GFK-1466

GE Fanuc Manual Series 90-30

Temperature Control Module

GE Fanuc Automation

Programmable Control Products

Temperature Control Module for the Series 90™-30 PLC

User's Manual

GFK-1466 October 1997

Warnings, Cautions, and Notes as Used in this Publication

Warning

Warning notices are used in this publication to emphasize that hazardous voltages, currents, temperatures, or other conditions that could cause personal injury exist in this equipment or may be associated with its use.

In situations where inattention could cause either personal injury or damage to equipment, a Warning notice is used.

Caution

Caution notices are used where equipment might be damaged if care is not taken.

Note

Notes merely call attention to information that is especially significant to understanding and operating the equipment.

Content of This Manual

Chapter 1.	**Introduction:** This chapter provides a brief overview of the hardware and software used to set up and operate the Temperature Control Module (TCM).
Chapter 2.	**Installing the Temperature Control Module:** This chapter describes the user interfaces of the TCM and how to install the module on the Series 90-30 baseplate.
Chapter 3.	**Configuration:** This chapter explains how to configure the TCM using the Logicmaster 90-30/20/Micro programming software configuration function. This includes a description of the %I, %AI, %Q, and %AQ data that is transferred between the PLC CPU and the TCM each sweep.
Chapter 4.	**Operation and Field Wiring Information:** This chapter provides a general description of the TCM operation. It also gives the details of the user's connections to the TCM, and provides the details on the PID parameters and how they are used.
Chapter 5.	**Autotuning:** This chapter explains in detail how to run the autotuning feature of the TCM after installation.
Appendix A.	**Typical Parameter Download Program:** This appendix describes how to set up and download programs to the TCM from the PLC.
Appendix B:	**Specifications:** This appendix provides environmental and general specifications of the TCM module.
Appendix C:	**Applications Examples:** This appendix provides examples of applications using the TCM.

Related Publications

GFK-0356	Series 90™-30 Programmable Controller Installation Manual
GFK-0466	Logicmaster™ 90 Series 90™-30/20/Micro Programming Software User's Manual
GFK-0467	Series 90™-30/20/Micro Programmable Controller's Reference Manual

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Chapter 1 Introduction

The Temperature Control Module (TCM), *catalog number IC693TCM302,* is a high performance control module providing eight channels of thermocouple input and eight channels of control output in a single Series 90-30 module. Each channel can operate in closed or open loop mode relieving the PLC of providing the temperature control functions

This manual describes the TCM hardware and firmware, and gives an example of how to send and receive the configuration parameters.

Features of the TCM

High Performance

The TCM is a high performance module that provides temperature monitoring and temperature control functions, and is designed to be used in a wide variety of applications.

Temperature Monitoring

The TCM has the following capabilities:

- Eight thermocouple channels (J, K, or L) + 1 RTD compensation channel or external reference value
- 12 bits or 0.2°C resolution
- ± 1°C accuracy with automatic calibration
- ± 12V common mode voltage capability
- Open thermocouple and reverse connection detection capability
- Detection and indication of out-of-tolerance temperature readings

Temperature Control

The TCM controls the temperature in eight independent zones within ±1°C of the specified temperature for each zone. Two modes of operations can be used on a per zone basis: Auto mode or Manual mode.

Auto Mode

The TCM implements closed-loop PID (Proportional - Integral - Derivative) temperature control. The PWM (Pulse Width Modulation) output period for each zone is programmable from 0.1 to 60 seconds. The PWM output duty cycle for each zone, which is automatically generated based on the PID coefficients, extends from 0 to 100 % of the output period with 0.1% resolution. PID coefficients for each zone under control are down-loaded values from the Series 90-30 CPU.

Manual Mode

The TCM implements an open-loop duty cycle control. The duty cycle of each output channel can be set from 0 to 100% with 0.1% resolution. The PWM output period for each zone is programmable from 0.1 to 60 seconds.

Diagnostic functions

The TCM performs the following diagnostics:

- Power on self test (POST) including memory and peripheral circuitry testing.
- Continuous monitoring and indication of the external power condition using a front panel LED.
- Checks thermocouple condition for each zone and reports two types of fault: 1) open-circuit and 2) reverse polarity. In the case of a thermocouple fault, the zone controller can maintain a fixed (manual) duty cycle output or can turn off the output immediately.
- Reports thermocouple error status of each individual zone.

Table 1-1. Firmware Compatibility

Released Firmware Revision	Catalog Number	Logicmaster 90 Version
2.28	IC693TCM302A	4.01, or later

Overview of TCM Operations

The TCM is an intelligent Series 90-30 I/O module capable of monitoring the temperature and controlling up to eight thermocouples and associated heaters. The TCM allows a PLC (Programmable Logic Controller) user to combine the logic and control functions of the Series 90-30 PLC with a high performance temperature controller. One or several TCMs can be used to provide temperature control of various configurations of heaters.

The TCM and the Series 90-30 PLC

The TCM and the Series 90-30 PLC operate together to provide open or closed loop temperature control. Reference and configuration data is transferred every PLC sweep from the Series 90-30 PLC CPU (Central Processing unit) and the TCM using %Q and %AQ data. In addition, feedback of each temperature, output setting, and channel status is returned to the PLC in the %I and %AI data.

The %Q data sent to the TCM is used for quick control of each of the eight output channels. In contrast, parameter data is sent to the TCM using groups of %AQ data to reduce the demand on the PLC I/O services. Full feedback of the TCM temperatures, outputs, and status is provided every PLC sweep for minimum system delays.

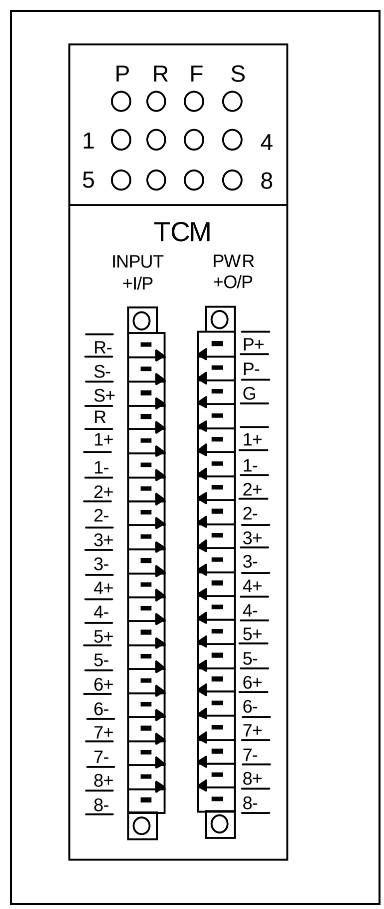
To use the TCM, configure it as a Foreign module, with the default ID of 3, using the Logicmaster Configuration software. The module is assigned to a particular slot and rack like any other PLC module. The data transfer sizes are set to 64 %I, 28 %AI, 24 %Q, and 3 %AQ words of data communicated between the PLC and the TCM.

Chapter 2 Installing the Temperature Control Module

This chapter describes the TCM and how to install it on the Series 90-30 PLC baseplate. The chapter is divided into the following sections.

Section 1: Description of the TCM

This section describes the LED indicators viewable on the faceplate and the TCM connections to field devices.



LED Indicators

The TCM indicator panel has 12 LEDs providing output and module status indications that are described below.

(P) External Power. *Green, normally ON*. This light indicates that the external and internal power supplies are on.

(R) Run. *Green, normally ON*. Lights steady when the TCM CPU is running properly. Alternately flashes with the red Fault LED if the internal CPU is unable to run to indicate total module failure.

(F) Fault. *Red, normally off*. The fault light flashes upon module startup and extinguishes when the TCM CPU runs. The fault light flashes with the Run LED when a total module failure has occurred.

(S) Short. *Red, normally off*. This LED lights when a short circuit is detected on one of the output channels.

Output Status LEDs. *Green*. The eight output status LEDs indicate the output status of the corresponding channel. The LEDs light when the associated output channel is energized. These lights will flash briefly if a short circuit is present across the output along with the red Short LED to indicate that a shorted output condition exists.

Thermocouple and RTD Connections

The front left connector on the TCM provides connections to the eight thermocouples (T/C) and 4-wire RTD (resistive temperature device). The connections are detailed in Table 2-1.

The front right connector on the TCM provides connections to the external power supply, the solid state relay drive outputs (O/P), and the frame or chassis ground. These connections are detailed in the following table. The external power supply is 18 to 36VDC at 2 amps.

The plug-in connectors used for the TCM are manufactured by Phoenix Contact (part number MC1.5/20-STF-3.5) and provide easy field connections with a small (3mm flat) screwdriver.

Table 2-1. Pin Assignments for TCM Connectors

Left Connector		Right Connector	
Pin (top=1)	**Connection**	**Pin (top=1)**	**Connection**
1	RTD –	1	External power +
2	RTD – sense	2	External power –
3	RTD + sense	3	Chassis ground
4	RTD +	4	N.C.
5	T/C 1 +	5	O/P 1 +
6	T/C 1 –	6	O/P 1 –
7	T/C 2 +	7	O/P 2 +
8	T/C 2 –	8	O/P 2 –
9	T/C 3 +	9	O/P 3 +
10	T/C 3 –	10	O/P 3 –
11	T/C 4 +	11	O/P 4 +
12	T/C 4 –	12	O/P 4 –
13	T/C 5 +	13	O/P 5 +
14	T/C 5 –	14	O/P 5 –
15	T/C 6 +	15	O/P 6 +
16	T/C 6 –	16	O/P 6 –
17	T/C 7 +	17	O/P 7 +
18	T/C 7 –	18	O/P 7 –
19	T/C 8 +	19	O/P 8 +
20	T/C 8 –	20	O/P 8 –

User Replaceable Fuse

The TCM has a 2 Amp user replaceable fuse. The 2 Amp fuse, located on the TCM circuit board behind the front bezel, becomes visible for replacement by removing the front bezel. If the P LED is not lit, it may be an indication that the fuse has blown and should be replaced.

Section 2: Installing the TCM

The TCM can operate in any Series 90-30 CPU or expansion baseplate (Series 90-30 release 3 or later). The maximum number of TCMs that can be added to a system depends upon the memory available in the PLC CPU.

The configuration files created by the Logicmaster 90 configuration software must match the physical configuration of the modules.

To install the TCM on the baseplate, follow these steps:

1. Use the Logicmaster 90 software, or the Hand Held Programmer to stop the PLC. This will prevent the local application program, if any, from initiating any command that may affect operation of the module.
2. Power-down the Series 90-30 PLC.
3. Align the module with the desired base slot and backplane connector. Tilt the module upward so that the top rear hook of the module engages the slot on the baseplate.
4. Swing the module down until the connectors mate and the lock-lever on the bottom of the module snaps into place engaging the baseplate notch.
5. Refer to Table 2-1 for wiring requirements.
6. Power up the PLC rack. The Run LED on the TCM will turn on steady when the onboard CPU has completed its power-up diagnostics.
7. Repeat this procedure for each TCM module.

Configure the TCM module(s) as described in Chapter 3 - *Configuring the TCM.*

Chapter 3 Configuration

The TCM is configured using the Logicmaster 90-30 configuration software. Configuring the TCM is a two-part procedure consisting of:

1. I/O Rack Configuration
2. Module Configuration

I/O Rack Configuration

The TCM is configured using the Logicmaster 90-30 software in the same way as other Series 90-30 modules. The software is used to define the type and location of all modules present in the PLC racks. This is done by completing setup screens which represent the modules in a baseplate and saving the information to a configuration file, which is then downloaded to the PLC CPU.

Once a baseplate and slot location for the TCM is defined, you can continue to the second part of the TCM configuration, *Module Configuration*.

Module Configuration

This section is divided into two parts:

1. Setting the Configuration Parameters
2. Definitions of the %Q, %AQ, %I and %AI data parameters and results.

Setting the Configuration Parameters

As with the I/O Rack Configuration, Module Configuration is done by completing screens in the Logicmaster 90-30 configuration software. The Hand Held Programmer can only configure the *Module* and *Serial Port* Configuration Data.

Module Configuration Data

During each PLC sweep certain data is automatically transferred both ways between the TCM and the PLC CPU. The TCM-to-CPU Interface Data references the starting locations defined for the automatic transfers. The configuration parameters for the Module Configuration Data are described in Table 3-1.

