User’s Manual

Temperature Control and Monitoring Modules and PID Control Module

IM 34M6H61-01E

Yokogawa Electric Corporation
Applicable Product:

- Model Code : F3CT04-0N  
  Name : Temperature Control and Monitoring Module

- Model Code : F3CT04-1N  
  Name : Temperature Control and Monitoring Module

- Model Code : F3CR04-0N  
  Name : Temperature Control and Monitoring Module

- Model Code : F3CR04-1N  
  Name : Temperature Control and Monitoring Module

- Model Code : F3CV04-1N  
  Name : PID Control Module

The document number and document model code for this manual are given below.  
Refer to the document number in all communications; also refer to the document number  
or the document model code when purchasing additional copies of this manual.

- Document No. : IM 34M6H61-01E  
- Document Model Code : DOCIM
Important

■ About This Manual

- This Manual should be passed on to the end user.
- Before using the controller, read this manual thoroughly to have a clear understanding of the controller.
- This manual explains the functions of this product, but there is no guarantee that they will suit the particular purpose of the user.
- Under absolutely no circumstances may the contents of this manual be transcribed or copied, in part or in whole, without permission.
- The contents of this manual are subject to change without prior notice.
- Every effort has been made to ensure accuracy in the preparation of this manual. However, should any errors or omissions come to the attention of the user, please contact the nearest Yokogawa Electric representative or sales office.

■ Safety Precautions when Using/Maintaining the Product

- The following safety symbols are used on the product as well as in this manual.

⚠️

**Danger.** This symbol on the product indicates that the operator must follow the instructions laid out in this instruction manual to avoid the risk of personnel injuries, fatalities, or damage to the instrument. The manual describes what special care the operator must exercise to prevent electrical shock or other dangers that may result in injury or the loss of life.

🔧

**Protective Ground Terminal.** Before using the instrument, be sure to ground this terminal.

🔩

**Function Ground Terminal.** Before using the instrument, be sure to ground this terminal.

تردد

**Alternating current.** Indicates alternating current.

---

**Direct current.** Indicates direct current.
The following symbols are used only in the instruction manual.

⚠️ **WARNING**

Indicates a “Warning”.
Draws attention to information essential to prevent hardware damage, software damage or system failure.

⚠️ **CAUTION**

Indicates a “Caution”
Draws attention to information essential to the understanding of operation and functions.

**TIP**

Indicates a “TIP”
Gives information that complements the present topic.

**SEE ALSO**

Indicates a “SEE ALSO” reference.
Identifies a source to which to refer.

- For the protection and safe use of the product and the system controlled by it, be sure to follow the instructions and precautions on safety stated in this manual whenever handling the product. Take special note that if you handle the product in a manner other than prescribed in these instructions, the protection feature of the product may be damaged or impaired. In such cases, Yokogawa cannot guarantee the quality, performance, function and safety of the product.

- When installing protection and/or safety circuits such as lightning protection devices and equipment for the product and control system as well as designing or installing separate protection and/or safety circuits for fool-proof design and fail-safe design of processes and lines using the product and the system controlled by it, the user should implement it using devices and equipment, additional to this product.

- If component parts or consumable are to be replaced, be sure to use parts specified by the company.

- This product is not designed or manufactured to be used in critical applications which directly affect or threaten human lives and safety — such as nuclear power equipment, devices using radioactivity, railway facilities, aviation equipment, air navigation facilities, aviation facilities or medical equipment. If so used, it is the user’s responsibility to include in the system additional equipment and devices that ensure personnel safety.

- Do not attempt to modify the product.

### Exemption from Responsibility

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- No portion of the software supplied by Yokogawa Electric may be transferred, exchanged, or sublet or leased for use by any third party without prior permission by Yokogawa Electric.
General Requirements for Using the FA-M3

- Avoid installing the FA-M3 in the following locations:
  - Where the instrument will be exposed to direct sunlight, or where the operating temperature exceeds the range 0°C to 55°C (32°F to 131°F).
  - Where the relative humidity is outside the range 10 to 90%, or where sudden temperature changes may occur and cause condensation.
  - Where corrosive or flammable gases are present.
  - Where the instrument will be exposed to direct mechanical vibration or shock.
  - Where the instrument may be exposed to extreme levels of radioactivity.

- Use the correct types of wire for external wiring:
  - Use copper wire with temperature ratings greater than 75°C.

- Securely tighten screws:
  - Securely tighten module mounting screws and terminal screws to avoid problems such as faulty operation.
  - Tighten terminal block screws with the correct tightening torque as given in this manual.

- Securely lock connecting cables:
  - Securely lock the connectors of cables, and check them thoroughly before turning on the power.

- Interlock with emergency-stop circuitry using external relays:
  - Equipment incorporating the FA-M3 must be furnished with emergency-stop circuitry that uses external relays. This circuitry should be set up to interlock correctly with controller status (stop/run).

- Ground for low impedance:
  - For safety reasons, connect the [FG] grounding terminal to a Japanese Industrial Standards (JIS) Class 3 Ground. For compliance to CE Marking, use cables such as twisted cables which can ensure low impedance even at high frequencies for grounding.

- Configure and route cables with noise control considerations:
  - Perform installation and wiring that segregates system parts that may likely become noise sources and system parts that are susceptible to noise. Segregation can be achieved by measures such as segregating by distance, installing a filter or segregating the grounding system.

- Configure for CE Marking Conformance:
  - For compliance with CE Marking, perform installation and cable routing according to the description on compliance to CE Marking in the “Hardware Manual” (IM34M6C11-01E).

- Keep spare parts on hand:
  - Stock up on maintenance parts including spare modules, in advance.
Discharge static electricity before operating the system:
- Because static charge can accumulate in dry conditions, first touch grounded metal to discharge any static electricity before touching the system.

Never use solvents such as paint thinner for cleaning:
- Gently clean the surfaces of the FA-M3 with a cloth that has been soaked in water or a neutral detergent and wringed.
- Do not use volatile solvents such as benzine or paint thinner or chemicals for cleaning, as they may cause deformity, discoloration, or malfunctioning.

Avoid storing the FA-M3 in places with high temperature or humidity:
- Since the CPU module has a built-in battery, avoid storage in places with high temperature or humidity.
- Since the service life of the battery is drastically reduced by exposure to high temperatures, take special care (storage temperature should be from –20°C to 75°C).
- There is a built-in lithium battery in a CPU module and temperature control module which serves as backup power supply for programs, device information and configuration information. The service life of this battery is more than 10 years in standby mode at room temperature. Take note that the service life of the battery may be shortened when installed or stored at locations of extreme low or high temperatures. Therefore, we recommend that modules with built-in batteries be stored at room temperature.

Always turn off the power before installing or removing modules:
- Failing to turn off the power supply when installing or removing modules, may result in damage.

Do not touch components in the module:
- In some modules you can remove the right-side cover and install ROM packs or change switch settings. While doing this, do not touch any components on the printed-circuit board, otherwise components may be damaged and modules may fail to work.
Introduction

■ Overview of the Manual

The FA-M3 Range-free Multi-controller builds on a new concept developed by Yokogawa, a company specializing in measurement, control and information processing.

This manual for the Temperature Control and Monitoring module and the PID Control module explains the specifications, functions and information required for operating the module. It is especially useful when you perform pre-operation engineering.

■ Applicable CPU Modules

The CPU modules with which the modules covered in this manual can be used are listed in the table below.

Use the hardware appropriate for the measurement input type of your application.

<table>
<thead>
<tr>
<th>Type</th>
<th>FA-M3 (CPU modules) which can be connected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F3SP21</td>
</tr>
<tr>
<td>F3CT04</td>
<td>✓</td>
</tr>
<tr>
<td>F3CR04</td>
<td>✓</td>
</tr>
<tr>
<td>F3CV04</td>
<td>✓</td>
</tr>
</tbody>
</table>
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1. Overview

The Temperature Control and Monitoring module or PID Control module has the following models with different input types and output types.

<table>
<thead>
<tr>
<th>Model No</th>
<th>No. of channels</th>
<th>Input*1</th>
<th>Output*2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Time proportional PID output</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Open collector</td>
</tr>
<tr>
<td>F3CT04-0N</td>
<td>4</td>
<td>Thermocouple or mV</td>
<td>✓</td>
</tr>
<tr>
<td>F3CT04-1N</td>
<td>4</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>F3CR04-0N</td>
<td>4</td>
<td>Resistance temperature detector</td>
<td>✓</td>
</tr>
<tr>
<td>F3CR04-1N</td>
<td>4</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>F3CV04-1N</td>
<td>4</td>
<td>DCV</td>
<td>✓</td>
</tr>
</tbody>
</table>

*1: 4-channel batch setting
*2: Individual channel setting

The module has the following features:
- Each module allows 4-point control, or 4-point monitoring.
- Using a Multi-range method, the range for all 4 channels of the same sensor type can be easily changed using the rotary switch.
- Control output adopts a Universal method. Each channel can be freely set to either time proportioning PID output (open collector output and voltage pulse output) or continuous PID output (4-20mA output, F3C□04-IN only) via data registers. It can also be used as a regulator for heating/cooling.
- In addition to the auto-tuning function, our proven “Super” technology, based on fuzzy theory is incorporated as a standard feature and effectively suppresses overshooting to provide optimum temperature control.
- Settings including PID parameters and target values are stored in the module and read at power-up to start temperature control automatically when the module is ready.
2. Specifications

2.1 Components and their Functions

- **Input type selector switch**: Selects the input type for Ch 1-4. All channels will be set to the same input type.
- **Power supply frequency selector switch**
- **Reference junction compensator**
- **I/O terminal block**: 18-point detachable terminal block, M3.5 self-tapping screws used for terminal.

*The module is shipped with RJCs (reference junction compensator) connected between the following pairs of terminals: No.5-7 and No.6-8.*

**CAUTION**

- Do not remove the reference junction compensators (RJC) installed between pins 5 and 7, and pins 6 and 8. The module is shipped with these RJCs installed using a specified torque. Do not operate the module with any RJC removed, or with loosened terminal screws.

---

**Figure 2.1** F3CT04-0N, F3CT04-1N Front Panel
Figure 2.2 F3CR04-0N, F3CR04-1N Front Panel

Figure 2.3 F3CV04-1N Front Panel
2.2 External Dimensions and Weight

2.2.1 External Dimensions

![Figure 2.4: External Dimensions](image)

2.2.2 Weight

250g
2.3 Input Specifications

2.3.1 Measurement Input Method: Multi-Range Method

- **Selecting the input type or instrument range**
  To select the input type, specify the module model when placing an order. The instrument range can be changed for all four channels simultaneously using the rotary switch.

- **Specifying the measurement range**
  The measurement range can be specified by setting the maximum and minimum values (RH, RL).

- **Measurement input bias**
  A desired correction can be added to the measurement input.
  
  | Bias setting range | -100.0 to 100% with respect to instrument range |

- **Measurement input filter**
  A first order delay filter can be used to remove noise from the input.
  
  | Filter setting range | OFF or 1 to 120 seconds (Time constant) |
  |                      | (OFF: no filtering)                  |

- **Burnout (See Table 2.1 for the burnout detection sequence for discontinuity in a thermocouple and a resistance temperature detector)**
  In case of a burnout
  - The ERR lamp of the display unit flashes (for all channels 1-4)
  - The control output will be set to the preset output value.
  - A warning will be generated if the measurement upper limit warning is set.
    (The lamp and input relay turns on.)

  **TIP**
  - When a warning is generated, the associated device (input relay: X□□□□) in this module turns on and the ALM LED on the display unit on the front of the module lights.
  - If an external junction output is required when a warning is generated, use a Ladder or BASIC program to receive the signal and outputs it through the junction output module.

Table 2.1 Burnout Detection Sequence

<table>
<thead>
<tr>
<th>Input type and location of discontinuity</th>
<th>Burnout detection (Operation and timing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC voltage (DCV) input</td>
<td>Burnout not detected.</td>
</tr>
<tr>
<td>Thermocouple input</td>
<td>- Gradually increases to reach the measurement upper limit to be detected as B.OUT.</td>
</tr>
<tr>
<td></td>
<td>- Detected as B.OUT approximately 30 seconds after discontinuity has occurred.</td>
</tr>
<tr>
<td></td>
<td>(The timing differs slightly with the TC type.)</td>
</tr>
<tr>
<td>Resistance temperature detector input</td>
<td>- Reaches the measurement upper limit to be detected as B.OUT.</td>
</tr>
<tr>
<td>(Discontinuity at A or B)</td>
<td>- Detected as B.OUT approximately 5 seconds after discontinuity has occurred.</td>
</tr>
<tr>
<td>Resistance temperature detector input</td>
<td>- Gradually increases to reach the measurement upper limit to be detected as B.OUT.</td>
</tr>
<tr>
<td>(Discontinuity at b)</td>
<td>- Detected as B.OUT approximately 30 seconds after discontinuity has occurred.</td>
</tr>
</tbody>
</table>

(Note) B.OUT as shown in the above table refers to the “burnout detected” state.
<table>
<thead>
<tr>
<th>Measurement input type</th>
<th>Input type (range)</th>
<th>Range code*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thermocouple/mV type</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JIS</td>
<td>K -200 to 1300°C</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>K -199.9 to 999.9°C</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>K -199.9 to 500.0°C</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>J -199.9 to 800.0°C</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>T -199.9 to 400.0°C</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>B 0 to 1800°C</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>S 0 to 1700°C</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>R 0 to 1700°C</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>N 0 to 1300°C</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>W 0 to 2300°C</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>E -199.9 to 800°C</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td>DIN L -199.9 to 800°C</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td>U -199.9 to 400°C</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td>Platinel 2 0 to 1390°C</td>
<td>D</td>
</tr>
<tr>
<td></td>
<td>mV 0 to 10 mV</td>
<td>E</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.0 to 200.0°C</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0.0 to 100.0°C</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>-100.0 to 100.0°C</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>JPt100 -199.9 to 500.0°C</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>-199.9 to 200.0°C</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>-199.9 to 100.0°C</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>-199.9 to 640.0°C</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Pt100 -199.9 to 500.0°C</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>0.0 to 200.0°C</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>0.0 to 100.0°C</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>-100.0 to 100.0°C</td>
<td>8</td>
</tr>
</tbody>
</table>

*: The range code will be the same as the number at the rotary switch’s setting position.
### 2.3.2 Input Specifications

#### Table 2.3 Input Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of channels</td>
<td>4 (Note) The maximum number of available channels is restricted if the input sampling cycle is not 500 ms.</td>
</tr>
<tr>
<td>Input sampling cycle</td>
<td>500 ms (4CH), 250 ms (2CH)* or 125 ms (1CH)*</td>
</tr>
<tr>
<td></td>
<td>*: If the cycle is 250 ms or 125 ms, the maximum number of channels available to one module is restricted to the number shown within the brackets ( ).</td>
</tr>
<tr>
<td>Thermocouple/ mV input</td>
<td>Input resistance 1 MΩ or more</td>
</tr>
<tr>
<td></td>
<td>Allowable signal source resistance 250 Ω or less</td>
</tr>
<tr>
<td></td>
<td>Burnout detection Available</td>
</tr>
<tr>
<td></td>
<td>Allowable input voltage ±10 V or less</td>
</tr>
<tr>
<td></td>
<td>Standards compliance JIS / IEC / DIN (L and U)</td>
</tr>
<tr>
<td>Resistance temperature detector input</td>
<td>Input resistance 1 MΩ or more</td>
</tr>
<tr>
<td></td>
<td>Allowable wiring resistance 10 Ω or less / wire (No variation allowed among 3 wires)</td>
</tr>
<tr>
<td></td>
<td>Burnout detection Available</td>
</tr>
<tr>
<td></td>
<td>Standards compliance JIS '89 JPt100, Pt100 / IEC / DIN</td>
</tr>
<tr>
<td>DC voltage input</td>
<td>Input resistance 1 MΩ</td>
</tr>
<tr>
<td></td>
<td>Allowable signal source resistance 2 kΩ or less (with approx. -0.1% reading error per 1kΩ)</td>
</tr>
<tr>
<td></td>
<td>Allowable input voltage ±10 V or less</td>
</tr>
<tr>
<td>Noise reduction ratio</td>
<td>Normal mode 40dB (50/60Hz) or more</td>
</tr>
<tr>
<td></td>
<td>Common mode 120dB (50/60Hz) or more</td>
</tr>
</tbody>
</table>

### 2.3.3 Measurement Precision

#### Table 2.4 Measurement Precision

<table>
<thead>
<tr>
<th>Input type</th>
<th>Voltage</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermocouple (JIS, ANSI, DIN)</td>
<td>B¹, S, R, K², J², T³, N, W, E, L (DIN), U (DIN), Platinel 2</td>
<td>±0.30% of F.S. ±1 digit ¹⁶</td>
</tr>
<tr>
<td>Resistance temperature detector (JIS/DIN)</td>
<td>Pt100², JPt100⁴</td>
<td>±0.30% of F.S. ±1 digit ¹⁶</td>
</tr>
<tr>
<td>Voltage</td>
<td>DCV³, mV DC⁵</td>
<td>±0.20% of F.S. ±1 digit ¹⁶</td>
</tr>
</tbody>
</table>

¹: 0 to 400°C range : ±5% of F.S. ±1 digit ¹⁵
²: -100°C or less : ±0.50% of F.S. ±1 digit ¹⁵
³: 0°C or less : ±0.50% of F.S. ±1 digit ¹⁵
⁴: 0 to 100°C range : ±0.50% of F.S. ±1 digit ¹⁵
⁵: 0 to 10mV range : ±0.30% of F.S. ±1 digit ¹⁵
⁶: 0 to 1V range : ±0.30% of F.S. ±1 digit ¹⁵

*¹: F.S. refers to the instrument range. For details on the instrument range, see Section 5.5.1. The 1 digit error is generated when the value is represented. The size of “1 digit” depends on the input range.

Reference junction compensation error is not included for thermocouple input. (For details on reference junction compensation error, see Section 2.6.1.)
2.4 Control Output Specifications

2.4.1 Universal Method (selectable for each channel)

- **Selecting output type**
  
The desired output type can be selected from Table 2.6 (Section 2.4.3) by setting mode registers.

- **Selecting Auto/Manual output**
  
  In addition to Auto output, manual output is available to directly control the operation output using data received from the CPU module via registers. (See Section 5.7.1.)

- **Selecting the control mode**
  
  In addition to normal control output, Heating/Cooling Control and Setting Output are available. (See Section 5.2.)

⚠️ **CAUTION**

When initialization completes after power is turned on, this module starts controlling based on the settings stored in the module.

2.4.2 Control Specifications

<table>
<thead>
<tr>
<th>Table 2.5 Control Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Item</strong></td>
</tr>
<tr>
<td>Control function</td>
</tr>
<tr>
<td>Control cycle</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Loop-back function</td>
</tr>
</tbody>
</table>

*1: Heating/Cooling control uses an analog output module or junction output module for cooling control output.

