FCX-AIII Series of New Type Differential Pressure/Gauge Pressure Transmitters

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1. Introduction

Since the market launch in 1989 of the FCX series of differential pressure and gauge pressure transmitters which are equipped with a unique micro-machined capacitance silicon sensor, Fuji Electric has continued to develop this series and has subsequently released the FCX-A/C series and the FCX-AII series in 1995 and 2000, respectively. During this time, one-million of these FCX series pressure transmitters have been put into operation at plants throughout the world, and have been well received. Recently, Fuji Electric has developed the FCX-AIII series of pressure transmitters which feature further performance improvements and an even smaller size. The external appearance of the FCX-AIII series of pressure transmitters is shown in Fig. 1.

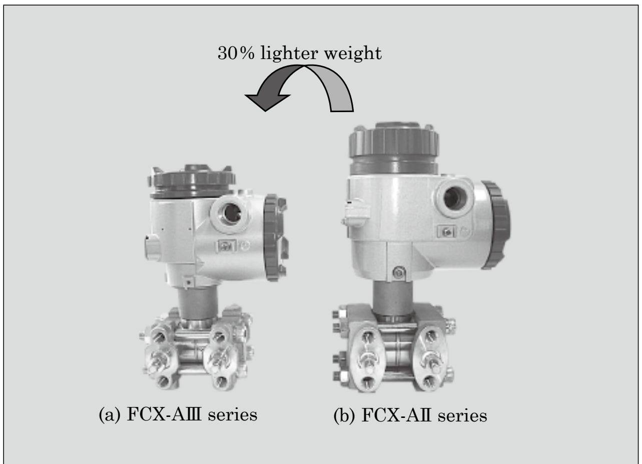
2. Features

The FCX-AIII series of differential pressure and gauge pressure transmitters have the following features.

(1) Long-term stability

An improved S/N ratio of the sensor signal realizes long-term stability of ±0.1% over 10 years.

Fig.1 External appearance of FCX-AIII series of differential pressure transmitters



(2) Smaller size and lighter weight

Establishment of a technique for directly welding together the sensor housing and the main unit, and development of a small diameter seal diaphragm enable the realization of a differential pressure transmitter having a mass of 3.1 kg, which is 70% of the prior model.

(3) High-speed response

Reducing the power supply voltage for the electronics unit enables high-speed calculations to be performed without an increase in power consumption. As a result, a measurement value update cycle of 60 ms, which is 50% of prior model, was realized.

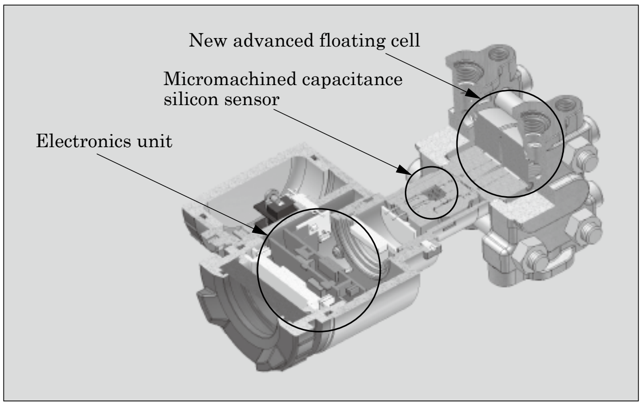
(4) Enhanced onsite adjustment function (3 push-buttons)

To realize an onsite adjustment function without a handheld communicator (HHC), a field configurator unit with LCD display has been developed so that onsite settings and adjustments can be implemented using three buttons mounted on the configurator unit. Configurator unit is available as an option.

3. Structure

Figure 2 shows the internal structure of the FCX-AIII series of differential pressure transmitters. The internal structure is configured from a micro-capacitive silicon sensor, a new advanced floating cell and an

Fig.2 Internal structure of FCX-AIII series of differential pressure transmitters



electronics unit.

