UT100 SERIES OF TEMPERATURE CONTROLLERS

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We have developed the UT100 series of temperature controllers. In contrast to the existing Green series of digital indicating controllers which can cover a wide range of process control, the UT100 series controllers are low priced and are intended mainly for temperature control. The UT100 controller is a traditional PID controller that features the newly developed auto-turning control function, Omakase, which permits optimum control with the same degree of ease as operating a thermostat. Moreover, in spite of being a low price controller, the models of the UT100 series have a variety of functions including a universal power supply, universal input, PID control, ON/OFF control, heating/cooling control, and optional communication capability.

This paper describes the main specifications, Omakase (auto-turning control function), cost-saving design, and how to produce a variety of products in a short leadtime.

INTRODUCTION

In recent years, the restrictions of ISO14001 standards and HACCP have meant that temperature control and monitoring have become a necessity in a wider range of fields. Together with the demand for high-precision control performance, has come the need for increased diversity in terms of input sensors, control methods, and manipulated-variable output signals, as well as improved ease of operability.

Table 1 shows the main specifications of the UT100 series. The universal power supply, universal input, and a variety of outputs and options allow the UT100 series to be applied in a wide range of temperature control applications. Furthermore, the UT100 series boasts a large, easy-to-see LED display (see Figure 1), which conforms to various safety standards as well as the EMC standard (CE, CSA, and UL).

The main purpose for the development of the UT100 series was to create a compact temperature controller at a low price which incorporated numerous functions including a self-tuning function that enabled the controller to be ready for operation immediately after installation.

Figure 1 External View of UT100 Series

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Table 1 Basic Specifications of UT100 Series

Model		UT130	UT150	UT152	UT155
External dimensions (W×H×D in mm)		48 × 48 × 100	48 × 48 × 100	48 × 96 × 100	96 × 96 × 100
Display		Single 3-digit display	Dual 4-digit displays		
Input	Type	Thermocouple, RTD	Thermocouple, RTD, DC voltage		
	Accuracy	0.3% of F.S.			
	ADC resolution	15 bits			
	Measurement interval	500 msec			
Output	Type	Relay, voltage pulse	Relay, voltage pulse, 4-20 mA		
	Accuracy (4-20 mA)	–	0.3% of F.S.		
	ADC resolution (4-20 mA)	–	11 bits		
Control		ON/OFF control, PID control, heating/cooling PID control			
		Omakase (Dynamic auto-tuning control), SUPER function*			
Option		Alarm, communication, heater burn-out alarm	Alarm, communication, heater burn-out alarm, retransmission output, external contact input		
Power supply		100-240 V AC			
International standard		CE, CSA, UL			

* SUPER function: An overshoot suppression function based on fuzzy inference.

OMAKASE (DYNAMIC AUTO-TUNING CONTROL)

Before operating the temperature controller it is necessary to install the panel and wiring, set the setpoint value, and tune the PID values, the last of which is the most difficult and requires experience to do it. The self-tuning function Omakase, permits optimum PID values to be obtained automatically without tuning PID values.

2.1 Method of Calculating PID Values

Figure 2 shows a block diagram of Omakase control.

With Omakase control, the setpoint (SP), measured value (PV), deviation (DV), and control output (OUT) are continuously monitored, and PID values are calculated when one of the following 3 situations arises:

(1) Power ON
(2) Setpoint value is changed.
(3) The process becomes unstable due to disturbance.

The calculated PID values are written to the PID computation block to be used for PID control computation, which continues without interruption.

As for the cases (1) and (2), PID values are calculated from the variation in measured value at power-on and a setpoint change respectively. As shown in Figure 3, the lag time (L) and the maximum slope (R) of the process to be controlled are obtained first, then PID values are obtained based on Ziegler-Nichols's step response method.

$P = KRL$ K: constant
$I = 2L$
$D = 0.5L$

In the case of (3), the operation to obtain PID values starts when the measured value deviates from the setpoint by 2°C or more due to disturbance. As shown in Figure 4, PID values are calculated from the amplitude (AMP), period of vibration (T), and control output at that time. This calculation is performed based on the Ziegler-Nichols's ultimate sensitivity method.

2.2 Control Example of an Electric Furnace

We evaluated control using a small electric furnace. The following is a description of the evaluation.