*2: The target control value is sent to control output as operation output.
2.4.3 Output Specifications

Table 2.6 Output Type Code

<table>
<thead>
<tr>
<th>Control output type</th>
<th>Specifications</th>
<th>Resolution</th>
<th>OUTSEL setting for output type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Collector Output (Time proportional output)</td>
<td>Rated load voltage: 24 VDC</td>
<td>10 ms or 0.05%, whichever is larger</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Maximum load current: 0.1 A/point, 0.4 A/common</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ON time voltage between terminals: Up to 2V</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>OFF time leakage current: Up to 0.1 mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cycle time: 1 to 240 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>External power supply: 24 VDC ±10% 100 mA (note)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage Pulse Output (Time proportional output)</td>
<td>ON voltage: F3CT04, F3CR04</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Approximately 6 VDC or more (Load resistance 600 Ω or more)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>F3CV04</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Approximately 12 VDC or more (Load resistance 600 Ω or more)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>OFF voltage: 0.5 VDC or less</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cycle time: 1 to 240 s</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>External power supply: 24 VDC ±10% 200 mA (note)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-20 mA Current Output (Continuous output)</td>
<td>Load resistance: 600 Ω or less</td>
<td>0.05%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Accuracy: ±1.0%</td>
<td></td>
<td>Applicable only to F3C04-IN</td>
</tr>
<tr>
<td></td>
<td>Output update cycle: 500 ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fast PID mode: 250 ms (using hardware for 2 channels)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very Fast PID mode: 125 ms (using hardware for 4 channels)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>External power supply: 24 VDC ±10% 200 mA (note)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Note) This module requires the use of a 24 VDC external power supply with a capacity matching the external output used. However, no external power supply is required if only the temperature input function is used, leaving the output terminals on this module unused.

2.4.4 On/Off Control

- **Selecting ON/OFF Control**
  ON/OFF Control can be selected by setting the Proportional Band parameter of the PID Control to “0”.

- **Hysteresis band**
  With ON/OFF Control selected, the ON/OFF Hysteresis Band can be set.

2.4.5 Auto-tuning

The Auto-tuning function, available as a standard feature, can automatically set the PID constant (Limit Cycle Method), if activated.

⚠️ **CAUTION**

If the proportional band is set to “0”, auto-tuning is disabled.

2.4.6 Overshoot Suppression Function “Super”

The “Super” function, available as a standard feature, may be enabled or disabled through parameter setting.
2.5 Alarm Specifications

2.5.1 Process Alarm

- 2 alarm points can be set for each channel.

(See Section 5.8.2.)
2.6 Other General Specifications

2.6.1 Operating Environment

<table>
<thead>
<tr>
<th>Normal operating condition (in which the instrument is designed to operate properly continuously)</th>
<th>Ambient temperature</th>
<th>0 to 55°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient humidity</td>
<td>Relative humidity 20 to 90% (No condensation)</td>
<td></td>
</tr>
<tr>
<td>Reference junction temperature compensation error (note)</td>
<td>F3C04-0N</td>
<td>0 to 10°C; ±1.5°C</td>
</tr>
<tr>
<td>Reference junction temperature compensation error (note)</td>
<td>F3C04-1N</td>
<td>10 to 35°C; ±1°C</td>
</tr>
<tr>
<td>Reference junction temperature compensation error (note)</td>
<td>F3C04-1N</td>
<td>35 to 55°C; ±1.5°C</td>
</tr>
</tbody>
</table>

| Magnetic field | 400 AT/m or less |
| Warm-up time | 30 min. or more |

<table>
<thead>
<tr>
<th>Effect of operating environment</th>
<th>Effect of ambient temperature</th>
<th>Input stability: (±1μV/°C or ±0.01%/°C, whichever larger) or less</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature compensation error</td>
<td>0 to 10°C: ±1.5°C</td>
<td>0 to 15°C: ±0.01%/°C or ±1°C or less</td>
</tr>
<tr>
<td>Temperature compensation error</td>
<td>10 to 35°C: ±1°C</td>
<td>15 to 35°C: ±0.01%/°C or ±1°C or less</td>
</tr>
<tr>
<td>Temperature compensation error</td>
<td>35 to 55°C: ±1.5°C</td>
<td>35 to 55°C: ±0.01%/°C or ±1°C or less</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shipping/storage condition</th>
<th>Temperature</th>
<th>-25 to 70°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity</td>
<td>Relative humidity 5 to 95% (no condensation)</td>
<td></td>
</tr>
</tbody>
</table>

(Note) Specifications of the thermocouple input type that uses reference junction compensator (RJC).

2.6.2 Withstanding Voltage

Withstanding voltage:
- 1000 VAC between the input terminal and the case for 1 minute
- 1500 VAC between the output terminal and the case for 1 minute

2.6.3 Resistance between Input Terminals and Insulation

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Item Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3C04-0N</td>
<td>Resistance between input terminals</td>
</tr>
<tr>
<td>F3C04-1N</td>
<td>Insulation Between input terminal and internal circuit Photocoupler and transformer insulated</td>
</tr>
<tr>
<td></td>
<td>Between output terminal and internal circuit Photocoupler and transformer insulated</td>
</tr>
<tr>
<td></td>
<td>Between output terminals Not insulated</td>
</tr>
<tr>
<td>F3C04-0N</td>
<td>Insulation Between input terminals Not insulated</td>
</tr>
<tr>
<td>F3C04-1N</td>
<td>Between input terminal and internal circuit Photocoupler and transformer insulated</td>
</tr>
<tr>
<td></td>
<td>Between output terminal and internal circuit Photocoupler and transformer insulated</td>
</tr>
<tr>
<td></td>
<td>Between output terminals Not insulated</td>
</tr>
<tr>
<td>F3C04-1N</td>
<td>Insulation Between input terminal and internal circuit Photocoupler and transformer insulated</td>
</tr>
<tr>
<td></td>
<td>Between output terminal and internal circuit Photocoupler and transformer insulated</td>
</tr>
<tr>
<td></td>
<td>Between output terminals Not insulated</td>
</tr>
</tbody>
</table>

2.6.4 Current Consumption

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>F3C04-0N</td>
<td>250mA (5V DC)</td>
</tr>
<tr>
<td>F3C04-1N</td>
<td>200mA (24V DC external power supply, only when output is used)</td>
</tr>
</tbody>
</table>
3. Preparation

3.1 Startup Procedure

Figure 3.1 shows the sequence of steps to be performed before operating the Temperature Control and Monitoring module and the PID Control module.

![Flowchart of Startup Procedure](31FG01.VSD)

- Design overall system configuration
- Prepare external connecting devices
- Set module switches
- Attach module
- Wire module
- Set parameter handles
- Operate

(See Section 3.2)
(See Section 3.3)
(See Section 3.4)
(See Chapter 5)
3.2 Setting Switches

Figure 3.2 shows the names and locations of the switches. You may set the switches even after the module has been installed in the unit.

The switch setting will be read on power-up. Any switch setting changes made with the power switched on will not be reflected until power is turned off and on again. It should also be remembered that changing the switch setting will reset the hold data in the module to their factory setting. For more information, see Section 4.1.3 “Data Initialization”.
### 3.2.1 Input Type Selector Switch

You can select the desired input type by setting the rotary switch (pointing the arrow) to the appropriate number.

#### Table 3.1 Input Type

<table>
<thead>
<tr>
<th>Measurement input type</th>
<th>Input type (range)</th>
<th>Register representation *1</th>
<th>Rotary switch</th>
</tr>
</thead>
<tbody>
<tr>
<td>JIS</td>
<td>200 to 1300°C</td>
<td>200 to 1300</td>
<td>0</td>
</tr>
<tr>
<td>K</td>
<td>-199.9 to 999.9°C</td>
<td>-1999 to 9999</td>
<td>1</td>
</tr>
<tr>
<td>L</td>
<td>-199.9 to 800.0°C</td>
<td>-1999 to 8000</td>
<td>3</td>
</tr>
<tr>
<td>T</td>
<td>-199.9 to 400.0°C</td>
<td>-1999 to 4000</td>
<td>4</td>
</tr>
<tr>
<td>B</td>
<td>0 to 1800°C</td>
<td>0 to 1800</td>
<td>5</td>
</tr>
<tr>
<td>S</td>
<td>0 to 1700°C</td>
<td>0 to 1700</td>
<td>6</td>
</tr>
<tr>
<td>R</td>
<td>0 to 1700°C</td>
<td>0 to 1700</td>
<td>7</td>
</tr>
<tr>
<td>N</td>
<td>0 to 1300°C</td>
<td>0 to 1300</td>
<td>8</td>
</tr>
<tr>
<td>W</td>
<td>0 to 2000°C</td>
<td>0 to 2300</td>
<td>9</td>
</tr>
<tr>
<td>E</td>
<td>-199.9 to 800.0°C</td>
<td>-1999 to 8000</td>
<td>A</td>
</tr>
<tr>
<td>U</td>
<td>-199.9 to 400.0°C</td>
<td>-1999 to 4000</td>
<td>B</td>
</tr>
<tr>
<td>D</td>
<td>0 to 1390°C</td>
<td>0 to 1390</td>
<td>C</td>
</tr>
<tr>
<td>DC V type</td>
<td>0 to 10 mV</td>
<td>0 to 1000 (default)</td>
<td>E</td>
</tr>
<tr>
<td>mV</td>
<td>0 to 100 mV</td>
<td>Scalable over the range</td>
<td>F</td>
</tr>
<tr>
<td>Platinel 2</td>
<td>0 to 10 mV</td>
<td>-1999 to 9999</td>
<td>1</td>
</tr>
<tr>
<td>JPT100</td>
<td>-199.9 to 500.0°C</td>
<td>-1999 to 5000</td>
<td>0</td>
</tr>
<tr>
<td>PIC100</td>
<td>0.0 to 200.0°C</td>
<td>0 to 2000</td>
<td>1</td>
</tr>
<tr>
<td>PTC100</td>
<td>-100.0 to 100.0°C</td>
<td>-1000 to 1000</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>0.0 to 100.0°C</td>
<td>0 to 1000</td>
<td>7</td>
</tr>
</tbody>
</table>

*1: Represented with the decimal point removed. See Section 4.1.1, “Data Format”. All the channels will be assigned the same setting.

### 3.2.2 Power Supply Frequency Selector Switch

Sets the frequency of the AC power supply used by the system. Setting the frequency properly will reduce the effect of the AC component (noise) riding on the process input signal.
3.3 Attaching and Detaching Modules

- Attaching/Detaching Modules

Figure 3.3 shows how to attach this module to the base module. First hook the anchor slot at the bottom of the module to be attached onto the anchor pin on the bottom of the base module. Push the top of this module towards the base module until the anchor/release button clicks into place.

⚠️ CAUTION

Always switch off the power before attaching or detaching a module.

- Detaching Modules

To remove this module from the base module, reverse the above operation. Press the anchor/release button on the top of this module to unlock it and tilt the module away from the base module. Then lift the module off the anchor pin at the base.

⚠️ CAUTION

DO NOT bend the connector on the rear of the module by force during the above operation. If the module is pushed with improper force, the connector may bend causing an error.
Attaching Modules in Intense Vibration Environments

If the module is used in intense vibration environments, fasten the module with a screw. Use screws of type listed in the table below. Insert these screws into the screw holes on top of the module and tighten them with a Phillips screwdriver.

<table>
<thead>
<tr>
<th>Screw Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>M4-size Binder screw 12 to 15 mm long</td>
</tr>
<tr>
<td>(or 14 to 15 mm if fitted with a washer)</td>
</tr>
</tbody>
</table>

Figure 3.4  Tightening the Module
3.4  Wiring

3.4.1  Wiring Precautions

To wire the module, see Section 3.4.2, “Terminal Wiring Diagram” and observe the following precautions.

1. For thermocouple input, use the specified compensating wire.
2. For resistance temperature detector input, use a lead wire with low resistance with no resistance difference among the three wires. (10 Ω/wire or less)
3. To immune the input circuitry from noise, the following must be implemented
   a. The wiring for the input circuit must be kept as far away from the power supply or grounding circuitry.
   b. Twisting the input wire at short equal intervals can effectively protect against electromagnetic-induced noise.
   c. Using a shielded wire can effectively protect against static-induced noise. Strip off the outer shield to expose the wire, and ground it with an FG clamp.
   d. Two-point grounding should be avoided.
   e. Attach a ferrite core to the wire near the exit of the panel enclosure to reduce the effect of noise if the input wiring leads outside the panel enclosure.

![Diagram showing wiring and grounding setup]

Table 3.2  FG clamps and Ferrite core Recommended by Yokogawa

<table>
<thead>
<tr>
<th>FG clamp</th>
<th>Kitagawa Kogyo Industries Co.Ltd. FGC Series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrite core</td>
<td>Kitagawa Kogyo Industries Co.Ltd. RFC Series</td>
</tr>
<tr>
<td></td>
<td>TDK Corporation ZCAT Series</td>
</tr>
<tr>
<td></td>
<td>Tokin Corporation ESD-SR Series</td>
</tr>
</tbody>
</table>

(4) It is recommended that crimp contact (for 3.5mm screw) with insulating sleeve be used for connecting wire to a terminal.

Table 3.3  Connecting Method and Terminal Block Type Recommended by Yokogawa

<table>
<thead>
<tr>
<th>Connecting method</th>
<th>Terminal block type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Applicable wire size</td>
<td>0.3 to 1.25mm²</td>
</tr>
<tr>
<td>Wire connecting method</td>
<td>Solderless</td>
</tr>
<tr>
<td>Solderless terminal</td>
<td>For 3.5mm</td>
</tr>
<tr>
<td>Mounting torque</td>
<td>0.8N.m</td>
</tr>
</tbody>
</table>
(5) If an L-load such as an auxiliary relay is used for the open collector junction output, connect a diode in parallel with the load to form a surge suppressor circuit that prevents spark as shown in Figure 3.5.

Figure 3.5 Surge Suppressor
3.4.2 Terminal Wiring Diagram

**F3CT04-0N, F3CT04-1N**

Figure 3.6 shows the input/output terminal connection diagram for F3CT04-0N and F3CT04-1N. The output type for the control output can be freely set using the mode register. Connect the terminals to match the output type.

Figure 3.6   F3CT04-0N, F3CT04-1N Terminal Wiring Diagram

**CAUTION**

- Do not remove the reference junction compensators (RJC) installed between pins 5 and 7, and pins 6 and 8. The module is shipped with these RJC installed using a specified torque. Do not operate the module with any RJC removed, or with loosened terminal screws.
- Remember to securely tighten any terminal screw loosened for wiring.
F3CR04-0N, F3CR04-1N

Figure 3.7 shows the input/output terminal connection diagram for F3CR04-0N and F3CR04-1N. The output type for the control output can be freely set using the mode register. Connect the terminal to match the output type.

Input

Output

Open collector output

Voltage pulse output

4-20mA output (note)

*1: 24 VDC ±10% 100 mA

*2: 24 VDC ±10% 200mA

(note) 4-20mA output is available only for F3CR04-1N.

Figure 3.7  F3CR04-0N, F3CR04-1N Terminal Wiring Diagram

CAUTION

Remember to securely tighten any terminal screw loosened for wiring.
Figure 3.8 shows the input/output terminal connection diagram for F3CV04-1N. The output type for the control output can be freely set using the mode register. Connect the terminals to match the output type.

**CAUTION**

Remember to securely tighten any terminal screw loosened for wiring.
4. Input/Output and Parameters

The Temperature Control and Monitoring module and PID Control module is controlled by allocated input/output relays and the I/O data registers inside the modules. Of those internal data registers, those associated with the operation mode are referred to as "Mode Registers". This section describes the procedures for accessing the relays and data registers, as well as the assigned parameters.

4.1 Accessing the Module

The procedure for accessing the Temperature Control and Monitoring module and PID Control module within the FA-M3 is described below.

4.1.1 Data Format

These modules handle the following data formats internally with different formats for each parameter.

- Absolute value format
- Industrial unit format
- Industrial unit span (Industrial unit S) format
- Percentage format

The data formats are defined as follows:

1) Absolute value format
   The parameter is expressed in its own unit.
   The decimal point is ignored in internal data.

   (Example) Symbol  Actual data  Internal data
   USE    1        1
   PB     5.0      50
   RH     400     400

2) Industrial unit format
   Data in industrial unit.
   The decimal point is ignored in internal data

   (Example) Symbol  Actual data  Internal data
   SP     100.0    1000
(3) Industrial unit span (Industrial unit S) format
Span data in industrial unit. The span is obtained by (RH) -(RL).
The decimal point is ignored in internal data.
RH: Instrument range upper limit, RL: Instrument range lower limit

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Actual data</th>
<th>Internal data</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS</td>
<td>100.0</td>
<td>1000</td>
</tr>
</tbody>
</table>

(4) Percentage format
Data as a percentage.
The decimal point is ignored in internal data

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Actual data</th>
<th>Internal data</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT</td>
<td>50.0</td>
<td>500</td>
</tr>
</tbody>
</table>
4.1.2 Hold Data
All the parameters in the table in Section 4.2, "Mode Registers" and those in the tables in Section 4.3, "I/O Data Registers" with "Hold" marked as "✓" will hold their values even if power is turned off, making it unnecessary to set them each time power is turned off and on. Parameters that do not hold their values reset to their default when power is turned off and on.

4.1.3 Data Initialization
Even parameters that normally hold their data when power is turned off will be reset to default in the following case.
- If power is turned on after the input type has been changed with the rotary switch.

Initialization takes up to approximately 8 seconds. This maximum initialization time is required when parameters are initialized to change the input range, etc.

⚠️ CAUTION
If power is turned off during initialization, initialization may fail. Should initialization fail, re-select the rotary switch position, and perform initialization again.

⚠️ CAUTION
The data register ACK (write synchronization signal) resets to "0" during initialization. Do not write to a data register when ACK is "0". For more information, see Section 4.1.4.
4.1.4 Data Write Timing at Powering On

To write data to non-hold parameters, use a ladder sequence program or BASIC program after power is turned on.

Even for hold parameters, it is also necessary to write data using such a program if any change has been made to the previous data. The written data may be nullified by the initialization that occurs in the module after power is switched on. For this purpose, this module is provided with a data register ACK (write synchronization signal) that indicates whether data write is enabled or disabled as follows:

- 0: Write disabled
- 1: Write enabled

Always wait for the data register ACK to go "1" before you write data to a module parameter.

![Diagram showing changes in ACK during initialization](image)

Figure 4.1 Changes in ACK during Initialization
4.1.5 Setting Mode Registers

Changing the data in a mode register does not activate the changed data. The changed mode register data is activated only when the Setup mode register (Set Mode Data flag) is set to "1" after writing the data. When data is written to a mode register, the SETUP register will be automatically set to "0".

For the types and functions of mode register, see Section 4.2, “Mode Registers”, or Section 5.2, “Mode Register Parameters”.

![Mode Register Setting Sequence](image_url)

**Figure 4.2 Mode Register Setting Sequence**

**Tip**

The time required for a mode register setting is approximately 1 second.

