XC-E6TCA-P
Temperature control module

User's manual

Xinje Electronic Co., Ltd.

Catalog

1. Summarization

1.1 Introduction

XC-E6TCA-P is temperature control module. As the expansion module of PLC, it has 6 channels temperature signal input and support various types thermocouple. Each channel can self-study PID parameters and communicate with PLC. So based on this module, you can build your temperature control system with PLC, LCD screen and computer.

1.2 Features

- Support various types of thermocouple: K, J, S, E, N, T, R.
- DC-DC power supply isolated design, enhance the anti-jamming ability of the system
- Temperature display precision 0.1℃
- Each channel has independent PID parameters
- PID self-study under cooling, heating, transforming status
- FROM and TO instructions to communicate with PLC, enlarge the data storage space.

1.3 Using requirements

- PLC: hardware version 3.1e and above
- XCPpro software: version 3.1b and above
- Temperature sensor type: thermocouple K, S, E, N, J, T, R
- The measurement temperature should be higher than the module working temperature!

2 PID self-study introduction

2.1 PID knowledge

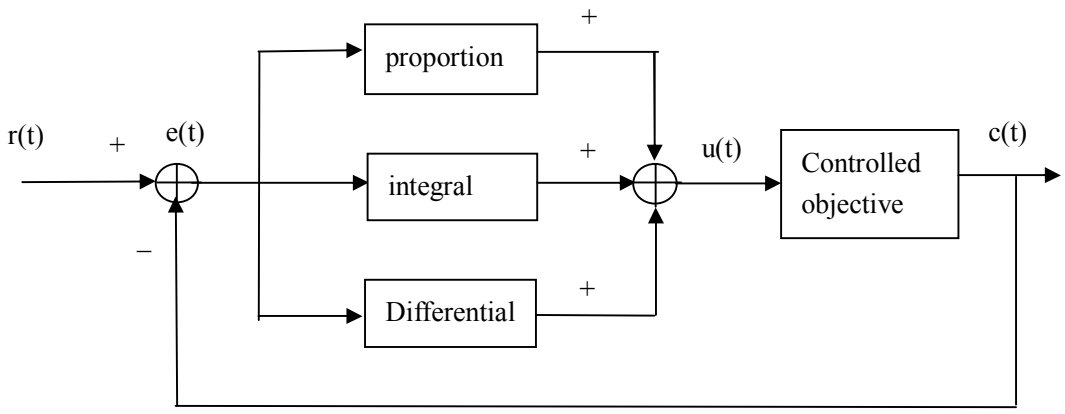
2.1.1 PID function

The most applied adjuster control rule is proportion-integral-differential control which is called PID for short in engineering field. PID controller has 70 years history since it is came out. It has

become one of the main industry control technologies because of its simple constitution, good reliability and stability and adjustable facility. We can use PID control technology under the following four conditions: the constitution and parameter of the control system are not commanded, can not get the precise mathematics model, other control technologies are unable to adopt, the constitution and parameter of the system controller only can be confirmed by experience and spot debug. It means the PID control technology is the most suitable way when the system or objective are unknown or unable to get the system parameters via effective measure method. PID controller calculates the control parameters according to system value differences based on proportion, integral, differential count.

XINJE PID control products are widely used and have high flexibility. There are only four parameters which need to be set: Kp, Ki, Kd, Diff.

PID control rule is as below:



PID control system principle figure

$$e(t) = r(t) - c(t) \quad (1\text{-}1)$$

$$u(t) = Kp\left[e(t) + \frac{1}{Ti}\int e(t)dt + TD\,\frac{d[e(t)]}{dt}\right] \quad (1\text{-}2)$$

e(t) is the windage, r(t) is the given value, c(t) is the actual value, u(t) is the control value
In formula (1-2), Kp is proportion coefficient, Ti is integral time coefficient, TD is differential time coefficient.

2.1.2 PID parameter

The functions of proportion parameter Kp, integral parameter Ki, differential parameter Kd, PID operation area Diff are as below:

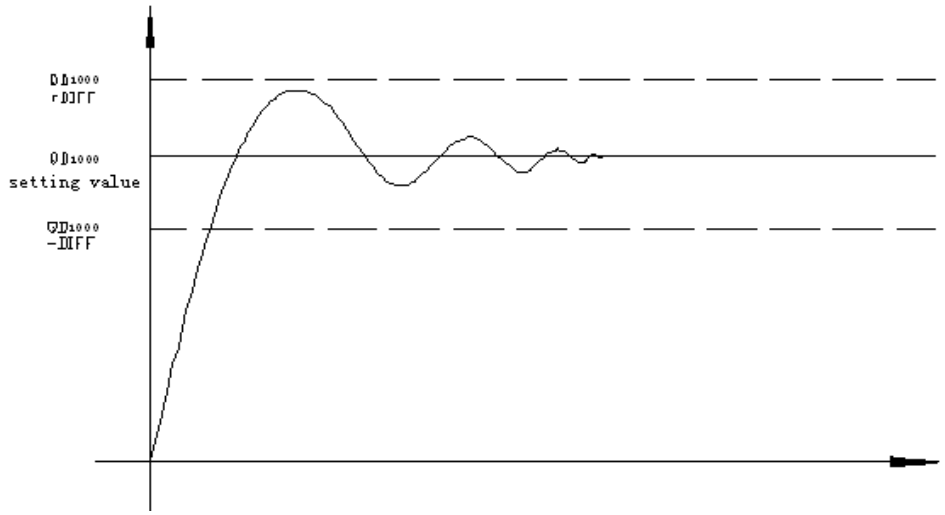
- Kp: Reflect the windage of system, control is carried out to reduce the windage once it appears.
- Ki: Be used to clear the still difference and improve the non-difference of system.
- Kd: Be used to control the change trend of the signal, reduce the system oscillation.
- Diff: To do PID control in defined area.
- Death: Death area parameter. Compared the current PID output with former PID output value,

if the minus value is less than the death area value, the module will abnegate the current value and output the former PID value.

