Fuji Electric's Latest High Functionality Temperature Controllers PXH, PXG and PXR, and Examples of their Application

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1. Introduction

In the temperature controller sector, as with burner control for small scale boilers and air conditioning control, general-purpose temperature controllers have been somewhat limited in capacity, and demand has been increasing year-by-year for middle-class controllers that support high-speed control and valve operation. Targeting this sector, in 2005 Fuji Electric introduced the PXG temperature controller, equipped with the world's top class of temperature control functions.

With the addition of the PXG temperature controller for middle-class applications to Fuji Electric's PXH high-speed high functionality temperature controller for the high-end sector and the PXR general-purpose temperature controller for the low-end sector, Fuji Electric has arranged a lineup of temperature controllers suitable for all temperature control applications.

The first half of this paper describes the latest high functionality temperature controllers and in particular, Fuji Electric's most recent model, the PXG. The latter half of this paper presents application examples of the PXH and the PXG.

Fig.1 Fuji Electric's lineup of high functionality temperature controllers
(top row: PXH, middle row: PXG, bottom row: PXR)

2. Overview of High Functionality Temperature Controllers

Figure 1 shows Fuji Electric's most recent lineup of high functionality temperature controllers, and Fig. 2 shows the relative positioning of these temperature controller models.

(1) PXH

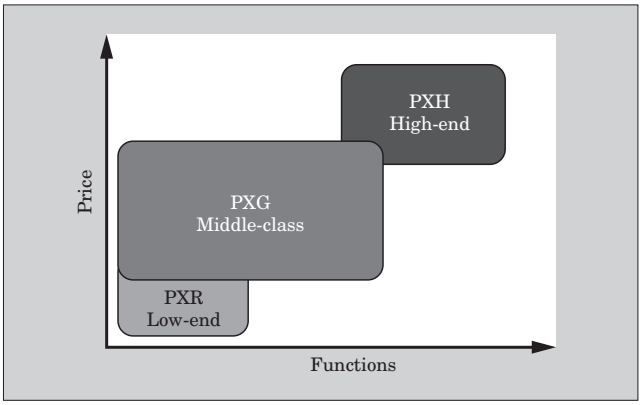
The PXH is positioned as a high-end model that chiefly supports high-speed control of pressure, flow rate and the like. Responsive to the semiconductor production equipment sector where highly precise control is required, the PXH is a high-speed and high-precision temperature controller.

The cycle times for input sampling and control calculation are 50 ms, which is Fuji's fastest speed, and the temperature indicator has a resolution of 0.01°C.

(2) PXG

The PXG was brought to the market in August 2005, and is Fuji Electric's most recent high functionality temperature controller. This controller handles application in the wide area between the high-end PXH temperature controller and the low-end PXR temperature controller. Functionally, the PXG covers the range extending from a portion of the high-end area to the entire low-end area. The main feature of the PXG is its multi-functionality that supports nearly all tempera-

Fig.2 Map of Fuji Electric's latest high functionality temperature controllers



ture control applications.

(3) PXR

Since functions were added in August 2003, the PXR has enjoyed wide support as Fuji Electric's predominant temperature controller. Having a low price and equipped with the standard features of a self-tuning function and fuzzy control, the PXR supports a wide range of applications and permits the addition of such options as remote setpoint, heater break alarm, a communication function, and the like.

3. Features of the PXG High Functionality Temperature Controller

The PXG product line consists of three models, the PXG4 having front panel dimensions of 48 × 48 (mm), the PXG5 having dimensions of 48 × 96 (mm), and the PXG9 having dimensions of 96 × 96 (mm). These models have input sampling and control calculation cycle times of 200 ms (300 ms for the position feedback type) and their measurement input accuracy is ±0.3 % FS. The high performance of these models is comparable to that of prior temperature controllers. (See Fig. 3.)