---

**CAUTION**

- Always check that SETUP register is "0" before writing to a register other than a mode register.
- Changing a mode register setting may reset the values of other registers that are not mode registers.
4.1.6 Accessing Using Ladder Sequence

To access this module from the CPU module using Ladder Sequence, use the following instructions.

See the sample program in Chapter 7, "Sample Programs".

- **For Mode Register and I/O Register**
  - Read (READ instruction)
    To read data, use the Special Module Read instruction, READ as follows:
    
    \[
    \text{READ SL n1 D k}
    \]
    
    - SL : Module slot number (3-digit)
    - n1 : Read start data position
    - D : Start device number to which read data is written
    - k : Number of data to transfer (word count)

  - Write (WRITE instruction)
    To write data, use the Special Module Write instruction, WRITE as follows:
    
    \[
    \text{WRITE S SL n2 k}
    \]
    
    - S : First device number storing the data to be written
    - SL : Module slot number (3-digit)
    - n2 : Data position to start writing
    - k : Number of data to transfer (word count)

- **Input Relay**
  
  Accesses an input relay allocated to the module.
  
  X\$mmnn
  - \$ : Unit number
  - mm : Slot number
  - nn : Relay number

- **Output Relay**
  
  Accesses an output relay allocated to the module.
  
  Y\$mmnn
  - \$ : Unit number
  - mm : Slot number
  - nn : Relay number
4.1.7 Accessing Using BASIC Statements

To access this module from a BASIC CPU module using BASIC programs, use the following BASIC statements.
Refer to the sample program in Chapter 7, “Sample Programs”.

● For Mode register
  - Read
    To read data, use the STATUS statement as follows:
    STATUS s, n; P
    s : Module slot number (3-digit)
    n : Data position to start reading
    P : Name of the variable for storing the data read
  - Write
    To write data, use the CONTROL statement as follows.
    CONTROL s, n; P
    s : Module slot number (3-digit)
    n : Data position to start writing
    P : Name of the variable storing the data to be written

● For I/O register
  - Read
    To read data, use the ENTER statement as follows:
    ENTER s, n NOFORMAT; P
    s : Module slot number (3-digit)
    n : Data position to start reading
    P : Name of the variable for storing the data read
  - Write
    To write data, use the OUTPUT statement as follows:
    OUTPUT s, n NOFORMAT; P
    s : Module slot number (3-digit)
    n : Data position to start writing
    P : Name of the variable storing the data to be written
● For I/O relay

- Read
  To read data, use the STATUS statement as follows:
  STATUS s, 100+n; P
  s : Module slot number (3-digit)
  n : Read data group number
  P : Name of the variable for storing the data read
  Data will be read as a group (16 bits).

- Write
  To write data, use the CONTROL statement as follows:
  CONTROL s, 100+n; P
  s : Module slot number (3-digit)
  n : Write data group number
  P : Name of the variable storing the data to be written
  Data will be written as a group (16 bits).
4.2 Mode Registers

The mode registers for the Temperature Control and Monitoring module, and PID Control module are shown below.

<table>
<thead>
<tr>
<th>CH</th>
<th>Data position</th>
<th>Ladder BASIC Symbol</th>
<th>Parameter</th>
<th>Data format</th>
<th>Data range</th>
<th>Default</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>-</td>
<td>513</td>
<td>1 SETUP</td>
<td>Mode Data Setting Flag</td>
<td>Absolute value</td>
<td>Write 1 to perform setting -&gt; Resets to “0” after completion</td>
<td>-</td>
<td>5.2.4</td>
</tr>
<tr>
<td>1</td>
<td>514</td>
<td>2 OUTSEL1</td>
<td>CH1 Output Type</td>
<td>Absolute value</td>
<td>0: Open Collector Output (Time proportional output) 1: Voltage Pulse Output (Time proportional output) 2: 4-20 mA Output (Continuous output) (note)</td>
<td>0</td>
<td>5.2.1</td>
</tr>
<tr>
<td>2</td>
<td>515</td>
<td>3 MD1</td>
<td>CH1 Control Mode</td>
<td>Absolute value</td>
<td>0: Normal Control 1: Fast PID Control 2: Heating/Cooling Control 3: Very Fast PID Control 4: Setting Output</td>
<td>0</td>
<td>5.2.2</td>
</tr>
<tr>
<td>2</td>
<td>516</td>
<td>4 DR1</td>
<td>CH1 Forward/Reverse Switch</td>
<td>Absolute value</td>
<td>0: Reverse Control 1: Forward Control</td>
<td>0</td>
<td>5.2.3</td>
</tr>
<tr>
<td>3</td>
<td>517</td>
<td>5 OUTSEL2</td>
<td>CH2 Output Type</td>
<td>Absolute value</td>
<td>0: Open Collector Output (Time proportional output) 1: Voltage Pulse Output (Time proportional output) 2: 4-20 mA Output (Continuous output) (note)</td>
<td>0</td>
<td>5.2.1</td>
</tr>
<tr>
<td>3</td>
<td>518</td>
<td>6 MD2</td>
<td>CH2 Control Mode</td>
<td>Absolute value</td>
<td>0: Normal Control 2: Heating/Cooling Control 3: Setting Output</td>
<td>0</td>
<td>5.2.2</td>
</tr>
<tr>
<td>3</td>
<td>519</td>
<td>7 DR2</td>
<td>CH2 Forward/Reverse Switch</td>
<td>Absolute value</td>
<td>0: Reverse Control 1: Forward Control</td>
<td>0</td>
<td>5.2.3</td>
</tr>
<tr>
<td>4</td>
<td>520</td>
<td>8 OUTSEL3</td>
<td>CH3 Output Type</td>
<td>Absolute value</td>
<td>0: Open Collector Output (Time proportional output) 1: Voltage Pulse Output (Time proportional output) 2: 4-20 mA Output (Continuous output) (note)</td>
<td>0</td>
<td>5.2.1</td>
</tr>
<tr>
<td>4</td>
<td>521</td>
<td>9 MD3</td>
<td>CH3 Control Mode</td>
<td>Absolute value</td>
<td>0: Normal control 1: Fast PID control 2: Heating/Cooling control 3: Setting output</td>
<td>0</td>
<td>5.2.2</td>
</tr>
<tr>
<td>4</td>
<td>522</td>
<td>10 DR3</td>
<td>CH3 Forward/Reverse Switch</td>
<td>Absolute value</td>
<td>0: Reverse Control 1: Forward Control</td>
<td>0</td>
<td>5.2.3</td>
</tr>
<tr>
<td>4</td>
<td>523</td>
<td>11 OUTSEL4</td>
<td>CH4 Output Type</td>
<td>Absolute value</td>
<td>0: Open Collector Output (Time proportional output) 1: Voltage Pulse Output (Time proportional output) 2: 4-20 mA Output (Continuous output) (note)</td>
<td>0</td>
<td>5.2.1</td>
</tr>
<tr>
<td>4</td>
<td>524</td>
<td>12 MD4</td>
<td>CH4 Control Mode</td>
<td>Absolute value</td>
<td>0: Normal control 2: Heating/Cooling Control 3: Setting Output</td>
<td>0</td>
<td>5.2.2</td>
</tr>
<tr>
<td>4</td>
<td>525</td>
<td>13 DR4</td>
<td>CH4 Forward/Reverse Switch</td>
<td>Absolute value</td>
<td>0: Reverse Control 1: Forward Control</td>
<td>0</td>
<td>5.2.3</td>
</tr>
</tbody>
</table>

(Note) 4-20mA Output (continuous output) type is available only for F3CT04-1N, F3CR04-1N, and F3CV04-1N modules.

The settings will be held even if power is turned off. See Section 4.1.5, “Setting Mode Registers” for details on how to perform the setting.

When using Heating/Cooling Control, be sure to see Section 5.11, “Heating/Cooling Control” for specific cautions.
### 4.3 I/O Data Registers

The I/O data registers for the Temperature Control and Monitoring module and the PID Control module are described below. Do not attempt to write to any register number not listed in this table, or to any (unused) register.

#### Table 4.2 I/O Data Registers (1/2)

<table>
<thead>
<tr>
<th>Data position no.</th>
<th>CH1</th>
<th>CH2</th>
<th>CH3</th>
<th>CH4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symbol</td>
<td>PVIN</td>
<td>Process Input</td>
<td>Industrial unit</td>
<td>RL to RH</td>
</tr>
<tr>
<td>Parameter</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data format</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Data range</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Default</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attribute (note)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold (note)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>129</td>
<td>193</td>
<td>—</td>
</tr>
<tr>
<td>2</td>
<td>66</td>
<td>130</td>
<td>194</td>
<td>—</td>
</tr>
<tr>
<td>3</td>
<td>67</td>
<td>131</td>
<td>195</td>
<td>—</td>
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<td>4</td>
<td>68</td>
<td>132</td>
<td>196</td>
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<td>5</td>
<td>69</td>
<td>133</td>
<td>197</td>
<td>—</td>
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<td>6</td>
<td>70</td>
<td>134</td>
<td>198</td>
<td>—</td>
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<td>7</td>
<td>71</td>
<td>135</td>
<td>199</td>
<td>—</td>
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<td>8</td>
<td>72</td>
<td>136</td>
<td>200</td>
<td>—</td>
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<td>9</td>
<td>73</td>
<td>137</td>
<td>201</td>
<td>—</td>
</tr>
<tr>
<td>10</td>
<td>74</td>
<td>138</td>
<td>202</td>
<td>—</td>
</tr>
<tr>
<td>11</td>
<td>75</td>
<td>139</td>
<td>203</td>
<td>—</td>
</tr>
<tr>
<td>12</td>
<td>76</td>
<td>140</td>
<td>204</td>
<td>—</td>
</tr>
<tr>
<td>13</td>
<td>77</td>
<td>141</td>
<td>205</td>
<td>—</td>
</tr>
<tr>
<td>14</td>
<td>78</td>
<td>142</td>
<td>206</td>
<td>—</td>
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<td>15</td>
<td>79</td>
<td>143</td>
<td>207</td>
<td>—</td>
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<td>16</td>
<td>80</td>
<td>144</td>
<td>208</td>
<td>—</td>
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<tr>
<td>17</td>
<td>81</td>
<td>145</td>
<td>209</td>
<td>—</td>
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<tr>
<td>18</td>
<td>82</td>
<td>146</td>
<td>210</td>
<td>—</td>
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<tr>
<td>19</td>
<td>83</td>
<td>147</td>
<td>211</td>
<td>—</td>
</tr>
<tr>
<td>20</td>
<td>84</td>
<td>148</td>
<td>212</td>
<td>—</td>
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<td>21</td>
<td>85</td>
<td>149</td>
<td>213</td>
<td>—</td>
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<td>22</td>
<td>86</td>
<td>150</td>
<td>214</td>
<td>—</td>
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<td>23</td>
<td>87</td>
<td>151</td>
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<td>—</td>
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<tr>
<td>24</td>
<td>88</td>
<td>152</td>
<td>216</td>
<td>—</td>
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<tr>
<td>25</td>
<td>89</td>
<td>153</td>
<td>217</td>
<td>—</td>
</tr>
<tr>
<td>26</td>
<td>90</td>
<td>154</td>
<td>218</td>
<td>—</td>
</tr>
<tr>
<td>27</td>
<td>91</td>
<td>155</td>
<td>219</td>
<td>—</td>
</tr>
<tr>
<td>28</td>
<td>92</td>
<td>156</td>
<td>220</td>
<td>—</td>
</tr>
<tr>
<td>29</td>
<td>93</td>
<td>157</td>
<td>221</td>
<td>—</td>
</tr>
<tr>
<td>30</td>
<td>94</td>
<td>158</td>
<td>222</td>
<td>—</td>
</tr>
<tr>
<td>31</td>
<td>95</td>
<td>159</td>
<td>223</td>
<td>—</td>
</tr>
<tr>
<td>32</td>
<td>96</td>
<td>160</td>
<td>224</td>
<td>—</td>
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<tr>
<td>33</td>
<td>97</td>
<td>161</td>
<td>225</td>
<td>—</td>
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<td>34</td>
<td>98</td>
<td>162</td>
<td>226</td>
<td>—</td>
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<tr>
<td>35</td>
<td>99</td>
<td>163</td>
<td>227</td>
<td>—</td>
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<tr>
<td>36</td>
<td>100</td>
<td>164</td>
<td>228</td>
<td>—</td>
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<td>37</td>
<td>101</td>
<td>165</td>
<td>229</td>
<td>—</td>
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<tr>
<td>38</td>
<td>102</td>
<td>166</td>
<td>230</td>
<td>—</td>
</tr>
<tr>
<td>39</td>
<td>103</td>
<td>167</td>
<td>231</td>
<td>—</td>
</tr>
<tr>
<td>40</td>
<td>104</td>
<td>168</td>
<td>232</td>
<td>—</td>
</tr>
<tr>
<td>41</td>
<td>105</td>
<td>169</td>
<td>233</td>
<td>—</td>
</tr>
<tr>
<td>42</td>
<td>106</td>
<td>170</td>
<td>234</td>
<td>—</td>
</tr>
<tr>
<td>43</td>
<td>107</td>
<td>171</td>
<td>235</td>
<td>—</td>
</tr>
<tr>
<td>44</td>
<td>108</td>
<td>172</td>
<td>236</td>
<td>—</td>
</tr>
<tr>
<td>45</td>
<td>109</td>
<td>173</td>
<td>237</td>
<td>—</td>
</tr>
</tbody>
</table>

(Note) For "Attribute", RO: Ready Only, RW: Read/Write, WO: Write only
For details on "Hold", see Section 4.1.2, "Hold Data"
### Table 4.2 I/O Data Registers (2/2)

<table>
<thead>
<tr>
<th>Data position no.</th>
<th>Symbol</th>
<th>Parameter</th>
<th>Data format</th>
<th>Data range</th>
<th>Default</th>
<th>Attribute (note)</th>
<th>Hold (note)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH1</td>
<td>CH2</td>
<td>CH3</td>
<td>CH4</td>
<td>46</td>
<td>110</td>
<td>174</td>
<td>238</td>
<td>MR</td>
</tr>
<tr>
<td>47</td>
<td>111</td>
<td>175</td>
<td>239</td>
<td>CH</td>
<td>Output Upper Limit</td>
<td>Percentage</td>
<td>OL+0.1 to 105.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>48</td>
<td>112</td>
<td>176</td>
<td>240</td>
<td>OL</td>
<td>Output Lower Limit</td>
<td>Percentage</td>
<td>-5.0 to OL-0.1%</td>
<td>0.0%</td>
</tr>
<tr>
<td>49</td>
<td>113</td>
<td>177</td>
<td>241</td>
<td>HYS</td>
<td>Hysteresis</td>
<td>Industrial unit</td>
<td>S</td>
<td>0 to RH-RL</td>
</tr>
<tr>
<td>50</td>
<td>114</td>
<td>178</td>
<td>242</td>
<td>CT</td>
<td>Cycle Time</td>
<td>Absolute value</td>
<td>1 to 120 s</td>
<td>30 s</td>
</tr>
<tr>
<td>51</td>
<td>115</td>
<td>179</td>
<td>243</td>
<td>CTC</td>
<td>Cooling Side Cycle Time</td>
<td>Absolute value</td>
<td>1 to 120 s</td>
<td>30 s</td>
</tr>
<tr>
<td>52</td>
<td>116</td>
<td>180</td>
<td>244</td>
<td>RLTHYS</td>
<td>Heating/cooling Hysteresis</td>
<td>Percentage</td>
<td>0.0 to 100.0%</td>
<td>0.5%</td>
</tr>
<tr>
<td>53</td>
<td>117</td>
<td>181</td>
<td>245</td>
<td>D.B</td>
<td>Dead Band</td>
<td>Percentage</td>
<td>-50.0 to 50.0%</td>
<td>0.5%</td>
</tr>
<tr>
<td>54</td>
<td>118</td>
<td>182</td>
<td>246</td>
<td>POUT</td>
<td>Output Upper Limit</td>
<td>Percentage</td>
<td>-5.0 to 105.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>55</td>
<td>119</td>
<td>183</td>
<td>247</td>
<td>HOUT</td>
<td>Output Value</td>
<td>Percentage</td>
<td>OL to OH</td>
<td>—</td>
</tr>
<tr>
<td>56</td>
<td>120</td>
<td>184</td>
<td>248</td>
<td>COUT</td>
<td>Cooling Side Output Value</td>
<td>Percentage</td>
<td>OL + C to OH C</td>
<td>—</td>
</tr>
<tr>
<td>57</td>
<td>121</td>
<td>185</td>
<td>249</td>
<td>PBC</td>
<td>Cooling Side Proportional Band</td>
<td>Absolute value</td>
<td>0: ON/OFF control, 0.0 to 999.9%</td>
<td>0.5%</td>
</tr>
<tr>
<td>58</td>
<td>122</td>
<td>186</td>
<td>250</td>
<td>TIC</td>
<td>Cooling Side Integral Time</td>
<td>Absolute value</td>
<td>0 (OFF), 1 to 6000 s</td>
<td>240 s</td>
</tr>
<tr>
<td>59</td>
<td>123</td>
<td>187</td>
<td>251</td>
<td>TDC</td>
<td>Cooling Side Derivative Time</td>
<td>Absolute value</td>
<td>0 (OFF), 1 to 6000 s</td>
<td>60 s</td>
</tr>
</tbody>
</table>

(Note) For “Attribute”, RO: Ready Only, RW: Read/Write, WO: Write only
For details on “Hold”, see Section 4.1.2, “Hold Data”.

### Table 4.3 I/O Data Registers for Reading Group Data

<table>
<thead>
<tr>
<th>Data position</th>
<th>Symbol</th>
<th>Parameter</th>
<th>Data format</th>
<th>Data range</th>
<th>Default</th>
<th>Attribute (note)</th>
<th>Hold (note)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>CH1PV</td>
<td>CH1 Process Value</td>
<td>Industrial unit</td>
<td>RL to RH</td>
<td>—</td>
<td>RO</td>
<td>—</td>
<td>5.1</td>
</tr>
<tr>
<td>61</td>
<td>CH2PV</td>
<td>CH2 Process Value</td>
<td>Industrial unit</td>
<td>RL to RH</td>
<td>—</td>
<td>RO</td>
<td>—</td>
<td>5.1</td>
</tr>
<tr>
<td>62</td>
<td>CH3PV</td>
<td>CH3 Process Value</td>
<td>Industrial unit</td>
<td>RL to RH</td>
<td>—</td>
<td>RO</td>
<td>—</td>
<td>5.1</td>
</tr>
<tr>
<td>63</td>
<td>CH4PV</td>
<td>CH4 Process Value</td>
<td>Industrial unit</td>
<td>RL to RH</td>
<td>—</td>
<td>RO</td>
<td>—</td>
<td>5.1</td>
</tr>
</tbody>
</table>

(Note) For “Attribute”, RO: Ready Only, RW: Read/Write, WO: Write only
For details on “Hold”, see Section 4.1.2, “Hold Data”.