(1) When power is turned on
(2) When hunting is caused by disturbance

Result (1)

Figure 5 shows the change in measured value starting with room temperature and continuing until the setpoint value (500°C) is reached. The solid line shows the result of Omakase control operation. The optimum PID values were calculated automati-

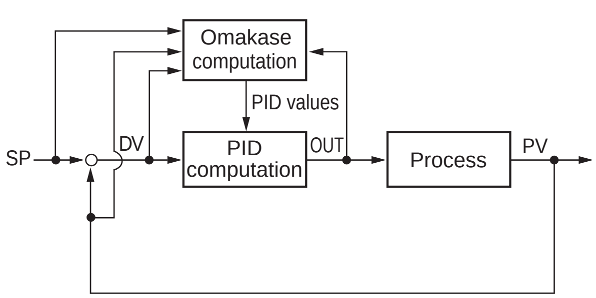

Figure 2 Block Diagram of Omakase Control

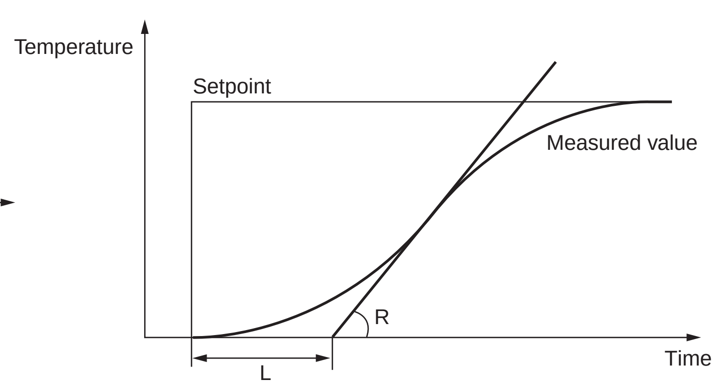

Figure 3 Calculation of PID Values at Controller Startup

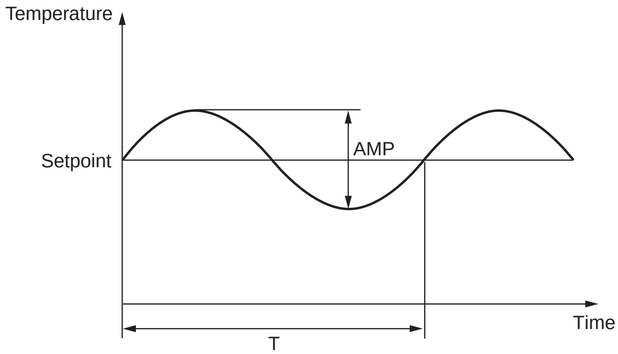

Figure 4 Calculation of PID Values at Disturbance

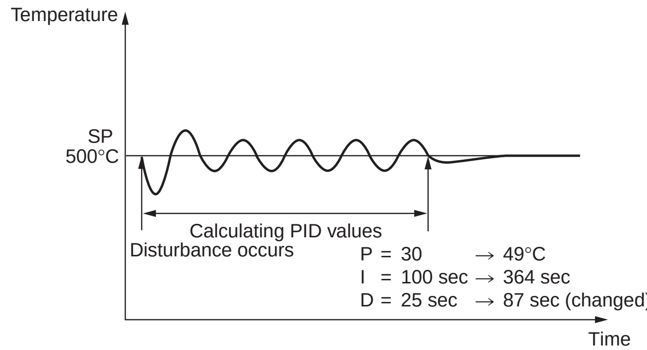

Figure 6 When Subjected to a Disturbance

cally, and a good control result that suppressed any overshoot was obtained. The broken line demonstrates control performed without using Omakase control. The PID values were unsuitable for the process and caused a large overshoot.

Result (2)

Figure 6 shows how the process converged when subjected to a disturbance. The solid line shows the result when using Omakase control. The PID values were changed so allow the hunting to settle; measured values were stabilized and a good control result was acquired. Although not revealed in the figure, a good control result was also acquired when the setpoint was changed after reaching the stable condition.

By using Omakase control, the temperature of an electric furnace can thus be controlled without setting PID values.

HARDWARE CONFIGURATION

As part of the effort to reduce the price, we decreased the amount of printed circuit boards (PCB) in the controller. Careful scrutinization of every part of the electronic circuits, enabled a 50% reduction in terms of PCB area, and the internal unit formerly configured by 2 PCBs (excluding the display section) has been reduced to only one PCB, including optional specifications (UT152/155).

Other control output specifications and optional specifications besides Omakase control are specified at ordering, to fulfil the aim of developing a product that can be used immediately after purchasing.