2.1.3 PID control characteristic

The PID control is like this way: when measure value is less than QD-Diff, the controller full-scale outputs; when measure value is more than QD+Diff, the controller stops outputing; when it is among the area of (QD-Diff, QD+Diff), the controller does the PID adjustment.

PID control curve:



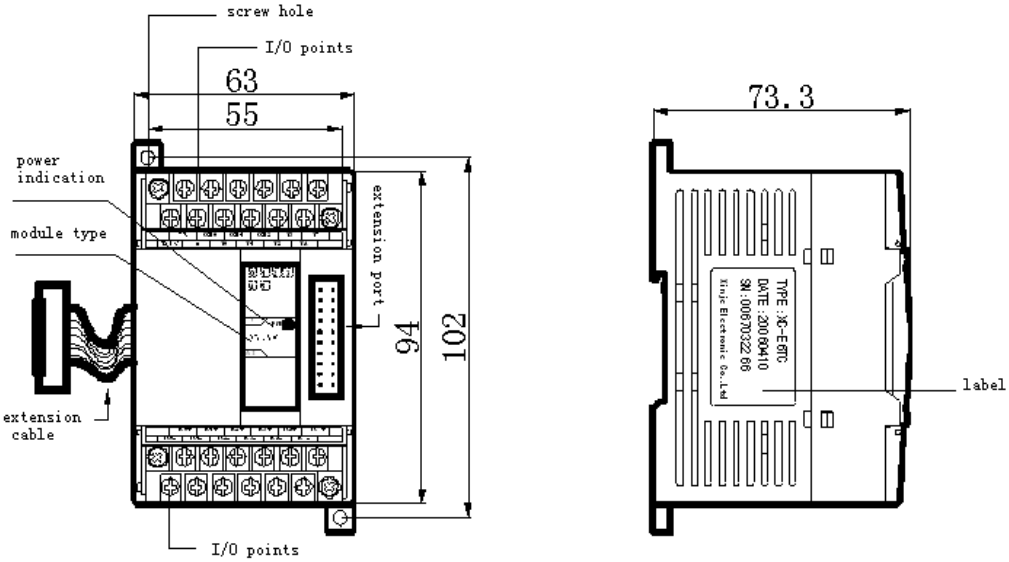
Reference value: Kp=20~100; Ki=5~20; Kd=200~800; DIFF=100~200.

2.2 Self-study knowledge

If the user does not know how to set the PID parameters, they can choose self-study mode which makes the system to find the optimal parameters automatically (sampling time, Kp, Ti, TD).

3 Module specs and parameters

3.1 Dimension and function



The function of each part:

Name	Function
Power indication	The light is on when power on
Module type	The type of this module
Expansion port	Connect with other module
I/O points	Connect with analog I/O and exterior device, enable to tear down
DIN rail pothook	For installation, pull down the pothook when tear down
Mounting hole	Use M3 screw for installation
Expansion cable	Use the cable to connect the module with PLC

General specs:

Item	Specs
Environment	No causticity gas
Environment temperature	0℃~60℃
Conservation temperature	-20~70℃
Environment humidity	5~95%
Conservation humidity	5~95%
Measure temperature range	0℃ ~ 1000℃
Temperature signal input channel	6 channels
Resolution	0.1℃

Integrated precision	0.1℃
Transform speed	20ms per channel
Installation	Fix the module with M3 screw or assemble it on DIN46227 rail (Width 35mm)
Outline dimension	63mm×102mm×73.3mm

3.2 I/O points

The I/O points of XC-E6TCA-P are as below:

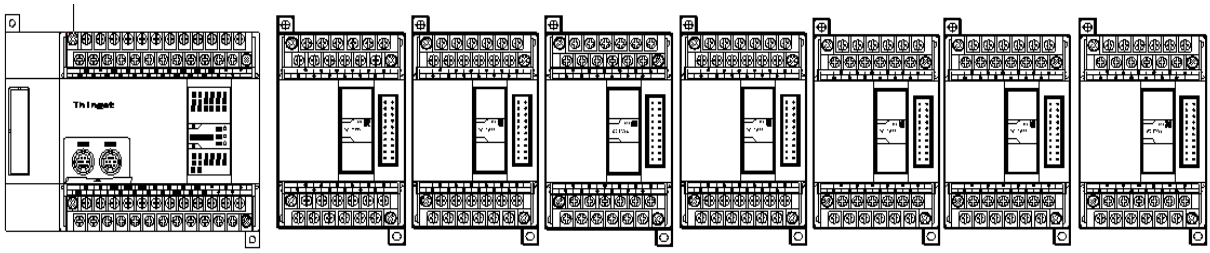
	0V	COM0	COM1	COM2	Y3	Y5	
	24V	.	.Y0	Y1	Y2	Y4	

	TC0+	TC1+	TC2+	TC3+	TC4+	TC5+	
	TC0-	TC1-	TC2-	TC3-	TC4-	TC5-	

Name	Note		
Input points (TC0+,TC0,…,TC5+,TC5-)	6 channels	Analog input: thermocouple temperature sensor Range: 0℃～1000℃	
Output points (Y0~Y5)	6 channels	Analog output	Digital form: 0~4095
		On-off output	Mark-space ratio form: Y point output when put through