**TIP**

- Successive channel numbers, CH1PV, CH2PV, CH3PV, and CH4PV are assigned so that multiple channels can be read at a time for a PV.
- CH1PV, CH2PV, CH3PV, CH4PV has the same data as PV for CH1, PV for CH2, PV for CH3, and PV for CH4, respectively.
### 4.4 I/O Relays

The Temperature Control and Monitoring module and the PID Control module have the following I/O relays.

<table>
<thead>
<tr>
<th>Terminal number</th>
<th>Symbol</th>
<th>Parameter</th>
<th>Data range</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH1 CH2 CH3 CH4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X01 X09 X17 X25</td>
<td>AL1R</td>
<td>Alarm 1</td>
<td>0: Normal, 1: Alarm 1 generated</td>
<td>5.8.1</td>
</tr>
<tr>
<td>X02 X10 X18 X26</td>
<td>AL2R</td>
<td>Alarm 2</td>
<td>0: Normal, 1: Alarm 2 generated</td>
<td>5.8.1</td>
</tr>
<tr>
<td>X03 X11 X19 X27</td>
<td>COR</td>
<td>Cooling Side Operating Output</td>
<td>0: OFF, 1: ON</td>
<td>5.11.1</td>
</tr>
<tr>
<td>X04 X12 X20 X28</td>
<td>HOR</td>
<td>Heating Side Operating Output</td>
<td>0: OFF, 1: ON</td>
<td>5.11.1</td>
</tr>
<tr>
<td>X05 X13 X21 X29</td>
<td>B.OUT</td>
<td>Burnout</td>
<td>0: Normal, 1: Burnout occurred</td>
<td>5.8.1</td>
</tr>
<tr>
<td>X06 X14 X22 X30</td>
<td>FUNCER</td>
<td>Function Error</td>
<td>0: Normal, 1: Function error occurred</td>
<td>5.8.1</td>
</tr>
<tr>
<td>X07 X15 X23 X31</td>
<td>CPUERR</td>
<td>CPU Error</td>
<td>0: Normal, 1: CPU error occurred</td>
<td>5.8.1</td>
</tr>
<tr>
<td>X08 X16 X24 X32</td>
<td>(Not Used)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y33 Y41 Y49 Y57</td>
<td>R/S</td>
<td>Run/Stop</td>
<td>0: RUN, 1: STOP</td>
<td>5.7.2</td>
</tr>
<tr>
<td>Y34 Y42 Y50 Y58</td>
<td>A/M</td>
<td>Auto Output/Manual Output</td>
<td>0: Auto output, 1: Manual output</td>
<td>5.7.1</td>
</tr>
<tr>
<td>Y35 Y43 Y51 Y59</td>
<td>L/R</td>
<td>Local/Remote</td>
<td>0: Local, 1: Remote</td>
<td>5.4.2</td>
</tr>
<tr>
<td>Y36 Y44 Y52 Y60</td>
<td>S1/S2</td>
<td>Set Point 1/Set Point 2</td>
<td>0: Set point 1, 1: Set point 2</td>
<td>5.4.1</td>
</tr>
<tr>
<td>Y37 Y45 Y53 Y61</td>
<td>PVE</td>
<td>Internal Input/PV External Setting</td>
<td>0: Internal Input, 1: PV External Setting</td>
<td>5.5.8</td>
</tr>
<tr>
<td>Y38 Y46 Y54 Y62</td>
<td>N/LBK</td>
<td>Normal Control mode/Loop-Back mode</td>
<td>0: Normal Control Mode, 1: OUT-PVIN Loop-Back Mode</td>
<td>5.5.7</td>
</tr>
<tr>
<td>Y39 Y47 Y55 Y63</td>
<td>OUT/EXOUT</td>
<td>Normal Output/External Output</td>
<td>0: Normal Output, 1: External Output</td>
<td>5.7.3</td>
</tr>
<tr>
<td>Y40 Y48 Y56 Y64</td>
<td>(Not Used)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*1: Expressed in X mmnn. Read only.

\[ i \] : Unit number  
\[ m \] : Slot number  
\[ n \] : Terminal number

*2: Expressed in Y mmnn. Read/Write.

\[ i \] : Unit number  
\[ m \] : Slot number  
\[ n \] : Terminal number

---

**CAUTION**

Input and output relay settings are not held when power is turned off.

---

**Reference**

Relay registers can be accessed from BASIC using the following group numbers. For more information, see Section 4.1.7, "Accessing using BASIC Statements".

Input
- Group1: Terminal relays 01 to 16
- Group2: Terminal relays 17 to 32

Output
- Group1: Terminal relays 33 to 48
- Group2: Terminal relays 49 to 64
5. Parameters: Meaning and Function

This chapter describes the parameters used by the Temperature Control and Monitoring module and the PID module, their types and functions, and the operation of the modules.

5.1 Operation Overview

Figure 5.1 shows the functional block diagram for one channel of the Temperature Control and Monitoring module and the PID Control module. (Use this as a reference for each procedure to be described subsequently).

The same operation applies to each channel.

![Functional Block Diagram](image-url)

**Figure 5.1 Functional Block Diagram**

- Setting data
- Read data
- Function module
- Actual I/O

4-20 mA continuous output (note) 4-20 mA continuous output is available only for F3CE04-1N.
The following parameters in Figure 5.1 can be read via I/O data registers.

- **PVIN (Process Input)**: Numerical data representing measured input data that has been biased or filtered.
- **PV (Process Value)**: Numeric value used as a basis for controlling.
- **CSP (Control Set Point)**: Target for PV. This module provides control to make the PV reasonably close to this value.
- **OUT (Output Value)**: Control output value sent to the operating end of a process (such as heater) to make PV approach CSP.

**TIP**

CH1PV, CH2PV, CH3PV and CH4PV are available as PVs (process values) to provide successive channel numbers so that multiple channels can be read at a time.

See Table 4.3, “I/O Data Registers”.

The output can be directly controlled by changing the following parameters in Figure 5.1 via I/O data registers.

- **EXPV (External PV)**: Specific data used as the basis for temperature control in place of PVIN.
- **SP1 (Set Point 1)**: Data normally used as CSP.
- **SP2 (Set Point 2)**: Data that can be used as CSP in place of SP1. To be used when using a sequence trigger to switch a preset setting.
- **RSP (Remote SP)**: Data used in remote set point control in which the data is varied continuously through a Ladder Sequence or BASIC program. Unlike SP1 or SP2, this data is not held. To hold the value, backup the value as hold data using a Ladder Sequence or BASIC program.
- **MOUT (Manual Output)**: Output data used to manually control the operating output from a Ladder Sequence or a BASIC program.
- **POUT (Preset Output)**: Output data generated as operation output when temperature control is off.
- **EXOUT (External Output)**: Specific data to be generated as control output regardless of temperature control being on or off during maintenance, debugging, etc. This value is held at power off.

**Output immediately after power is switched on**

Immediately after power is turned on until the completion of the initialization of the module, the control output is based on POUT (Preset output). You should write to POUT, in advance, the value to appear at the output terminal of this module when temperature control is off, such as immediately after powering on.

POUT (Preset output) data remains held when power is turned off.

**CAUTION**

On completion of initialization, the module enters auto-run mode and starts performing control.
The OUT (Output Data) value depends on the values of output type, control mode, and Auto-output/Manual output, as follows.

Table 5.1 Output Data

<table>
<thead>
<tr>
<th>Output type</th>
<th>Time Proportional Output (Open collector Voltage Pulse)</th>
<th>Continuous Output (4 to 20mA) (note)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PID Control</td>
<td>ON/OFF Control</td>
</tr>
<tr>
<td>Control method</td>
<td>PID calculation output (within the range OL to OH)</td>
<td>ON/OFF calculation data (ON or OFF)</td>
</tr>
<tr>
<td></td>
<td>(Proportional output with cycle time (CT) )</td>
<td></td>
</tr>
<tr>
<td>Auto-output</td>
<td></td>
<td>PID calculation output (within the range OL to OH)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PID calculation value (ON or OFF)</td>
</tr>
<tr>
<td>Manual output</td>
<td>Outputs MOUT value (within the range OL to OH)</td>
<td>Outputs MOUT value (within the range OL to OH)</td>
</tr>
<tr>
<td></td>
<td>(Proportional output with cycle time (CT) )</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(The output is OFF if OUT is less than 0% when AUTO is switched to MOUT, and ON if otherwise.)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Outputs MOUT value (within the range OL to OH)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(The output is OFF if OUT is less than 0% when AUTO is switched to MOUT, and ON if otherwise.)</td>
</tr>
</tbody>
</table>

(Note) Continuous Output (4-20mA) is available only for F3CT04-1N, F3CR04-1N and F3CV04-1N modules.

The ON output and OFF output for ON/OFF Control is as shown in Table 5.2.

Table 5.2 ON/OFF Control Output

<table>
<thead>
<tr>
<th>Output type</th>
<th>ON output</th>
<th>OFF output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open Collector Output (Time proportional output)</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>Voltage Pulse Output (Time proportional output)</td>
<td>Approx. 6V or more</td>
<td>Approx. 0V</td>
</tr>
<tr>
<td>4-20 mA output (Continuous pulse)</td>
<td>20 mA</td>
<td>4 mA</td>
</tr>
</tbody>
</table>

For the load condition for each output type, see Section 2.4.3, “Output Specifications”.
5.2 Mode Register Parameters

5.2.1 Output Type

Set the OUTSEL\textsubscript{n} mode register (output type of CH\textsubscript{n}) as follows:

0: Open Collector Output (Time proportional output)
1: Voltage Pulse Output (Time proportional output)
2: 4-20 mA Current Output (Continuous pulse) (note)

(note) 4-20 mA Current Output (Continuous pulse) is available only for F3CT04-1N, F3CR04-1N and F3CV04-1N modules.

5.2.2 Control Mode

The Temperature Control and Monitoring module and PID Control module are controllers with four 1-output channels that can be set up as fast controllers with control cycles of 250ms or 125ms.

They can also be used as controllers with 2 outputs (heating/cooling), and can output CSP (control set point), as is.

The MD\textsubscript{n} mode register (CH\textsubscript{n} control mode) can be set as follows:

0: Normal Control
1: Fast PID Control
2: Heating/Cooling Control
3: Very Fast PID Control
4: Setting Output

■ Normal Control

The Normal Control mode for the module supports 4 control points (4 channels) with control cycle time of 500 ms.

■ Fast PID Control, Very Fast PID Control

The module also supports Fast PID Control with control cycle time of 250 ms by using hardware for 2 channels for each control point, and Very Fast PID Control with control cycle time of 125 ms by using hardware for 4 channels for each control point.

If CH\textsubscript{1} is set to Fast PID Control (250ms), CH\textsubscript{2} will be disabled. Similarly, if CH\textsubscript{3} is set to Fast PID Control (250ms), CH\textsubscript{4} will be disabled. (CH\textsubscript{1} and CH\textsubscript{3} can both be set to Fast PID Control concurrently. CH\textsubscript{2} and CH\textsubscript{4} cannot be set to Fast PID Control.)

Only CH\textsubscript{1} can be set to Very Fast PID control, which will at the same time disable the other channels (CH\textsubscript{2}, CH\textsubscript{3} and CH\textsubscript{4}).

⚠️ CAUTION

For those channels which are disabled but their associated hardware are used to drive other channels such as CH\textsubscript{2} or CH\textsubscript{4} when CH\textsubscript{1} or CH\textsubscript{3} is set respectively to Fast PID Control mode, or CH\textsubscript{2}, CH\textsubscript{3}, and CH\textsubscript{4} when CH\textsubscript{1} is set to Very Fast PID Control mode, set the I/O Register USE (Channel Used/Not Used) to “1” (Used).
**Heating/Cooling Control**

One control point can control two outputs concurrently, one each on the cooling end and the heating end, with a control cycle of 500 ms.

The control output is as shown in Table 5.3.

<table>
<thead>
<tr>
<th></th>
<th>Open Collector Output, Voltage Pulse Output</th>
<th>4-20mA Output (Continuous output)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>- Data register OUT (Output data)</td>
<td>- Data register OUT (Output data)</td>
</tr>
<tr>
<td></td>
<td>- Relay register HOR</td>
<td>- Data register HOUT</td>
</tr>
<tr>
<td>Cooling</td>
<td>- Relay register COR</td>
<td>- Data register COUT</td>
</tr>
</tbody>
</table>

PID control parameters can be set independently for heating and cooling.

For more details on Heating/Cooling Control, see Section 5.11, “Heating/Cooling Control”.

**CAUTION**

Heating/Cooling Control mode is not available in Forward Control mode. To use Heating/Cooling Control mode, always set the mode register DRn (CHn Forward/Reverse Switch) to “0” (Reverse Control). The heating output data will appear at the output terminal of each channel.

**TIP**

To provide the cooling output in Heating/Cooling Control mode, an analog output module, or contact output module is required. Follow the steps below.

1. Read the data from the appropriate register (COR, COUT) of the module using Ladder Sequence/BASIC.
2. Convert the data thus read into a data type compatible with the output module using Ladder Sequence/BASIC.
3. From Ladder Sequence/BASIC, output the converted data to the analog output module or the contact output module.

**Setting Output**

CSP (Control Set Point) can be output as is, as the operation output. The control cycle is 500 ms.

The setting range for CSP (Control Set Point) is \( RL \leq CSP \leq RH \) (RL: Instrument range lower limit, RH: Instrument range upper limit)

The output type follows the value of the OUTSELn mode register (CHn output type).

Table 5.4   Output Type

<table>
<thead>
<tr>
<th>Open Collector Output, Voltage Pulse Output (Time proportional output)</th>
<th>CT (Cycle time): 1 to 240 s (RL: OFF, RH: ON)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 to 20mA output (Continuous pulse)</td>
<td>4-20 mA (RL: 4 mA, RH: 20 mA)</td>
</tr>
</tbody>
</table>
5.2.3 Forward/Reverse Switch

Under Forward/Reverse control, the output current or duration increases or decreases depending on whether PV (process value) is larger or smaller than CSP (Control Set Point) as shown in Table 5.5.

Table 5.5 Action under Forward/Reverse Control

<table>
<thead>
<tr>
<th></th>
<th>Reverse control</th>
<th>Forward control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relation of PV &amp; CSP</td>
<td>when PV&lt;CSP</td>
<td>when CSP&lt;PV</td>
</tr>
<tr>
<td>ON/OFF control</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>Continuous output</td>
<td>Current increases</td>
<td>Current decreases</td>
</tr>
<tr>
<td>(4-20mA output)</td>
<td>when PV&lt;CSP</td>
<td>when CSP&lt;PV</td>
</tr>
<tr>
<td>Time proportional output</td>
<td>ON time increases</td>
<td>ON time decreases</td>
</tr>
<tr>
<td>Direction of Output change</td>
<td>when PV&lt;CSP</td>
<td>when CSP&lt;PV</td>
</tr>
</tbody>
</table>

![Diagram showing output data and CSP relationship]

**CAUTION**

Heating/Cooling Control mode is not available in Forward Control mode. To use Heating/Cooling Control mode, always set the mode register DRn (CHn Forward/Reverse Switch) to "0" (Reverse Control).

5.2.4 Set Mode Data Flag

After writing the parameter setting, set the mode register SETUP (Set Mode Data flag) to "1" to assign the parameter to the channel. When the parameter has been assigned to the channel, it will be automatically reset to "0".

For more information, see Section 4.1.5, “Setting Mode Registers”.
5.2.5 Reading Setting Values

Settings made with the rotary switch or mode registers can be checked using the following data registers.

- **INSW (Input Range Code)**: Input Range Code set using the rotary switch
- **OUTSW (Output/Control Mode)**: The mode register settings OUTSELn (CHn Output Type), MDn (CHn Control Mode) and DRn (CHn Forward/Reverse Switch) will be indicated as follows. (Treat this register as a 4-bit binary number with each bit representing a mode register setting.)

<table>
<thead>
<tr>
<th>Bit</th>
<th>Setting</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0: Open collector output (Time proportional output)</td>
</tr>
<tr>
<td>2</td>
<td>0: Voltage pulse output (Time proportional output)</td>
</tr>
<tr>
<td>1</td>
<td>1: 4-20mA output (Continuous output)</td>
</tr>
<tr>
<td>0</td>
<td>0: Normal/Fast PID / Very Fast PID Control / Setting Output, 1: Heating/Cooling Control</td>
</tr>
<tr>
<td></td>
<td>1: Reverse Control, 1: Forward control</td>
</tr>
</tbody>
</table>

*(Example)* For Heating/Cooling Control in Reverse Control Mode with output as 4-20 mA data, the data register value will be “0110” = “6”.

*Figure 5.2 Encoding of OUTSW bits*
5.3 PID Control and Parameters

We describe below the parameters associated with PID control.

The Temperature Control and Monitoring module adopts a PID control of differentiation precedent type. The differentiation time is not relative to the rate of change between the target and the controlled variable, but relative to the change in the process data (PV).

5.3.1 Proportional Band

The Proportional Band is a parameter that controls the sensitivity of the proportional operation (see below). The behavior of the proportional action can be explained as a comparison to the simplest ON/OFF operation.

Setting the data register PB (Proportional Band) to “0” sets up ON/OFF Control mode. The following functions are also available in ON/OFF Control mode:

- Forward/Reverse switching
- Auto/Manual output switching
- The output type can be selected as Open Collector Output, Voltage Pulse Output, or 4-20 mA Output (4-20 mA Output type is available only for F3CT04-1N, F3CR04-1N, F3CV04-1N)

ON/OFF control has only two states, ON and OFF so that the control result cycles as shown in Figure 5.3. Setting the data register HYS (Hysteresis) to a smaller value reduces the cycle width, but results in the output alternating violently between ON and OFF. This causes the relay to chatter if the output type is a relay junction, thus reducing the life of the relay significantly. Should this be the case, set HYS to a larger value to prevent chattering.

<table>
<thead>
<tr>
<th>Control output (Reverse control example)</th>
<th>ON-OFF operation</th>
<th>Proportional operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control result</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offset (Steady state deviation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control Set Point</td>
<td></td>
<td>Control Set Point</td>
</tr>
<tr>
<td>Tends to oscillate</td>
<td></td>
<td>Target setting</td>
</tr>
<tr>
<td>(Fully open)</td>
<td></td>
<td>Measured temperature</td>
</tr>
<tr>
<td>(Completely closed)</td>
<td></td>
<td>Offset</td>
</tr>
<tr>
<td>No intermediate state</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output data (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Deviation</td>
<td></td>
<td>- Deviation</td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>+ Deviation</td>
<td></td>
<td>+ Deviation</td>
</tr>
</tbody>
</table>

Figure 5.3 Proportional Operation
Proportional Band (PB) refers to the amount of change in the input (%) (or deviation amount (%)) that will produce a 0% to 100% change in the control output. The smaller the PB setting, the larger is the output change for a small deviation (difference between the measured input value and the control set point), resulting in an oscillating control output result. In this case, however, the offset (the difference between the final output and the control set point) will be reduced. ON/OFF Control can be considered as a control where the proportional band is reduced to an infinitesimal degree (Proportional Band = 0%).

