YPK110 FIELDBUS TO PNEUMATIC CONVERTER

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Yokogawa released the 5502 analog current to pneumatic converter and 5503 valve positioner in 1961, and the PK200 analog current to pneumatic converter and VP200 valve positioner in 1992. These models have been chosen for many plant control applications. Furthermore, it released the YVP110 Foundation Fieldbus valve positioner in 1999, endeavoring to improve the efficiency and usability of positioners and to reduce lifecycle cost through online diagnostics. Meanwhile, demand for Foundation Fieldbus to pneumatic converters has grown as 1) pneumatic signals are now used for final control elements even in fieldbus instrumentation, 2) there are requests to convert plants instrumented with pneumatic control devices into fieldbus-networked plants, and 3) many instruments need to be driven directly by pneumatic pressure. We therefore developed the YPK110 fieldbus to pneumatic converter. This paper introduces the structure, control method, and online diagnostics of the YPK110.

INTRODUCTION

Recent improvements in digital signal processing and network technologies have enabled advanced functions to be built into field devices, such as diagnostics and local controls, which could not be incorporated in traditional 4-20 mA analog field devices. Also, due to international standardization initiatives for field networks such as Foundation Fieldbus, it has become possible to freely choose field devices from many different manufacturers in order to build the optimum field network system.

As a result of such technological progress and standardization, there is a growing trend toward replacing the pneumatic or analog instrumentation of plants with fieldbus-based instrumentation, and many customers are revamping by replacing their pneumatic instrumentation with the latest Foundation Fieldbus-based instrumentation. Some of these projects require system conversion to Foundation Fieldbus instrumentation while leaving the existing final control elements such as control valves and pneumatic positioners in order to minimize the switching cost. At the same time, the so-called "hot cut-over," the method of replacing equipment without shutting down the plant, is required.

To meet these requirements, we have developed the YPK110 fieldbus to pneumatic converter that can start controlling various valves and pneumatic positioners without requiring individual adjustments after installation on site. Its unique control algorithm, structure, and functions are introduced below. Figure 1 shows the appearance of the YPK110, and Table 1 the general specifications.

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Figure 1 YPK110 Fieldbus to pneumatic Converter

Table 1 General Specifications of YPK110

Power supply	9 to 32 V DC
Communication	Digital two-way communication (Foundation Fieldbus)
Supply air pressure	130 to 150 kPa (for 20-100 kPa standard output) 230 to 260 kPa (for 40-200 kPa doubled output)
Output pressure	20 to 100 kPa standard output 40 to 200 kPa doubled output
Output signal	Pa, bar, psi
Power consumption	Max. 17 mA (16 mA typical)
Function blocks	1 Analog Output 2 Discrete Inputs 1 PID control function (optional) 1 Output Splitter
Linearity	±0.2% of full span
Repeatability	0.1% of full span
Hysteresis	0.2% of full span
Air consumption	0.32 Nm^3/h or less (@140 kPa)
Air delivery	6.6 Nm^3/h or more (@140 kPa)
Weight	2.4 kg
Mounting	2" pipe or wall mounting
Ambient temperature	–40 to 85°C

STRUCTURE OF YPK110

Figure 2 shows the block diagram of the YPK110. The digital signal input via the fieldbus is transferred to the media access unit (MAU), fieldbus modem, then microprocessor (CPU) for computation and conversion into an analog signal, which is input to the current to pneumatic (I/P) converter. There, the current is converted into the pneumatic pressure (nozzle back pressure) *Pn*, and amplified by the control relay, and transferred to the valve, pneumatic positioner, or the like as the output pressure *Po*. This output pressure *Po* is also returned to a pressure sensor in the YPK110 for feedback control.

In the YPK110, the air exhausted from the I/P converter and control relay is utilized to maintain the inside of the YPK110 casing at a positive pressure, thereby preventing the external humidity and ambient gases from intruding into the casing. For this, two pressure sensors, one for measuring the output pressure *Po* and the other for the ambient pressure *Pa*, are incorporated and the correction by ambient air pressure is performed at all times based on the differential pressure between them. At the same time, a built-in temperature sensor is used for temperature compensation to eliminate the errors on pressure measurement from changes in temperature.

