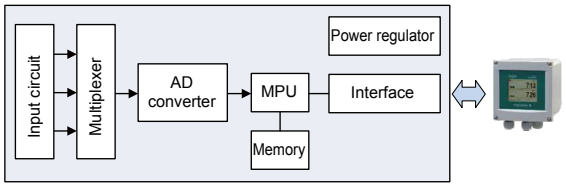


Figure 4 Block diagram of sensor chip

On the sensor chip, a power regulator is implemented; this is usually not included in the conventional structure as shown in Figure 2. The number of components on the sensor chip has been reduced to one third of the previous model for miniaturization and low power consumption, which is an essential requirement for a two-wire device. As a result, the mounting area has been reduced to one sixth of the previous model and the power consumption has been reduced to approximately 10 mW. Thus, the small sensor chip of approximately only 44 mm × 11 mm in size has achieved all the required functions. For responding to use in hazardous areas, the circuit of the sensor chip conforms to intrinsically safe explosion proof standards. Major components in Figure 4 are briefly explained as follows.

- Power regulator
  A DC/DC converter is mounted on the sensor chip to eliminate the effect of fluctuation in supplied power voltage and generated power used in it.
- Input circuit and AD converter
  The signal from the sensor electrode is received by the input circuit and converted into digital data by the AD converter.
- MPU and memory
  A one-chip microcomputer is used for various controls and a non-volatile memory is built in to keep sensor-specific data such as calibration data.

SENCOM Module of FLXA21

The SENCOM module is a sensor module installed in FLXA21 to connect with a SENCOM sensor. Figure 5 shows an internal structure of FLXA21 and a SENCOM module. The FLXA21 offers system extensibility due to its modular structure, and the module developed for SENCOM is only the sensor module. The SENCOM module will also be applicable to SENCOM sensors to be released in the future.

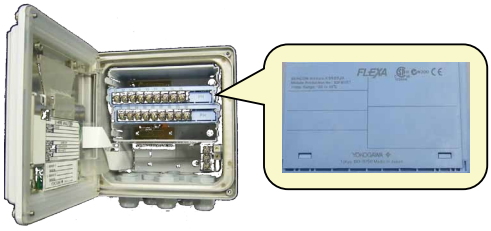


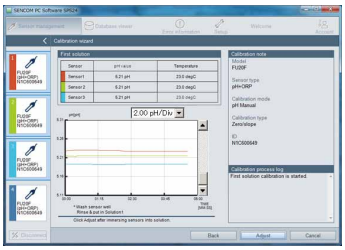
Figure 5 Internal structure of FLXA21 and SENCOM modules

PC software SPS24

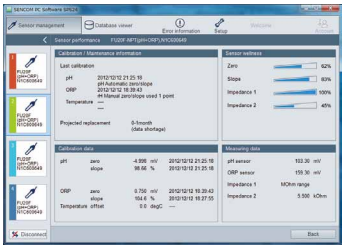
SPS24 is software running on Windows PCs that performs data management and calibration for SENCOM sensors. It can calibrate four SENCOM sensors simultaneously, and offers functions utilizing characteristics of a PC, such as trend graph display and collective sensor data display. In addition, since it can manage sensor data collectively, it offers functions emphasizing user convenience, such as outputting data in Excel spreadsheets and printing a report for each sensor.

Figure 6 shows examples of main screen, calibration screen, and sensor status display screen. In the calibration screen, a trend graph for multiple sensors is displayed with different colors assigned to each sensor. In the status display screen, the sensor status is displayed in a bar graph and is visually understandable.

Main screen



Calibration screen



Status display screen

Figure 6 SPS24 screen examples

Software of SENCOM module

The software of the SENCOM module is described in this section. Figure 7 shows the software structure of the SENCOM module.

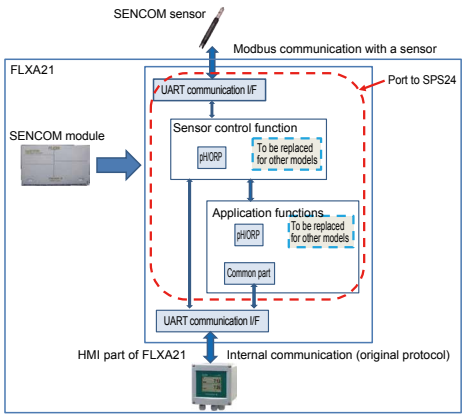


Figure 7 Software structure of the SENCOM module

- Implementation in SENCOM module
  A SENCOM module is interfacing with the HMI

part of FLXA21 and a SENCOM sensor. It has two roles: sensor control function and application functions including calibration, temperature compensation, prediction of the time for maintenance or replacement of a sensor and sensor wellness diagnosis.