(Reverse Operation example)

![Proportional Band Diagram](image)

**Figure 5.4 Operation with Different Proportional Band Values**

When fine-tuning the proportional band obtained by auto-tuning (see Section 5.10), or when adjusting the proportional band manually, note the following points.

- Always adjust upwards from a smaller value to a larger value.
- If oscillations appear, it means that the PB setting is too small.
- Adjusting the PB will not eliminate the offset.

![Conceptual Diagram of the Effect of Proportional Band Size](image)

**Figure 5.5 Conceptual Diagram of the Effect of Proportional Band Size**
5.3.2 Integration Time

A function that automatically reduces the offset (steady state deviation) that would theoretically be unavoidable in a proportional operation is called an integration operation (I operation) with the integration time (TI) being the parameter that defines the sensitivity of the integration operation.

The integration operation increases or decreases its output in proportion to the integral of the deviations (the product of the deviation width and the deviation duration). The integration operation is used in conjunction with the normal proportional operation to yield the proportional integration operation (PI operation).

The integration time (TI) is defined as the length of time required for the integration operation alone to produce the same amount of change that the proportional operation alone would produce, given a stepped deviation.

The longer the integration time, the slower will be the output change. Conversely, the shorter the integration time, the faster will be the output change. To disable the integration operation, set TI to “0”. Setting the TI value too short causes the output to oscillate much as it does when the proportional band is set too low, the only difference being that oscillations caused by the integration operation are characterized by longer cycle times than those caused by proportional band.

When adjusting the integration time manually, note the following points:
- The adjustment is primarily for reducing the offset.
- Always adjust downwards from a longer time to a shorter time.
- Appearance of oscillations with longer cycle time than that of oscillations that appear when the proportional band is reduced indicates that the integration time setting is too short.

- If the Integration time (TI) is too short, long cycle oscillations will appear in the measured value.

Figure 5.6 Integration Operation

Figure 5.7 Concept of Integration operation
5.3.3 Differentiation Time

If the time constant or the wasted time of the controlled device is too long, the proportional operation or proportional integration operation alone cannot provide a fast enough corrective operation, often resulting in overshooting. One way to get around this problem is to take into account the tendency (whether it is increasing or decreasing) of the process data so that appropriate corrective operation can be triggered earlier. The operation that changes the output in proportion to the differential (rate of change) of PV (process input) is called the differentiation operation (D operation) with the differentiation time (TD) being the parameter defining the sensitivity of the differentiation operation.

The differentiation operation is used in conjunction with normal proportional operation to yield the proportional differentiation operation (PD operation).

Differentiation time (TD) is defined as the length of time required for the differentiation operation alone, to produce the same amount of output change that the proportional operation alone would produce during the PD operation given a deviation with a specific gradient.

![Figure 5.8 Differentiation Operation](image1.png)

A long differentiation time strengthens the correction action and causes oscillations in the output. Oscillations due to the differentiation operation have short cycles.

Setting the differentiation time to “0” disables the differentiation operation. Always set TD to “0” for fast response inputs such as pressure or flow rate, or inherent oscillating inputs such as optical sensor.

When adjusting the TD parameter manually, note the following points:
- Always adjust upwards from a shorter time to a longer time.
- Appearance of oscillations with short cycle indicates that the differentiation time setting is too large.

![Figure 5.9 Concept of Differentiation Operation](image2.png)

- If the differentiation time (TD) is too long, short-cycle oscillations will appear in the measured temperature.
5.3.4 Manual Reset

The setting for the data register MR (Manual Reset) is only valid when the integration time (TI) is set to “0”. With the integration operation turned off (leaving only the proportional operation or the proportional differentiation operation enabled), a phenomenon occurs where the deviation between the control set point and the measured data remains unchanged (offset = steady state deviation). The parameter used for reducing this steady state deviation manually is Manual Reset.

5.3.5 Hysteresis

The operation to provide a gap around the ON/OFF operating points (target control value) as required to prevent the control output chattering during ON/OFF Control is known as hysteresis (HY).

![Figure 5.10 Operation with Hysteresis](53FG51.VSD)

5.3.6 Cycle Time

The basic cycle in PID control Time Proportional Output mode during which the repeating relay output or Voltage Pulse Output goes ON and then goes OFF once (Open Collector Output, Voltage Pulse Output) is referred to as the cycle time. The ON-time ratio in the cycle time is proportional to the control output data. Setting the cycle time lower provides granular control with higher frequency, but at the same time reduces the ON, OFF period, thus shortening the life of the relay. A typical setting for a relay output is 10 to 30 seconds with a setting range of 1 to 240 seconds.

(Figure 5.11 compares two operations with different cycle times but the same control output data =50%)

![Figure 5.11 Cycle Time](53FG61.VSD)
5.3.7 Anti-reset

If a large deviation persists such as at the start of a control operation, the integration operation output time may accumulate causing an overshoot exceeding the measured input.

To prevent this, the system is equipped to suspend the PID calculation and suppress over-integration (anti-reset windup capability).

Data register AR (Anti-reset) is a parameter that defines the deviation width between the PV and the CSP (Control Set Point) for resuming a suspended PID calculation.

AR : 0 (default)
When the output reaches the upper or lower limit and the PID calculation is suspended, the point at which to resume the PID calculation will be automatically set by the module.

: 0.1 to 999.9% unit (%)

When the output reaches the upper or lower limit and the PID calculation is suspended, the point at which to resume the PID calculation is set as a deviation width. Set the deviation width (AR) as follows:

\[
AR = \left| \frac{PV \text{ (Process Value)} - CSP \text{ (Control Set Point)}}{PB \text{ (Proportional Band)}} \right| \times 100
\]

Figure 5.12 Anti-reset Windup

TIP
Even if AR is set to a value other than "0", MV may continue to remain fixed at OH until PV exceeds CSP depending on the relationship among P, I, and D. This happens, for example, when the result of the PID calculation, which is resumed according to the AR setting, exceeds OH.
5.4 Control Set Point Related Parameters

Parameters related to the selection of the CSP (Control Set Point) is described below.

5.4.1 Set Point 1/Set Point 2

Either SP1 (Set Point 1) or SP2 (Set Point 2) may be selected as the control set point. (see Section 5.1.)

Set the output relay S1/S2 (Set Point 1/Set Point 2) as follows:

0: Set Point 1
1: Set Point 2

At power-on, this setting defaults to "0" (Set Point 1).

The current selection can be obtained by reading the output relay S1/S2. Write the data for Set Point 1 to data register SP1, and the data for Set Point 2 to data register SP2. Both SP1 and SP2 are hold data.

5.4.2 Local/Remote

Either Local (SP1 or SP2) or Remote setting (RSP) may be selected to be used as the control set point. (see Section 5.1.)

Set the output relay L/R (Local/Remote) as follows:

0: Local
1: Remote

At power-on, this setting defaults to "0" (Local).

The current selection can be obtained by reading this output relay L/R.

Write the remote set point to data register RSP. Whether Local is set to Set Point 1 (SP1) or Set Point 2 (SP2) is determined by output relay S1/S2 (Set Point 1/Set Point 2). (see Section 5.4.1)

When switching the control set point from Remote (RSP) to Local (SP1 or SP2), set SP tracking (SP.TR) to one of the following two operations. The default setting is No SP tracking (SP.TR=1).

SP.TR=1 : The Control Set Point (CSP) will take the value of the pre-set set point (SP1 or SP2).

SP.TR=0 : The Remote Set Point (RSP) is copied to the set points (SP1 or SP2), with the Control Set Point (CSP) remaining unchanged.
5.5 Input Processing Related Parameters

Parameters related to pre-processing and selection of measured input data are described below.

Measurement units peculiar to the Temperature Control and Monitoring module and PID Control module are explained below.

**Industrial Unit**: Value in industrial unit appropriate for the range

**Industrial Unit Span**: Value of width in industrial unit appropriate for the span (Industrial Unit S)

The relationship between Industrial unit, and Industrial unit span (Industrial S) is shown below (For the range -200 to 1200°C).

![Figure 5.13 Relationship between Industrial Unit and Industrial Unit S](image)

### 5.5.1 Instrument Range Upper Limit, Instrument Range Lower Limit

**For Thermocouple Input and Resistance Temperature Detector Input**

Selecting the input type with the rotary switch sets the parameters RL and RH automatically. These settings are referred to as the instrument range. (see Section 2.3, "Input Specifications"). Any desired measuring range can be set up within the instrument range by changing RL and RH. Parameter RL is used to specify the lower limit of the range, parameter RH to specify the upper limit of the range. The range width (RH-RL) is referred to as the span and is expressed in Industrial unit S.

![Figure 5.14 Range Upper/Lower Limits](image)

**CAUTION**

- The accuracy specifications for the module are always of the instrument range.
- Any measuring range set up does not affect the accuracy of the instrument.
For DC Voltage Input (mV type, DCV type)

The scale of the instrument range selected using the rotary switch is set to RL=0, RH=1000.

The scale of the instrument range can be changed by specifying RL and RH.

Example of scaling a 1-5V DC input to 0-8000 (Example where RL=0, RH=8000 and DEC.P=1)

<table>
<thead>
<tr>
<th>Instrument range array</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>DVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>200.0</td>
<td>400.0</td>
<td>600.0</td>
<td>800.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Scaling default values

| 0.0 | 25.0 | 50.0 | 75.0 | 100.0 |

Figure 5.15 Scale Conversion of DC Voltage Input

5.5.2 Decimal Point Position

The decimal point position can only be set for DC voltage input (mV type, DC type). For DC voltage input, write the code (0 to 3) to the data register DEC.P to specify the decimal point position (the number of digits after decimal point) on the scale.

For thermocouple input, or resistance temperature detector input, selecting the input type with the rotary switch sets the decimal point position appropriate for the input type automatically. In this case, the decimal point position cannot be altered.
5.5.3 Linearization

The raw measured input data must be pre-processed for each input type. For thermocouple input, thermo-electromotive force is converted to temperature. For resistance temperature detector input, resistance is converted to temperature. It is also in this block that input is processed with RH and RL.

![Linearization diagram]

Figure 5.16 Linearization

<table>
<thead>
<tr>
<th>Input type</th>
<th>IN1</th>
<th>OUT1</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermocouple</td>
<td>thermo-electromotive force of the thermocouple</td>
<td>Temperature data</td>
<td>- Zero junction compensator error detection - Burnout error detection</td>
</tr>
<tr>
<td>Resistance temperature detector</td>
<td>Resistance of resistance temperature detector</td>
<td>Temperature data</td>
<td>- Burnout error detection</td>
</tr>
<tr>
<td>DC voltage</td>
<td>DC voltage</td>
<td>DC voltage data</td>
<td>—</td>
</tr>
</tbody>
</table>

5.5.4 Channel Used/Not Used

Channel Used/Not Used is used to bypass processing for channels that are normally unwired (unused). Whether to perform processing for a channel can be specified for each channel as follows:

- 0: Not used
- 1: Used

Setting the data register USE to "0" (Not used) causes I/O data processing for the channel to be bypassed. As a result, the output is 0% and no burnout error will be detected.

To use only the output leaving the input unused, re-wire the input terminals appropriately as follows and activate the output to prevent burnout errors.

- F3CT04: Short the + Input and - Input for each channel.
- F3CR04: Short b and B for each channel, and connect a 100 Ω resistor between this point and A.

⚠️ CAUTION

- Setting the data register USE for a channel to "0" does not change the control cycle.
- To change the control cycle, set the Control Mode to Fast PID Control, or Very Fast PID Control. (See Section 5.2.2.) To activate Fast PID control or Very Fast PID control, be sure to set the data register USE to "1".
5.5.5 Input Correction

Input Correction adds a specific bias to the input and can be used to compensate for a physical condition thought to make the measured value smaller than the real value by a fixed amount, and to compensate for data that tends to differ from those yielded by other instruments by an amount within the precision tolerance.

Set the data register BS to any value from -(RH-RL) to (RH-RL).

![Input Correction Diagram](image1)

**Figure 5.17** Input Correction

5.5.6 Input Filter

Input Filter is used on input data that fluctuates violently and is set as a 1st order delay time constant.

Set the data register FL to 0 (OFF) or any value from 1 to 120 seconds.

Setting the data register FL to "0" disables the filter function.

![Filter Diagram](image2)

**Figure 5.18** Filter
5.5.7 Normal Control Mode/Loop-back Mode

Selects either the process Input or the loop-backed unaltered OUT (control output) value as the value to be used as the process value (see Section 5.1).

Set the output relay N/LBK (Normal Control Mode/Lop-Back Mode) as follows:

- 0: Normal Control Mode
- 1: Loop-Back Mode

The loop-back mode can be used when debugging an application program in the absence of wiring associated with temperature control. Input correction and input filter functions are also enabled in Loop-back mode.

At power-on, the setting defaults to "0" (Normal control mode).
This should be set to "1" (Loop-back mode) primarily during debugging.
The current selection can be obtained by reading this output relay N/LBK.

TIP
Loop-back mode is disabled in Heating/Cooling Control mode.

5.5.8 PV Process Input/EXPV External PV

Either Process input (PVIN) or External PV (EXPV) may be selected to be used as the process value (See Section 5.1).

Set the output relay PV/E (PV Process input/EXPV External PV) as follows:

- 0: PV process input
- 1: EXPV external PV

At power-on, the setting defaults to "0" (PV process input).
Current selection can be obtained by reading this output relay PV/E.
External PV data is to be written to the data register EXPV.

5.5.9 PV Limiter

Places a limit on IN4 as -5 to +105% of the range defined by RL (Instrument Range Lower Limit) and RH (Instrument Range Upper Limit) to produce OUT4. OUT4 = PV.

![PV Limiter Diagram](image)

Figure 5.19 PV Limiter
5.6 SP Gradient Setting Related Parameters

SP gradient setting can be used if you do not want the Control Set Point (CSP) to change abruptly, or if you want the CSP to change at a certain rate.

SP gradient setting will not be activated until the changing rate of the Control Set Point (CSP) is specified. By default, the changing rate is not specified (or set to "0") leaving the gradient setting function disabled. To enable the function, set SP Up Gradient (SPR.UP) and SP Down Gradient (SPR.DN) to specify the changing rate. The time unit is specified by setting Gradient Setting Time Unit (SPR.TM).

This setting prevents an abrupt change in the control set point (CSP) that would occur with any of the following 5 events.

1. Local/Remote (L/R) has been switched to Remote.
2. Target setting (SP1 or SP2) has been overwritten.
3. Set Point 1 (SP1) / Set Point 2 (SP2) has been switched.
4. Local/Remote (L/R) has been switched to Local.
5. Power has been turned on.
6. System has been switched from STOP to RUN.

In all the above cases, CSP will approach SP1 at the specified gradient but with different initial values. In cases (1) to (4), CSP approaches the new control set point starting from the old CSP value immediately before the event while in cases (5) and (6), it approaches the new control set point (SP1 or SP2) starting from the process input data (PV) at the beginning of the operation. Note however that in case (4), if SP tracking is set to (SP.TR=0), CSP will not change as specified by the SP gradient setting because it is tracked to RSP. For SP tracking, see Section 5.4.2, “Local/Remote".
5.7 Output Related Parameters

The parameters related to output data selection are described below.

5.7.1 Auto output/Manual Output

The output data can be selected from the data obtained from the control operation or MOUT (Manual output) (see Section 5.1).

Set the output relay A/M (Auto-output/Manual output) as follows:

0: Auto-output
1: Manual output

The output will be switched “bumpless” when Auto/Manual switching occurs. This means that when the mode is changed from Auto to Manual, the output data from Auto mode continues to be output as the output data in Manual mode, overwriting and nullifying any MOUT (Manual output) data which may be set before the mode was changed. After selecting Manual mode, you should wait at least 500 ms before writing MOUT data.

The current selection can be obtained by reading the output relay A/M.

⚠️ CAUTION

At power-on, the setting defaults to “0”.

5.7.2 RUN/STOP (Preset Output)

The output mode can be selected from RUN or STOP, RUN being the mode in which control is in operation while STOP being the mode in which control is not in operation. (see Section 5.1). In RUN mode, the data obtained from the control operation or MOUT (Manual output) will be output whereas in STOP mode, POUT (Preset output) will be output. Set the output relay R/S (RUN/STOP) as follows:

0: RUN
1: STOP

Current selection can be obtained by reading the output relay PV/E.

The preset output data that is output in STOP mode is to be written to the data register POUT. POUT is of hold-data type.

⚠️ CAUTION

At power-on, the setting defaults to “0” (RUN).

⚠️ TIP

- This preset output data, not the output data obtained from control operation, will also be output in case of burnout error, or A/D conversion error.
- Output upper/lower limits do not apply to preset output data.
5.7.3 Normal Output/External Output

The output data can be selected from OUT (Output Data) or EXOUT (External Output).
(see Section 5.1).
Set the output relay OUT/EXOUT (Normal Output/External Output) as follows:
0: Normal Output
1: External output
The current selection can be obtained by reading the output relay OUT/EXOUT.
Write the external output data to the data register EXOUT. The output upper/lower limits
do not apply on the output specified by EXOUT.

⚠️ CAUTION

At power-on, the setting defaults to "0" (Normal Output).

5.7.4 Output Upper Limit, Output Lower Limit

Limits can be placed on the output data except on preset output data (in STOP mode, or in
case of burnout or A/D error). This function can be used to ensure a base heat quantity at
the lowest output, or to disallow heating from operating at 0% or 100% to protect the
equipment. The actual control output can be limited to the range set by Output Lower limit
(OL) and Output Upper Limit (OH).

![Output Limits Diagram](image-url)

Figure 5.20 Output Limits
5.8 Alarm Related Parameters

Parameters related to alarm and errors are described below.

5.8.1 Alarm/Error Relays

Error Relays and Registers

The error relays, and registers used in the Temperature Control and Monitoring module and PID Control module are described below.

- **Input relay: CPUERR (data register CPUERC)**

  If the CPU in the module fails, this relay will be set to “1” indicating a fatal error.

  0: Normal
  1: Error occurred

  The details of the error is stored in the data register CPUER.C (CPU Error Code) as follows:

  **Table 5.7 Data Register CPUER.C Error Codes and their Description**

<table>
<thead>
<tr>
<th>CPUER.C</th>
<th>Name</th>
<th>Description of Error</th>
<th>Corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RAM Error</td>
<td>Pattern data Write/Read error</td>
<td>Failure mode (Repair)</td>
</tr>
<tr>
<td>2</td>
<td>ROM error</td>
<td>Checksum error</td>
<td>Failure mode (Repair)</td>
</tr>
<tr>
<td>3</td>
<td>System data error</td>
<td>System data lost</td>
<td>Failure mode (Repair)</td>
</tr>
</tbody>
</table>

- **Input relay: FUNERR (Data register FUNER.C)**

  If a function error occurs in the module, this relay will be set to “1”, indicating a medium severity error.