The PXG inherits its hardware and internal construction from the PXR, which has a long track record of success. The control algorithm, which is the core software asset, is also inherited, but the PXG realizes enhanced peripheral functions and improved operability. (See Table 1.)

Representative functions of the PXG are introduced below. (See Table 2.)

(1) Control functions

In addition to functions for ON/OFF control, fuzzy control, self-tuning control, PID control and heating/cooling PID control that have equipped prior models, the PXG is also equipped with motor drive valve control, position feedback control, and 8 types control algorithm of PID2 control, and implements heating control with not only a heater, but also with steam, to support temperature control based on position feedback control. Moreover, after the completion of a batch process, control stops, but temperature monitoring and temperature alarm functions often continue to operate in a temperature controller. For this type of application, the PXG is newly equipped with a control standby function that stops the control and PID2 control that helps to suppress overshoot upon return to the control loop (rise in temperature) from a standby state.

(2) 16-step ramp soak function

A ramp soak function with up to 4 patterns having 16 steps (32 segments) is provided as a standard function. This function is a simple programmed operating function. The PXG is also equipped with functions for continuous start mode upon return from a power failure, a guarantee soak function to compensate the control time of constant temperature sections, a PV start function, status event output, time signal event output, a delay start function that starts automatically when a certain amount of time has elapsed after power was turned on, a function for pattern switching based on digital input, and operational control, and the PXG specifications are comparable to those of a programmable controller.

(3) Soft start function

The PXG is equipped with a soft start function that suppresses the control output below a certain value for a predetermined amount of time. This function

Fig.3 Fuji Electric's PXG high functionality temperature controller

Table 1 PXG control algorithm and features

Control algorithm	Features, application example, etc.
ON/OFF control (2-position control, 3-position control)	2-position control: simple ON/OFF control, 3-position control: Heating and cooling ON/OFF control (Used in equipment requiring not-high controllability and low cost.)
PID control	Used in control systems that include lead/lag factors. (Widely used for general temperature control.)
PID2 control	For a heating control system in which the control loop temporarily becomes an open loop, PID2 control can reduce the overshoot at the return to the control loop. (Used in batch furnace operations and the like.)
Fuzzy control	A fuzzy algorithm is used to improve overshoot and the disturbance response at the startup of a process. (Widely used for general temperature control.)
Self-tuning control	Self-tuning control automatically performs the PID tuning. Used when desired to reduce the labor involved in making adjustments. (Widely used for general temperature control.)
Heating and cooling PID control	Control is implemented using both heating and cooling. Used in control systems where heat is absorbed or generated due to the dissolution of resin and so on. (Used in plastics molding machines, etc.)
Motor drive valve control (servo control)	Implements motor drive valve control using a motor drive valve that is not equipped with a potentiometer. (Used in low-cost motor drive valve control systems.)
Position feedback control	Position feedback control receives positional information from a potentiometer and adjusts the valve position. (Used in flow rate control etc. in a plant.)

Table 2 List of new PXG functions

Function	Function summary
16-step ramp/ soak function	16-step (32-segment) large capacity program Usage may be split among up to 4 patterns. Continuous start possible upon return from a power failure. Guarantee soak, PV start Status may be output. Control may be based on a digital input.
Soft start function	Limits control output when power is turned ON for a certain amount of time. May start at an arbitrary time with a digital input trigger.
PID pallet (8 types)	8 groups of setting values (SV), PID setting Setting value (SV) and PID groups switchable as independent or linked. Switchable according to digital input or front panel user key.
Changeover of SV (8 types)	
Loop break alarm function	Capable of detecting control loop disconnection without an externally attached current transformer.
Load short-circuit alarm function	Using an externally attached current transformer, able to detect short-circuit of SSR and the like.
Event function (approx. 100 types)	Total of approximately 100 types of temperature alarms, timer operation and status events supported.
Digital input function (approx. 45 types)	Approximately 45 types of digital input functions supported.
Loader communication function	Provided with an RS-232C loader communication port. Custom loader software can be downloaded for free from the home page.
Digital input (5 points)	5 points can be provided for both digital input and output.
Digital output (5 points)	
Retransmission function	In addition to the 4 to 20 mA range, the voltage output is selectable. Voltage range can be switched from 0 to 10, 2 to 10, 0 to 5 and 1 to 5 V.
User key	User keys are provided on the front panel, and in addition to A/M switching, 27 types of functions may be assigned arbitrarily.
All displays off	Each parameter, including PV and SV, can be set arbitrarily for display or non-display. All displays off can also be specified.
Output designated function at fault	Control output during fault and during standby can be fixed to a designated value.
Output designated function during standby	
Startup mode select function	Control mode at startup is selectable from auto/manual/standby.
Universal input	Supports all types of input Supported with parameter switching only.