Table 3-1. Configuration Parameters for Configuration Data

Configuration Parameter	Description	Values	Defaults
Reference Address	Start address for %I reference type (64 bits)	CPU dependent	%I0001 or next higher reference
Reference Address	Start address for %Q reference type (24 bits)	CPU dependent	%Q0001 or next higher reference
Reference Address	Start address for %AI reference type (28 words)	CPU dependent	%AI0001 or next higher reference
Reference Address.	Start address for %AQ reference type (3 words)	CPU dependent	%AQ0001 or next higher reference

Discrete Status Bits (%I)

The following table gives the definition of all the %I bits transferred to the PLC every sweep. These bits indicate the current status of the TCM.

Table 3-2. %I Bits Transferred to the PLC Every Sweep

Bit	Status
1	Channel #1 Upper Alarm
2	Channel #1 Lower Alarm
3	Channel #1 Upper Deviation
4	Channel #1 Lower Deviation
5	Channel #1 TC Error
6	Channel #1 PWM output short
7	Channel #1 Zone Error
8	Channel #2 Upper Alarm
9	Channel #2 Lower Alarm
10	Channel #2 Upper Deviation
11	Channel #2 Lower Deviation
12	Channel #2 TC Error
13	Channel #2 PWM output short
14	Channel #2 Zone Error
15	Channel #3 Upper Alarm
16	Channel #3 Lower Alarm
17	Channel #3 Upper Deviation
18	Channel #3 Lower Deviation
19	Channel #3 TC Error

Bit	Status
33	Channel #5 TC Error
34	Channel #5 PWM output short
35	Channel #5 Zone Error
36	Channel #6 Upper Alarm
37	Channel #6 Lower Alarm
38	Channel #6 Upper Deviation
39	Channel #6 Lower Deviation
40	Channel #6 TC Error
41	Channel #6 PWM output short
42	Channel #6 Zone Error
43	Channel #7 Upper Alarm
44	Channel #7 Lower Alarm
45	Channel #7 Upper Deviation
46	Channel #7 Lower Deviation
47	Channel #7 TC Error
48	Channel #7 PWM output short
49	Channel #7 Zone Error
50	Channel #8 Upper Alarm
51	Channel #8 Lower Alarm

Table 3-2. %I Bits Transferred to the PLC Every Sweep - Continued

20	Channel #3 PWM output short	52	Channel #8 Upper Deviation
21	Channel #3 Zone Error	53	Channel #8 Lower Deviation
22	Channel #4 Upper Alarm	54	Channel #8 TC Error
23	Channel #4 Lower Alarm	55	Channel #8 PWM output short
24	Channel #4 Upper Deviation	56	Channel #8 Zone Error
25	Channel #4 Lower Deviation	57	RTD short/open
26	Channel #4 TC short/open	58	Spare
27	Channel #4 PWM output short	59	TCM unit in Autotuning Mode
28	Channel #4 Zone Error	60	TCM unit in Calibration Mode
29	Channel #5 Upper Alarm	61	Operating Normally
30	Channel #5 Lower Alarm	62	Spare
31	Channel #5 Upper Deviation	63	External Voltage Failure
32	Channel #5 Lower Deviation	64	TCM Error

Channel #n Upper Alarm: This bit is set when the Channel “n” current temperature is above the value of the Upper Alarm temperature.

Channel #n Lower Alarm: This bit is set when the Channel “n” current temperature is below the value of the Lower Alarm temperature.

Channel #n Upper Deviation: This bit is set when the Channel “n” current temperature is above the value of the Upper Deviation Band.

Channel #n Lower Deviation: This bit is set when the Channel “n” current temperature is below the value of the Lower Deviation Band. This bit together with the previous bit could be used for an ON/OFF controlling of a cooling fan.

Channel #n TC Error and CH #n Zone Error: These bits code the Channel “n” thermocouple failure according to the following table:

Table 3-3. Channel Thermocouple Failure Bits

Zone Error Code	T/C Error
00	No error detected
01	Open thermocouple
10	Zone error (N/A)
11	Reverse thermocouple

Channel #n PWM output short: This bit is set when a short-circuit condition is detected on the Channel “n” output driver.

RTD short/open: This bit is set when the RTD is either in a short-circuit or an open-circuit condition.

TCM unit in Autotuning Mode: This bit is set when the TCM unit is in the autotuning mode. During this period (which can last up to a few tens of minutes) the control parameters of each channel being tuned are measured and calculated. As soon as all sets of control parameters have been calculated and reported (via %AI reference +21 - %AI reference +27) to the PLC, this bit is automatically cleared.

TCM unit in Calibration Mode: This bit is set when the TCM unit is in full calibration mode. During this period (approximately 3 seconds) temperature measurement is suspended. The PLC unit can prevent the TCM unit from going into calibration mode by setting the %Q reference +22 bit.

TCM Operating Normally: This bit is a heart-beat that will indicate to the PLC that the TCM unit is operating normally and that returned information is a reliable indication of the state of the TCM.

External Voltage Failure: This bit is set when the external voltage (+24V) is missing.

TCM Error: This bit is set when the TCM unit has found some fault condition. An error code (%AI28) accompanies this bit to provide more detailled information. It can be either a hardware problem or a parameter error (that is, some parameter value is out of range).

The reported errors have different priorities and they can mask the errors of a lower priority. The following table shows the relation between the error flags:

Table 3-4. Relation Between Error Flags

Priority	Error Flag	Masks
1	External Voltage Failure	2, 3, 4, 5, 6, 7, 8
2	Compensation Temperature out of range (0°C - 60°C)	3, 4, 5, 6, 7
3	Ch#n open/Reverse TC	4, 5, 6, 7
4	Ch#n Upper Alarm	5, 6, 7
5	Ch#n Upper Deviation	6, 7
6	Ch#n Lower Alarm	7
7	Ch#n Lower Deviation	none
8	TCM Error	none
9	PWM Output Shorted	none

Discrete Commands (%Q)

Discrete command bits (%Q's) activate the corresponding functions. Command bits (with the exception of %Q reference +19, +20 and +24) must be maintained, (that is, they will keep the corresponding function active only as long as the bit is set to a '1'). These bits are downloaded from the PLC to the TCM every PLC sweep and control the TCM functions. Each bit is listed in the table below, followed by a detailed description.

Table 3-5. %Q Discrete Command Bit Definitions

Bit	Command	Bit	Command
1	CH #1 Auto/Manual Mode	13	CH #7 Auto/Manual Mode
2	CH #1 Enable/Disable Output	14	CH #7 Enable/Disable Output
3	CH #2 Auto/Manual Mode	15	CH #8 Auto/Manual Mode
4	CH #2 Enable/Disable Output	16	CH #8 Enable/Disable Output
5	CH #3 Auto/Manual Mode	17	Spare
6	CH #3 Enable/Disable Output	18	Spare
7	CH #4 Auto/Manual Mode	19	Autotuning Method
8	CH #4 Enable/Disable Output	20	Do Autotuning
9	CH #5 Auto/Manual Mode	21	Spare
10	CH #5 Enable/Disable Output	22	Disable Calibration Mode
11	CH #6 Auto/Manual Mode	23	Spare
12	CH #6 Enable/Disable Output	24	Spare (Cancel Autotuning)

Channel #n Auto/Manual Mode: When this bit is set the channel #n closed-loop control procedure will be activated. The temperature will be controlled per the Set-Point. When this bit is set to ‘0’, the output will operate with a period and duty-cycle as specified by the corresponding parameters .

Channel #n Enable/Disable Output: This bit enables output driver for channel #n. When this bit is cleared, the channel #n output will be disabled.

Autotuning Method: When the TCM unit is to perform the autotuning procedure, this bit indicates which of two possible autotuning methods will be used. If the bit is set, the *step response* method will be used (suitable for situations where there is interference between zones) otherwise the *relay response* autotuning method will be used (suitable for zones that operate completely independent of each other).

Do Autotuning: This bit commands the TCM unit to perform the autotuning process **(see Figure 3-1**). When the TCM is commanded to do an Autotuning sequence (%Q reference + 20 is set) the recommended new parameters are multiplexed back to the PLC in register %AI reference +21 to %AI reference +27. This information should be validated by the user and then sent back to the TCM if parameters are acceptable. **The TCM does not store the parameters automatically, it requires the PLC to send the new parameters.** This ensures that the new values will be validated by the user

Before the user sets this bit, the following settings should be prepared:

- Required autotuning method set up (%Q reference +19)
- The channels which will not be used must be inactive or must have disabled outputs.
- The tuned channels must be active with the enabled outputs in the MANUAL mode.
- A non-zero setpoint temperature must be set for each channel that will be tuned.
- Only channels which do not exhibit any thermocouple error will be tuned.

- The channels which will not be tuned but which will maintain constant heating (determined by their Manual Output values) must have the setpoint temperature set to zero.
- The bit must be cleared at least during one PLC sweep before it will be used again.
- The autotuning in progress can be canceled at any time by raising the %Q reference +24 bit.
- User must create validation process in ladder logic to acknowledge that the new parameters are to be used and re-mapped into the reference table. The new values will then be sent to the TCM.

PID Autotuning Sequence

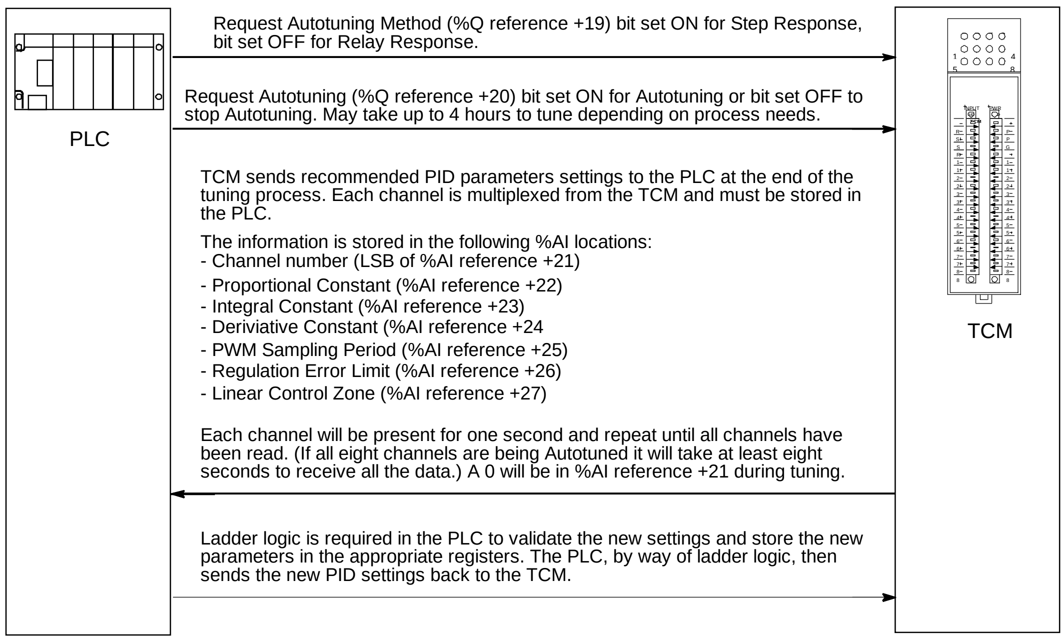


Figure 3-1. PID Autotuning Sequence

Disable Calibration Mode: This bit indicates that the TCM must not perform the full calibration cycle during which the temperatures are not measured for about 3 seconds. Otherwise full calibration will be performed whenever the internal temperature will change more than 3.2 °C.

Feedback Data (%AI)

These registers contain feedback data from the TCM and are uploaded to the PLC every sweep.

Table 3-6. TCM Feedback Data

%AI	Value	%AI	Value
1	Channel #1 Current Temp	15	Channel #8 Current Temp
2	Channel #1 Current % Power	16	Channel #8 Current % Power
3	Channel #2 Current Temp	17	RTD Current Temp
4	Channel #2 Current % Power	18	Internal Current Temp
5	Channel #3 Current Temp	19	Diagnostic value #1
6	Channel #3 Current % Power	20	Diagnostic value #2
7	Channel #4 Current Temp	21	DOI / Channel Number
8	Channel #4 Current % Power	22	Proportional Constant
9	Channel #5 Current Temp	23	Integral Constant
10	Channel #5 Current % Power	24	Derivative Constant
11	Channel #6 Current Temp	25	PWM (sampling) Period
12	Channel #6 Current % Power	26	Regulation Error Limit
13	Channel #7 Current Temp	27	Linear Control Zone
14	Channel #7 Current % Power	28	TCM Error Code

Channel #n Current Temp: Indicates the current temperature of channel "n". This will be active at all times as long as the thermocouple is operable. If the thermocouple is lost (open) this value will change to the maximum measurable temperature. The same maximum temperature is reported if the used compensation temperature is invalid (that is, if it is out of the range 0°C - 60°C).