  0: Normal
  1: Error occurred

  The details of the error is stored in the data register FUNER.C (Function error code) as follows:

  **Table 5.8 Data register FUNER.C Error Codes and their Description**

<table>
<thead>
<tr>
<th>FUNER.C</th>
<th>Name</th>
<th>Description of Error</th>
<th>Corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>A/D error</td>
<td>A/D converter failure, PV=105%, OUT=PROUT</td>
<td>Failure mode (Repair)</td>
</tr>
<tr>
<td>400</td>
<td>Parameter error</td>
<td>Parameter lost, Lost parameter initialized</td>
<td>Check parameters.</td>
</tr>
<tr>
<td>500</td>
<td>RJC error</td>
<td>RJC failure, zero junction compensation ignored</td>
<td>Failure mode (Repair)</td>
</tr>
<tr>
<td>600</td>
<td>CAL error</td>
<td>Calibration data lost, running on default calibration data</td>
<td>Failure mode (Repair)</td>
</tr>
</tbody>
</table>

- **Input relay: B.OUT**

  If a burnout error occurs, this relay will be set to “1”, indicating a process failure.

  0: Normal
  1: Error occurred

  For more details, see Chapter 6, “Errors and Troubleshooting”
## Alarm Relay

- **Input relay: AL1R, AL2R**

  The states of Alarm 1 and Alarm 2 are represented as follows (see Section 5.8.2):
  
  0: Normal
  1: Alarm
5.8.2 Alarm Setting, Alarm Type, Alarm Hysteresis, Alarm Wait Reset

2 points of alarm check are available for each input channel. To disable the alarm function, set both the data registers AL1 (Alarm type 1) and AL2 (Alarm type 2) to "0" (OFF).

The alarm types and codes are shown in Table 5.9.

The alarm lamp, ALM LED on the front of the module will light if Alarm 1 or Alarm 2 has occurred on any one of the channels 1-4.

### Table 5.9 Alarm Codes and Alarm Types

<table>
<thead>
<tr>
<th>Alarm Type</th>
<th>Alarm Action (ON/OFF represents the state of the relay junction.)</th>
<th>Alarm Type Code</th>
<th>Alarm Action (ON/OFF represents the state of the relay junction and (Lamp ON)/(Lamp OFF) the state of the lamp)</th>
<th>Alarm Type Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>No alarm</td>
<td></td>
<td>0</td>
<td>Hysteresis</td>
<td>7</td>
</tr>
<tr>
<td>Measured value upper limit</td>
<td>Hysteresis</td>
<td>1</td>
<td>Deviation upper/lower limit</td>
<td>17</td>
</tr>
<tr>
<td>Measured value lower limit</td>
<td>Hysteresis</td>
<td>2</td>
<td>Within deviation upper/lower limits</td>
<td>18</td>
</tr>
<tr>
<td>Deviation upper limit</td>
<td>Hysteresis</td>
<td>3</td>
<td></td>
<td>For codes 3 and 4, wait is disabled</td>
</tr>
<tr>
<td>Deviation lower limit</td>
<td>Hysteresis</td>
<td>4</td>
<td>Example of alarm on measured value lower limit with wait action</td>
<td>For codes 13 and 14, wait is enabled</td>
</tr>
</tbody>
</table>

#### Wait Enable and Wait Disable

With alarm wait enabled, when power is turned on, or the control set point (CSP) is changed, no alarm will be issued until the process value reaches the normal region at least once, even if an error condition exists. In other cases, an alarm will be issued if an error condition occurs.
When the data register ALM.RST (Alarm Wait Reset) is set to "1" with "Wait" enabled, the system will reset the alarm signal and enter Alarm Wait state even if an error condition exists. ALM.RST will then return to "0" automatically. This function is not available if Wait is disabled.

Setting the Alarms

To use the alarm function, write the following parameters to the data registers.

Table 5.10 Alarm Setting Parameters

<table>
<thead>
<tr>
<th>Alarm1</th>
<th>Alarm2</th>
<th>Parameter</th>
<th>Specifying method</th>
<th>Data range</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL1</td>
<td>AL2</td>
<td>Alarm Type</td>
<td>To be selected from alarm type codes</td>
<td></td>
</tr>
<tr>
<td>A1</td>
<td>A2</td>
<td>Alarm Setting</td>
<td>To be specified in Industrial unit</td>
<td>Any value between 0 – 100% of RL-RH, or RH – RL</td>
</tr>
<tr>
<td>HY1</td>
<td>HY2</td>
<td>Alarm Hysteresis</td>
<td>To be specified in Industrial unit</td>
<td>Any value between 0 – 100% of RH - RL</td>
</tr>
</tbody>
</table>

CAUTION

Specify deviation alarm setting as a width value. (The negative sign is not required even for the lower limit.)

CAUTION

Specify the deviation alarm setting such that Alarm setting > Alarm hysteresis.
5.9 Overshoot Suppression Function

The overshooting suppressing function "Super" is effective in the following situations:
- For suppressing overshooting
- For handling large load fluctuation
- For speeding up the start-up process
- For handling frequent changes in the settings

The overshoot suppressing function, "Super", that calculates the process characteristics (wasted time, time constant), monitors the deviation and changes the control set point to a slightly lower temporary value automatically when it detects a risk of overshooting. In the range where overshooting is less unlikely, it restores the temporary control set point to its normal value gradually. This function is based on fuzzy theory that acts on the PID control parameters, as indicated by such "fuzzy" terms as "slightly" or "gradually". It calculates and theorizes on ambiguous information expressed in expressions (words) of feelings.

Figure 5.21 Overshoot Suppressing Function

To enable or disable the overshoot suppressing function "Super", set the data register SC (Super code) as follows:
- 0: Super OFF (Disable)
- 1: Super ON (Enable)

Writing "1" to SC (Super code) enables Super, and writing "0" disables it. Setting Super to OFF disables it and normal PID control will run according to the parameters. The module is shipped with Super set to "OFF".
**CAUTION**

The “Super” function is available only in PID operation. Therefore, if any one of Proportional Band (data register PB), Integration Time (data register TI) or Differentiation Time (data register TD) is set to “1”, “Super” will not be activated even if Super code (data register SC) is set to “1”.

**TIP**

- This module is capable of Auto-tuning (See Section 5.10), whereby it calculates and sets the PID constants* automatically. Effective controlling can be achieved easily with auto-tuning and with the Super code (data register SC) set to “1”.
  
  *: Proportional Band (data register PB), Integration Time (data register TI), Differentiation Time (data register TD)

- Note, however, that some control systems may not allow the use of Auto-tuning. For more details, see Section 5.10, “Auto-tuning”

- **“Super” and Local/Remote**

  - **Local mode**

    If CSP (Control Set Point) is changed when "Super" is ON, the control operation is as follows:

    With no gradient setting

    When SP is changed, the output will be controlled such that it will be prevented from overshooting with PV < SP.

    ![Diagram](image1)

    When SP is changed, the output will be controlled such that it will be prevented from overshooting with PV > SP.

    ![Diagram](image2)

    With gradient setting

    When SP is changed, the output will be controlled such that it will be prevented from overshooting with PV < SP.

    ![Diagram](image3)

    When SP is changed, the output will be controlled such that it will be prevented from overshooting with PV > SP.

    ![Diagram](image4)

    **Figure 5.22  “Super” Action in Local Mode**

  - **Remote mode**

    Since Remote mode is for direct control of the CSP (Control Set Point) from a ladder sequence or BASIC program, setting Super code (data register SC) to “1” does not activate “Super”.
5.10 Auto-tuning

Auto-tuning calculates and sets PID constants automatically. It is disabled in ON/OFF control mode (Proportional Band set to "0"). Auto-tuning operates on the "Limit Cycle" method.

Auto-tuning is activated when "1" (ON) is written to the data register AT (Auto-tuning). The module will temporarily become an ON/OFF controller and starting from the result, calculates the appropriate Proportional Band (PB), Integration Time (TI) and Differential Time (TD), and sets its own parameters.

Completion of auto-tuning is indicated by AT resetting to "0" when the result of the tuning (PB, TI, TD) takes effect.

If output upper limit (OH) /output lower limit (OL) is set, the ON/OFF control for continuous output (4 - 20mA) during Auto-tuning will run with its output limited by OH and OL. If the output is time proportional, Auto-tuning will run between 100% and 0% unrestricted by OH and OL.

**CAUTION**

Auto-tuning should not be used in the following control systems:

1. Fast response control systems such as flow control or pressure control systems
2. Any process whose output must never be ON/OFF, even temporarily.

[Examples] - Any process where large stress on the operating end must be avoided.
- Any process where the quality of the product may be affected if the measured value exceeds the tolerance range.
Even though CSP (Control Set Point) may be changed during auto-tuning, tuning will continued with the control set point at the beginning of auto-tuning unchanged. After auto-tuning completes, control will start with the new CSP gradient settings (SPR.UP, SPR.DN) are ignored during auto-tuning.

Changes in the PID constants during auto-tuning will generally never take effect as they will be overwritten at the completion of Auto-tuning, except in the case where auto-tuning is aborted so that the parameters are not overwritten.

To exit auto-tuning before it is completed, set the data register AT (Auto-Tuning) to "0" (Stop). Auto-tuning will then stop, leaving the PID constants as they were before Auto-tuning started.

A burnout error or A/D conversion error during Auto-tuning terminates Auto-tuning, generating POUT (Preset Output), leaving the PID constants as they were before Auto-tuning started.

Auto-tuning lasting approximately 22 hours or more will be terminated as timeout with the operation exactly the same as when auto-tuning is exited before it is completed.
5.11 Heating/Cooling Control

The Temperature Control and Monitoring module performs heating/cooling control when
the Control Mode register MDn (mode register) is set to “2”.

**CAUTION**

- Forward control for heating/cooling control is not available in the Temperature
  Control and Monitoring module. When using heating/cooling control, always write
  “0” to the mode register Forward/Reverse switch DRn to set it to Reverse control.
- The Temperature Control and Monitoring module is not equipped with a cooling
  control output terminal for heating/cooling control. Using the cooling control output
  requires an analog output module or junction output module. An unused output
  terminal of the temperature/monitor, if any, can also be used for this purpose. For
  use of such an output terminal, see Section 8.2, "Using the Monitor and Output
  separately”

5.11.1 Control Output of Heating/Cooling Control

The Temperature Control and Monitoring module has its control output fed to the
following relays and registers in heating/cooling control mode. The heating control
output will be applied to the output terminal of the module as specified by the mode
register setting.

**Figure 5.11 Control Output of Heating/Cooling Control**

<table>
<thead>
<tr>
<th>Open Collector Output, Voltage Pulse Output</th>
<th>4 - 20mA Output (for Continuous Output)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating Input relay H0R</td>
<td>Data register OUT, HOUT</td>
</tr>
<tr>
<td>Cooling Input relay C0R</td>
<td>Data register COUT</td>
</tr>
</tbody>
</table>

**TIP**

The state of the above registers and relays will be fed to an analog output module or junction output via
a sequence CPU to provide the cooling output of heating/cooling control.
- For continuous output
  Read the data register COUT above using a sequence CPU, adjust the scale if necessary and then
  feed it to the analog output module.
- For time proportional or ON/OFF output
  Read the input relay COR using a sequence CPU and feed it to the junction output module. If the
  cooling output is voltage pulse output, take note of the logic.
5.11.2 Operation in Heating/Cooling Control

The operation and restrictions in heating/cooling control is described below.

(1) Heating Output, Cooling Output, and Control Calculation

The Temperature Control and Monitoring module has its internal control output data separated into heating output and cooling output to provide heating/cooling control. Although calculation parameters can be specified separately for heating and cooling (See Table 5.12, "Heating/Cooling Parameters"), the outputs are not calculated independently. Instead, parameters are selected to calculate the internal output, which, in turn, will be separated into the heating output and cooling output. It should be noted that as the cooling output of the temperature/monitor module is intended as auxiliary, the cooling calculation parameters are also treated as auxiliary in the output calculation except in the case where the heating side is set as an ON/OFF control.

Figure 5.24 shows the concepts of the parameters and control calculation, illustrating the equilibrium with a certain SP where two diagrams are combined, one showing the relationship between the process input and internal output data, and the other showing the relationship between the internal control output and heating and cooling outputs. This figure is used to explain the process for determining the heating/cooling output data from the process input below.

*1 First, calculate the internal control output from the relationship between PV and SP. The proportional band used in this calculation is the one for heating (except when the heating is under ON/OFF control). Specify the proportional band as a ratio to the input span (RH - RL).

*2 The internal control output data thus calculated will be separated into heating control output, and cooling control output. If the dead band (to be discussed later) is set to 0%, or the proportional bands for heating and cooling are set to the same value, the separation will be as follows:
   - When internal control output is 0%, heating output is 0% and cooling output is 100%
   - When internal control output is 50%, heating output is 0% and cooling output is 0%
   - When internal control output is 100%, heating output is 100% and cooling output is 0%

*3 The internal control output data range is limited by the heating and cooling output limits OH, and OHC, and the calculation upper and lower limits in calculation. The example in Figure 5.24 has its internal control output data range limited by the internal control output data equivalent to OH and OHC. The upper/lower limits in calculation are ±200%.

The heating and cooling outputs may be limited by the ratio of heating proportional band to cooling one, such as when the cooling proportional band is set too high compared to the heating one, or when the dead band is set too large. For example, if the cooling proportional band is set 10 times higher than the heating proportional band, a cooling output of 100% would be obtained theoretically when the calculated internal control output is -450% (assuming the dead band to be 0%). However, with the internal control output limited to -200% as previously described, no cooling output larger than 50% can actually be obtained.

*4 The dead band is a range provided in the vicinity of 50% of the internal control output where both the heating and cooling outputs are zero. The size of the dead band must be specified as a ratio to the size of the proportional band.
Figure 5.24  Heating/Cooling Control Operation

Table 5.12 lists the parameters related to Heating/Cooling Control. For details on the register numbers or data ranges, see Section 4.3, "I/O Data Registers".

Table 5.12  Heating/Cooling Control Parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Register</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead band</td>
<td>D.B</td>
<td>Set the relationship for 0% heating and cooling output.¹</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specified as a ratio to the proportional band.¹</td>
</tr>
<tr>
<td>Proportional band</td>
<td>PB</td>
<td>Take into account the heating and cooling capacity ratio.</td>
</tr>
<tr>
<td></td>
<td>PBC</td>
<td></td>
</tr>
<tr>
<td>Integration time</td>
<td>TI</td>
<td>Setting this to &quot;0&quot; nullifies the integration term.</td>
</tr>
<tr>
<td></td>
<td>TIC</td>
<td></td>
</tr>
<tr>
<td>Differentiation time</td>
<td>TD</td>
<td>Setting this to &quot;0&quot; nullifies the differentiation term.</td>
</tr>
<tr>
<td></td>
<td>TDC</td>
<td></td>
</tr>
<tr>
<td>Hysteresis</td>
<td>RLYHYS</td>
<td>Specified as a ratio to the proportional band.¹</td>
</tr>
<tr>
<td>Cycle time</td>
<td>CT</td>
<td></td>
</tr>
<tr>
<td>Manual output</td>
<td>MOUT</td>
<td>Both restricted by the upper and lower limits.</td>
</tr>
<tr>
<td></td>
<td>MOUTC</td>
<td></td>
</tr>
<tr>
<td>Preset output</td>
<td>POUT</td>
<td>Neither restricted by upper and lower limits.</td>
</tr>
<tr>
<td></td>
<td>POUTC</td>
<td></td>
</tr>
<tr>
<td>Output upper limit</td>
<td>OH</td>
<td>Restricts the maximum of both outputs.</td>
</tr>
<tr>
<td></td>
<td>OHC</td>
<td></td>
</tr>
<tr>
<td>Output lower limit</td>
<td>OL</td>
<td>Restricts the minimum of both outputs.</td>
</tr>
<tr>
<td></td>
<td>OLC</td>
<td></td>
</tr>
</tbody>
</table>

¹  Use the heating proportional band to compute the ratio unless it is set to "0". If the heating proportional band is set to "0" and the cooling proportional band to any value other than "0", use the cooling proportional band instead. If the heating and cooling proportional bands are both set to "0", perform setting treating the proportional bands as "100%".

²  If the integration term for either heating or cooling is nullified, then both the integration terms for heating and cooling will be nullified.
(2) Considerations when running auto-tuning

As explained above, the cooling output of the heating/cooling control is treated as an auxiliary function in Temperature Control and Monitoring module. Therefore, during auto-tuning, the 100% and 0% output terminals of the heating side, but not the cooling output, are used. If auto-tuning does not run well with only the heating outputs because of the characteristic of the control object, use the cooling output to run auto-tuning. For the procedure, see Section 5.11.3, "Auto-tuning in Heating/Cooling".

TIP

In auto-tuning for heating/cooling control, the proportional gain tends to be set larger than should be in either of the cases. It is, therefore, recommended that the proportional band setting obtained from auto-tuning be doubled to lower the gain.

(3) Overshoot suppression function should not be used.

The overshoot suppressing function “Super” of the Temperature Control and Monitoring module does not work properly for heating/cooling control. The function is available, but would very likely fail to suppress overshooting, or even allow a larger overshooting to develop. Therefore, we recommend that you do not use the Overshoot Suppressing function “Super” in heating/cooling control.

(4) Output may not be switched over “bumpless”.

In normal PID control (including Fast and Very Fast), the output does not change abruptly when Auto/Manual switching takes place. But in heating/cooling control, it does when Manual is switched to Auto. This is because the manual outputs for heating and cooling are designed to be controlled separately so that Auto run starts with an internal control output of 50% (output at equilibrium).

On the other hand, if Auto is switched to Manual, the control output for heating and cooling will be inherited as manual output. For details on how to specify the manual output, see Section 5.7.1, “Auto output/Manual output”.

(5) Linking to Auto/Manual, Run/Stop operations

Both heating and cooling outputs will be switched to Auto Output/Manual Output/Preset Output by the operation of output relays (Auto/Manual switching, and Run/Stop switching).

(6) Design the system such that heating and cooling outputs are equal.

With unbalanced heating and cooling outputs, consistent control is hard to achieve. It is strongly recommended that your system be so designed as to have equal heating and cooling power.

If this is practically hard or impossible, adjust the proportional band to have their loop gains closer to each other for improved consistency. For this procedure, see Section 5.11.3, “Auto-tuning in Heating/Cooling Control Mode”.


5.11.3 Auto-tuning in Heating/Cooling Control Mode

The Temperature Control and Monitoring module uses the 100% output and 0% output on the heating side during auto-tuning in heating/cooling control mode, leaving the cooling output unused. This is because the cooling output is intended as an auxiliary function. For this reason, appropriate PID constants may not be obtained in a system with adequate heat insulation where the temperature does not fall without cooling output. If this is the case, run auto-tuning using the cooling output as shown below.

(1) Generate maximum cooling output at minimum output during auto-tuning

The maximum cooling output will be used for auto-tuning in heating/cooling control. When the heating output data OUT is 0% (OL if OL is set) during auto-tuning, the cooling output becomes maximum, thus solving the problem of the temperature remaining too high making auto-tuning impossible. This processing must be handled using an application program such as a sequence program. For more information, see Section 7, "Sample Programs".