3.1 Micromachined capacitance silicon sensor

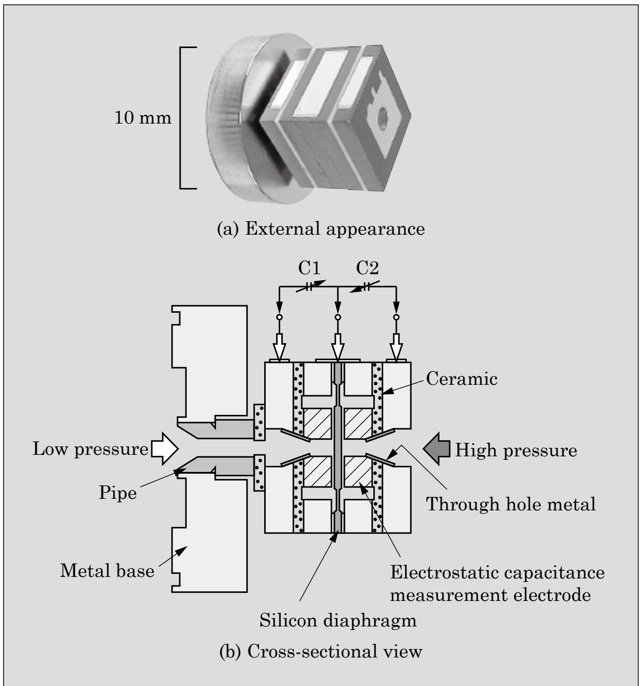
Figure 3 shows the sensor structure of the FCX-AIII series of differential pressure transmitters. The sensor is structured such that a pair of electrostatic capacitance measurement electrodes (fixed electrodes) face both sides of a silicon diaphragm (moveable electrode) positioned at the center of the sensor. Pressure applied to the sensor causes the diaphragm made of monocrystalline silicon to deform. The amount of displacement is proportional to the differential pressure and can be sensed with high accuracy based on the differential electrostatic capacitances C_1 and C_2. Thus, the sensor signal F, which is proportional to the differential pressure, can be computed according to the following formula by measuring the electrostatic capacitances C_1 and C_2.

$$F = (C_1 - C_2)/(C_1 + C_2 - 2C_S) \quad \cdots (1)$$

Owing to the excellent properties of monocrystalline silicon, this sensor exhibits low elastic hysteresis. Moreover, when displaced, since the silicon diaphragm having a center disk maintains its parallel orientation with respect to fixed electrodes that form electrostatic capacitance, the sensor exhibits good linearity and there is no need to perform complicated linearity computations.

For the FCX-AIII series, the S/N ratio of the sensor was improved in order to enhance long-term stability. In the electrostatic capacitance pressure sensor, as described above, the static electric capacitance formed by the silicon diaphragm and the fixed electrodes changes in accordance with pressure changes. In an ideal sensor, the sensor signal is only affected by electrostatic capacitance formed between the diaphragm and the fixed electrodes, but in an actual sensor, however, other capacitance is included, i.e., electrostatic capacitance (stray capacitance) formed by the wiring pattern or the like. Through a reconsideration of the sensor structure, this stray capacitance has been minimized, and the difference in stray capacitances on the high-pressure side and the low-pressure side has been reduced. As a result, long-term stability of ±0.1% over 10 years has been realized.

Fig.3 Sensor structure of the FCX-AIII series of differential pressure transmitters



3.2 Sensor unit

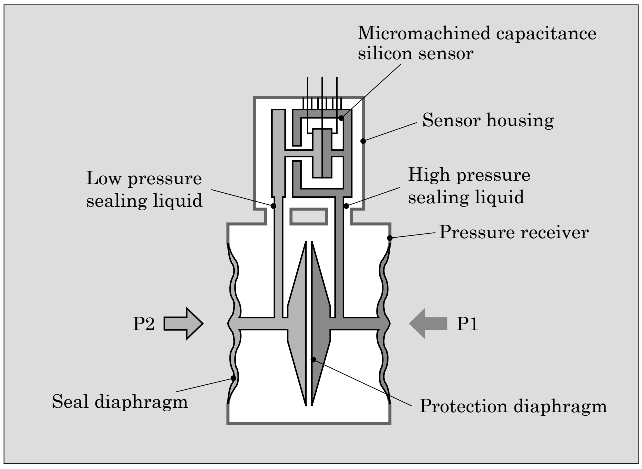
In order to make the sensor unit smaller and lighter weight, a directly coupled structure for the sensor housing and pressure receiver, and a smaller diameter of seal diaphragm were realized.

