The New Generation Electronic Transmitter "FCX-A/C Series"

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1. Introduction

Fuji Electric has developed the FCX series of electronic pressure transmitters, on the market since 1989. These transmitters are important sensors in the field of industrial process instrumentation. This series has been widely used and favorably accepted by global users because of its unparalleled features, including ±0.1% accuracy within full range and traditional/smart convertibility.

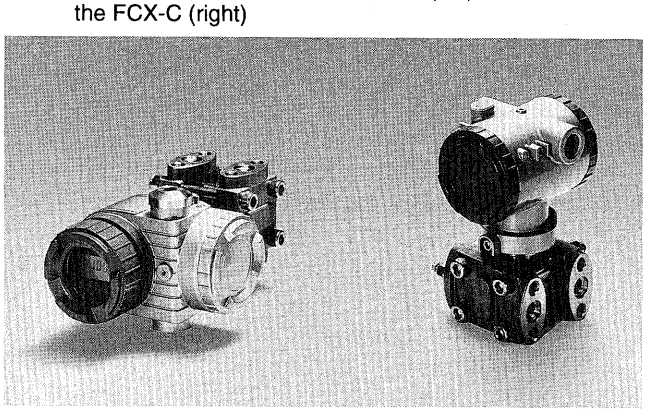
As users and products increase, needs for transmitters with improved performance and functions as well as needs for smaller, lighter, portable and handy transmitters with conventional performance, grow. Based on such market requirements, we developed the advanced FCX-A series and the compact FCX-C series, both of which are introduced below.

2. Developmental Concept

The first of our development concepts was to further develop the FCX series, available since 1989, incorporating user requirements.
These requirements are as follows.
(1) Improved performance
(2) Enhanced functions and compactness
(3) Pursuit of technical continuity

The second concept was to coordinate the FCX series as one family to closely match a variety of market needs. This was achieved by developing the performance-oriented and highly advanced FCX-A series as well as the popular FCX-C series which is small, light weight and handy.

Fig. 1 External appearance of the FCX-A (left) and the FCX-C (right)



3. Characteristics

The features of the FCX-A/C are listed below.
(1) Common features of the FCX-A/C
- Easy upgrade of functions from a traditional to a smart type
- Interchangeable sensor and electronic units

(2) Features of the FCX-A
- Advanced performance
- Broad measuring range and full line of models

(3) Features of the FCX-C
- Small size and light weight

4. Structure

Figure 2 shows the internal structure of an FCX-A series differential pressure transmitter.

The transmitter consists of a capacitance type silicon sensor element (hereinafter referred to sensor) which transforms the quantity of input pressure to capacitance, and a sensor and electronic units.