(2) Adjusting the Capacity Difference between Heating and Cooling

If there is a significant difference between the heating and cooling capacities, run auto-tuning using the cooling output and then adjust the respective proportional bands using the following coefficients.

Given a heating capacity of A watt and a cooling capacity B watt,

Heating coefficient: \( \frac{2A}{A+B} \)

Cooling coefficient: \( \frac{2B}{A+B} \)

Multiply each proportional band obtained from auto-tuning by the appropriate coefficient and set the results as PB or PBC.

If the ratio between heating and cooling proportional bands is too large, the control output may be restricted. It is therefore recommended that the control system be designed with similar heating and cooling capacities, if possible. For details on restrictions, see Section 5.11.2, "(1) Heating Output, Cooling Output, and Control Calculation".

TIP

If the heating and cooling capacity ratio cannot be obtained, use the time ratio between the heating output time and cooling output time during auto-tuning. It can be safely assumed that "Heating capacity A: Cooling capacity B = Cooling time D : Heating time C". In this case,

Heating coefficient: \( \frac{2D}{C+D} \)

Cooling coefficient: \( \frac{2C}{C+D} \)
6. Errors and Corrective Actions

6.1 Self-Diagnosis

The Temperature Control and Monitoring module and PID module run self-diagnosis at power-on and during operation.

Table 6.1 lists the symptom, output state, and corrective action for each error condition. If any error is encountered, take an appropriate corrective action according to this table.
<table>
<thead>
<tr>
<th>No.</th>
<th>State</th>
<th>Checking purpose</th>
<th>Faulty condition</th>
<th>Checking</th>
<th>Error detection</th>
<th>Corrective action</th>
<th>Module status</th>
<th>Corrective action</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Check for faulty condition</td>
<td>RAM error</td>
<td>Write/Read check</td>
<td>All CH: CPU = ON, CPU.C = 1</td>
<td>Stop operation</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>01</td>
<td></td>
<td></td>
<td>ROM error</td>
<td>Sum check</td>
<td>All CH: CPU = ON, CPU.C = 2</td>
<td>Stop operation</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>02</td>
<td></td>
<td></td>
<td>System data error</td>
<td>Sum check</td>
<td>All CH: CPU = ON, CPU.C = 3</td>
<td>Type CTOL, Run with no channel unused</td>
<td>(Normal)</td>
<td>(Normal)</td>
</tr>
<tr>
<td>03</td>
<td></td>
<td></td>
<td>Calibration data error</td>
<td>Sum check</td>
<td>Error CH: FUNCE = ON, FUNCE.C = 600</td>
<td>Initialize calibration data and run</td>
<td>out of precision</td>
<td></td>
</tr>
<tr>
<td>04</td>
<td></td>
<td></td>
<td>Parameter error</td>
<td>Sum check</td>
<td>Error CH: FUNCE = ON, FUNCE.C = 400</td>
<td>Initialize faulty parameter and run</td>
<td>(Normal)</td>
<td></td>
</tr>
<tr>
<td>05</td>
<td></td>
<td></td>
<td>R/C error</td>
<td>Range check</td>
<td>Error CH: FUNCE = ON, FUNCE.C = 300</td>
<td>Turn off zero junction compensation and run</td>
<td>No RJC correction</td>
<td></td>
</tr>
<tr>
<td>06</td>
<td></td>
<td></td>
<td>ADC error</td>
<td>Range check</td>
<td>Error CH: FUNCE = ON, FUNCE.C = 300</td>
<td>Turn off AT</td>
<td>0%</td>
<td>A POUT</td>
</tr>
<tr>
<td>07</td>
<td></td>
<td></td>
<td>Checking the process</td>
<td>PV burnout error</td>
<td>Range check</td>
<td>Error CH: BOUT = ON</td>
<td>Turn off AT</td>
<td>105%</td>
</tr>
<tr>
<td>08</td>
<td></td>
<td></td>
<td></td>
<td>PV&lt; OVER error</td>
<td>Range check</td>
<td>Run at PV = 105% - 9%</td>
<td>Limit (Normal)</td>
<td></td>
</tr>
<tr>
<td>09</td>
<td></td>
<td></td>
<td></td>
<td>AT error</td>
<td>Time out</td>
<td>Run with P.I.D before AT</td>
<td>(Normal)</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td>WDT</td>
<td>Runaway</td>
<td>Program normal operation</td>
<td>—</td>
<td>Reset CPU</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td>Power supply</td>
<td>Power OFF</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td>Set-up mode</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td>Unused CH</td>
<td>—</td>
<td>Operation of unused CH</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Table 6.1 Error symptoms and corrective actions**

**Notes:**
- *Normal: Normal operation*
- *A: Auto, M: Manual, POU: Preset output*
- *RDY lamps light after initialization is completed*
- *CPU.E: CPU error state relay, CPU.C: CPU error code register*
- *FUNCE: Function error state relay, FUNCE.C: Function error code register*
- *BOUT: Burnout state relay*
- *WDT: Watchdog timer*
- *If Alarm 1 or Alarm 2 occurs on any one of Ch. 1 - 4, the corresponding input relay goes ON.*
- *If Alarm 1 or Alarm 2 occurs on any one of Ch. 1 - 4, the LED lights.*
For details on input burnout, See Table 6.2.

**Table 6.2  Operation in Response to Burnout**

<table>
<thead>
<tr>
<th>Input type (and discontinuity location)</th>
<th>Burnout detection (Action and time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct current voltage (DCV) input</td>
<td>No burnout detection</td>
</tr>
</tbody>
</table>
| Thermocouple input                     | - Increases gradually to reach the measurement upper limit to be detected as burnout  
                                           - Detected as burnout within approximately 30 s after discontinuity (varies slightly with thermocouple type) |
| Resistance temperature detector input (Discontinuity location b)* | - Increases to reach the measurement upper limit to be detected as burnout  
                                                                          - Detected as burnout within approximately 30 s after discontinuity |

*: Locations A, B, and b represent the terminal locations on this module. (See Figure 2.2 in Section 2.1).
6.2 Error Precedence

6.2.1 CPU Errors

If an error occurs in CPU (when the input relay CPUERR turns ON. See Section 4.4), the error details will be written to the data register CPUER.C in the error code format shown in Table 6.3. This data register can be read by the user to obtain the error details.

If more than one CPU errors occur simultaneously, the error code with the highest precedence will be written to the data register.

Table 6.3 CPU Error Codes (CPUER.C)

<table>
<thead>
<tr>
<th>Error code</th>
<th>Error</th>
<th>Description</th>
<th>Corrective action</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RAM error</td>
<td>Pattern data Read/Write error</td>
<td>Faulty (repair)</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>ROM error</td>
<td>Sum check error</td>
<td>Faulty (repair)</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>System data error</td>
<td>Sum check error</td>
<td>Faulty (repair)</td>
<td>3</td>
</tr>
</tbody>
</table>

6.2.2 Function Errors

If an error occurs with an internal function (when the input relay FUNCRR turns ON. See Section 4.4), the error details will be written to the data register FUNCER.C in the error code format shown in Table 6.4. This data register can be read by the user to obtain the error details. This type of error disables the control loop partially.

If more than one function errors occur simultaneously, the error code with the highest priority will be written to the data register.

Table 6.4 Function Error Codes (FUNCER.C)

<table>
<thead>
<tr>
<th>Error code</th>
<th>Error</th>
<th>Description</th>
<th>Corrective action</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>A/D error</td>
<td>A/D converter faulty</td>
<td>Faulty (repair)</td>
<td>3</td>
</tr>
<tr>
<td>400</td>
<td>Parameter error</td>
<td>Parameter lost</td>
<td>Check parameter</td>
<td>4</td>
</tr>
<tr>
<td>500</td>
<td>RJC data</td>
<td>RJC faulty</td>
<td>Faulty (repair)</td>
<td>2</td>
</tr>
<tr>
<td>600</td>
<td>CAL error</td>
<td>Calibration data lost</td>
<td>Faulty (repair)</td>
<td>1</td>
</tr>
</tbody>
</table>
7. Sample Programs

Following is a sample program for using the Temperature Control and Monitoring module installed in Slot 2 to control temperature as specified in Tables 7.1 and 7.2. Take adequate measures against stress, etc. on the target control device, debug and test-run the program to ensure safety before running the program in an actual system.

7.1 Sample Program for Normal Control

Table 7.1 Specifications of the Sample Program for Normal Control

<table>
<thead>
<tr>
<th>Item</th>
<th>Setting</th>
<th>Remark</th>
<th>Block name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermocouple input</td>
<td>Type K</td>
<td>Temperature range -200 to 500°C</td>
<td></td>
</tr>
<tr>
<td>Power supply frequency</td>
<td>50 Hz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Set point</td>
<td>100°C</td>
<td></td>
<td>MAIN</td>
</tr>
<tr>
<td>Output type</td>
<td>Voltage pulse</td>
<td>Using SSR</td>
<td>MODE</td>
</tr>
<tr>
<td>Control mode</td>
<td>Normal</td>
<td></td>
<td>MODE</td>
</tr>
<tr>
<td>Control direction</td>
<td>Reverse</td>
<td></td>
<td>MODE</td>
</tr>
<tr>
<td>Cycle time</td>
<td>5 s</td>
<td>Resolution 10ms</td>
<td>INIT</td>
</tr>
<tr>
<td>Input filter</td>
<td>10 s</td>
<td>1st order delay, time constant</td>
<td>INIT</td>
</tr>
<tr>
<td>Overshoot suppression</td>
<td>Available</td>
<td>Super</td>
<td>INIT</td>
</tr>
<tr>
<td>Auto-tuning</td>
<td>Available</td>
<td></td>
<td>AT</td>
</tr>
</tbody>
</table>

First, use the rotary switch and dip switches on the module front to set the input range, and power supply frequency (See Section 3.2, "Setting Switches"), then turn on the power to download the program. This sample program is divided into 5 blocks, namely, MAIN, MODE, INIT, AT, and DEBUG, but it can also be created as a single block.

After the program is downloaded, run the temperature module in the Loop-back mode (see Section 5.5.7, "Normal Control Mode/Loop-back Mode") to debug the program. If no problem is encountered, exit the loop-back mode to prepare the system for process control. At this point, you should pay careful attention to the operation of the system because there is a significant difference in response time between the actual system and the Loop-back mode system used in debugging and the PID has not been properly selected for the actual system. Auto-tuning, therefore, must be run with the actual system to adjust for improved performance characteristics. However, do not run Auto-tuning for systems for which the module is not suited.
7.1.1 Setting Mode Registers

The "MODE" program block selects the output type, specifies control mode, selects Reverse control mode and sets the mode registers. These settings will remain held by the battery built into the module and need not be re-written each time.

To write the settings to the module, set the output relay OUT.set. Relay READY is the signal that indicates that the module start-up procedure has been completed and is controlled by the value of the write sync signal register (ACX) which is checked in "Main" (to be discussed later in section 7.1.3, "Main"). Writing to the mode registers takes place when both of these conditions are satisfied to set OUT.wr.

The second last line activated by OUT.wr is the trigger that enables the written settings. The value of this register will be automatically reset to "0" when setting is done. At the same time, the output type, control mode, and control direction will be reflected in the data registers. To check whether the values are properly set, read the register, if necessary.
7.1.2 Initial Settings

The “INIT” program block sets the cycle time for the time proportional output, the input filter and enables the overshoot suppression function “Super”. These settings will remain held by the battery built into the module, and need not be re-written each time.

Setting relay INI.set causes the data to be written to the module to activate the cycle time, the input filter time constant, and Super.

Relay READY is a signal that indicates completion of the start-up procedure and is controlled by the value of the write sync signal register (ACK) which is checked in “Main” (to be discussed later in Section 7.1.3, “Main”) Writing takes place when both these conditions are satisfied to set INIT.wr.
### 7.1.3 Main

The "Main" program block checks the value of the Write Sync Signal register (ACX) to control the Startup Completed flag READY. Setting values, process values, or output data are also read from the module as required.

![Diagram of Main program block](image)

- **Start-up completed flag area**
  - Read ACK signal to confirm that start-up procedure has been completed.
  - Start-up completed flag area
  - Read ACK
  - Set Start-up completed flag

- **Specify Set Point 1**
  - Specify Set Point 1
  - Write 1000 2 33 1

- **Read registers as necessary**
  - Read parameters

### 7.1.4 Auto-tuning

The "AT" program block starts Auto-tuning, stops Auto-tuning and checks for its completion.

![Diagram of Auto-tuning program block](image)

- **Start auto tuning**
  - AT.start
  - Write 1 2 41 1

- **Stop auto tuning**
  - AT.stop
  - Write 0 2 41 1

- **Check status of auto tuning**
  - Read auto tuning flag
  - Proportional Band, PB
  - Integration Time, TI
  - Differentiation Time, TD

Setting the relay AT.start writes "1" to the Auto-tuning flag (AT), starting Auto-tuning. To exit Auto-tuning before it is completed, set AT.stop. The completion of Auto-tuning can be determined by monitoring register AT, which resets to "0" upon completion.
7.1.5 Off-Line Debugging

The “DEBUG” program block performs setting for debugging the sequence program before the devices for the temperature control loop are ready. This program block will not be needed after debugging is done and after the object for the temperature control has been completed.

Putting the temperature control module in loop-back mode allows you to check the operation of the application program including starting and stopping of AT, setting of the target value and reading of the process values and control amount. Note, however, that the response of the process in loop-back mode is different from that of the actual system. The 1st order delay filter configured in Section 7.1.2, “Initial Settings” is used as the control object here.

⚠️ CAUTION ⚠️

Before migrating to the actual system, make sure that the PID constants used in the off-line debugging will not adversely affect the actual control object.
### 7.2 Sample Program for Heating/Cooling Control

#### Table 7.2 Specifications of Sample Program for Heating/Cooling Control

<table>
<thead>
<tr>
<th>Item</th>
<th>Setting</th>
<th>Remark</th>
<th>Block name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermocouple input</td>
<td>Type K</td>
<td>Temperature range -200 to 500°C</td>
<td></td>
</tr>
<tr>
<td>Power supply frequency</td>
<td>50 Hz</td>
<td>To be set using switches on the module front</td>
<td></td>
</tr>
<tr>
<td>Set point</td>
<td>100°C</td>
<td>MAIN</td>
<td></td>
</tr>
<tr>
<td>Output type</td>
<td>Voltage Pulse</td>
<td>Using SSR</td>
<td>MODE</td>
</tr>
<tr>
<td>Control mode</td>
<td>Heating/Cooling</td>
<td>MODE</td>
<td>MODE</td>
</tr>
<tr>
<td>Control direction</td>
<td>Reverse</td>
<td>MODE</td>
<td>MODE</td>
</tr>
<tr>
<td>Cooling output</td>
<td>F3YD08</td>
<td>Using 4 slot, 1ch</td>
<td>COOLDRV</td>
</tr>
<tr>
<td>Cycle time</td>
<td>5 s</td>
<td>Resolution 10ms</td>
<td>INIT</td>
</tr>
<tr>
<td>Cycle time (Cooling)</td>
<td>5 s</td>
<td>Resolution 10ms</td>
<td>INIT</td>
</tr>
<tr>
<td>Input filter</td>
<td>10 s</td>
<td>1st order delay, time constant</td>
<td>INIT</td>
</tr>
<tr>
<td>Overshoot suppression</td>
<td>No</td>
<td>Super</td>
<td>INIT</td>
</tr>
<tr>
<td>Auto-tuning</td>
<td>Yes</td>
<td>AT</td>
<td></td>
</tr>
</tbody>
</table>

First, use the rotary switch and dip switches on the module front to set the input range and power supply frequency (see Section 3.2, “Setting switches”), and then turn on the power to download the program.

This sample program is divided into 6 blocks, namely, MAIN, MODE, INIT, AT, DEBUG, and COOLDRV but it can be created as a single block.

After the program is downloaded, the External Input function of the Temperature Monitoring module will be used to debug the program. If no problem is encountered, deselect External Input to allow process control. At this point, you should pay careful attention to the operation of the system because there is a significant difference in response time between the actual system and the test system used in debugging and the PID has not been properly selected for the actual system. Auto-tuning, therefore, must be run with the actual system to adjust for improved performance characteristics. However, do not run Auto-tuning for systems for which the module is not suited.
7.2.1 Setting Mode Registers

The "MODE" program block specifies the output type and control mode, selects Reverse control mode and sets the mode registers. These settings will remain held by the battery built into the module and need not be re-written each time.

To write the settings to the module, set the output relay OUT.set. Relay READY is the signal that indicates that the module start-up procedure has been completed and is controlled by the value of the write sync signal register (ACX) which is checked in "Main" (to be discussed later in section 7.2.3, "Main"). Writing to the mode registers takes place when both of these conditions are satisfied to set OUT.wr.

The second last line activated by OUT.wr is the trigger that enables the written settings. The value of this register will be automatically reset to "0" when setting is done. To check whether the settings are proper, read the registers, if necessary.
7.2.2 Initial Settings

The “INIT” program block sets the cycle time for the time proportional output, the input filter and disables the overshoot suppression function “Super”. These settings will remain held by the battery built into the module, and need not be re-written each time.

Setting relay INI.set causes the data to be written to the module to set the cycle times, the input filter time constant, and to disable the Super function.

Relay READY is a signal that indicates completion of the module start-up procedure and is controlled by the value of the write sync signal register (ACK) which is checked in “Main” (to be discussed later in Section 7.2.3, “Main”) Writing takes place when both these conditions are satisfied to set INIT.wr.

CAUTION

In heating/cooling control, Super may not perform properly. You are well-advised not to use “Super” in heating/cooling control.
7.2.3 Main

The “Main” program block checks the value of the Write Sync Signal register (ACX) to control the Startup Completed flag READY. Setting values, process values, or output data are also read from the module as required.

![Diagram of the Main program block]

7.2.4 Cooling Output

The “COOLDRV” program block outputs the cooling output relay to the junction output module in Slot 4.

![Diagram of the Cooling Output program block]

During normal operation, the cooling output relay will be loaded and send as output to the junction output module. During auto-tuning, the heating output relay is reversed and send as output because the cooling output relay is disabled during auto-tuning.

TIP

- The cooling output to be delivered continuously using an analog output module will be determined not by the output relay but by the value of the Output Register (OUT) data register.
- During normal operation, data will be read from the cooling output register, and sent as output to the analog output module.
- Because the cooling output register is disabled during auto-tuning, monitor the heating output and outputs the maximum cooling output (OHC) when the heating output is equal to the lower limit of the heating output (OL).
7.2.5 Auto-tuning

The "AT" program block starts Auto-tuning, stops Auto-tuning and checks for its completion.

Setting the relay AT.start writes "1" to the Auto-tuning flag (AT), starting Auto-tuning. To exit Auto-tuning before it is completed, set AT.stop. The completion of Auto-tuning can be determined by monitoring register AT, which resets to "0" upon completion.