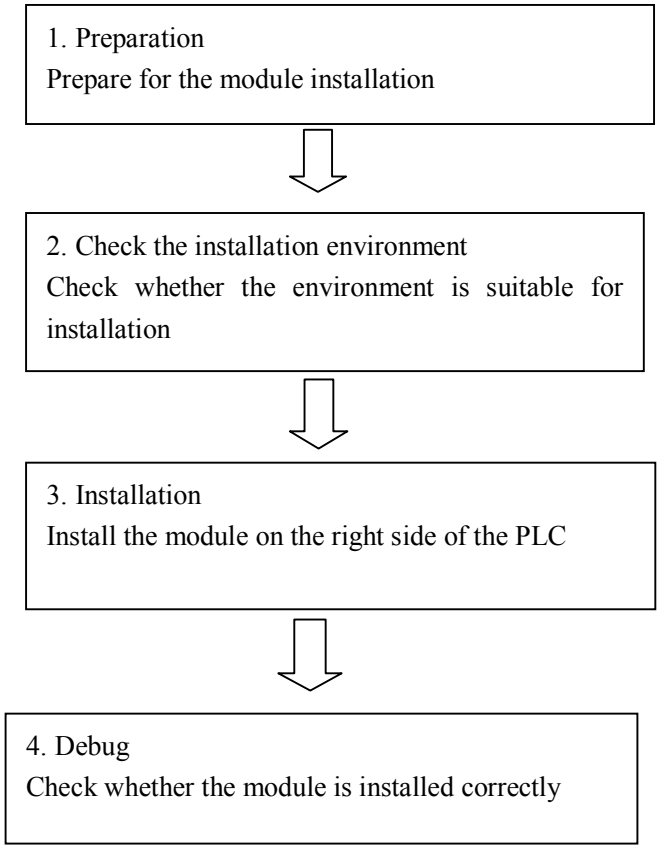
3.3 Module configuration

XC series PID control module can fix on the right side of XC series PLC, expansion units, special module.



XINJE PLC can extend 7 modules and 1 BD board. The type can be I/O on-off quantity, analog quantity, temperature control module, etc.

3.4 Installation steps and environment



(1) Do not install the module under below environment:

sunshine 	temperature more than 0-50℃ 	humidity more than 35-85% RH 
dew 	causticity and inflammability gas 	dust, salt, iron bits and lampblack 
oscillation and crash 	splash water, oil and medicine 	strong electric or magnetic field 

Installation request:

Please install the module on DIN46277 rail (width 35mm) or use M3 screw to fix the module.

Attention:

- Confirm the type and choose the suitable module.
- Do not let the iron or wire bits drop into the module.
- Confirm the module type again before installation.
- Make sure the connection is stable, if the wire is loose the data will be incorrect and result in circuit shorting.

 ***Make sure the power is cut off for installation and layout***

4 Module address

4.1 Work mode

XC-E6TCA-P can connect with various types of thermocouple. In order to configure them, we give a number for each type:

No.	1	2	3	4	5	6	7
Sensor type	K	S	E	N	J	T	R

To choose the thermocouple type for each channel, you should set the data in FD8250 and FD8251 of PLC.

FD8250

channel 1				**channel 0**			
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Write type NO.				Write type NO.			
channel 3				**channel 2**			
Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8
Write type NO.				Write type NO.			

FD8251:

channel 5				**channel 4**			
Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
Write type NO.				Write type NO.			
/				/			
Bit15	Bit14	Bit13	Bit12	Bit11	Bit10	Bit9	Bit8

For example: channel 0 is type K(No.1), channel 1 is type E(No.3), channel 5 is type S(No.2), so FD8250=31H, FD8251=20H.

4.2 Module data address

Parameters	Explanation				
	Channel	Ch0	Ch1	……	Ch5
Display temperature Unit: 0.1 ℃	Module 1	ID100	ID101	ID10×	ID105
	Module 2	ID200	ID201	ID20×	ID205
	……	ID×00	ID×01	ID×0×	ID×05
	Module 7	ID700	ID701	ID70×	ID705
PID output (return to the X input of PLC)	Module 1	X100	X101	X10×	X105
	Module 2	X200	X201	X20×	X205
	……	X×00	X×01	X×0×	X×05
	Module 7	X700	X701	X70×	X705
Connection state of thermocouple(0 is connection, 1 is cut connection)	Module 1	X110	X111	X11×	X115
	Module 2	X210	X211	X21×	X215
	……	X×10	X×11	X×1×	X×15
	Module 7	X710	X711	X71×	X715
Enable signal	Module 1	Y100	Y101	Y10×	Y105
	Module 2	Y200	Y201	Y20×	Y205
	……	Y×00	Y×01	Y×0×	Y×05
	Module 7	Y700	Y701	Y70×	Y705
PID self-study error signal bit(0 is normal, 1 is error)	Module 1	X120	X121	X12x	X125
	Module 2	X220	X221	X22x	X225
	…..	Xx20	Xx21	Xx2x	Xx25
	Module 7	X720	X721	X72x	X725
self-study PID control bit	self-study triggered signal, enter into self-study mode when setting 1. After ending self-study, PID parameters and temperature control period value are refreshed, the bit value is cleared to be 0. The user can read the bit to know the state. 1 means self-study is ongoing. 0 means self-study has ended.				
PID output (The result)	Digital quantity output range is 0~4095. When the PID output is analog quantity (steam valve open degree or silicon-controlled conduction angle), the value can be transmitted to the analog quantity output module in order to realize the control demand.				
PID parameters (P, I, D)	The best PID parameters got from the PID self-study. If the current PID parameters can not meet the control requirements, users can set the experience PID parameters to make the module work according to the user setting value.				
PID calculation range (Diff) Unit: 0.1℃	PID arithmetic is effective in the range of T (setting temperature) ±Diff. In real temperature control environment, when the temperature is lower than T- Diff, the PID output is the maximum value; when the temperature is higher than T+Diff, the PID output is the minimum value.				
Temperature difference value δ Unit: 0.1℃	(sampling temperature value + temperature difference value δ) / 10 = display temperature. At the time the display temperature is the most close to the real temperature. This parameter is a sign value with the unit of 0.1℃, the value is retained when th power is cut off, the defaulted value is 0.				
Set temperature	The target temperature of the control system. Range from 0~1000℃, precision degree is 0.1℃.				