The FCX series has continued to use the same basic structure for the sensor unit, and the advanced floating cell structure which has an extensive record of success has also continued to be used. In the previous advanced floating cell structure, however, the sensor housing and the pressure receiver were welded together with a pipe disposed in-between, and the length of this pipe was an obstacle to miniaturization. Therefore, in the newly developed FCX-AIII series, this pipe was eliminated, a structure that directly couples the sensor housing and the pressure receiver was devised, and the technique for welding this directly coupled structure was established. Figure 4 shows the new advanced floating cell structure that was developed for the FCX-AIII series.

Also, the shape of the seal diaphragm was designed using a numerical analysis method based on the finite element method, and despite the miniaturization of the sensor unit, an optimal waveform diaphragm that does not degrade pressure transmission characteristics was realized.

The directly coupled structure of the sensor housing and the smaller diameter of the seal diaphragm enabled the realization of a 30% reduction in size and

Fig.4 New advanced floating cell structure



weight compared to prior models.

3.3 Electronics unit

Figure 5 shows a schematic diagram of the electronic circuit contained the electronics unit. Pressure is detected as electrostatic capacitance by the sensor, and the sensor capacitance is converted into pulses by ASIC and the pulses are counted by a gate array to form a digital value that the CPU uses to compute the pressure. In recent years, due to requests for higher speed response, the power supply voltage has been reduced so that high-speed computations can be realized with low power consumption. Specifically, the power supply voltage for the CPU and gate array has been reduced, and the CPU's internal operating clock has been increased to twice the prior rate in order to realize higher speed computations. Moreover, in order to limit power consumption without increasing the clock frequency during the pulse counting in the gate array, a circuit that detects rising and falling clock edges was devised. Accordingly, with the same clock frequency as used previously, the same resolution can be obtained in half the counting time as before. As a result, high-speed response can be realized with a measurement value update cycle of 60 ms and dead time of 120 ms, which are double high speed response compared with the previous response speed. Figure 6 shows the step response of the FCX-AⅢ series.

Fig.5 Schematic diagram of electronic circuit

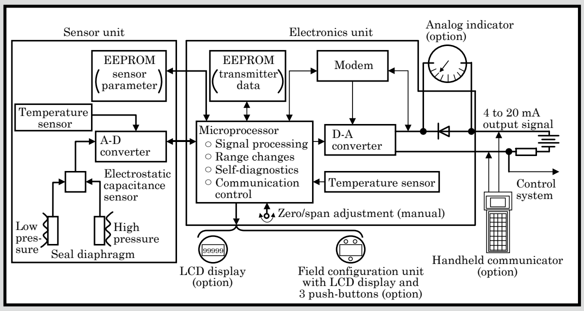
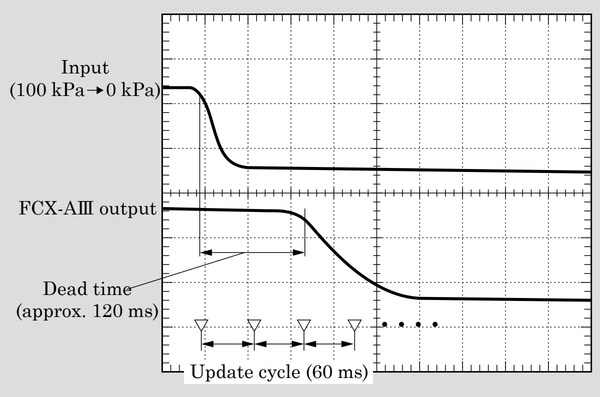