Channel #n Current % Power: Indicates the current power output in percent x10 for channel "n".

Diagnostic Value #1 - #2: These are two 16-bit words present at the internal TCM RAM specified by the corresponding address of diagnostic parameter. If the value of Address of Diagnostic Parameter #n is zero, then the Firmware Version number will be returned. This is a debug tool/version verification feature not expected to be used in normal operating modes.

Channel Number, **Proportional Constant**, **Integral Constant**, **Derivative Constant**, **PWM Sampling Period**, **Regulation Error Limit** and **Linear Control Zone** are reported to the PLC at the end of the autotuning process. The least significant byte of %AI reference +21 indicates the number of channels (1 - 8) whose control parameters are being reported. The following six words are the control parameters of that channel. A zero value of the Channel Number indicates that the following parameters are not valid. Each set of parameters is valid for a one second interval.

DOI - Digital Output Image: The most significant byte of %AI reference +21 contains an image of the eight green LEDs on the front panel, that is, each individual bit represents a current status of one digital output. If a bit is set, it indicates that the output channel is driven, a reset bit indicates that the output channel is not currently driven.

TCM Error Code: If the TCM Error %I bit is set, this value will indicate which fault the TCM has encountered. This value will remain valid as long as the TCM Error Bit is set.

A TCM Error Code can represent some internal hardware problem (Least Significant Byte) and/or some parameter error (Most Significant Byte). This is seen in the next two tables.

Table 3-7. Internal hardware Error Code Bits

Internal Hardware Error Bit (LSB):	Error:
Bit 1	EPROM check sum error
Bit 2	RAM error
Bit 3	N/A (0)
Bit 4	N/A (0)
Bit 5	N/A (0)
Bit 6	N/A (0)
Bit 7	N/A (0)
Bit 8	Internal Voltage failure

Table 3-8. Parameter Error Code Bits

Parameter Error (MSB):	Error:
Least significant digit	Number of the parameter which is beyond its limits
Most significant digit	The channel number to which an incorrect parameter belongs

Parameter Data (%AQ)

The %AQ data is used to send control parameters, and all other data used by the TCM to carry out its functions from the PLC. This table is constantly downloaded to the TCM module

Table 3-9. %AQ Control Parameters

%AQ	Value
1	Group #
2	Parameter 1 Value
3	Parameter 2 Value

The following table lists the parameter definitions of each group number.

Table 3-10. Parameter Definitions for Group Numbers

Group #	Parameter #	Parameter Name	Units
0	1 2	Address of Diagnostic Parameter#1 Address of Diagnostic Parameter#2	4 digit hexadecimal number 4 digit hexadecimal number
1	1 2	Channel #1 Set Point Channel #1 Manual Output	0.1°C 0.1 % (of PWM period)
2	1 2	Channel #1 Regulation Error Limit Channel #1 Linear Control Zone	0.1°C 0.1°C
3	1 2	Channel #1 External Comp Temperature Channel #1 Bias	0.1°C 0.1% (of PWM period)
4	1 2	Channel #1 Integral Constant Channel #1 Proportional Constant	0.01 0.001
5	1 2	Channel #1 Derivative Constant Channel #1 PWM Period	0.1 10 - 6000 (10 x milliseconds)
6	1 2	Channel #1 Upper Deviation Channel #1 Lower Deviation	0.1°C 0.1°C
7	1 2	Channel #1 Upper Alarm Channel #1 Lower Alarm	0.1°C 0.1°C
8	1 2	Channel #1 Channel Configuration Channel #1 Spare	

A similar set of 16 control parameters will be downloaded to channel #2 with group number values of 9 through 16, etc. For the last (8th) channel, the control parameters will be downloaded with group numbers of 57 through 64. The Channel #n Channel Configuration bits are shown in Table 3-11.

Table 3-11. Channel Configuration Bits

Bit Numbers	Definition
Bit 2:1	00 - Type K thermocouple; 01 - Type J thermocouple 10 - Type L thermocouple; 11 - Not used
Bit 3	0 - Turn off PWM output immediately on T/C loss 1 - Continue with Manual PWM value on T/C loss
Bit 4	0 - Internal compensation 1 - External compensation using RTD
Bit 5	0 - Manual to Auto transition uncompensated 1 - Manual to Auto transition bumpless
Bit 6	0 - error flags not suppressed in Manual mode 1 - error flags suppressed when in Manual mode
Bit 7	0 - Use internal or RTD compensation reference 1 - Use external temperature compensation reference
Bit 8	0 - Channel is inactive 1 - Channel is in use
Bit 9*	0 - Programmed PWM period 1 - Fixed PWM period of 1 second (firmware version 2.28 and later)
Bit 10	0 - Set Point parameter is used 1 - Alternate Setpoint is used instead of Set Point parameter (firmware version 2.28 and later)

* This applies only to zones operating in manual mode.

If any of the transferred parameters are beyond the limit value, they will be ignored with the current value of the parameter being used. The corresponding Parameter Error code will be sent to the PLC unit (%AI 28). Table 3-12 contains the preset parameter limits.

Table 3-12. Preset Parameter Limits

Low Limit	Parameter Number - Name	High Limit
0	1 - Set point	6500
0	2 - Manual Output	1000
1	3 - Regulation Error Limit	6500
1	4 - Linear Control Zone	6500
0	5 - External Compensation Temperature	6500
-1000	6 - Bias	1000
0	7 - Proportional Constant	32000
0	8 - Integral Constant	32000
0	9 - Derivative Constant	32000
10	A - PWM Period	6000
0	B - Upper Deviation	6500
0	C - Lower Deviation	6500
200	D - Upper Alarm	6500
0	E - Lower Alarm	6500
0	F- Channel Configuration	0x3FF
0	0 - Alternate Setpoint (firmware version 2.28 and later)	32000

Chapter 4 Operation and Field Wiring Information

This chapter is divided into two sections:

Section 1: Principles of Operation for the Temperature Controller

Section 2: Field Wiring Information

Section 1: Principles of Operation

Temperature Control

PID Control Parameters

Each zone receives a set of PID parameters from the Series 90-30 CPU for closed-loop control. Individual parameter action (proportional, integral, derivative) for each zone can be disabled by setting the parameter to 0.

Operating Temperature Setpoint

For each zone, an operating temperature setpoint from 0°C to 450°C for J and L thermocouples, or from 0°C to 600°C for K thermocouples can be set. The temperature is given in 0.1°C increments.

Temperature Tolerance Bands

For each zone, two temperature tolerance bands, labeled *deviation* and *alarm*, can be preset above and below the temperature setpoint. Each zone temperature regulator operates within these bands. The band temperature range extends from 0°C to 450°C (600 °C), given in 0.1°C increments. With these two tolerance bands the following conditions can be checked:

1. If the current temperature is outside the lower/upper deviation band, the temperature is recorded and a temperature control error is reported.
2. If the current temperature is outside the lower/upper alarm band, the temperature is recorded, a temperature control error is reported and in the case of the upper alarm, the zone output is turned off.

PWM Output Period

For each zone, the PWM output period in both auto and manual modes is defined by the user to reflect the time constants of the process under control. The PWM output period ranges from 0.1 seconds to 60 seconds in 0.01 second increments to accommodate any process.

Version 2.27 only:

With 1% resolution on the duty-cycle, the minimum PWM output period should be 800 milliseconds (1000 milliseconds) for 60Hz (50 Hz) power line frequency if the zero-crossing method is used to control heaters.

Version 2.28 and later:

The duration of the output pulse is always an integer multiple of 8 milliseconds. This ensures full utilization of zero-crossing switching elements. A linear interpolation method (DDA) ensures the full resolution of the duty cycle throughout the entire range of the PWM output period.

Auto-Tuning

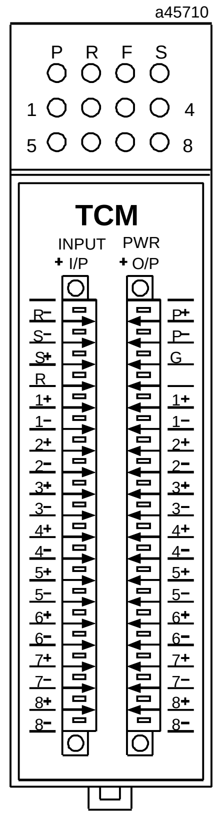
In the TCM firmware, two autotuning methods are implemented. The first method is the *Relay Feedback Method* and it is suitable for independent zones. The other method is the *Step Response Method* and it is suitable for interdependent zones.

Section 2: Field Wiring Information

The field wiring to the TCM consists of two screw locking 20-pin connectors. These connectors are diagrammed below with their connections.

TB1

1 RTD -
2 RTD - SENSE
3 RTD + SENSE
4 RTD+
5 J/K/L1+
6 J/K/L1-
7 J/K/L2+
8 J/K/L2-
9 J/K/L3+
10 J/K/L3-
11 J/K/L4+
12 J/K/L4-
13 J/K/L5+
14 J/K/L5-
15 J/K/L6+
16 J/K/L6-
17 J/K/L7+
18 J/K/L7-
19 J/K/L8+
20 J/L/L8-



STATUS LEDs

P = power R= run
F = fault S = short circuit
Channel LEDs, channels 1 to 8

TB2

1 External Power +
2 External Power Return
3 Chassis Ground
4 No Connection
5 CH1+
6 CH1-
7 CH2+
8 CH2-
9 CH3+
10 CH3-
11 CH4+
12 CH4-
13 CH5+
14 CH5-
15 CH6+
16 CH6-
17 CH7+
18 CH7-
19 CH8+
20 CH8-

The thermocouple inputs are labeled on the diagram above as J/K/L1 +, J/K/L1 – to J/K/L8 +, J/K/L8– and the digital outputs are labeled CH1+,CH1– to CH8+,CH8–.

Figure 4-1. TCM Field Wiring Connections

The following figure is an example of typical wiring from field devices to the TCM module.

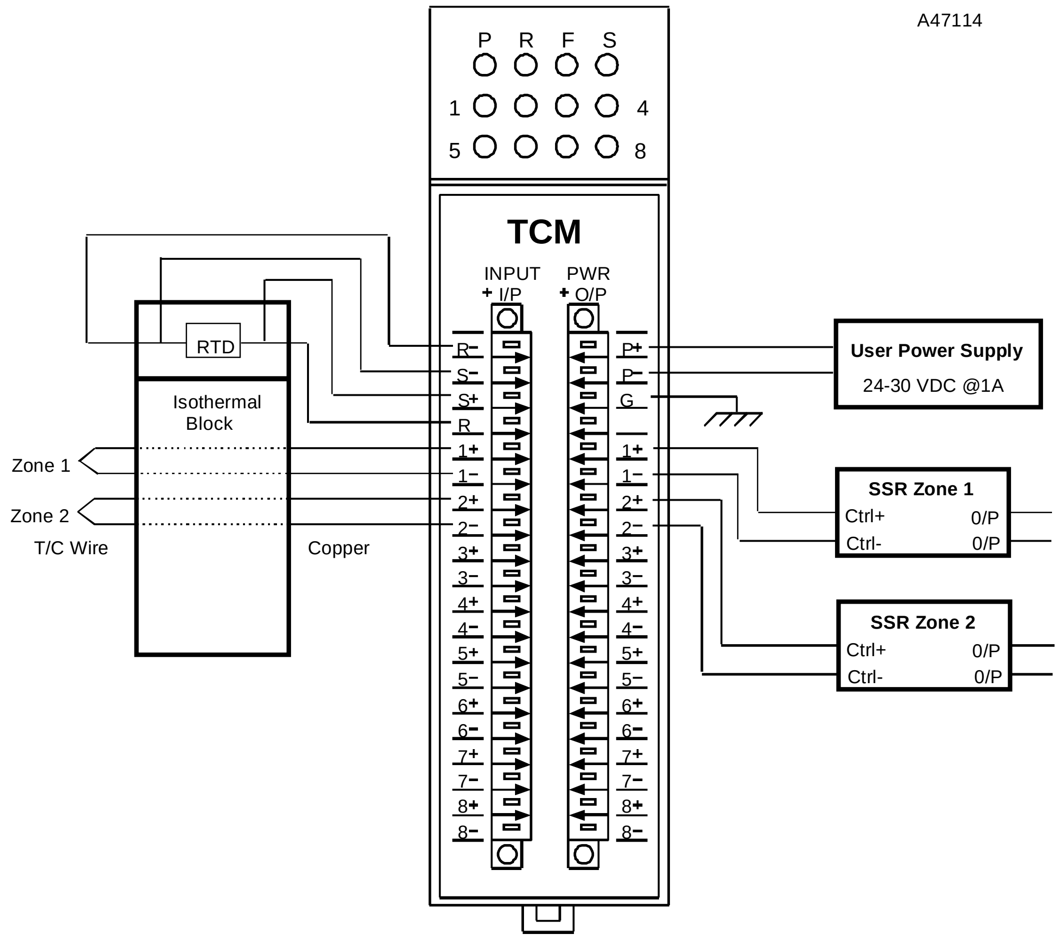


Figure 4-2. Example of Field Wiring

Cold Junction Compensation

Thermocouples can only measure relative, not absolute, temperature. To measure the true temperature using a thermocouple, its value must be compensated. For the TCM, either a temperature measuring IC (mounted inside), a resistive temperature device - RTD (mounted externally), or an external temperature value as the source of the compensation temperature can be used. The combination of both the relative thermocouple reading and the compensation temperature give the true temperature measurement.