Unit: 0.1℃	
Temperature control period Unit: 0.1s	The temperature control period range from 0.5 to 200 seconds, the minimum precision is 0.1 second. The set value = real value × 10. For example: if the real temperature control period is 0.5 seconds, user should set 5 seconds in the module.
Adjusting environment temperature Unit: 0.1℃	If user realizes that the environment temperature is different from display temperature, they can write the correct environment temperature into the module. Then the module will calculate the temperature difference δ and save it. Temperature difference δ = adjusting environment temperature－sampling temperature. Unit: 0.1℃. For example, under the caloric balance condition, users measured the environment temperature is 60℃ with mercury thermometer, but the display temperature is 55℃ (sampling temperature is 550), temperature difference δ is 0. At this time, users can set the parameter to be 600, then the temperature difference δ is 50 (5 ℃). Display temperature = (550 + 50) / 10 = 60 ℃. **Attention: when setting the adjusting environment temperature, make sure it is the same as environment temperature. It is very important because the incorrect parameter will result in mistake of calculating temperature difference δ and affect the display temperature.
self-study output range	The self-study output unit is percent. 100 means the mark-space ratio is 100% of the full-scale output, 80 means the mark-space ratio is 80% of the full-scale output.

4.2 Related address definition

When using the module, it needs to write and read the parameters, the parameters' address are as below:

1. Read instruction: FROM

The operating objective address:

Address	**Description**	
K0	Self-study PID control state signal	
K1	Ch0	PID output
K2	Ch1	PID output
:	:	:
K6	Ch5	PID output
K7	Ch0	PID parameter P
K8		PID parameter I
K9		PID parameter D
K10		PID parameter Diff
K11	Ch1	PID parameter P
K12		PID parameter I
K13		PID parameter D
K14		PID parameter Diff
:	:	:

K27	Ch5	PID parameter P
K28		PID parameter I
K29		PID parameter D
K30		PID parameter Diff
K31	Ch0	Temperature difference value
K32	Ch1	Temperature difference value
:	:	:
K36	Ch5	Temperature difference value

2. Write instruction: TO

The operating objective address:

Address	**Description**	
K0	Self-study PID trigger signal	
K1	Ch0	Setting temperature
K2	Ch1	Setting temperature
:	:	:
K6	Ch5	Setting temperature
K7	Ch0	PID parameter P
K8		PID parameter I
K9		PID parameter D
K10		PID parameter Diff
K11	Ch1	PID parameter P
K12		PID parameter I
K13		PID parameter D
K14		PID parameter Diff
:	:	:
K27	Ch5	PID parameter P
K28		PID parameter I
K29		PID parameter D
K30		PID parameter Diff
K31	Ch0	Temperature control period
K32	Ch1	Temperature control period
:	:	:
K36	Ch5	Temperature control period
K37	Ch0	Adjusting environment temperature
K38	Ch1	Adjusting environment temperature
:	:	:
K42	Ch5	Adjusting environment temperature
K43	Ch0	Self-study output range
K44	Ch1	Self-study output range

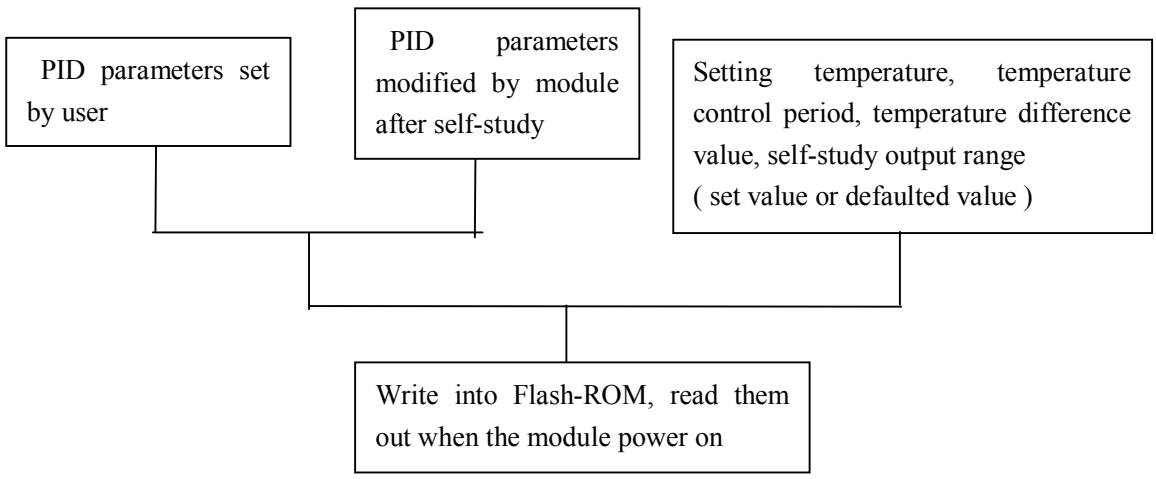
:	:	:
K48	Ch5	Self-study output range

The module can save the parameters which include temperature, PID parameters (P, I, D, Diff...), temperature difference value, temperature control period, self-study output range, etc. The module will save the parameters after self-study finishing or user modifying then take out them to do related operations when rebooting.
The module's defaulted value of the parameters when leaving factory:

Parameter		**Defaulted value**					
Setting temperature (ºC)		CH0	CH1	CH2	CH3	CH4	CH5
		0	0	0	0	0	0
PID parameters	P	40	40	40	40	40	40
	I	1200	1200	1200	1200	1200	1200
	D	300	300	300	300	300	300
	Diff	10	10	10	10	10	10
Temperature control period (unit: 0.1s)		20	20	20	20	20	20
Temperature difference (Sign value)		0	0	0	0	0	0
self-study output range		100	100	100	100	100	100

5. Module work process and principle

The module work process is as below:
When the module power on, it reads the PID parameters, target temperature, temperature control period, self-study output range. So even the module power off and power on again, these parameter will still be kept.