The sensor control function manages application parameters such as calibration values kept in a sensor. As shown in Figure 8, if an inconsistency is found in application parameters in a sensor, they are automatically recovered by using those backed up in a SENCOM module. In addition, it can direct a sensor to start or stop measurement or to measure its impedance when a sensor is replaced in a hot-line state or calibrated.

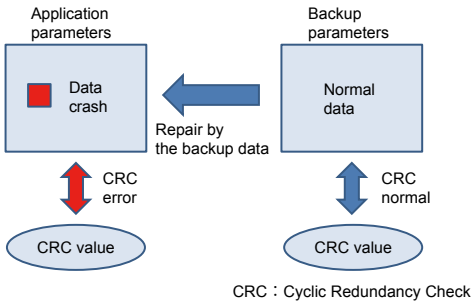


Figure 8 Auto recovery of application parameters

The sterilization detection function has been newly added to the application functions including calibration, temperature compensation, predictive maintenance, and sensor wellness diagnosis inherited from the analog sensor module.

- Porting to SPS24

SPS24, the PC software for calibration described above, includes some of the SENCOM module functions.

During the design of the software of the SENCOM module, its porting to SPS24 was taken into consideration. Thus, software for a sensor control function, application functions and a Modbus communication I/F in a SENCOM module were able to be ported to SPS24 with only modification for multiple sensor connection. The software for a simultaneous calibration function for multiple sensors was newly developed and added to the ported software, completing all the functions of SPS24. By porting and reusing the software enclosed by the red dashed line in Figure 7, the same level of quality as the SENCOM module has been ensured, and the load for the development was reduced by approximately 25% in software size.

Field Wireless System

The SENCOM sensors can be combined with the FN310, Yokogawa's field wireless multi-protocol module, and the FN110, the field wireless communication module, to build a wireless system as shown in Figure 9 conforming to the ISA100.11a, the international industrial wireless communications standard. The SENCOM sensor, FN310 and FN110 as a whole are battery-powered and perfectly wireless with both the signal line and the power line eliminated. Therefore, the combination of them has no restriction on the installation location and can be easily moved to other locations.

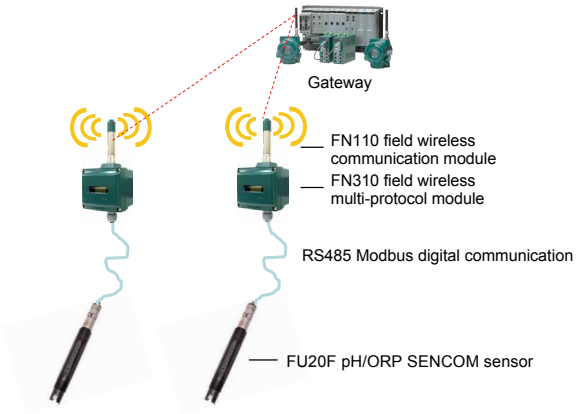


Figure 9 An example of connecting SENCOM sensors and wireless modules

FUTURE PERSPECTIVE

Currently, Yokogawa offers three pH/ORP sensors as SENCOM series sensor products. The SENCOM series sensor lineup is scheduled to be expanded to other sensors for liquid analysis such as for conductivity, inductive conductivity, dissolved oxygen, turbidity, and residual chlorine analysis. By enhancing diagnosis functions and maintenance functions in SENCOM sensors, Yokogawa will offer system solutions consistent with the FieldMate [3], Yokogawa's software for adjusting and setting field devices, and with the field wireless systems.

CONCLUSION

The SENCOM sensor, a smart sensor used in a liquid analyzer, can constitute an analyzer system that improves maintainability for customers and reduces the total cost by taking advantage of smart sensors. Furthermore, this analyzer system is flexible, inheriting the basic concept of extensibility of FLXA21. The SENCOM sensor is expected to contribute to expand Yokogawa's future analyzer business.

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