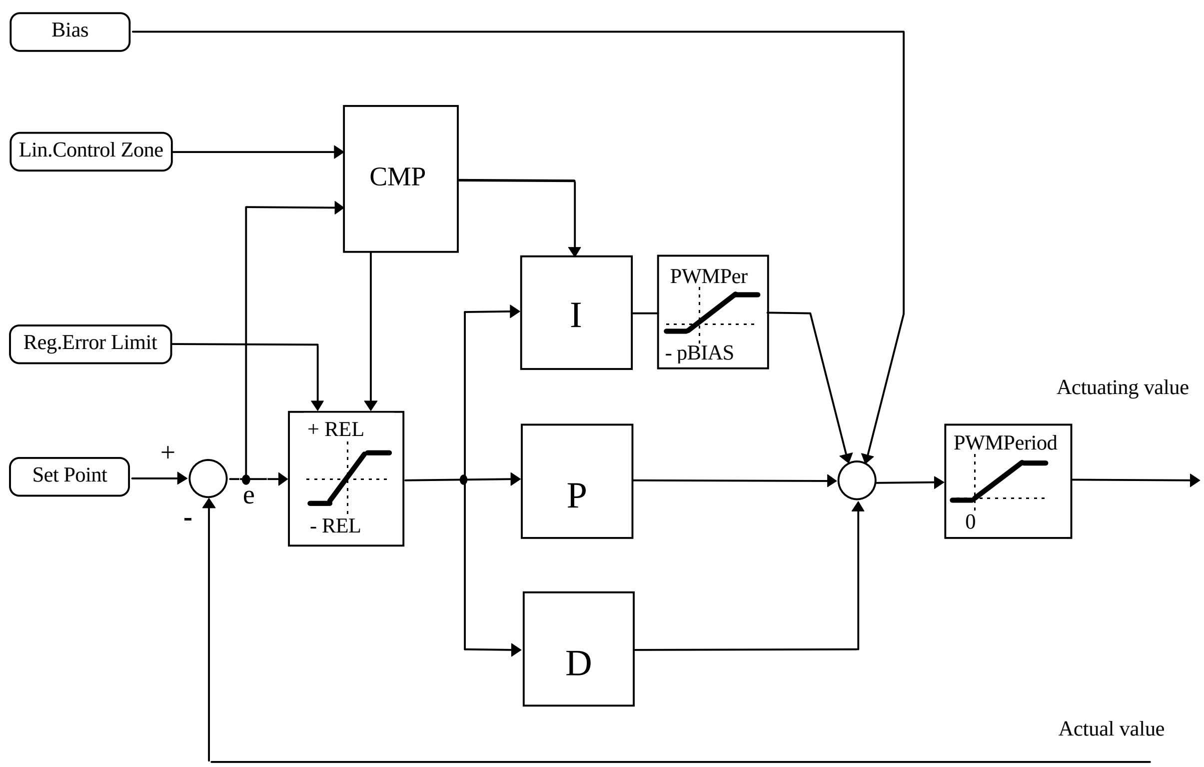
A thermocouple being used to measure temperature always has a reference thermocouple associated with it (commonly called the cold junction). All transitions or connections between dissimilar metals along the two wires from the measuring thermocouple junction and the TCM terminals will create additional thermocouple junctions. All but one of these junctions will be common to both of the signal paths with their effects canceling out. The remaining junction is called the cold junction. The cold junction is always present since the metals used in the measuring thermocouple will always transition to the copper leads used inside the TCM somewhere along the signal path. The location where this occurs is on the TCM terminal block (if the thermocouple leads are connected there) or on the isothermal thermocouple transition block (where the thermocouple leads are connected to the copper wires feeding the signal to the TCM terminal block).

If the thermocouple leads are connected directly to the TCM, the internal temperature measuring IC in contact with the connector is selected to provide the cold junction compensation to obtain the true temperature of the measuring thermocouple. The input terminal block is not a true isothermal connector and any temperature difference between the thermocouple connection and the IC will result in a similar difference or error in the temperature reading.

If the thermocouple leads are connected to an external connector block (with the connections from this block to the TCM made with a standard copper cable), the connector should be an isothermal block with an RTD to minimize measurement errors. The RTD allows measurement of the temperature of the cold junction for optimum cold junction compensation. In this case the TCM should be set to use the RTD temperature as the cold junction compensation source. This solution provides the best accuracy for TCM operation.

Closed-Loop Control

When a zone is in use (bit 8 of the Channel Configuration word is 1), its output is enabled, and the zone runs in the AUTO mode without any TC error being reported to the PLC, the closed-loop control function maintains a desired value of the temperature. The following block diagram represents the closed-loop control algorithm of one zone (channel):



The PID control block itself is only slightly modified from a conventional PID control block. The input information for the PID block at time T_i (where T equals the PWM period) is the regulation error e_i and the latest 4 measured temperatures x_i , x_{i-1}, x_{i-2}, x_{i-3} and the output information is the actuating value y_i . The following calculations are used to derive the actuating value:

$$y_i = KP\, e_i + \sum T\, KI\, e_i - KD/6T\, (x_i - x_{i-3} + 3(x_{i-1} - x_{i-2})) + BIAS$$

where:

KP is the proportional constant,

T is the sampling period equivalent to the PWM period,

KI is the integral constant,

KD is the derivative (differential) constant,

x_i, x_{i-1}, x_{i-2}, x_{i-3} are temperatures measured at time stamps T_i, T_{i-1}, T_{i-2}, T_{i-3},

BIAS is a constant value supplied by the PLC. The PLC can use it for *feedforward* method controlling, otherwise this value should be 0.

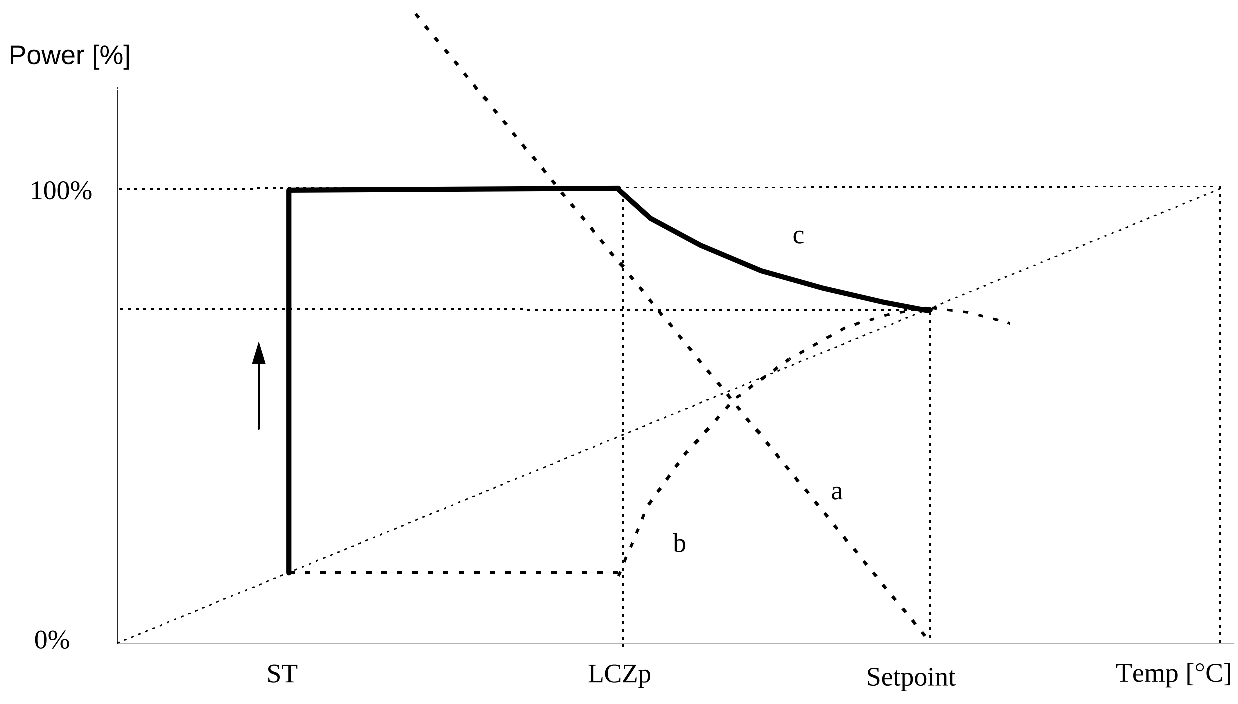
The actuating value y_i is clamped to zero value (if the result of calculation is a negative value) or directly to the PWMPeriod value (if the result is above the MaxTemp value) otherwise it is converted into a value of the duty cycle of the PWM period.

$Y_i = y_i$ / MaxTemp * PWMPeriod

The value of the MaxTemp depends on the thermocouple type.

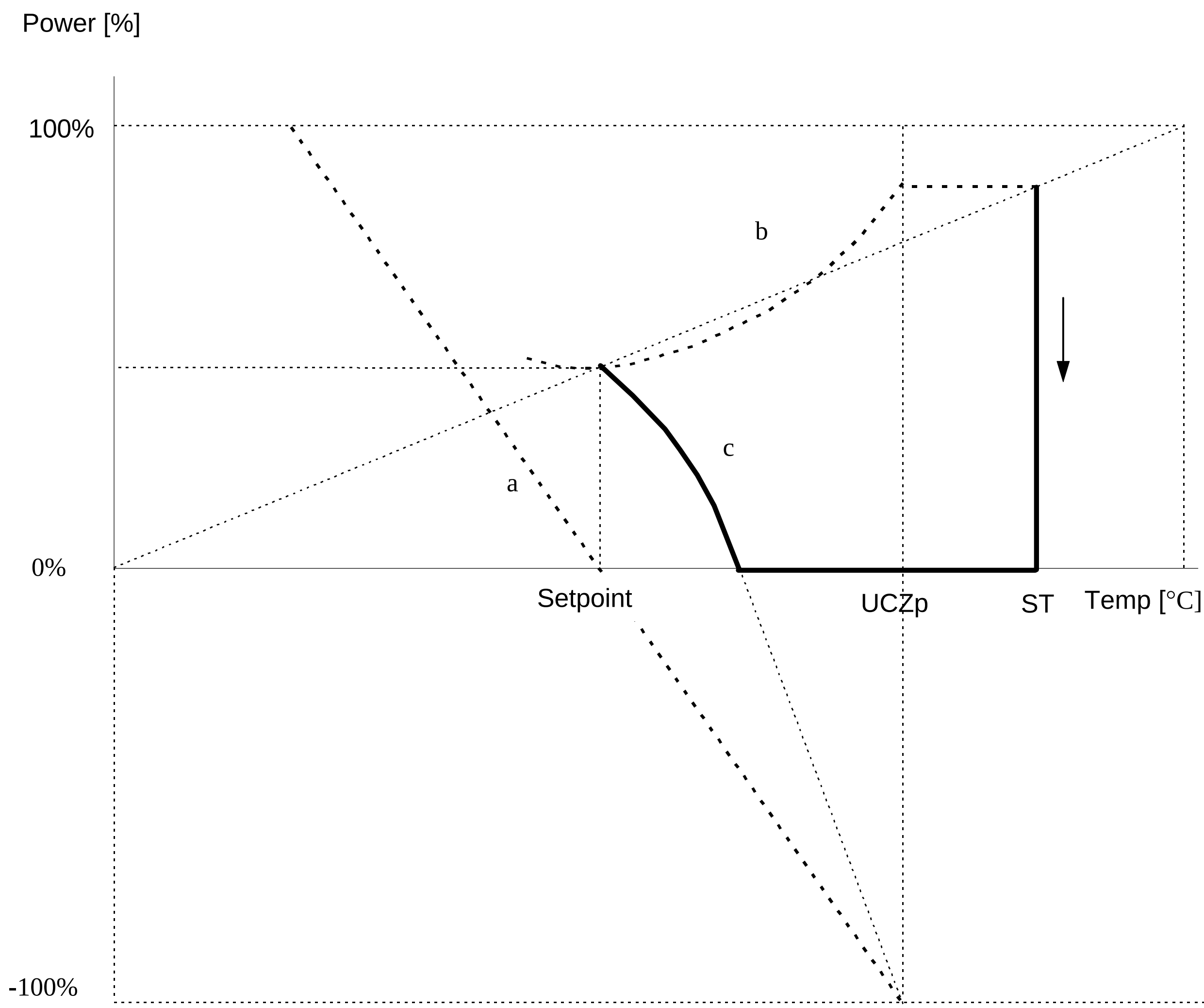
To suppress overshoots during the warm-up phase, the following two non-linearities are implemented in the control algorithm:

- The PLC unit sets the (linear) Control Zone value in units of 0.1 °C. For example, if this value is 250 (that is, 25°), the linear Control zone lies within ± 25°C around the Set point temperature. The contribution of the integral term is temporarily suspended if the current temperature is outside the Linear Control Zone and its content is frozen. The PWM output value is set up either to 100% (below the lower Control Zone point) or to 0% (above the upper Control Zone point).
- Within the linear Control zone the regulation error is limited to the Error Limit value, which is another parameter sent by the PLC unit and expressed in 0.1 °C. Such a limitation of the regulation error is equivalent to a control system which tracks the moving Set Point. Since the Set Point is ahead of the current temperature only by a relatively low value, even higher values of the PID constants can be used without a danger of overshoots.
  The following figure shows a situation when the new Set Point value is much higher than the current or the starting temperature (ST). The Error limit value is deliberately set up too high in order not to influence the regulation error.