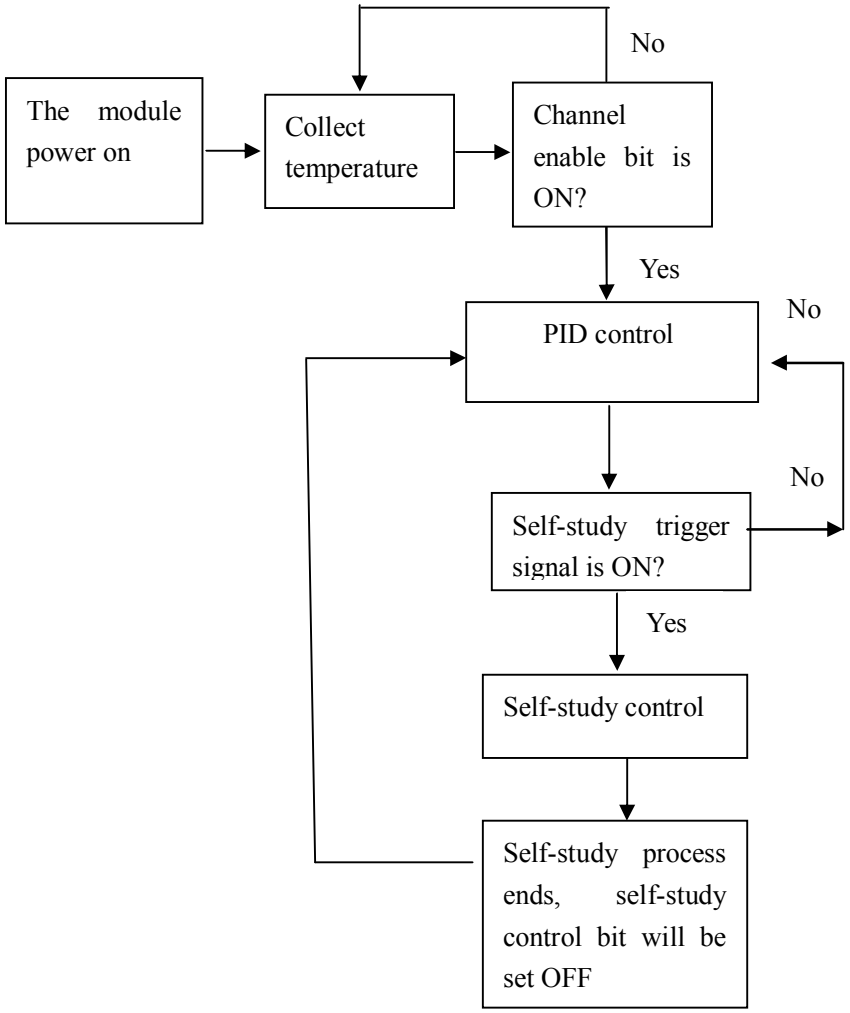


After power on and read all the parameters, the module starts to collect the temperature. Then write the target temperature, temperature control period, self-study output range into the module.
The module judges the enable signal of each channel, if the signal is ON, it starts the PID control for the object.
Meanwhile, the module will judge if there is self-study trigger signal.
If the trigger signal is ON, when the rise edge coming, the self-study process will begin and the state bit will be set ON; when the self-study process is completed, state bit and trigger signal will be set OFF; then the module enter into PID control.
If the self-study trigger signal is not ON, the module will keep doing PID control.

Pay attention to this:

The module does PID control process according to PID parameters, target temperature, temperature control period. If the temperature control period is 0, this channel will not output and only collect temperature.

The control process chart is as below:

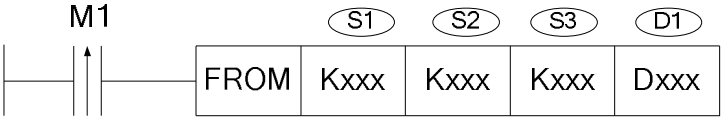


6. Write and read instructions

6.1 Instruction explanation

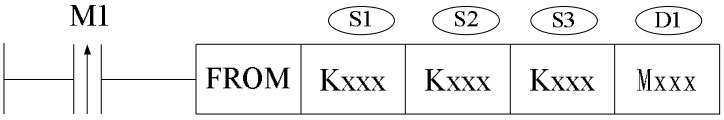
PLC can read and write parameters of XC-E6TCA-P via FROM and TO instruction.

1. Read instruction: **FROM**
This instruction can read the data from the module. It can divide into bit and word operation.
(1) word operation



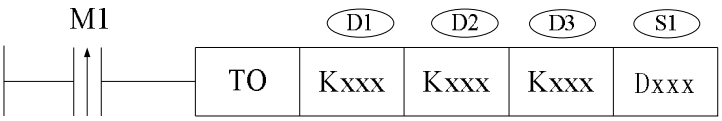
Function: read the data of the module and save them in PLC register, object operand unit is word.
Operand explanation:
S1: target module number. Operand: K, TD, CD, D, FD.
S2: the data head address of the module. Operand: K, TD, CD, D, FD.
S3: the register quantity (how many words). Operand: K, TD, CD, D, FD.
D1: the register head address of the PLC.