3.1 Structure

By reducing the power consumption of each component, we adopted an indirect feedback system, which simplified the resin sealing transformer and circuit scheme for the power supply section. This has increased board efficiency by reducing the area ratio of PCBs by 50% compared with former models, while securing the reinforced isolation between the primary and secondary circuits, which assures conformance to various safety standards including EMC standards.

With UT130/150 controllers, the display PCB and main PCB are fixed together using structural parts. And by directly soldering the soldering pads on each PCB, we eliminated the connectors and the amount of wires. In this way, we further simplified configuration and increased reliability at the same time.(Figure 7)

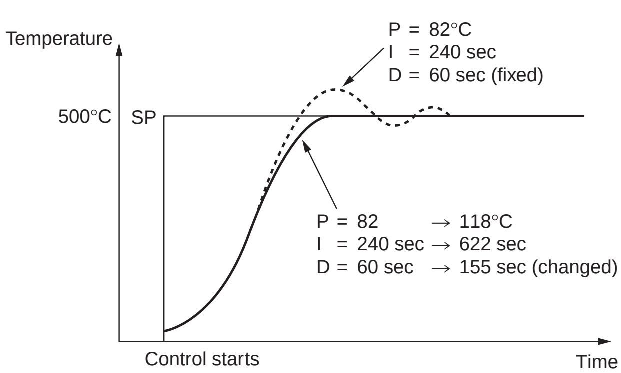

Figure 5 When Controller Starts Up

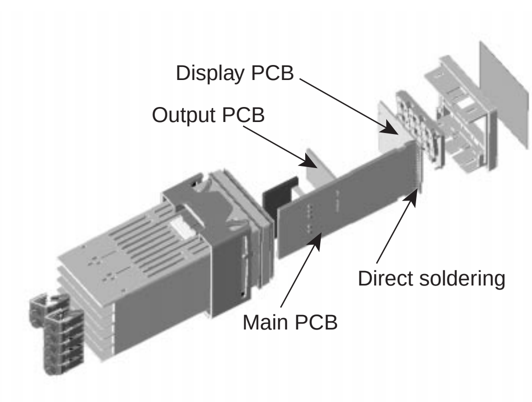

Figure 7 Structure of UT130

Table 2 Assembly Configuration

Model	Assembly	Number of PCB types	Number of intermediate assembly types	Number of final assembly types	Example of product specification
UT130/150	DISPLAY BOARD	2	–	2	UT130: Voltage pulse output, communication UT150: Two relay outputs, alarm, communication UT150: Relay output UT150: 4-20 mA output, alarm, retransmission output :
	MAIN BOARD	1	1	10	
	OPTION BOARD	1	2	16	
UT152/155	DISPLAY BOARD	2	–	2	UT152: Two 4-20 mA outputs, communication UT155: Voltage pulse output UT155: 4-20 mA output, alarm, communication UT155: Relay output, heater burn-out alarm :
	MAIN BOARD	1	2	144	
Common	OUTPUT BOARD	1	–	2	

3.2 Assembly Configuration

To maintain a product line-up that can accommodate the diverse needs of the market, we paid special attention to the assembly configuration to ensure the supply of products in short time periods, which is another market requisite.

We use only one type of PCB for each assembly and obtain different functions by selecting or specifying which parts are to be mounted on the PCB. On the manufacturing lines, we keep a stock of intermediate assembled PCBs in order to increase the efficiency of producing customized final assemblies by just adding parts according to the specifications (outputs and optional functions). With this manufacturing system, it has become possible to increase the speed with which we can complete and ship products. The assembly configuration is outlined in Table 2.

3.3 Mechanical Design

A high ratio of common parts are used in both our existing Green series controllers and UT100 series controllers: 50% for UT130/150 and 80% for UT152/155. This meant that we could develop the UT100 series in a short period with increased reliability.

Although the technical department had suspended its former use of three-dimensional CAD data at the prototype stage, with the development of the UT100 series it has reached the stage of producing a metal mold for mass production. The use of three-dimensional CAD data has significantly shortened the process of creating drawings. Moreover, since the shape can be recognized at a glance, the degree of completion of metal molds has increased and the number of corrections has been reduced. There has been a 60% reduction in the time period ranging from drawing creation to the completion of metal molds compared with previous methods.

CONCLUSION

We have demonstrated the benefits of the newly developed self-tuning function Omakase control in temperature control applications and have successfully incorporated it into the UT100 series. In the future we intend to develop a self-tuning algorithm that can be applied to general processes other than temperature control, and at the same time we aim to develop controllers with increased ease of use, not only in terms of control functions but also in other terms. ◆

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