suppresses the current consumption of the equipment when power is turned on, and enables energy-saving operation. In control having multiple zones, this function corrects inter-zone fluctuation during startup. The soft start function can be activated when the power supply is turned on or at any arbitrary timing.

(4) 8-setting changeover and PID pallet changeover function

The PXG is capable of storing 8 groups of setup values (SV) and PID groups, and this function can be switched between synchronous and non-synchronous operation using the front panel key or digital input. As a result, highly accurate control can be realized with a PID value that is appropriate for the temperature setting.

The PID pallets are specified for normal/reverse operation, and when combined with motor drive valve control, are capable of supporting summer/winter switching in an air conditioning application.

(5) Loader communication port

The PXG is equipped with a loader communication (RS-232C) port as a standard feature at the bottom of the main unit. Additionally, loader software for a PC is provided free of charge, and the setting of many parameters for multiple functions can be implemented easily and reliably.

(6) User key

The front panel is equipped with a user key that enables a user to select functions freely. The user key can be defined according to various applications, including automatic/manual switching, control start/stop, setting value changeover, ramp soak start/stop, and the like.

(7) Load short-circuit alarm function (option)

In addition to the previous heater break alarm function, measurement of the load current while the control output is OFF enables an alarm to be output, via a solid state relay (SSR) or the like, when trouble occurs at the operation side.

4. Example Application of New-type of Temperature Controller

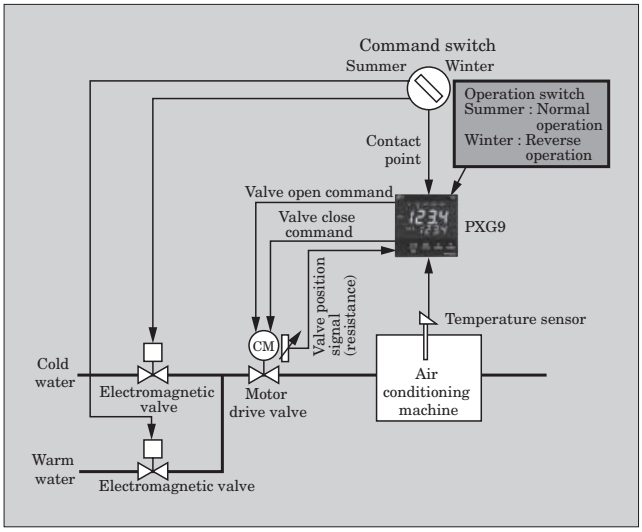
The PXG is equipped with functions that support various types of equipment. The PXH, in addition to a high level of basic performance, i.e., its input indicator accuracy and control calculation cycle, is also equipped with an abundance of inputs and outputs, a numerical value calculation function, and a T-link communication function for connection as an I/O device to Fuji Electric's programmable controller (PLC). The PXH is suitable for various applications ranging in size from a single apparatus to a plant facility. Example applications are described below.