(2) bit operation



Function: read the data of the module and save them in PLC coil, object operand unit is bit.
Operand explanation:
S1: target module number. Operand: K, TD, CD, D, FD.
S2: the data head address of the module. Operand: K, TD, CD, D, FD.
S3: the data quantity (how many bits). Operand: K, TD, CD, D, FD.
D1: the coil head address of the PLC. Operand: M, Dn.m.

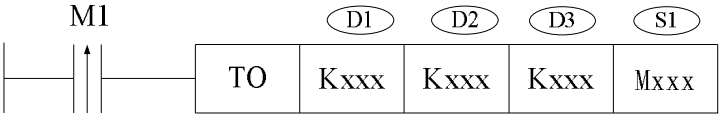
2. Write instruction: **TO**
This instruction can write the data to the module. It can divide into bit and word operation.
(1) word operation



Function: write the data of PLC register to the module, object operand unit is word.

Operand explanation:
D1: target module number. Operand: K, TD, CD, D, FD.
D2: the head address of the module. Operand: K, TD, CD, D, FD.
D3: the register quantity (how many words). Operand: K, TD, CD, D, FD.
S1: the register head address of the PLC.

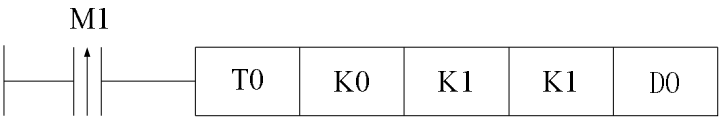
(2) bit operation



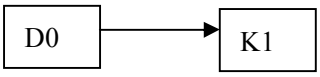
Function: write the data of PLC coil to the module, object operand unit is bit.
Operand explanation:
D1: target module number. Operand: K, TD, CD, D, FD.
D2: the head address of the module. Operand: K, TD, CD, D, FD.
D3: the data quantity (how many bits). Operand: K, TD, CD, D, FD.
S1: the coil head address of the PLC. Operand: M, Dn.m.

6.2 Instruction application

1. Set the target temperature

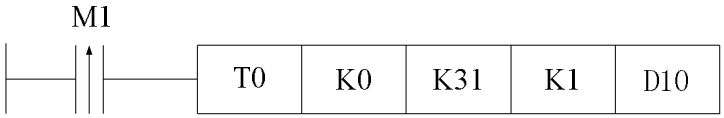


Explanation:
PLC register module address



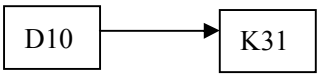
First save target temperature in D0, when set on M1, the data of D0 will write to module address K1(channel 0 set temperature).
D0=200 means the target temperature is 200 ºC.
Operand meaning:
TO: write instruction
K0: the module number is 0
K1: the data address in the module
K1: write word quantity is 1 word
D0: the PLC register saved the data

2. Set the temperature control period



Explanation:

PLC register module address



Write the temperature control period (D10) to module channel 0 (K31) when M1 is set on.

D10 = 25 means the temperature control period is 2.5 seconds.

Operand meaning:

TO: write instruction

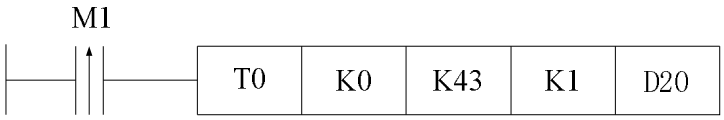
K0: module number is 0

K31: the data address in the module

K1: word quantity is 1 word

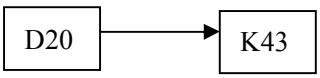
D10: the PLC register saved the data

3. Self-study output range



Explanation:

PLC register module address



Write the self-study output range (D20) to module channel 0 (K43) when M1 is set on.

D20 = 80 means the self-study output range is 80% of the full-scale.

Operand meaning:

TO: write instruction

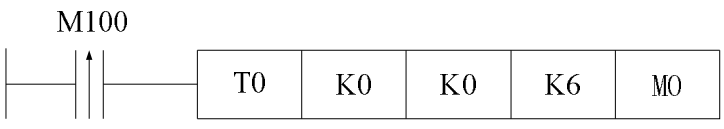
K0: module number is 0

K43: the data address in the module

K1: write word quantity is 1 word

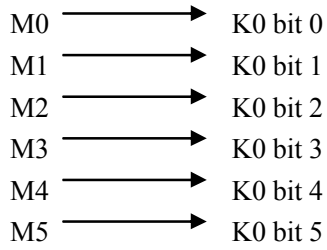
D20: the PLC register saved the data

4. Set on the self-study trigger bit



Explanation:

PLC coil module address



Write M0~M5 to the module address K0 when M100 is set on. If M0 = 1, start the self-study process of channel 0. If M1 = 1, start the self-study process of channel 1.....

Operand meaning:

TO: write instruction

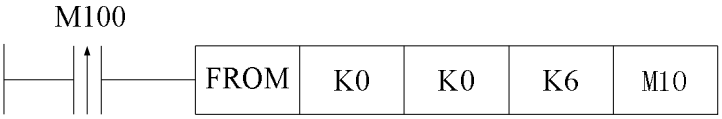
K0: module number is 0

K0: the data address in the module

K6: the write bit quantity is 6 bits

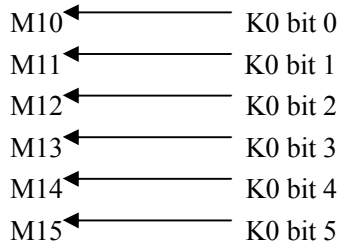
M0: the head address of the data in the PLC.