Fig. 2 Internal structure of the FCX-A series differential pressure transmitter

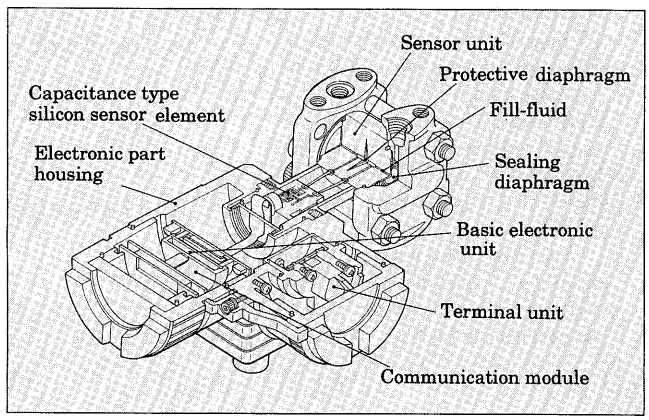


Fig. 3 Cross section of the FCX-A series differential pressure transmitter

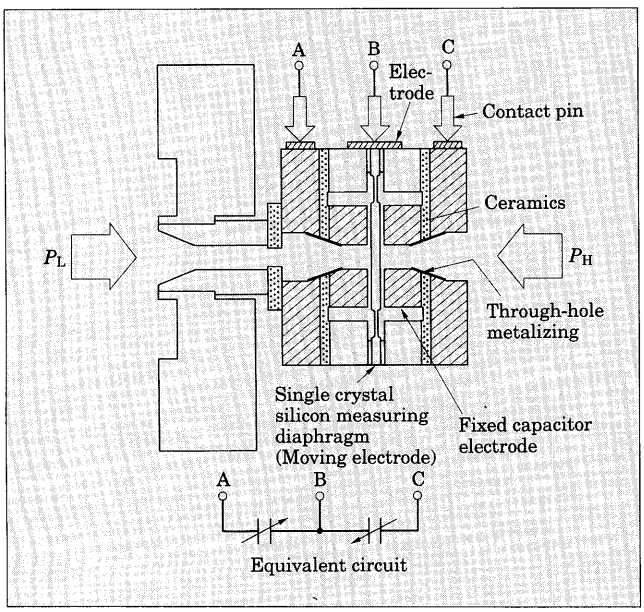


Fig. 4 Capacitance detecting circuit

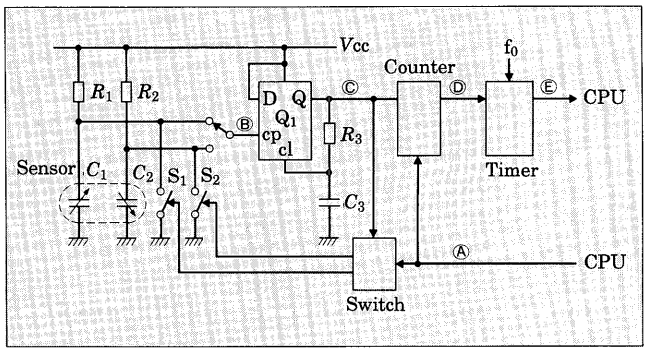
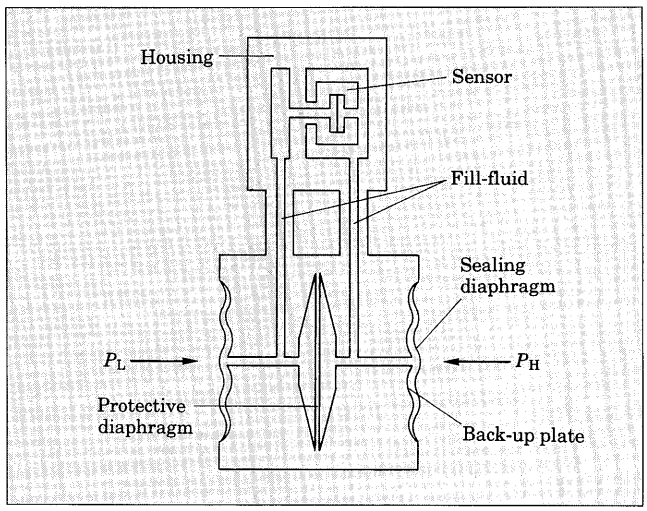


Fig. 5 Advanced floating cell construction



4.1 Capacitance type silicon sensor element

A cross section of the sensor is shown in Fig. 3.

A pair of fixed capacitance electrodes are arranged on opposite sides of a measuring diaphragm (moving electrode), which is placed in the center of the sensor.

The input pressure is transformed into a displacement proportional to the differential pressure with the measuring diaphragm, made of single crystal silicon. The displacement is detected as a differential change between those capacitances. The advantages of the sensor used in the FCX-A/C series transmitters are described below.

(1) Improved temperature characteristics

Variation of temperature characteristics is minimal because the thermal expansion coefficient and Young's modulus temperature coefficient of the silicon which comprises the sensors, are both small. Moreover, the signal-to-noise ratio and thus temperature characteristics are an improvement over the previous model. This is achiebed by changing the capacitance according to input pressure.

(2) High accuracy

Because of the superior properties of single crystal silicon and the ideal parallel displacement of the measuring diaphragm, which is achieved by the adoption of a grooved center disk, hysteresis is extremely small and linearity is satisfactory.

4.2 Principle of measurement

The sensors transform the quantity of input pressure into the difference of capacitances C_1 and C_2. The signal value proportional to the pressure is given from the following well-known equation, where C_S represents the linearity correction factor.