PNEUMATIC PRESSURE CONTROL IN YPK110

The devices to be driven by the YPK110 vary widely in load capacity. Pneumatic positioners require tens of cubic centimeters but direct drive of a valve may require hundreds or sometimes thousands of cubic centimeters (a booster relay is often used for capacities of 3000 cc or more). Besides, the length of the pneumatic signal piping between YPK110 and valve may also vary widely from less than 1 m to 5 m or more since the YPK110 will be installed on a panel or mounted on a stanchion pipe for ease of maintenance. Even where the load conditions differ greatly as above, stable control of valves and valve positioners without adjustments is required.

Furthermore, the control relay, which is an essential component for amplifying the output pressure, is structurally associated with a dead band within which the output pressure does not respond to changes in the input pressure, and this makes control difficult. To solve these challenges, the YPK110 adopts a new control approach as described below.

(1) Basic Algorithm

Figure 3 illustrates the control block diagram. The PK200 analog I/P converter has a PID control algorithm with a derivative action time longer than the integral action time,

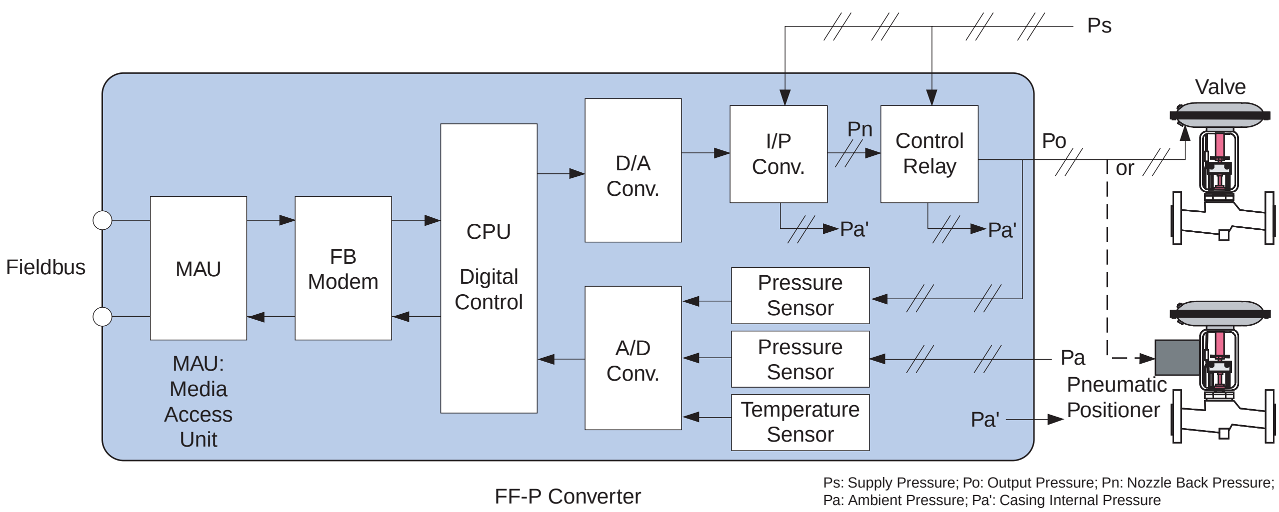

Figure 2 Block Diagram of YPK110

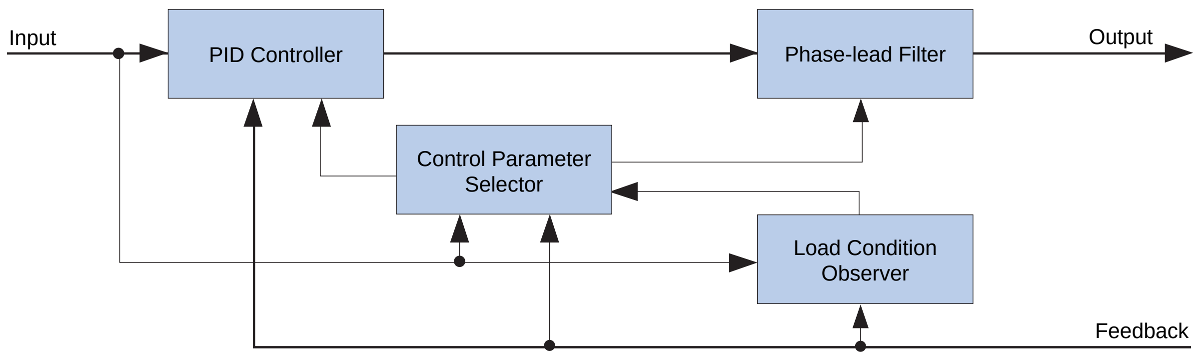

Figure 3 Control Block Diagram of YPK110

and its stable controllability is field-proven. The YPK110 also adopts PID control as its basic algorithm. However, since the YPK110 implements discrete digital computations, the phase lag caused by the sampling interval when controlling quickly responding small-capacity valves may cause oscillations in valve control. On the other hand, the limitation of current consumption prevents the sampling interval from being shortened. To solve this, a phase-lead filter is inserted.

(2) Load Condition Estimation