ST - Starting temperature
LCZp - Lower Control Zone point
a - contribution of the proportional term Pp
b - contribution of the integral term Ip
c - combined contribution of Pp + Ip

The following figure shows a situation when the new Set Point value is much lower than the current temperature (ST).



ST - Starting temperature

UCZp - Upper Control Zone point

a - contribution of the proportional term Pp

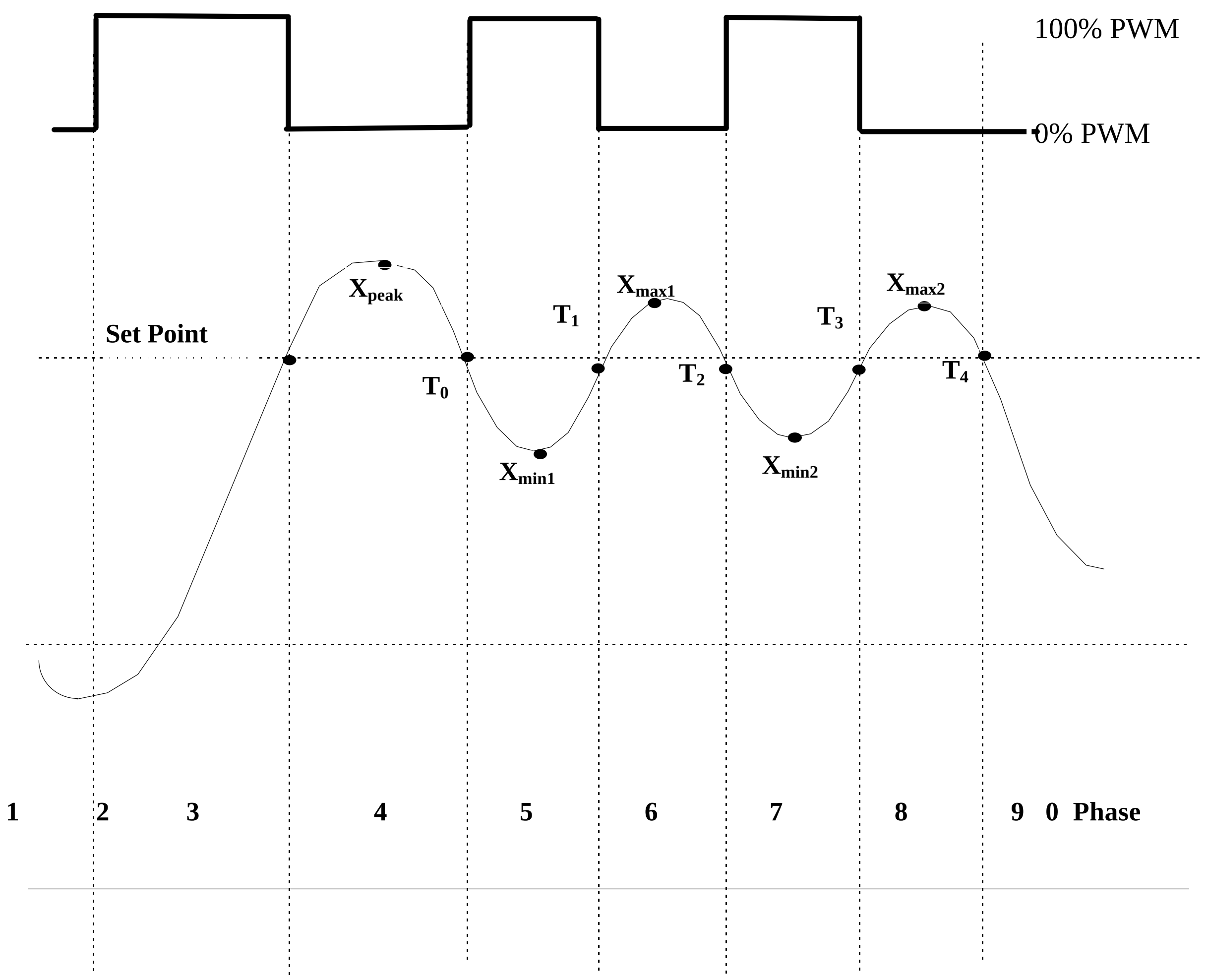
b - contribution of the integral term Ip

c - combined contribution of Pp + Ip

Chapter 5 Autotuning

Relay Feedback Method

The process is based on the Relay Feedback method for identifying the dynamic behavior of a controlled process. The TCM unit applies a sequence of ON/OFF pulses to each tuned channel, so the process variable oscillates with a specific high/low amplitude and a specific period.



The series of pulses forces the process variable (controlled temperature) to oscillate around the setpoint temperature. This temperature is the *switching temperature* and whenever the actual temperature crosses the switching temperature, the output (actuating value) changes from 0% to 100% or vice versa.

The whole autotuning process is initialized by the PLC when it has sent the command to start the autotuning (%Q reference +20). From that time onward the %Q and %AQ data are ignored by the TCM unit, except for %Q reference +24, which can be used at any time to stop the autotuning.

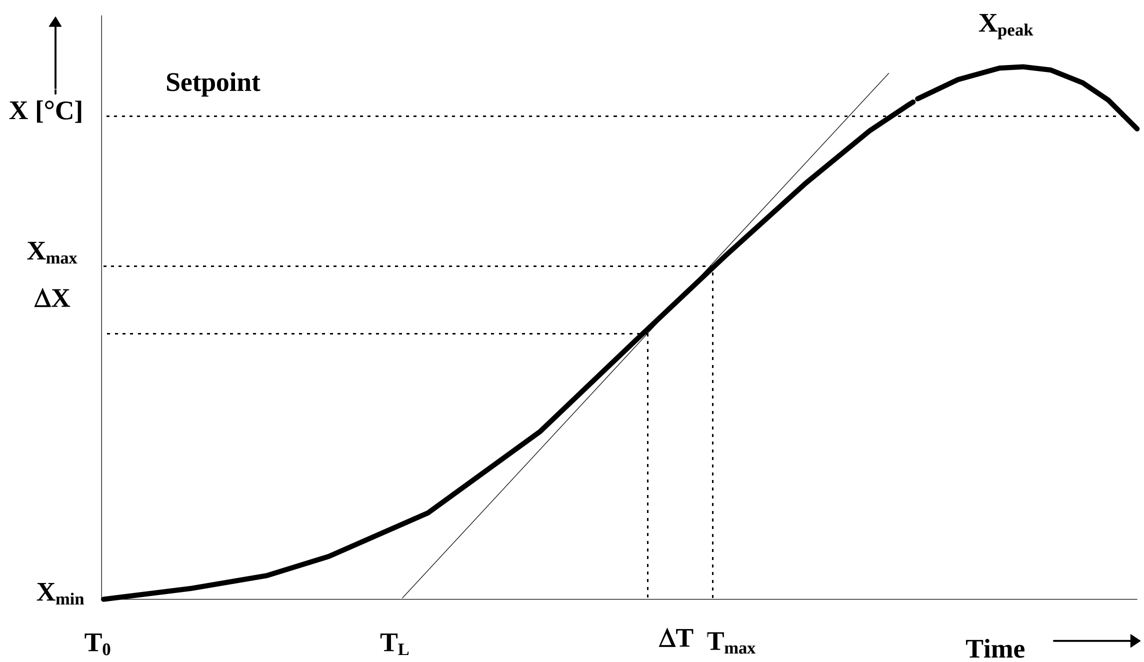
This process will finish automatically after 2.5 zone cycles.

The PID parameters are finally calculated

- Proportional constant
- Integral constant
- Derivative constant
- Sampling (PWM) period
- Regulation Error Limit
- Linear Control Zone

Step Response Method

This method of autotuning is based on the step response of an open-loop system. Such a response is shown in the following figure:



The step-response method determines PID parameters based on the transport delay, TL, and the maximum slope of the zone's response to a unit-step (0 to 100%) output. This autotuning method should be best for situations where the zone being tuned may be affected by adjacent zones.

Version 2.27 only: To apply this method, at first the PLC must send some *reasonable* value of the PWM Period parameter to each channel which will be tuned. This value will be used as a sampling period during the autotuning process. As the reasonable sampling period is considered such a period, during which the temperature change is in a range between 3°C and 8°C. For example, if the user knows that the zone in question requires approximately 10 minutes to be heated up from the ambient temperature (25°C) to the Set Point temperature (225°C), the optimal PWM (sampling) Period is 15 seconds (that is, the value of 1500), which would yield approximately 5°C temperature changes.

Version 2.28 and later: Due to firmware enhancements, this method does not require the PLC to send any seed PWM period.

The control parameters returned include:

- Proportional constant
- Integral constant
- Derivative constant

- Period
- Regulation Error Limit
- Linear Control Zone

The above six calculated parameters are sent back to the PLC unit including the channel number as the %AI reference +21 **-** %AI reference +27 words in 1 second intervals. The TCM unit does not adopt these parameters automatically. These parameters must be copied to the appropriate %R table and, after the PLC sends them to the TCM unit, they will be used as the PID parameters of the appropriate channel.

In some cases PID parameters returned by the TCM unit will not yield the optimal behavior of a controlled zone because of too many factors which influence the system. It is then recommended to modify the user's PLC program in such a way that some (or all) returned PID parameters are multiplied or divided by suitable constants before they are copied to the %R table. Alternatively, these parameters could be modified by the user directly within the %R table. Usually it is sufficient to modify the Integral Constant and/or the Proportional Constant.

Optimizing PID Parameters: Fine-Tuning Examples

Example 1

Symptom: System exhibits excessive overshoot or excessive steady-state fluctuation

Reason: System is underdamped.

Corrective Action: Increase the system's damping by increasing KD and/or decreasing KI and/or decreasing KP parameters.

Example 2

Symptom: System responds too slowly to changes in temperature setpoint or thermal transients.

Reason: System is overdamped.

Corrective Action: Decrease the system's damping by decreasing KD and/or increasing KI and/or increasing KP parameters.

In general, varying the system response could be done within the PLC program through introduction of a *damping adjustment* coefficient, $\mathbf{X_d}$. This value would be used to modify the tuning parameters returned from the TCM. To increase damping, the KI coefficient would be divided by $\mathbf{X_d}$ and the KD coefficient would be multiplied by $\mathbf{X_d}$. Typically, $\mathbf{X_d}$ would be assigned a value between 0.5 and 2.0.

Appendix A Typical Parameter Download Program

This appendix describes how to set up and download parameters to the TCM from the PLC CPU. The parameters are stored in the PLC %R table and sent in a predefined group of 3 words to the TCM each sweep. It takes then 65 sweeps to update all the parameter data in the TCM on start-up. The program to parse the configuration data and send it to a TCM can be set up as in the following programming example.