$(C_1 - C_2)/(C_1 + C_2 - 2C_S)$ ·····(1)

The process of detecting the capacitances to acquiring the signal proportional to the pressure are explained in Fig. 4.

Capacitance C_1 is charged through a resistor R_1. A Flip-flop Q_1 turns over when the potential of C_1 reaches a set threshold voltage of Q_1. Simultaneously, a pulse with a time constant of R_3C_3 is generated and given to a switch. Then, C_1 is discharged through the short circuit S_1.

The n times repetition of the charging and discharging is counted and its required time T_1, which is proportionl to capacitance C_1, is measured by a timer T, which is a digital value. The digital value T_2 which is proportional to capacitance C_2 can also be attained in a similar manner.

A microprocessor carries out the calculation below using T_1, T_2 and the linearity correction factor T_C . A result proportional to the pressure is then acquired.

$$\frac{T_1 - T_2}{T_1 + T_2 - 2T_c} = \frac{C_1 - C_2}{C_1 + C_2 - 2C_s} \propto (P_H - P_L) \quad \cdots\cdots\cdots(2)$$

4.3 Sensor unit

The advanced floating cell construction, which has a long history of use in the former FCX series, is adopted by the sensor unit for differential pressure.

Measured input pressure is transmitted to the sensor by its addition to the inner fill-fluid via a sealing