4.1 Example application of PXG to the cold/warm water control for an air conditioning machine

An air conditioning machine is supplied with cold water in the summer and warm water in the winter. The PXG is equipped with a function for switching the control operation (normal or reverse operation) according to a contact input, and as shown in Fig. 4, by connecting the contact point of an command switch to the PXG, the control operation for the electric motor

valve can be switched to summer or winter settings in response to an increase or decrease in measured temperature values, thereby enabling air conditioning control to be implemented with a single control unit. Moreover, the PXG used here may be driven directly, and because the presence or absence of the valve position signal input can be specified, a motor drive valve that does not output the valve position may also be used.

Fig.4 Example of PXG application to cold/warm water control for air conditioning machine



4.2 Example application of PXH to combustion control

In the combustion control of an industrial furnace or boiler, because of compliance with energy-savings measures and because of environmental problems and the like, there is a great need to control the ratio of air and fuel in order to achieve optimal combustion. Since it is necessary to control the mass flow rate of combustion gas and air after having been compensated for changes in density due to temperature and pressure fluctuations, multiple analog inputs and calculation functions are required, and therefore, a process controller (Fuji Electric's compact controller class) had previously been used for combustion control. However, as shown in Fig. 5, the PXH may also be used for combustion control. The PLC and PXH are connected by a T-link, and since the PLC treats the PXH's inputted measurement values, control calculated values and so on as I/O data, the flow rate setting of the combustion gas and air is calculated by the PLC, and can be provided to each PXH as a remote setup value. The temperature and pressure flow rate compensation calculation is embedded in the PXH as a control template, so that the user only has to set the various constants.