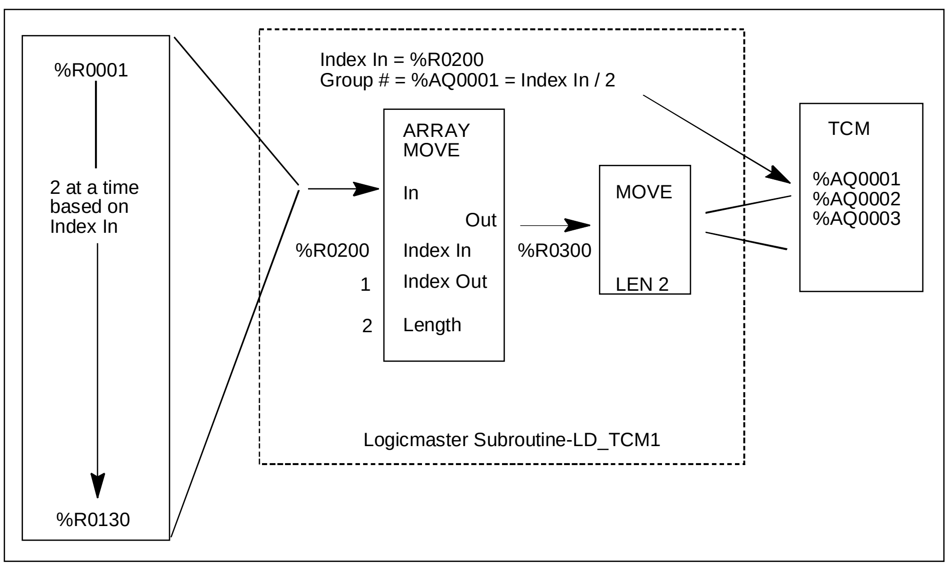
In this example the TCM is configured at:

%I0001 (length 64)
%Q0001 (length 24)
%AI0001 (length 28)
%AQ0001 (Length 3)

The parameter values to be sent to the TCM are located in %R0001 to %R0130. There are 16 parameters per channel plus 2 diagnostic parameters. These 130 parameters are continuously sent (2 at a time) to the TCM to make sure the TCM always has the latest values.

The Index into the register array is located in %R0200. It is initialized to 1 and incremented by 2 each PLC scan. When it reaches 131 it is set back to 1 to repeat the process.

The Group number for the TCM is located in %AQ0001. Dividing the Index number in % R0200 by 2 each PLC scan creates it. The Group number has a range of 0 to 64.



```
02-24-97  14:03     GE FANUC SERIES 90-30/90-20/MICRO (v6.01)       Page     1
                              TCM download example

                 GGGG EEEEE       FFFFF  AAA  N   N U   U  CCCC
                G     E           F     A   A NN  N U   U C
                G GGG EEEE        FFF   AAAAA N N N U   U C
                G   G E           F     A   A N  NN U   U C
                 GGG  EEEEE       F     A   A N   N  UUU   CCCC

           AAA  U   U TTTTT  OOO  M   M  AAA  TTTTT IIIII  OOO  N   N
          A   A U   U   T   O   O MM MM A   A   T     I   O   O NN  N
          AAAAA U   U   T   O   O M M M AAAAA   T     I   O   O N N N
          A   A U   U   T   O   O M   M A   A   T     I   O   O N  NN
          A   A  UUU    T    OOO  M   M A   A   T   IIIII  OOO  N   N

(****************************************************************************)
(*                                                                          *)
(*                               Program:  FOREN                            *)
(*                                                                          *)
(*        PLC PROGRAM ENVIRONMENT               HIGHEST REFERENCE USED      *)
(*    ---------------------------------       ---------------------------   *)
(*                INPUT (%I):      512                   INPUT:      NONE   *)
(*               OUTPUT (%Q):      512                  OUTPUT:      NONE   *)
(*             INTERNAL (%M):     1024                INTERNAL:      NONE   *)
(*           GLOBAL DATA (%G):    1280             GLOBAL DATA:      NONE   *)
(*            TEMPORARY (%T):      256               TEMPORARY:      NONE   *)
(*             REGISTER (%R):     1024                REGISTER:   %R0429    *)
(*         ANALOG INPUT (%AI):      64            ANALOG INPUT:      NONE   *)
(*        ANALOG OUTPUT (%AQ):      32           ANALOG OUTPUT:   %AQ003    *)
(*                                                                          *)
(*                      PROGRAM SIZE (BYTES):      384                      *)
(*                                                                          *)
(*                                                                          *)
(****************************************************************************)
```

```
(******************************************************************************)
(*                                                                            *)
(*                              BLOCK:  _MAIN                                 *)
(*                                                                            *)
(*                                                                            *)
(*                            BLOCK SIZE (BYTES):   132                       *)
(*                        DECLARATIONS (ENTRIES):   251                       *)
(*                                                                            *)
(*                                                                            *)
(*                           HIGHEST REFERENCE USED                           *)
(*                        ----------------------------                        *)
(*                                                                            *)
(*                              INPUT (%I):      NONE                         *)
(*                             OUTPUT (%Q):      NONE                         *)
(*                           INTERNAL (%M):      NONE                         *)
(*                        GLOBAL DATA (%G):      NONE                         *)
(*                          TEMPORARY (%T):      NONE                         *)
(*                           REGISTER (%R):      NONE                         *)
(*                      ANALOG INPUT (%AI):      NONE                         *)
(*                     ANALOG OUTPUT (%AQ):      NONE                         *)
(*                                                                            *)
(******************************************************************************)


|[  START OF LD  PROGRAM  FOREN   ]       (*                                  *)
|
|[     VARIABLE DECLARATIONS      ]

              V A R I A B L E   D E C L A R A T I O N   T A B L E

          REFERENCE     NICKNAME         REFERENCE DESCRIPTION
          ---------     --------     --------------------------------
          %I0001        CH1_HAL      Channel #1 High Alarm
          %I0002        CH1_LAL      Channel #1 Low Alarm
          %I0003        CH1_HD       Channel #1 High Dev.
          %I0004        CH1_LD       Channel #1 Low Dev
          %I0005        CH1_TCE      Channel #1 T/C Error
          %I0006        CH1_OE       Channel #1 Output Shorted
          %I0007        CH1_CE       Channel #1 Zone Error
          %I0008        CH2_HAL      Channel #2 High Alarm
          %I0009        CH2_LAL      Channel #2 Low Alarm
          %I0010        CH2_HD       Channel #2 High Dev.
          %I0011        CH2_LD       Channel #2 Low Dev
          %I0012        CH2_TCE      Channel #2 T/C Error
          %I0013        CH2_OE       Channel #2 Output Shorted
          %I0014        CH2_CE       Channel #2 Zone Error
          %I0015        CH3_HAL      Channel #3 High Alarm
          %I0016        CH3_LAL      Channel #3 Low Alarm
          %I0017        CH3_HD       Channel #3 High Dev.
          %I0018        CH3_LD       Channel #3 Low Dev
          %I0019        CH3_TCE      Channel #3 T/C Error
          %I0020        CH3_OE       Channel #3 Output Shorted
          %I0021        CH3_CE       Channel #3 Zone Error
          %I0022        CH4_HAL      Channel #4 High Alarm
          %I0023        CH4_LAL      Channel #4 Low Alarm
          %I0024        CH4_HD       Channel #4 High Dev.
          %I0025        CH4_LD       Channel #4 Low Dev
          %I0026        CH4_TCE      Channel #4 T/C Error
          %I0027        CH4_OE       Channel #4 Output Shorted
          %I0028        CH4_CE       Channel #4 Zone Error
          %I0029        CH5_HAL      Channel #5 High Alarm
          %I0030        CH5_LAL      Channel #5 Low Alarm
          %I0031        CH5_HD       Channel #5 High Dev.
          %I0032        CH5_LD       Channel #5 Low Dev
          %I0033        CH5_TCE      Channel #5 T/C Error
          %I0034        CH5_OE       Channel #5 Output Shorted
          %I0035        CH5_CE       Channel #5 Zone Error
          %I0036        CH6_HAL      Channel #6 High Alarm
          %I0037        CH6_LAL      Channel #6 Low Alarm
          %I0038        CH6_HD       Channel #6 High Dev.
          %I0039        CH6_LD       Channel #6 Low Dev
          %I0040        CH6_TCE      Channel #6 T/C Error
```