Fig. 6 Block diagram of the electronic circuit

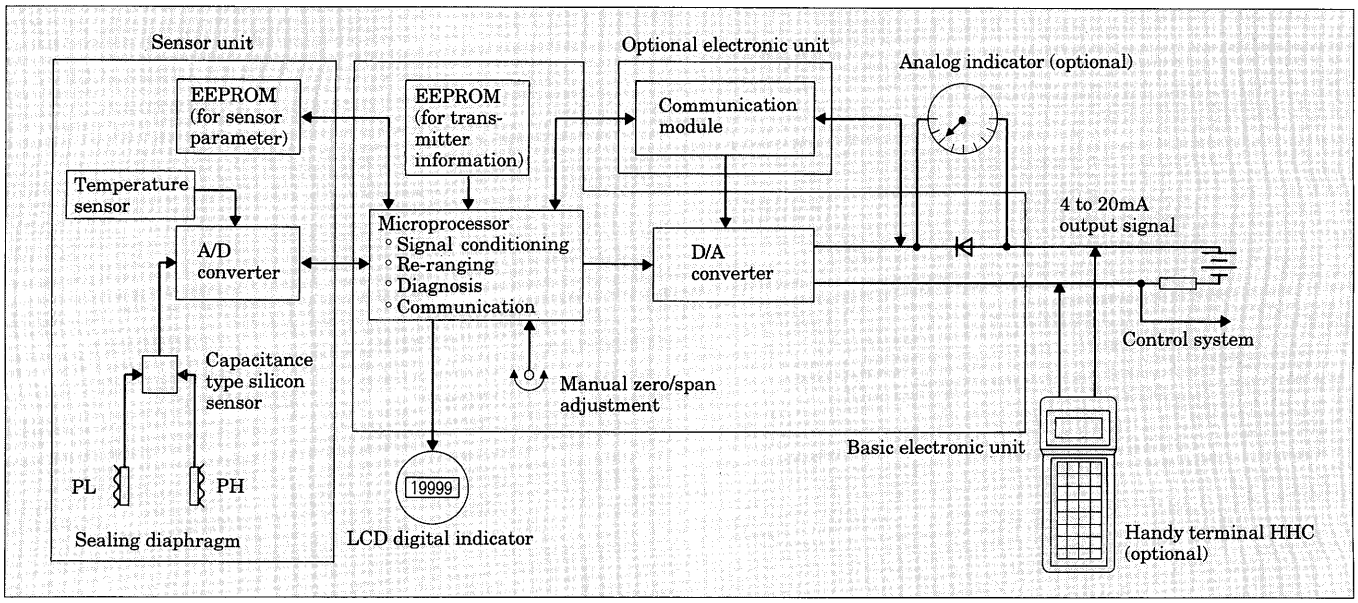


Table 1 Principal specifications of the FCX-A/C series transmitter

Specifications \ Type		FCX-A			FCX-C		
		Differential pressure		Gauge pressure	Differential pressure		Gauge pressure
		Low range	Middle/high range		Low range	Middle/high range	
Upper range limit (URL)		1 kPa 6 kPa	32 kPa, 64 kPa, 130 kPa, 500 kPa, 2,000 kPa, 3,000 kPa	64 kPa, 500 kPa, 3,000 kPa, 10,000 kPa, 50,000 kPa	6 kPa	32 kPa, 130 kPa, 500 kPa, 2,000 kPa	130 kPa, 500 kPa, 3,000 kPa, 10,000 kPa
Accuracy rating		±0.1 % (±0.075 %*)			±0.1 %		
Temperatur effects	Zero	(0.25% span + 0.2% URL)/55℃	(0.2% span + 0.05% URL)/55℃		(0.5% URL)/55℃	Span≧1/2.5 URL : (0.5% span)/55℃ Span<1/2.5 URL : (0.2% URL)/55℃	
	Total	(0.3% span + 0.2% URL)/55℃	(0.25% span + 0.05% URL)/55℃		(0.5% span + 0.5% URL)/55℃	Span≧1/2.5 URL : 1 % span/55℃ Span<1/2.5URL : (0.5% span + 0.2% URL)/55℃	
Static pressure effect	Zero	0.2% URL/ 1 , 3.2 MPa	0.1% URL/10 MPa	—	0.4% URL/3.2 MPa	0.2% URL/10 MPa	—
Over pressure effect (zero)		0.3% URL/ 1 , 3.2 MPa	0.3% URL/16 MPa 0.5% URL/42 MPa	0.2% URL/ Pressure rating	0.4% URL/3.2 MPa	0.4% URL/14 MPa	0.3% URL / Pressure rating
Output, Power supply		DC 4 to 20 mA, DC 10.5 to 45 V					
Temperature limit	Process	−40 to +120℃		−40 to +100℃	−40 to +100℃		
	Ambient	−40 to 85℃					
Pressure rating		3.2 MPa or 10 MPa	16 MPa or 42 MPa	150% URL or 300% URL	3.2 MPa	14 MPa	150% URL or 300% URL
Process connection		Rc 1/4 or NPT 1/4					NPT 1/2
Mass		4.4 kg		3.4 kg	3.4 kg		1.9 kg

* : Optional

diaphragm.

When excessive pressure is added, the protective diaphragm is distorted and the fill-fluid shifts. As a result, the sealing diaphragm strikes against a back-up plate, and the sensor is protected by the suppression of an increase in inner pressure.

Moreover, the sensor, surrounded by incompressible fluid, floats in a housing. The characteristics variation of the sensor by static pressure is small, as the internal and external pressure of the sensor remain the same when static pressure is added.

For pressure transmitter in the FCX-C series, no cover is used for the sensor unit to reduce size and weight. The unit is reduced to 1/2.6 in weight, and the total weight of the FCX-C series pressure transmitter is reduced to 49% of the earlier model, realizing easy portability.

4.4 Electronic circuit and ASIC mounting

Figure 6 shows the block diagram of the electronic

Fig. 7 Linearity characteristics of the FCX-A series differential pressure transmitter

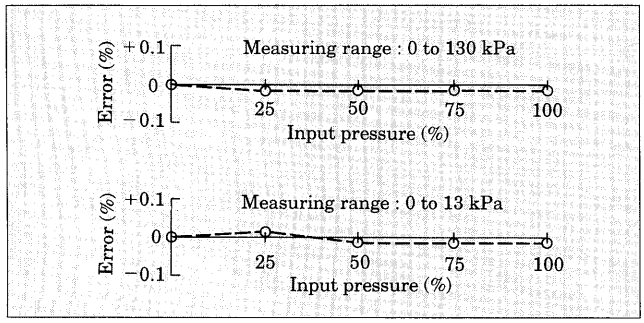
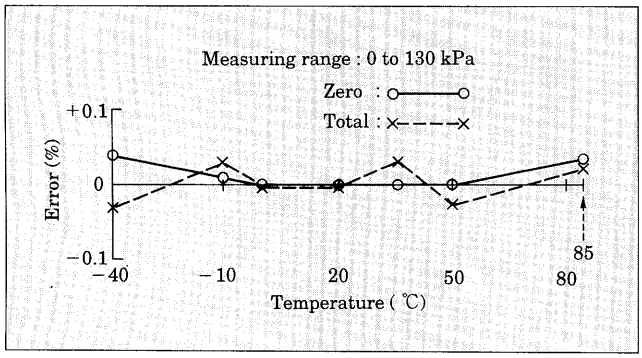