Fig.5 Example of PXH application to combustion control

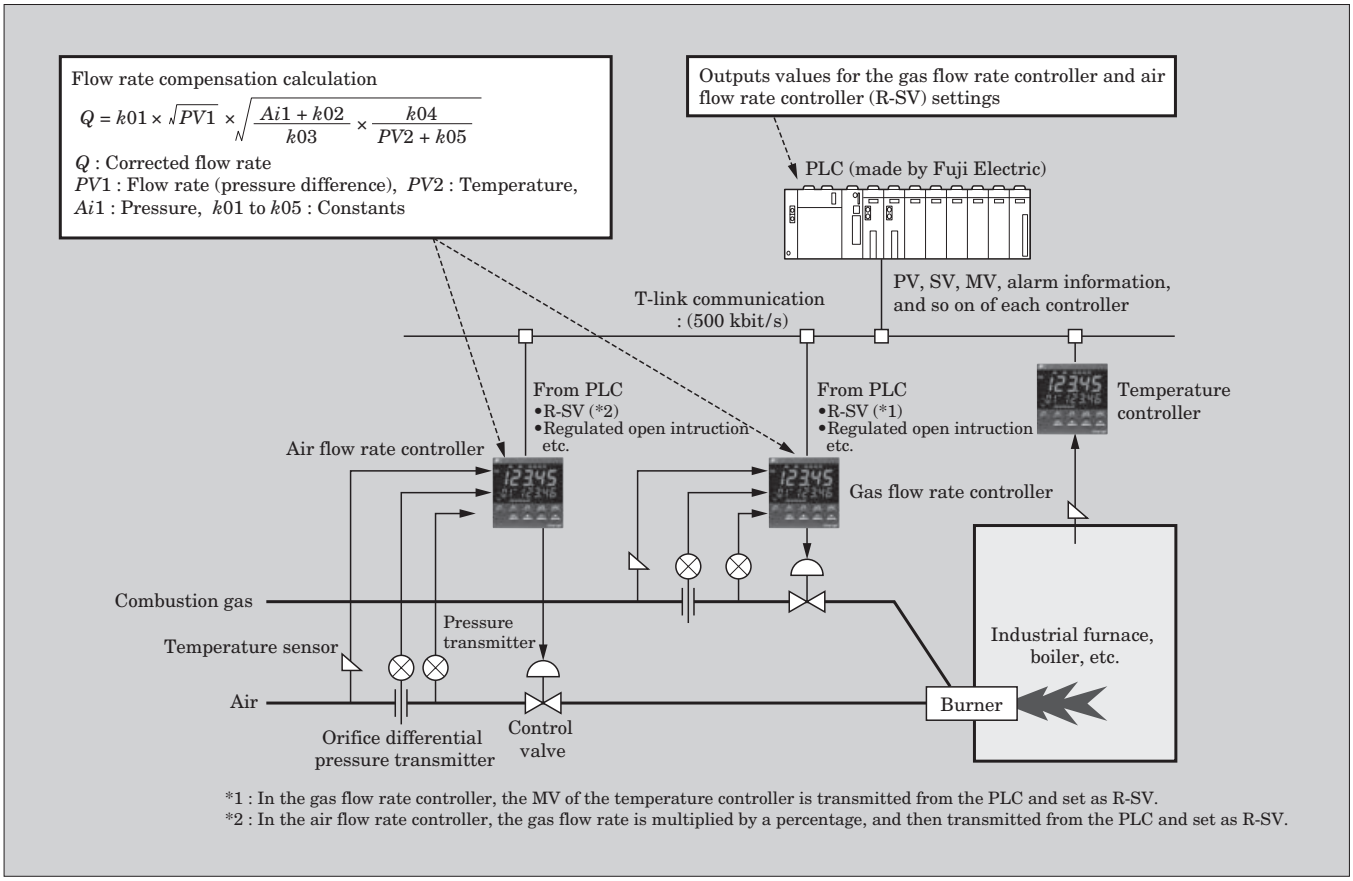
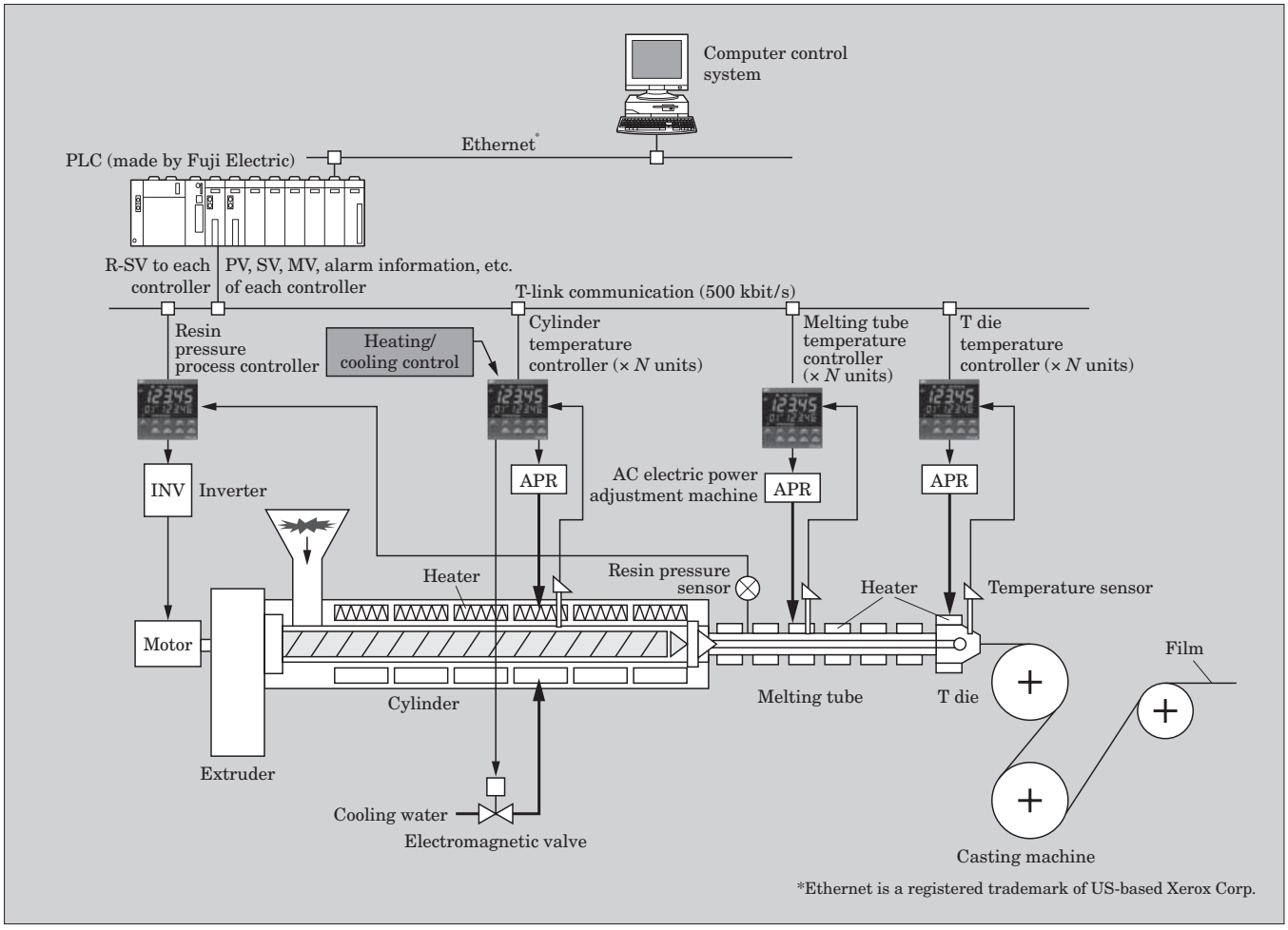