%I0041	CH6_OE	Channel #6 Output Shorted
%I0042	CH6_CE	Channel #6 Zone Error
%I0043	CH7_HAL	Channel #7 High Alarm
%I0044	CH7_LAL	Channel #7 Low Alarm
%I0045	CH7_HD	Channel #7 High Dev.
%I0046	CH7_LD	Channel #7 Low Dev
%I0047	CH7_TCE	Channel #7 T/C Error
%I0048	CH7_OE	Channel #7 Output Shorted
%I0049	CH7_CE	Channel #7 Zone Error
%I0050	CH8_HAL	Channel #8 High Alarm
%I0051	CH8_LAL	Channel #8 Low Alarm
%I0052	CH8_HD	Channel #8 High Dev.
%I0053	CH8_LD	Channel #8 Low Dev
%I0054	CH8_TCE	Channel #8 T/C Error
%I0055	CH8_OE	Channel #8 Output Shorted
%I0056	CH8_CE	Channel #8 Zone Error
%I0057	RTD_ERR	RTD Short/Open
%I0058	SP_I02	TCM Spare %I #2
%I0059	IN_TUN	TCM in Autotuning mode
%I0060	IN_CAL	TCM in Calibration mode
%I0061	TCM_OK	TCM Operating Normally
%I0062	PWM_SC	Some TCM Output Shorted
%I0063	T_24VER	TCM 24V Output Pwr Error
%I0064	TCM_ERR	TCM Error Present
%Q0001	CH1_AUT	Channel #1 Auto Mode
%Q0002	CH1_ENA	Channel #1 Output Enable
%Q0003	CH2_AUT	Channel #2 Auto Mode
%Q0004	CH2_ENA	Channel #2 Output Enable
%Q0005	CH3_AUT	Channel #3 Auto Mode
%Q0006	CH3_ENA	Channel #3 Output Enable
%Q0007	CH4_AUT	Channel #4 Auto Mode
%Q0008	CH4_ENA	Channel #4 Output Enable
%Q0009	CH5_AUT	Channel #5 Auto Mode
%Q0010	CH5_ENA	Channel #5 Output Enable
%Q0011	CH6_AUT	Channel #6 Auto Mode
%Q0012	CH6_ENA	Channel #6 Output Enable
%Q0013	CH7_AUT	Channel #7 Auto Mode
%Q0014	CH7_ENA	Channel #7 Output Enable
%Q0015	CH8_AUT	Channel #8 Auto Mode
%Q0016	CH8_ENA	Channel #8 Output Enable
%Q0017	SP_Q01	Spare %Q Bit #1
%Q0018	SP_Q02	Spare %Q Bit #2
%Q0019	METH_AT	AT Method: 0-Relay / 1-Step
%Q0020	DO_ATUN	Do Autotuning
%Q0021	SP_Q03	Spare %Q Bit #3
%Q0022	DIS_CAL	Disable Overall Calibration
%Q0023	SP_Q04	Spare %Q Bit #4
%Q0024	CANCEL	Cancel Autotuning process
%R0001	D_ADR1	Diagnostic Address #1
%R0002	D_ADR2	Diagnostic Address #2
%R0003	CH1_SP	CH1 Set Point
%R0004	CH1_MO	CH1 Manual Output
%R0005	CH1_ELB	CH1 Error Limit Band
%R0006	CH1_LCZ	CH1 Linear Control Zone
%R0007	CH1_ECT	CH1 External Compensation Temp.
%R0008	CH1_BIS	CH1 Bias
%R0009	CH1_KP	CH1 Proportional Constant
%R0010	CH1_KI	CH1 Integral Constant
%R0011	CH1_KD	CH1 Derivative Constant
%R0012	CH1_PER	CH1 PWM Period
%R0013	CH1_UDE	CH1 Upper Deviation
%R0014	CH1_LDE	CH1 Lower Deviation
%R0015	CH1_UAL	CH1 Upper Alarm (Fatal)
%R0016	CH1_LOA	CH1 Lower Alarm
%R0017	CH1_CFG	CH1 Channel Configuration
%R0018	CH1_SPR	CH1 Spare
%R0019	CH2_SP	CH2 Set Point
%R0020	CH2_MO	CH2 Manual Output
%R0021	CH2_ELB	CH2 Error Limit Band
%R0022	CH2_LCZ	CH2 Linear Control Zone
%R0023	CH2_ECT	CH2 External Compensation Temp.
%R0024	CH2_BIS	CH2 Bias
%R0025	CH2_KP	CH2 Proportional Constant

```
%R0026        CH2_KI       CH2 Integral Constant
%R0027        CH2_KD       CH2 Derivative Constant
%R0028        CH2_PER      CH2 PWM Period
%R0029        CH2_UDE      CH2 Upper Deviation
%R0030        CH2_LDE      CH2 Lower Deviation
%R0031        CH2_UAL      CH2 Upper Alarm
%R0032        CH2_LOA      CH2 Lower Alarm
%R0033        CH2_CFG      CH2 Channel Configuration
%R0034        CH2_SPR      CH2 Spare
%R0035        CH3_SP       CH3 Set Point
%R0036        CH3_MO       CH3 Manual Output
%R0037        CH3_ELB      CH3 Error Limit Band
%R0038        CH3_LCZ      CH3 Linear Control Zone
%R0039        CH3_ECT      CH3 External Compensation Temp.
%R0040        CH3_BIS      CH3 Bias
%R0041        CH3_KP       CH3 Proportional Constant
%R0042        CH3_KI       CH3 Integral Constant
%R0043        CH3_KD       CH3 Derivative Constant
%R0044        CH3_PER      CH3 PWM Period
%R0045        CH3_UDE      CH3 Upper Deviation
%R0046        CH3_LDE      CH3 Lower Deviation
%R0047        CH3_UAL      CH3 Upper Alarm
%R0048        CH3_LOA      CH3 Lower Alarm
%R0049        CH3_CFG      CH3 Channel Configuration
%R0050        CH3_SPR      CH3 Spare
%R0051        CH4_SP       CH4 Set Point
%R0052        CH4_MO       CH4 Manual Output
%R0053        CH4_ELB      CH4 Error Limit Band
%R0054        CH4_LCZ      CH4 Linear Control Zone
%R0055        CH4_ECT      Ch4 External Compensation Temp.
%R0056        CH4_BIS      CH4 Bias
%R0057        CH4_KP       CH4 Proportional Constant
%R0058        CH4_KI       CH4 Integral Constant
%R0059        CH4_KD       CH4 Derivative Constant
%R0060        CH4_PER      CH4 PWM Period
%R0061        CH4_UDE      CH4 Upper Deviation
%R0062        CH4_LDE      CH4 Lower Deviation
%R0063        CH4_UAL      CH4 Upper Alarm
%R0064        CH4_LOA      CH4 Lower Alarm
%R0065        CH4_CFG      CH4 Channel Configuration
%R0066        CH4_SPR      CH4 Spare
%R0067        CH5_SP       CH5 Set Point
%R0068        CH5_MO       CH5 Manual Output
%R0069        CH5_ELB      CH5 Error Limit Band
%R0070        CH5_LCZ      CH5 Linear Control Zone
%R0071        CH5_ECT      CH5 External Compensation Temp.
%R0072        CH5_BIS      CH5 Bias
%R0073        CH5_KP       CH5 Proportional Constant
%R0074        CH5_KI       CH5 Integral Constant
%R0075        CH5_KD       CH5 derivative Constant
%R0076        CH5_PER      CH5 PWM Period
%R0077        CH5_UDE      CH5 Upper deviation
%R0078        CH5_LDE      CH5 Lower Deviation
%R0079        CH5_UAL      CH5 Upper Alarm
%R0080        CH5_LOA      CH5 Lower Alarm
%R0081        CH5_CFG      CH5 Channel Configuration
%R0082        CH5_SPR      CH5 Spare
%R0083        CH6_SP       CH6 Set Point
%R0084        CH6_MO       CH6 Manual Output
%R0085        CH6_ELB      CH6 Error Limit Band
%R0086        CH6_LCZ      CH6 Linear Control Zone
%R0087        CH6_ECT      CH6 External Compensation Temp.
%R0088        CH6_BIS      CH6 Bias
%R0089        CH6_KP       CH6 Proportional Constant
%R0090        CH6_KI       CH6 Integral Constant
%R0091        CH6_KD       CH6 Derivative Constant
%R0092        CH6_PER      CH6 PWM Period
%R0093        CH6_UDE      CH6 Upper Deviation
%R0094        CH6_LDE      CH6 Lower Deviation
%R0095        CH6_UAL      CH6 Upper Alarm
%R0096        CH6_LOA      CH6 Lower Alarm
%R0097        CH6_CFG      CH6 Channel Configuration
%R0098        CH6_SPR      CH6 Spare
```

%R0099	CH7_SP	CH7 Set Point
%R0100	CH7_MO	CH7 Manual Output
%R0101	CH7_ELB	CH7 Error Limit Band
%R0102	CH7_LCZ	CH7 Linear Control Zone
%R0103	CH7_ECT	CH7 External Compensation Temp.
%R0104	CH7_BIS	CH7 Bias
%R0105	CH7_KP	CH7 Proportional Constant
%R0106	CH7_KI	CH7 Integral Constant
%R0107	CH7_KD	CH7 Derivative Constant
%R0108	CH7_PER	CH7 PWM Period
%R0109	CH7_UDE	CH7 Upper Deviation
%R0110	CH7_LDE	CH7 Lower Deviation
%R0111	CH7_UAL	CH7 Upper Alarm
%R0112	CH7_LOA	CH7 Lower Alarm
%R0113	CH7_CFG	CH7 Channel Configuration
%R0114	CH7_SPR	CH7 Spare
%R0115	CH8_SP	CH8 Set Point
%R0116	CH8_MO	CH8 Manual Output
%R0117	CH8_ELB	CH8 Error Limit Band
%R0118	CH8_LCZ	CH8 Linear Control Zone
%R0119	CH8_ECT	CH8 External Compensation Temp.
%R0120	CH8_BIS	CH8 Bias
%R0121	CH8_KP	CH8 Proportional Constant
%R0122	CH8_KI	CH8 Integral Constant
%R0123	CH8_KD	CH8 Derivative Constant
%R0124	CH8_PER	CH8 PWM Period
%R0125	CH8_UDE	CH8 Upper Deviation
%R0126	CH8_LDE	CH8 Lower Deviation
%R0127	CH8_UAL	CH8 Upper Alarm
%R0128	CH8_LOA	CH8 Lower Alarm
%R0129	CH8_CFG	CH8 Channel Configuration
%R0130	CH8_SPR	CH8 Spare
%AI0001	CH1_TMP	Channel #1 Current Temp
%AI0002	CH1_PWR	Channel #1 Power Output
%AI0003	CH2_TMP	Channel #2 Current Temp
%AI0004	CH2_PWR	Channel #2 Power Output
%AI0005	CH3_TMP	Channel #3 Current Temp
%AI0006	CH3_PWR	Channel #3 Power Output
%AI0007	CH4_TMP	Channel #4 Current Temp
%AI0008	CH4_PWR	Channel #4 Power Output
%AI0009	CH5_TMP	Channel #5 Current Temp
%AI0010	CH5_PWR	Channel #5 Power Output
%AI0011	CH6_TMP	Channel #6 Current Temp
%AI0012	CH6_PWR	Channel #6 Power Output
%AI0013	CH7_TMP	Channel #7 Current Temp
%AI0014	CH7_PWR	Channel #7 Power Output
%AI0015	CH8_TMP	Channel #8 Current Temp
%AI0016	CH8_PWR	Channel #8 Power Output
%AI0017	RTD_TMP	Current RTD Temperature
%AI0018	INT_TMP	Internal Temperature
%AI0019	DIAG_1	Diagnostic Value #1
%AI0020	DIAG_2	Diagnostic Value #2
%AI0021	CH_ANUM	Channel Number Tuning Values
%AI0022	CH_KP	Channel Proportional Gain
%AI0023	CH_KI	Channel Integral Gain
%AI0024	CH_KD	Channel Derivative Gain
%AI0025	CH_PWMP	Channel Sampling (PWM) period
%AI0026	CH_SP1	Spare 1
%AI0027	CH_SP2	Spare 2
%AI0028	ERR_CD	TCM Error Code
%AQ001	GROUP#	Parameter Group Number
%AQ002	PARM_1	Parameter #1
%AQ003	PARM_2	Parameter #2

```
                    I D E N T I F I E R    T A B L E

          IDENTIFIER     IDENTIFIER TYPE          IDENTIFIER DESCRIPTION
          ----------     ---------------     --------------------------------
          LD_TCM2        SUBROUTINE          Load TCM #1 With Data
          FOREN          PROGRAM NAME

|[       BLOCK DECLARATIONS       ]


              +-------+
        SUBR  1 |LD_TCM2|       LANG: LD  (* Load TCM #1 With Data         *)
              +-------+

|[     START OF PROGRAM LOGIC     ]
|
| << RUNG 4  STEP #0001 >>
|
|ALW_ON  +-------------+
+--] [---+ CALL LD_TCM2+
|        | (SUBROUTINE)|
|        +-------------+
|
|[      END OF PROGRAM LOGIC      ]
|


(*****************************************************************************)
(*                                                                           *)
(*                               BLOCK:  LD_TCM2                             *)
(*                                                                           *)
(*                                                                           *)
(*                              BLOCK SIZE (BYTES):   226                    *)
(*                          DECLARATIONS (ENTRIES):     0                    *)
(*                                                                           *)
(*                                                                           *)
(*                          HIGHEST REFERENCE USED                           *)
(*                       -----------------------------                       *)
(*                                                                           *)
(*                               INPUT (%I):      NONE                       *)
(*                              OUTPUT (%Q):      NONE                       *)
(*                            INTERNAL (%M):      NONE                       *)
(*                         GLOBAL DATA (%G):      NONE                       *)
(*                           TEMPORARY (%T):      NONE                       *)
(*                            REGISTER (%R):   %R0429                        *)
(*                        ANALOG INPUT (%AI):     NONE                       *)
(*                       ANALOG OUTPUT (%AQ):  %AQ003                        *)
(*                                                                           *)
(*****************************************************************************)


|[  START LD SUBROUTINE  LD_TCM2  ]
|
|[     VARIABLE DECLARATIONS      ]

          V A R I A B L E   D E C L A R A T I O N   T A B L E

          REFERENCE     NICKNAME          REFERENCE DESCRIPTION
          ---------     --------     --------------------------------
                          NO  VARIABLE  TABLE  ENTRIES


                    I D E N T I F I E R    T A B L E

          IDENTIFIER     IDENTIFIER TYPE          IDENTIFIER DESCRIPTION
          ----------     ---------------     --------------------------------
                         NO  IDENTIFIER  TABLE  ENTRIES
```

```
|[   START OF SUBROUTINE LOGIC    ]
|
| << RUNG 3  STEP #0001 >>      /* During the first scan an internal   */
|                               /* variable %R0200 is set to a value   */
|FST_SCN +-----+                /* of 1                                */
+--] [---+MOVE_+-
|        | INT |
|        |     |
| CONST -+IN  Q+-%R0200
| +00001 | LEN |
|        |00001|
|        +-----+
|
| << RUNG 4  STEP #0003 >>      /* With every scan a value of the internal */
|                               /* variable %R0200 is divided by 2 and an  */
|ALW_ON  +-----+                /* integral part of the result is copied   */
+--] [---+ DIV_+-               /* to the output variable GROUP# (%AQ0001) */
|        | INT |                /* as the Group Number                     */
|        |     |
|%R0200 -+I1  Q+-GROUP#
|        |     |
| CONST -+I2   |
| +00002 +-----+
|
| << RUNG 5  STEP #0005 >>  /* With every scan a next pair from the 130       */
|                           /* parameter data words, starting at the register */
|                           /* %R0001 (D_ADR1) are copied to the pair of      */
|                           /* internal variables (%R0300 and %R0301). The    */
|                           /* internal variable %R0200 is used as a pointer  */
|                           /* to a subarray of these 2 parameter words. The  */
|                           /* 2 parameters are then copied from these 2      */
|                           /* internal variables to the output variables     */
|                           /* Parm_1 (%AQ0002 and %AQ0003).                  */
|
|ALW_ON  +-----+                 +-----+
+--] [---+ARRAY+-----------------+MOVE_+-
|        |MOVE_|                 | INT |
|        | INT |                 |     |
|D_ADR1 -+SR DS+-%R0300  %R0300 -+IN  Q+-PARM_1
|        | LEN |                 | LEN |
|        |00130|                 |00002|
|%R0200 -+SNX  |                 +-----+
|        |     |
| CONST -+DNX  |
|  00001 |     |
|        |     |
| CONST -+N    |
|  00002 +-----+
|
| << RUNG 6  STEP #0008 >>      /* With every scan a value of the pointer    */
|                               /* (%R0200) is increased by 2. If it reaches */
|                               /* a value greater or equal to 131, it is    */
|                               /* reset to an initial value of 1.           */
|ALW_ON  +-----+                 +-----+
+--] [---+ ADD_+-----------------+ GE_ |
|        | INT |                 | INT |
|        |     |                 |     |         +-----+
|%R0200 -+I1  Q+-%R0200  %R0200 -+I1  Q+---------+MOVE_+-
|        |     |                 |     |         | INT |
|        |     |                 |     |         |     |
| CONST -+I2   |          CONST -+I2   |  CONST -+IN  Q+-%R0200
| +00002 +-----+          +00131 +-----+  +00001 | LEN |
|                                                |00001|
|                                                +-----+
|
|
|[    END OF SUBROUTINE LOGIC     ]
```

```
|
Program: FOREN              C:\LM90\FOREN             Block: LD_TCM2(SUBR 01) 02-
24-97  14:03     GE FANUC SERIES 90-30/90-20/MICRO (v6.01)   Contents    1
```

***** L O G I C   T A B L E   O F   C O N T E N T S *****

Appendix B Specifications

The Temperature Control Module is expected to continue with uninterrupted operation in any combination of the operating environmental or electrical conditions specified below. Under no condition specified, operating or non-operating, will the TCM suffer permanent damage.