Small-capacity valves and short pneumatic piping have a fast response, whereas large-capacity valves and long pneumatic piping result in a slow response. As shown in Figure 4, when the input requires air charging to raise the pressure, the YPK110 predicts the estimated output pressure as at one second later based on the differential coefficient read by a built-in pressure sensor. If the estimated output pressure deviates from the target pressure, the control parameters such as the proportional gain, derivative time, and integral time are changed whenever necessary. When the input requires air exhausting to lower the pressure, the load condition observer is determined based on the stored control parameter settings that were applied during air inletting and when the parameter settings were selected.

(3) Control Parameter Selection

As shown in Figure 5, the YPK110 stores a total of eight combinations of control parameter settings chosen based on the above-mentioned load condition observer, and it switches over the parameter settings automatically while estimating the load capacity at all times. The individual parameter settings can be tuned and set up optionally by the user.

(4) Control Characteristics

Figure 6 shows the step response waveforms of a YPK110 when connected to two kinds of actual, fixed-capacity loads: one with the capacity of 20 cc, and the other of 1000 cc. The tubing was 6-mm outside diameter, 4 mm inside diameter, and 10 m long. For both cases, individual setups such as tuning were not performed. The input levels applied were 50 ± 50% of the full span. With the effect of the above-mentioned load condition observer and control parameter selection function, even though the connected capacity differs by a factor of 50 times, excellent response characteristics were exhibited at both air inletting and air exhausting: it took approximately 2 seconds to reach 90% of the step after a change, and 6 seconds or less to stabilize within ± 0.1% of the step. In addition, overshoots and other undesired behaviors were not observed.