Fig. 8 Temperature characteristics of the FCX-A series differential pressure transmitter

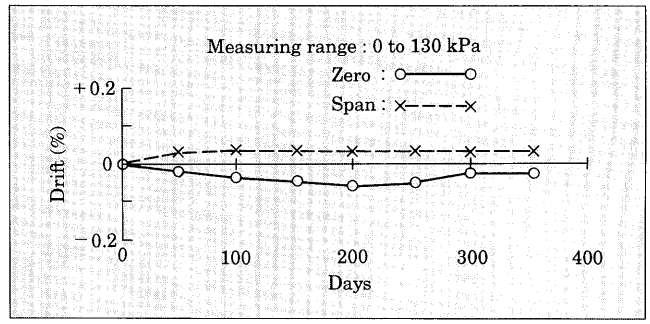


circuit. Differential pressure is detected in the form of capacitance and its measured value signal. Together with an output signal of a temperature sensor, it is digitalized with an analog-to-digital converter and transferred to the microprocessor. Using such signals and the data for the linearity correction for temperature compensation, which have been previously stored in the sensor unit's EEPROM (Electrically Erasable and Programmable Read Only Memory) , the microprocessor executes the calculation described above. Furthermore, in the FCX-A/C series, the temperature characteristics have been improved by the introduction of an advanced correction algorithm for compensation of the non-linearity of the characteristics. The result of the calculation is converted to a 4 to 20mA current signal with a digital-to-analog converter and then transmitted.

The FCX-A/C series can provide either the traditional or the smart type of transmitter. The former has a DC 4 to 20mA analog output with an accuracy rating of 0.1%, and the latter has an additional function to superimpose a digital signal for remote maintenance on a similar analog output. As the basic electronic unit is commonly used in both types and the difference in the circuit structure is the use of plug in the communication module, changeover from one type to another (we call it traditional/smart convertibility) is easily accomplished. The communication module is "bilingual", able to communicate with either Fuji's own protocol or HART protocol.

To reduce the size of the electronic unit, we developed a small ASIC (Application Specific Integrated Circuit) in which the microprocessor, EEPROM, LSI, etc. were integrated. As a result, the mounting space of the printed circuit board can be reduced and compactness of the whole electronic circuit has been achieved.

Fig. 9 Long-term stability of the FCX-A series differential pressure transmitter



5. Principal Specifications

Table 1 shows the principal specifications of the FCX-A/C series pressure transmitters. To flexibly meet various process requirements, the FCX-A series is available with options.

Hazardous location together with explosion-proof and intrinsic safety approvals, are now being applied for in Japan, the United States of America, Canada and leading European countries.

6. Characteristics

The principal characteristics of the smart transmitter with a maximum span of 130kPa are shown in Fig. 7 through 9. The accuracy of the characteristics satisfy the rated value of 0.1%, even when the range is 1/10 of maximum span.

High level temperature correction using microprocessor calculation shows that the effects of temperature on the characteristics are extremely minimal.

Through long-term stability tests it has been proven that the output of both zero and span values are stable.

7. Conclusion

Due to our two separate product lines, market needs, will be better met. These product lines consist of the FCX-A series with advanced performance and functions, and the FCX-C series, which is compact and handy.

Furthermore, by applying the newly developed technologies of the capacitance sensor, ASIC, etc. to the "Fieldbus", which is now being studied in various fields and is expected to prosper in the future, we hope to develop a transmitter that is more flexible, easily maintained and having even multiple advanced functions.