Tests and Approvals

- **Shock and Vibration:**

  IEC68-2-2-6 (1982), J1SC0911 (1984)

- **Agency approvals:**

  UL508; CSA C22.2, number 142

  FCC Part 15, Subpart B, Class A

  CE Mark for compliance with EMC Directive

- **Reliability Specifications:**

  Passive components class: Industrial grade.

  Solid-state devices: Plastic packages.

  Calculated MTBF: 100,000 operating hours.

Hazardous Locations

This equipment is suitable for use in Class 1, Division 2, Groups A, B, C, D, or **non-hazardous locations only.**

Warning

Explosion Hazard -Substitution of components may impair suitability for Class 1, Division 2.

Explosion Hazard - Do not disconnect equipment unless power has been switched-off or the area is known to be non-hazardous.

TCM Specifications

Operating Temperature:	0C. to 55°C.(32° to 131°F) **-** [Inlet]
Storage Temperature:	-40°C. to +85°C.(-40°F to +185°F)
Humidity:	5% to 95% (Non condensing)
External Power Supply:	18 to 36VDC (2.5A inrush)
Shock:	Operating: 15g equivalent, 11 ms, 3 axis positive and negative
Vibration:	Operating: 3.5mm, 5 to 9Hz; 1.0g, 9 to 150Hz
Power Supply Current:	150mA (5VDC from backplane) 100mA (24VDC from external supply) + output current
Thermocouple Impedance:	35 Ohms maximum
RTD:	100 Ohms @ 0°C (32°F). (α = 0.00392)
Output Voltage Range	18 to 30 volts DC
Output Characteristics:	
Output Current (ON State)	100mA maximum sourcing
Overload Threshold Current	700 mA typical, 2 milliseconds minimum
Off-State Leakage	0.1 mA maximum
Isolation from PLC Backplane	1000 volts

Maximum Number of Modules/System:

PLC Model	
Model 311	2 (limited by %AI)
Model 313	2 (limited by %AI)
Model 323	2 (limited by %AI)
Model 331	5 (limited by %AI)
Model 340	5 (limited by %I)
Model 341	8 (limited by %I)
Model 351	32 (limited by %I)
Model 352	32 (limited by %I)

Appendix C Applications

Heating and Cooling of a Zone

One simple way to improve quality of a zone temperature control is adding cooling as well as heating. In many cases the heaters maintaining working temperatures are oversized, that is, they require less than 50% of the power output to maintain their steady-state temperature. The cooling effect of the environment is in such cases much slower and the system becomes highly non-linear. Forced cooling can improve the overall behavior of the control system.

The simplest way to incorporate cooling into such system is to add a non-proportionally (ON/OFF) controlled fan. The cooling fan can be easily controlled by a Programmable Logic Controller (PLC) which communicates with the TCM unit. The PLC can, for that purpose, use two flag bits returned by the TCM unit for every zone with every sweep. These bits are the Upper and the Lower Deviation bits. If these flags are set up properly around the Set Point value (that is, around the controlled temperature), the PLC can use one or both of them to control an Output Module which in turn can directly control (turn ON / turn OFF) the cooling fan.

Both deviation flag bits exhibit a fixed hysteresis of ± 0.5 °C if the corresponding Upper/Lower Deviation temperatures are set to a value of 0.5 °C or more. If a value of the Upper/Lower Deviation temperature is below 0.5 °C, the hysteresis will be limited between a value of the Set Point and a value of the Set Point plus/minus a value of the Upper/Lower Deviation temperature + 0.5 °C. In other words, the Set Point temperature limits the lower part of the Upper Deviation hysteresis and it limits the upper part of the Lower Deviation hysteresis.

For example (see Figure C-1), if the Set Point temperature equals 200 °C and the Upper Deviation temperature is set to 3 °C, each time the current temperature rises above the temperature of 203.5 °C the cooling fan will be turned on. It will be on until the current temperature drops below a value of 202.5 °C. If the Upper Deviation temperature is set to 0 °C, each time the current temperature rises above the temperature of 200.5 °C the cooling fan can be turned on. It will be on until the current temperature drops below 200 °C.

If such fixed hysteresis loops are too narrow, both, the upper and lower deviation flag bits could be used to control the cooling fan (Figure C-2). The PLC unit will require addition of a simple program which would simulate a hysteresis by a flip-flop circuit controlled by both deviation flag bits. The Upper Deviation flag bit will turn on the output and the Lower Deviation flag bit will turn off the output of the flip-flop circuit.

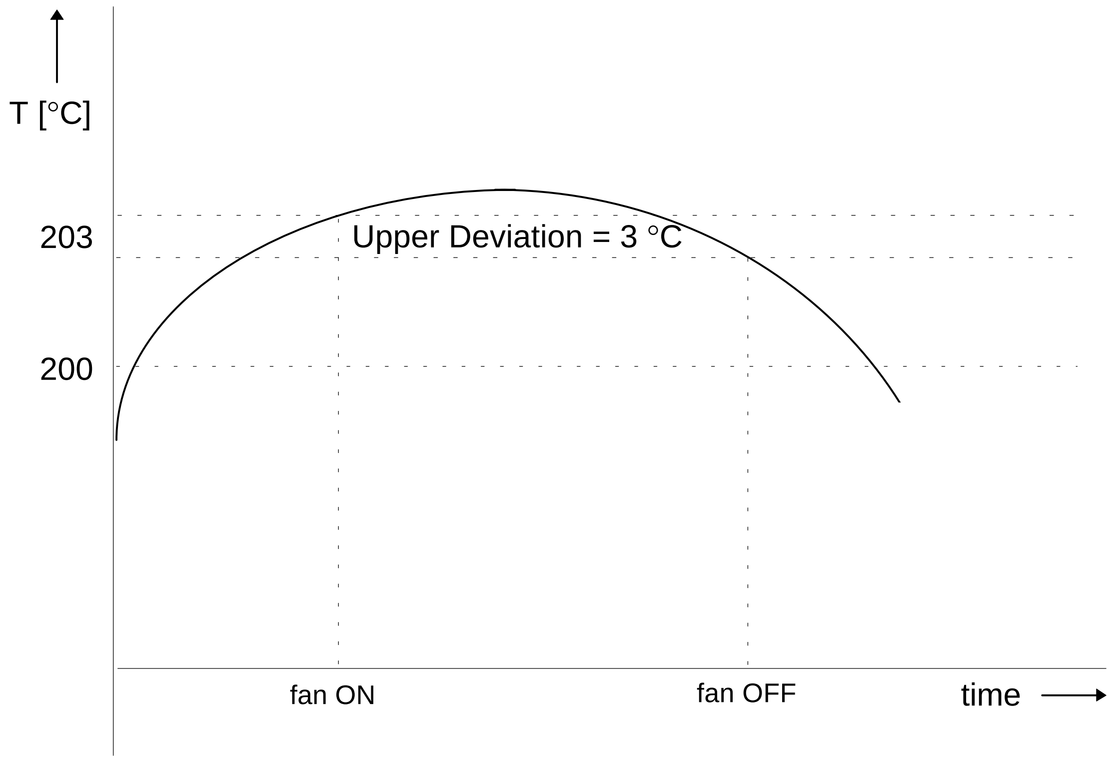


Figure C-1. Heating and Cooling Example 1

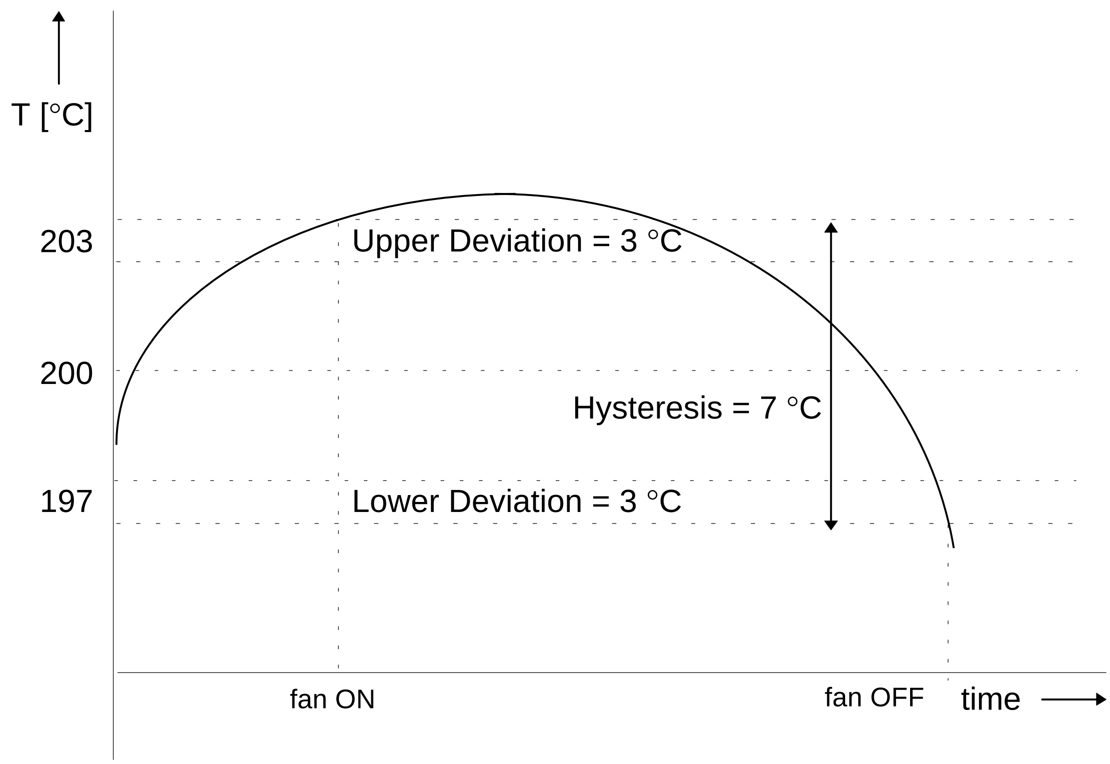


Figure C-2. Heating and Cooling Example 2

Implementing Low Voltage Bake-out

A heater system consisting of one or more heaters (zones) can run in a *bake-out* mode when an adequate low voltage is applied to heaters. Such a mode could be required when there is a danger of condensation in the heaters.

For such a purpose any unused zone can be used. The output of that zone can control a switch, which will apply either a low voltage (for example, 24 V) or a full, that is, a regular voltage to a (set of) heater(s). The zone must be configured to run in the *MANUAL* mode and its output value must be set to 100%. The thermocouple connected to the input of that zone should measure some average temperature of the system. The Upper Alarm temperature of that zone should be set to a value, T_d, which corresponds to a *switching* temperature from the baking to the regular mode. Now, while the current temperature of that zone is below the switching temperature, the output of that zone will be permanently in the ON position while the low voltage is applied to the rest of heaters. If the average temperature rises above T_d, the output will be automatically turned off because of the Upper Alarm condition and the controlled switch now will apply the regular operating voltage to the rest of heaters.

If, as a switching temperature between *baking* and *regular* mode, the temperature of a controlled zone itself must to be used, the Lower Alarm flag bit could be used for such a purpose. Such an arrangement would require the use of an Output Module (together with a suitable routine in the PLC program) to directly control the applied voltage to the heaters.

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