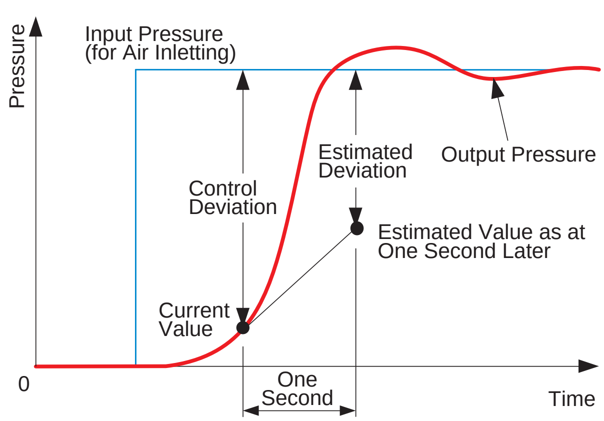

Figure 4 Load Condition Estimation

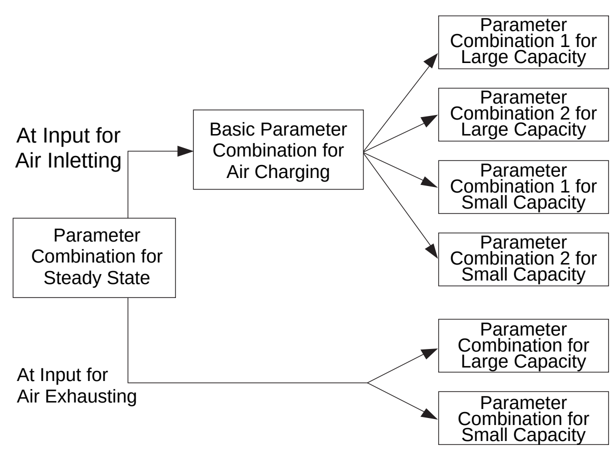

Figure 5 Control Parameter Selection

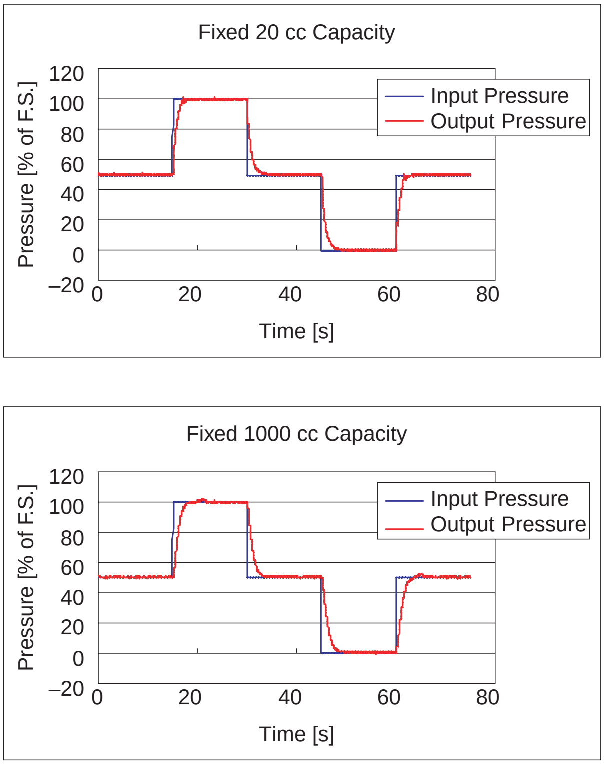

Figure 6 Control Characteristics

DIAGNOSTICS OF YPK110

The YPK110 implements self-diagnostics (see the next paragraph for details) and integration functions (the air pressure rise/fall time, total air pressure, air pressure output time, and air pressure low-cutoff time) for online diagnostics of the valve and control device. The device temperature and measured output pressure can also be represented as parameters. These enable not merely diagnostics of the YPK110 itself but also detection of a drop in the supply air pressure and leakage in piping. Moreover, by comparing the current working statuses with previously collected data values, the service life of the valve can be predicted.

The major items monitored by the YPK110's self-diagnostics include:

- Deviation warning/error
- Operation point drift warning
- Temperature out of range
- Pressure out of range
- Temperature sensor failure
- Pressure sensor failure
- A/D converter failure

CONCLUSION

The features of the new YPK110 fieldbus to pneumatic converter were outlined above.

The YPK110 is a low-cost optimum solution for revamping of the existing pneumatic instrumentation of plants into fieldbus-based instrumentation while leaving the existing final control elements and plant utility, and can also be used as a leading-edge signal converter to convert fieldbus signals into pneumatic signals at new plants. It can control actuating cylinders, long-stroke valves such as gate valves, and small-capacity valves, that cannot be handled by a valve positioner.

These merits will reduce the total cost not only of renewing existing plants but also building new ones. We will continue to expand the lineup of the fieldbus devices and develop functions for reducing lifecycle cost in response to customer and market needs. ◆

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