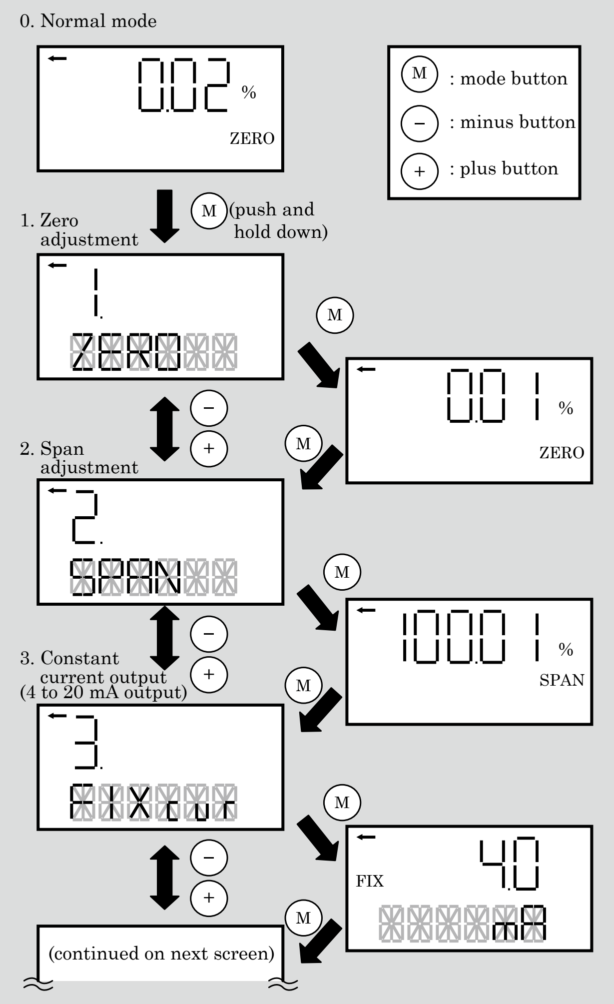
Fig.6 Step response characteristics of the FCX-AIII series



As communication functions, the Fuji protocol communication and the HART protocol communication are equipped as standard, and models that support the Foundation Fieldbus (FF) and the Profibus are also being incorporated into the product lineup. The FF extends the function blocks (FB), and provides a full lineup of AI × 2 points (pressure, temperature), PID control, IT (integrator), AR (arithmetic block), IS (input selector) and SC (signal characterizer) functions for field devices. A Link Master, which can be operated as a replacement when a master such as DCS is down, is also provided and enhances system safety specifications.

On the other hand, a field configurator unit with LCD display and 3 push-buttons is available as an option so that the main functions can be set easily and quickly without using digital communications such as described above. As an optional specification in previous models, a local adjustment unit with LCD display was limited to only implementing the setting and adjusting of basic functions, such as damping settings, zero adjustment, span adjustment, current output

Fig.7 Example of screen transitions for the display unit with 3 push-buttons



correction, and output switching between pressure and flow rate. With the three new push-buttons, owing to menu-assisted operation, the same function setting and adjustment as HHC using a digital communication are available with the transmitter unit only, thereby the onsite adjustment functions with the transmitter unit have been further improved. Figure 7 shows an example of screen transitions for the display unit with 3 push-buttons.

4. Main Specifications

Table 1 lists the main specifications of the FCX-AIII series of differential pressure and gauge pressure transmitters.

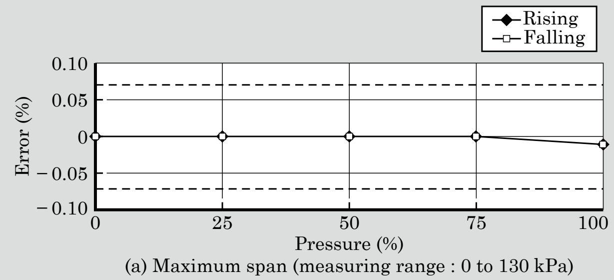
In addition to the L-shaped amp case that was standard with the previous models, a T-shaped amp case is also available. The T-shaped case was requested by overseas users, and for horizontal piping work, has the advantage of allowing the indicator to be viewed from the side.