Setting the relay Twice doubles the proportional band. This is used when the proportional gain is too large, resulting in an oscillating behavior. Also adjust for the capacity difference between heating and cooling.
7.2.6 Off-Line Debugging

The "DEBUG" program block performs setting for debugging the sequence program before the devices for the temperature control loop are ready. In heating/cooling control, the Loop-back function is disabled for the module so a sequence program is used to create an appropriate process as the control object with the External Process Input used as the process input. This program block will not be needed after debugging is done and after the object for the temperature control has been completed.

Using this block with the External Input of the temperature control module allows you to check the operation of the application program including starting and stopping of AT, setting of the target value and reading of the process values and control amount. Note, however, that the process response in such a setup is different from the response from the actual system. Here, the above model created for off-line debugging is used as the control object. This model assumes the power of the heating element to be 1000 [W], and that of the cooling element to be 2000 [W], the power dissipation to be proportional to the process value D02007, and the thermal capacity of the control object to be 1000 [J/K/°C].

⚠️ CAUTION ⚠️

Before migrating to the actual system, make sure that the PID constants used in the off-line debugging will not adversely affect the actual control object.
8. Sample Applications

This chapter briefly describes some sample applications and functions that can be implemented using the Temperature Control and Monitoring module and PID Control module in conjunction with FA-M3 Ladder sequence or BASIC application programs *. Various ladder or BASIC programs can be used, often in combination in actual implementation.

Program creation is explained using the functional block diagram in Section 5.1, “Operation Overview”.

*: User programs created on a FA-M3 ladder sequence CPU or BASIC CPU

This chapter describes the following sample applications:

8.1 Input Correction
8.2 Using Monitor and Output Separately
8.3 Program Pattern Control
8.4 Cascade Control
8.1 Input Correction

8.1.1 Overview

Input correction is sometimes required to correct the sensor output using methods such as polygonal line calculation.

A Ladder sequence or BASIC application program can be used to perform the polygonal calculation.

⚠️ **CAUTION**

If the Ladder sequence or BASIC application program stops, control cannot continue.

8.1.2 Programming Procedure

(1) From the Ladder sequence or BASIC application program (hereafter called "AP program"), set the selector switches (output relays) in the Temperature Control and Monitoring module, or PID Control module (hereafter called "this module") as follows:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Setting</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/S</td>
<td>0: RUN</td>
<td>Run/Stop</td>
</tr>
<tr>
<td>A/M</td>
<td>0: Auto Output</td>
<td>Auto Output/Manual Output</td>
</tr>
<tr>
<td>L/R</td>
<td>*</td>
<td>Local/Remote</td>
</tr>
<tr>
<td>S1/S2</td>
<td>*</td>
<td>Set Point 1/ Set Point 2</td>
</tr>
<tr>
<td>PV/E</td>
<td>1: PV External Setting</td>
<td>Internal Input/PV External Setting</td>
</tr>
<tr>
<td>N/LBK</td>
<td>0: Normal Control</td>
<td>Normal Control/Loop-Back</td>
</tr>
<tr>
<td>OUT/EXOUT</td>
<td>0: Normal Output</td>
<td>Normal Output/External Output</td>
</tr>
</tbody>
</table>

*: Set according to the application

(notes) The output relay numbers depend on the channel used.

For details on the output relay numbers, see Section 4.4, "I/O Relays".

For details on the output method, see Section 4.1.7, "Accessing Using BASIC Statements".

(2) Use the AP program to read Process Input (PVIN) register data obtained from the sensor input by this module and perform calculation (e.g. polygonal line calculation) on the data. Write the calculation result to the External PV (EXPVB) register of this module.

Subsequent processing is the same as with normal control.

Note that the register numbers for Process Input (PVIN) and External PV (EXPV) depend on the channel used (see Section 4.3, "I/O Data Registers"). For details on the output method, see Section 4.1.7, "Accessing Using BASIC Statements".

(3) Figure 8.1 shows the functional block diagram.

The paths in bold will be used.
8.1.3 Functional Block Diagram

![Functional Block Diagram](image)

**Figure 8.1** Input Correction Functional Block Diagram
8.2 Using Monitor and Output Separately

8.2.1 Overview

The input and output functions of the Temperature Control and Monitoring module or PID Control module (hereafter called "this module") can be used separately. For example, the temperature monitor and the analog output can be used separately.

8.2.2 Programming Procedure

(1) This function is realized by using a Ladder sequence or BASIC application program (hereafter called AP program) to set this module to Manual mode and write analog output data to the module.

(2) From the AP program, set the selector switches (output relays) in this module as follows:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Setting</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/S</td>
<td>0: Run</td>
<td>Run/Stop</td>
</tr>
<tr>
<td>A/M</td>
<td>1: Manual Output</td>
<td>Auto Output/Manual Output</td>
</tr>
<tr>
<td>L/R</td>
<td>–</td>
<td>Local/Remote</td>
</tr>
<tr>
<td>S1/S2</td>
<td>–</td>
<td>Set Point 1/Set Point 2</td>
</tr>
<tr>
<td>PV/E</td>
<td>0: Internal Input</td>
<td>Internal Input/PV External Setting</td>
</tr>
<tr>
<td>N/LBK</td>
<td>0: Normal Control</td>
<td>Normal Control/Loop-Back</td>
</tr>
<tr>
<td>OUT/EXOUT</td>
<td>0: Normal Output</td>
<td>Normal Output/External Output</td>
</tr>
</tbody>
</table>

Note: Setting has no meaning.

For details on the relay numbers, see Section 4.4, "I/O Relays".
For details on the output method, see Section 4.1.6, "Accessing Using Ladder Sequence" and Section 4.1.7, "Accessing Using BASIC Statements".

(3) The temperature monitor uses the AP program to read the Process Value (PV) register in this module.

(4) Analog output is provided when the AP program writes analog output data to the Manual Output (MOUT) register in this module. Note that the register numbers for Process Value (PV) and Manual Output (MOUT) depend on the channel used (see Section 4.3, "I/O Data Registers"). For details on the output method, see Section 4.1.6, "Accessing Using Ladder Sequence" and Section 4.1.7, "Accessing Using BASIC Statements".

(5) Figure 8.2 shows the Functional Block Diagram. The paths in bold will be used.
8.2.3 Functional Block Diagram

Figure 8.2 Functional Block Diagram for Separate Use of Monitor and Output
8.3 Program Pattern Control

8.3.1 Overview

Control using a program pattern can be achieved using a Ladder sequence or BASIC application program (hereafter called "AP program") to, say, change the temperature setting with time.

8.3.2 Programming Procedure

1. Use an AP program to generate a program pattern to change the settings for the Temperature Control and Monitoring module or PID Control module.

2. From the AP program, set the selector switches (output relays) in this module as follows:

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Setting</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/S</td>
<td>0: RUN</td>
<td>Run/Stop</td>
</tr>
<tr>
<td>A/M</td>
<td>0: Auto output</td>
<td>Auto Output/Manual Output</td>
</tr>
<tr>
<td>L/R</td>
<td>1: Remote</td>
<td>Local/Remote</td>
</tr>
<tr>
<td>S1/S2</td>
<td>*</td>
<td>Set Point 1/Set Point 2</td>
</tr>
<tr>
<td>PV/E</td>
<td>0: Internal input</td>
<td>Internal Input/PV External Setting</td>
</tr>
<tr>
<td>N/LBK</td>
<td>0: Normal control</td>
<td>Normal Control/Loop-Back</td>
</tr>
<tr>
<td>OUT/EXOUT</td>
<td>0: Normal output</td>
<td>Normal Output/External Output</td>
</tr>
</tbody>
</table>

   *: Set according to the application.
   (note) The output relay numbers depend on the channel used.
   For details on the relay numbers, see Section 4.4, "I/O Relays".
   For details on the output method, see Section 4.1.6, "Accessing Using Ladder Sequence" and Section 4.1.7, "Accessing Using BASIC Statements".

3. Write the settings generated by the AP program's program pattern to the Remote Set Point (RSP) register in this module. The module will perform control using this data. The operation is controlled by the program, which changes the Remote Set Point (RSP) register data over time.

4. An AP program can also be used to read the Process Value (PV) register in this module and write the PV data on a display device connected to the FA-M3. Note that the register numbers for Remote Set Point (RSP) and Process Value (PV) depend on the channel used (see Section 4.3, "I/O Data Registers"). For details on the output method, see Section 4.1.6, "Accessing Using Ladder Sequence" and Section 4.1.7, "Accessing Using BASIC Statements".

5. Figure 8.3 shows the Functional Block Diagram. The paths in bold will be used.
8.3.3 Functional Block Diagram

Figure 8.3 Program Pattern Control Block Diagram
8.4 Cascade Control

8.4.1 Overview

Cascade control can be realized using a Ladder sequence or BASIC application program (hereafter called "AP program") together with two channels (hereafter called "the channels") on the Temperature Control and Monitoring module or PID Control module (hereafter called “this module”). Cascade control is a feed-back control system in which the target control set point for one controlled device changes according to the output signal from another controlled device, primarily to minimize the effects of external disturbances.

The example here is a system in which a liquid product is heated in an oven and the temperature of the product (liquid) is controlled at the exit of the oven (see Figure 8.4). The input to Channel 1 (CH1) on this module measures the temperature of the product at the exit of the oven, and the input to Channel 2 (CH2) measures the temperature of the oven.

The oven is assumed to be controlled by a heater controlled by this module. The cascade controller has three states: Cascade (C), Auto (A) and Manual (M).

8.4.2 Programming Procedure

(1) The AP program performs the following functions:
   - Data transfer between CH1 and CH2, and range conversion at data transfer.
   - Setting the selector switches (output relays) in this module.
   - Mode switching between Cascade (C), Auto (A) and Manual (M) using output relays.

(2) Write AP program code to perform the following two data transfers and range conversions between CH1 and CH2.
   - Calculate and set the Remote Set Point (RSP) for CH2 in cascade control mode.
     Convert CH1 OUT range [0.0 - 100.0%] to CH2 RSP temperature range [RH - RL].
     \[ \text{[RSP for CH2]} = \text{[OUT for CH1]} \times \frac{\text{[RH for CH2]} - \text{[RL for CH2]}}{100} + \text{[RL for CH2]} : \text{Formula (1)} \]
   - Calculate and set the Manual Output (MOUT) for CH1 in auto control mode.
     Convert CH2 SP1 temperature range [RH - RL] to CH1 MOUT range [0.0 - 100.0%].
     \[ \text{[MOUT for CH1]} = \frac{\text{[SP1 for CH2]} - \text{[RL for CH2]}}{\text{[RH for CH2]} - \text{[RL for CH2]}} \times 100 : \text{Formula (2)} \]

(3) From the AP program, set the selector switches (output relays) in this module as follows:
Table 8.4  Output Relay Settings for Cascade Control

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Setting</th>
<th>CH1</th>
<th>CH2</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>R/S</td>
<td>0: RUN</td>
<td>0: RUN</td>
<td>Run/Stop</td>
<td></td>
</tr>
<tr>
<td>A/M</td>
<td>(see Table 8.5)</td>
<td>(see Table 8.5)</td>
<td>Auto Output/Manual Output</td>
<td></td>
</tr>
<tr>
<td>L/R</td>
<td>0: Local</td>
<td>(see Table 8.5)</td>
<td>Local/Remote</td>
<td></td>
</tr>
<tr>
<td>S1/S2</td>
<td>*</td>
<td>0: Set Point 1</td>
<td>Set Point 1/Set Point 2</td>
<td></td>
</tr>
<tr>
<td>PV/E</td>
<td>0: Internal Input</td>
<td>0: Internal Input</td>
<td>Internal Input/PV External Setting</td>
<td></td>
</tr>
<tr>
<td>N/LBK</td>
<td>0: Normal Control</td>
<td>0: Normal Control</td>
<td>Normal Control/Loop-Back</td>
<td></td>
</tr>
<tr>
<td>OUT/EXOUT</td>
<td>-</td>
<td>0: Normal Output</td>
<td>Normal Output/External Output</td>
<td></td>
</tr>
</tbody>
</table>

*:  Set according to the application.
-:  Setting has no meaning.

(note)  The output relay numbers depend on the channel used.
For details on the output method, see Section 4.1.6, "Accessing Using Ladder Sequence" and Section 4.1.7, "Accessing Using BASIC Statements".

(4)  The Control Set Point (CSP) for CH2 must be tracked to Set Point 1 or Set Point 2 (SP1, SP2) to prevent abrupt output change that may occur such as when switching from Cascade (C) mode to Auto (A) control.
To have the Control Set Point (CSP) tracked to Set Point 1 or Set Point 2 (SP1, SP2), set the SP Tracking Mode (SP.TR) register to "0" (Tracking on) using the AP program. For the register number of the SP tracking mode (SP.TR) register, see Section 4.3, "I/O Registers". For details on the output method, see Section 4.1.6, "Accessing Using Ladder Sequence" and Section 4.1.7, "Accessing Using BASIC Statements".

(5)  The control mode switches according to the settings of the output relays, CH1, and CH2 as follows:
Table 8.5  Control Modes of Cascade Controller

<table>
<thead>
<tr>
<th>Mode</th>
<th>Output Relay</th>
<th>Processing of AP program</th>
<th>Mode Transition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CH1</td>
<td>CH2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A/M</td>
<td>A/M</td>
<td>R/L</td>
</tr>
<tr>
<td>Cascade (C)</td>
<td>0: Auto</td>
<td>0: Auto</td>
<td>1: Remote</td>
</tr>
<tr>
<td>Auto (A)</td>
<td>1: Manual</td>
<td>0: Auto</td>
<td>0: Local</td>
</tr>
<tr>
<td>Manual (M)</td>
<td>1: Manual</td>
<td>1: Manual</td>
<td>0: Local</td>
</tr>
</tbody>
</table>

(6) Figure 8.4 shows the Functional Block Diagram. The paths in bold will be used.

(note) If SP tracking mode is not set to Tracking On, do not make a transition to this mode.
8.4.3 Functional Block Diagram

Figure 8.4 Functional Block Diagram of Cascade Control

(note) The functional block diagram above is simplified for ease of explanation.
9. Troubleshooting

The Temperature Control and Monitoring module is a closed system that computes and outputs the operation control from the control set point and process input data. Therefore, problems such as "unstable input" or "no output" are often attributable to improper control parameters or input/output settings.

To troubleshoot a problem, first read Section 9.1, “Before Performing Checks” and then follow the steps in Section 9.2, “Checking for a Specific Problem”, which is organized according to the different problems that may be encountered, to check that all the connections and settings are correct.

For more details on the self-diagnosis and the procedure for actions to be taken when an error is detected, see Chapter 6, “Errors and Corrective Actions”.

9.1 Before Performing Checks

The Temperature Control and Monitoring module stores many settings internally. This means that temporary or incorrect data accidentally written during operation checks, test-runs, or debugging will remain even after the power has been switched off until they are over-written. The unintended settings would naturally result in unintended operation. If a module does not operate correctly but a replacement module does in the same environment, check that all the register settings of the module are proper or reset all of register settings to their factory defaults and perform any required setting again. For details on how to restore all the settings to their default values, see Section 4.1.3, "Data Initialization”.

9.2 Checking for a Specific Problem

(1) Input does not change or fluctuates widely

- Is the USE setting for the channel set to "Use"?
- Are the sensors and cables securely and correctly connected?
- Is the Input Filter (FL) setting appropriate?
- Is this module used for control? If so, are control parameter settings correct?
  See Section paragraph 9.2 (3) "Control Fails".
- If the above 4 checks find no problem, change the connection channel and repeat the checks. If a spare module is available, use the spare module and repeat the checks. If the same problem persists, check the sensors and cabling and rectify any fault. If the problem disappears, check the operation as instructed in Section 9.1, "Before Performing Checks"
(2) Any lamp other than RDY is lit or flashing

- Are sensors connected to all the channels? The USE setting of a channel not connected to a sensor must be set to “Not Used”.
- Is the sensor for reference junction compensator (RJC) for the F3CT04 module connected properly?
- Is the Alarm 1 or Alarm 2 relay (AL1R, 2R) set for any of the channels? If so, check the alarm type (AL1,2), alarm setting (A1,2), and alarm hysteresis (HY1, 2)
- Are the process inputs (PVIN 1-4) normal? Setting an input correction value (BS) causes an offset in the virtual value. The alarm outputs the result of the comparison to this value.
- If the above 4 checks find no problem, use the spare module and repeat the checks. If the same problem persists, check the sensors and cabling and rectify any fault. If the problem disappears, check the operation as instructed in Section 9.1, “Before Performing Checks”

(3) Control fails (with Oscillating Response)

- Is the control calculation a PID control or a ON/OFF control? For an ON/OFF control, oscillation occurs near the control set point.
- Does the data diverge? Check whether the directions of the control (DR1 - 4) are as intended.
- In the case of time proportional output, is the cycle time (CT) appropriate considering the system's response? In time proportional output, CT is practically the control cycle. Reducing CT can improve the system characteristics so long as the actuator is not affected.
- Are the PID constants obtained by Auto-tuning? Check that the values are appropriate. For details on how to start auto-tuning, see Section 5.10, ”Auto-tuning”. For details on how to adjust each item, see Section 5.3, “PID Control and Parameters”.
- Does the control output vary widely? Adjusting the PID parameters, input filter, and the positional relationship between the sensors and actuators may reduce the variation.
- Is there any interference between loops if several loops are used? If the sensors and actuators are too close to each other, the output of a loop may seriously affect the process values of another loop.
- Are PID parameters obtained by Auto-tuning used for a heating/cooling control? Run Auto-tuning again using the procedure described in Section 5.11.3, “Auto-tuning for Heating/Cooling” and adjust parameters as required.
- If the above 7 checks find no problem, change the connection channel and repeat the checks. If a spare module is available, use the spare module and repeat the checks. If the same problem persists, check the sensors and cabling and rectify any fault. If the problem disappears, check the operation as instructed in Section 9.1, ”Before Performing Checks”.
(4) No response even if control set point was changed

- Has the Control Set Point (CSP) been changed? If not, check that the SP gradient settings (SPR.UP, SPR.DN, SPR.TM) are set as intended. Setting the SP gradient cause the control target to change gradually.
- Is a 24 VDC power supply connected? Power supply is required to use the output of the module.
- Does the output change? If not, check the Output register (OUT). Also check that the output type (OUTSEL1 - 4) and the control direction (DR1 - 4) are set correctly. For an ON/OFF control, the output can only be either 0% or 100%.
- If the above 3 steps find no problem, performs the checks in Section 9.2 “(1) Input does not change or fluctuates widely”.

(5) Overshooting too far

- Is the overshoot suppression function "Super" used? If not, use enable and check the response.
- Is the overshoot suppression function "Super" used? For some PID parameters, “Super” actually worsens overshooting. Disable “Super” and check the response.
- If adjusting the PID parameters (refer to “5.3 PID Control and Parameters”) cannot suppress overshooting, try to suppress it by adjusting the Anti-Reset Windup (ARW) value.
- If control fails in steady state, also perform checks in Section 9.2, “(3) Control Fails”.
- If the above 5 checks find no problem, change the connection channel and repeat the checks. If a spare module is available, use the spare module and repeat the checks. If the problem disappears, check the operation as instructed in Section 9.1, “Before Performing Checks”.
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