Fig.6 Example of PXH application to a film manufacturing line



Furthermore, because the calculation is performed with floating decimal point industrial values, special considerations for scaling are unnecessary and engineering work is simplified.

4.3 Example application of PXH to a film manufacturing line

A film manufacturing line consists of raw material equipment, an extruder, a melting tube, a T die, a casting machine, a vertical drawing machine, a horizontal drawing machine, a haul-off unit and a winder, and process control of temperature, pressure and so on is performed for each piece of equipment. Each process is easily influenced by external disturbances, which have a large impact on product quality, and therefore a high level of control performance is required. In addition to having high-speed and highly precise control functions, the PXH is also provided with a 2-degrees-of-freedom PID function, a PID pallet change function, and functions and parameters for overshoot suppression and for improving the disturbance response. The PXH is well suited for application as a process controller from this equipment.

Figure 6 shows a process control distribution diagram in the periphery of the extruder.

(1) Temperature control

The cylinders of an extruder use a heating and cooling type PXH developed for extruder-use to suppress the effects of heat generated from the resin and to stabilize the resin temperature. Based on Fuji Electric's expertise accumulated through numerous deliveries to this sector, auto-tuning control is employed and control constants can be obtained separately on the heating and cooling sides to realize a high degree of controllability.

(2) Resin pressure control

The rotational speed of the extruder's motor is controlled so that the resin pressure becomes constant, and with 50 ms high-speed control calculations, appropriate control is implemented in response to rapidly changing resin pressure.

(3) High-speed communications via T-link

The control loop for a film manufacturing line has many points, and a host computer accumulates and manages all control results as quality data. By connecting Fuji Electric's PLC to the T-link (500 kbit/s), control data can be collected at high-speed.

5. Conclusion

Fuji Electric's multi-function temperature controllers, especially the PXG which is the latest model, and examples of their applications have been described.

Process control is diversifying toward DCSes (distributed control systems), PLCs and modularization, and there is deep-seated need for process controllers because of their convenience of use from a single unit, diffusion of risk, ease of maintenance, and the like. The process controllers described in this paper are optimal for such types of applications.

The authors will be grateful if this paper is a useful reference when selecting a temperature controller or building a system in the future.

Reference

(1) Venture Development Corporation. Industrial Electronic Temperature controllers Global Market Demand Analysis. Ninth Edition December 2005. Strategies and Recommendations. p.167-176.