For the gauge pressure transmitter and the absolute pressure transmitter, a direct mount screw-on type is also available.

5. Characteristics

Representative characteristics of the FCX-AIII series of differential pressure transmitters are shown in Figs. 8 and 9. Figure 8 shows the 0 to 130 kPa measuring range of a differential pressure transmitter having a maximum span of 130 kPa, and accuracy (input and output characteristics) in the case of a 0 to 13 kPa measuring range of 1/10 the span. The micromachined capacitance sensor is capable of maintaining good lin-

Fig.8 Accuracy of FCX-AIII series of differential pressure transmitters



(a) Maximum span (measuring range : 0 to 130 kPa)

(b) 1/10 span (measuring range : 0 to 13 kPa)

Table 1 Main specifications of the FCX-AIII series of differential pressure and gauge pressure transmitters

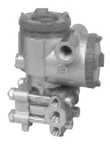
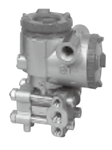
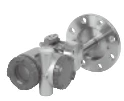
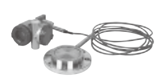
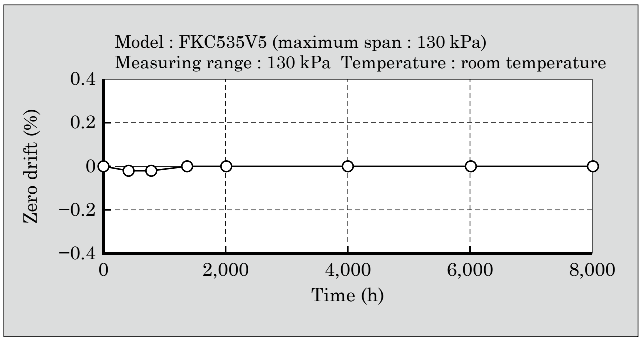
Model	Differential pressure transmitter 	Gauge pressure transmitter 	Absolute pressure transmitter 	Level transmitter 	Remote seal type differential pressure transmitter 	Remote seal type pressure ransmitter 	Direct mount type pressure transmitter 	Direct mount type absolute pressure transmitter 
Type	FKC	FKG	FKA	FKE, FKY	FKD, FKX	FKB, FKW	FKP	FKH
Max. span (kPa)	1 6 32 130 500 3,000	130 500 3,000 10,000 50,000	16 130 500 3,000	32 130 500	32 130 500	130 500 3,000 10,000 50,000	130 500 3,000 10,000	130 500 3,000
Mass (kg)	3.1	2.9	2.9	Approx. 9 to 19	Approx. 9 to 19	Approx. 4 to 18	2.2	2.2
Accuracy rating (%)	±0.065 (inside [ ]) ±0.1 (other)		±0.2	FKE : ±0.2 FKY : ±0.25	FKD : ±0.2 FKX : ±0.25	FKB : ±0.2 FKW : ±0.25	±0.1	±0.2
Output signal	DC 4 to 20 mA or electrical fieldbus signal							
Communications function	Fuji protocol and HART protocol							
Diaphragm material	316L SS Hastelloy C Monel Tantalum 316L SS + gold plating Gold & ceramic Coating		316L SS Hastelloy C Monel Tantalum	316L SS Hastelloy C Monel Tantalum Titanium Zirconium 316L SS + gold plating			316L SS	
Process connection	Rc 1/4 or NPT 1/4			Various flange standards			Rc1/4, Rc1/2, NPT1/4, NPT1/2	

Fig.9 Long-term stability of FCX-AIII series of differential pressure transmitters



earity even if turned down (measuring range reduced).

Figure 9 shows the long-term stability of zero point output. Due to the effect of an improved S/N ratio of the sensor, the zero point output is extremely stable over time.

6. Postscript

An overview of the newly developed FCX-AIII series of differential pressure and gauge pressure transmitters has been presented.

As the FCX-AIII series of transmitters penetrates global markets, new requirements are expected to emerge. Fuji Electric intends to continue to expand the model lineup and functions of this series and to move forward with improvements while responding to these requirements.