5. Read the self-study state bit



Explanation:

PLC coil module address



read self-study state bit of every channel and save them in M10~M15. If M10 is ON, then channel 0 is doing self-study; if M10 is OFF, the self-study process is completed or never begins. If M11 is ON, the channel 1 is doing self-study.....

Operand meaning:

FROM: read instruction

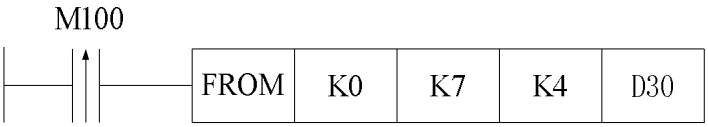
K0: the module number is 0

K0: the data address in the module

K6: read bit quantity is 6 bits

M10: the head address of the data saved in the PLC

6. Read PID parameters

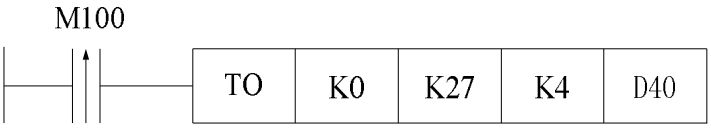


Explanation:

PLC register		module address
D30	←	K7
D31	←	K8
D32	←	K9
D33	←	K10

read the PID parameters (channel 0) and save them in D30~D33 of the PLC.
D30 = P, D31 = I, D32 = D, D33 = Diff parameter.
Operand meaning:
FROM: read instruction
K0: the module number is 0
K7: the data address of the module
K4: read word quantity is 4 words
D30: the head address of the data saved in the PLC

7. Write the PID parameters



Explanation:

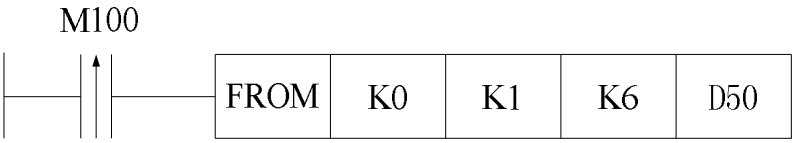
PLC register		module address
D40	→	K27
D41	→	K28
D42	→	K29
D43	→	K30

Users can save the PID parameters in D40~D43 then write them to the module channel 5.
Operand meaning:
TO: write instruction
K0: the module number is 0
K27: the data address in the module
K4: write word quantity is 4 words
D40: the head address of the data saved in the PLC

8. Open the enable bit signal
Explanation:

For module number one, channel 0~5 are corresponding to Y100~Y105; for module number two, channel 0~5 are corresponding to Y200~Y205..... So set on the corresponding enable bit to start the PID control for the channel.

9. Read PID output



Explanation:

PLC register		module address
D50	←	K1
D51	←	K2
D52	←	K3
D53	←	K4
D54	←	K5
D55	←	K6

During PID control process, users can read PID output of every channel and save them in D50~D55.

Operand meaning:

FROM: read instruction

K0: the module number is 0

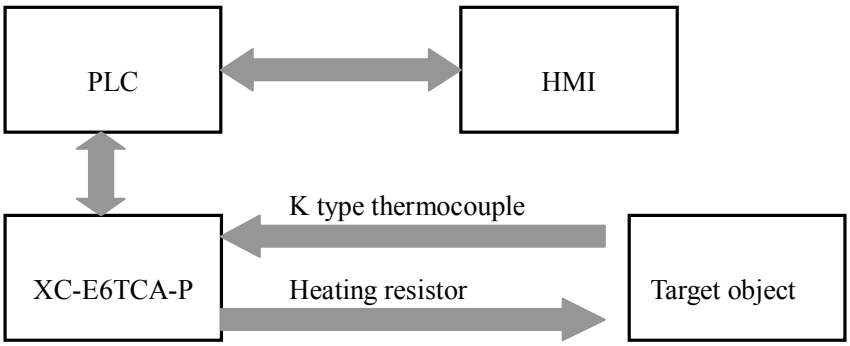
K1: data address in the module

K6: read word quantity is 6 words

D50: the head address of data in the PLC

7. Application example

For this example, we will control 5 channels of temperature by using XC-6TCA-P.
The whole control system includes TP series HMI, XC series PLC, XC-6TCA-P, K type thermocouple, heating resistor and other devices. The system chart is shown as following:



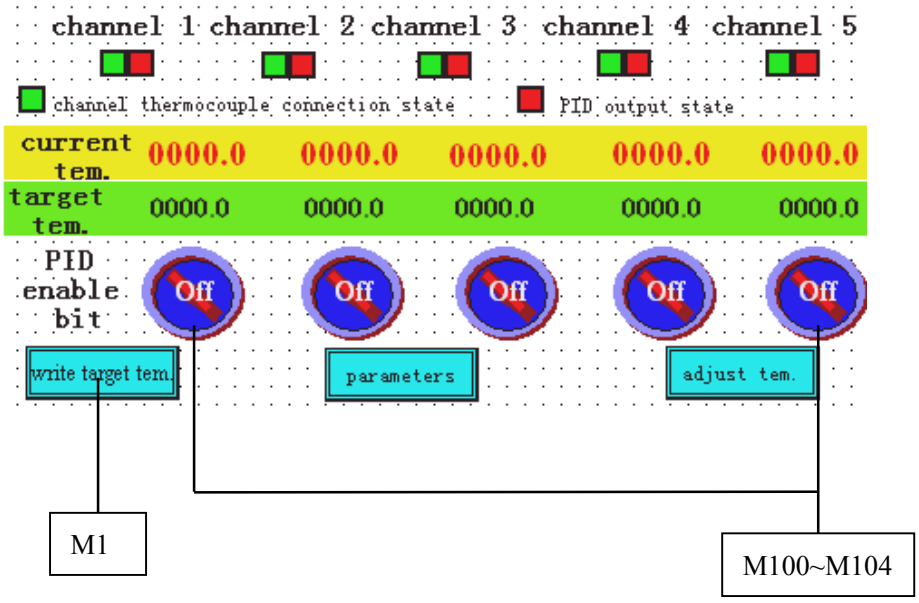
The control processes are as the following:

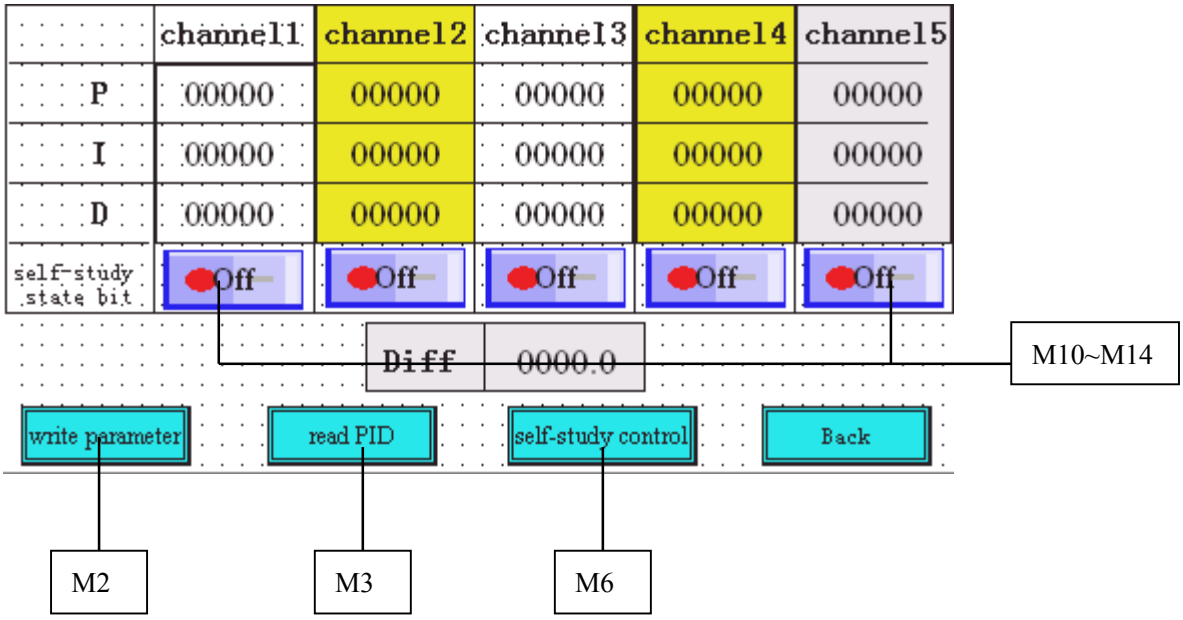
1. Power on the XC-6TCA-P to read the current temperature, display them on the HMI.
2. Write the target temperature, turn on “write target temperature” button on the HMI, the value will be written into XC-6TCA-P.
3. If user wants to modify the default PID parameters, input the PID value and turn on “PID enable bit” button on the HMI, XC-6TCA-P will enter PID control process.
4. If XC-6TCA-P needs to self-study, turn on the “self-study state bit” then turn on “self-study control bit” on the HMI to start the self-study process.
5. To monitor the “self-study state bit”, you can see if the self-study process is over.
6. Turn on “read PID parameters” to read the PID parameters of each channel.
7. If you want to adjust the ambient temperature, push the “adjust ambient temperature” button to enter the adjustment screen.

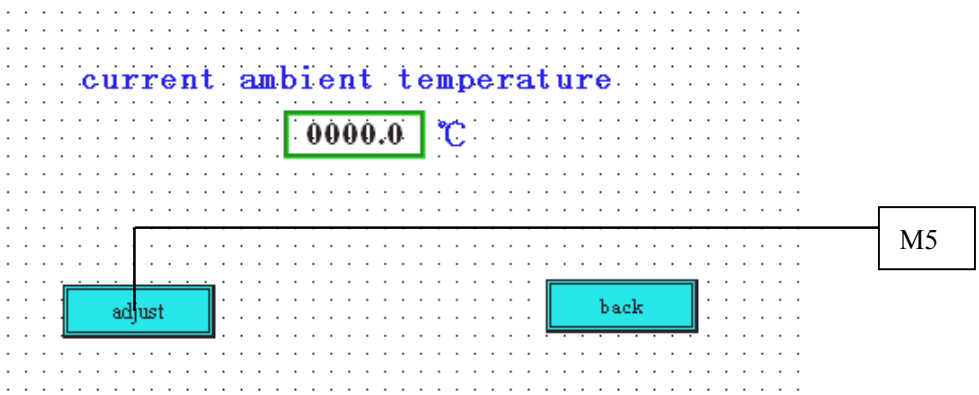
First of all, set the thermocouple types in the XCPpro software. As the 0~4 channels are K type thermocouple, set FD8250 to 1111H, FD8251 to 01H.
Next, please see the corresponding address of PLC and XC-6TCA-P.

PLC		XC-6TCA-P	Remark
M10-M14	↔	K0	Self-study enable bit
M100-M104	↔	Y100-Y104	0~4 channel PID enable bit
D4000-D4004	↔	K1-K5	0~4 channel target temperature
D4050-D4069	↔	K7-K26	0~4 channel P,I,D,DIFF values
D10-D14	↔	K37-K40	0~4 channel adjustment temperature

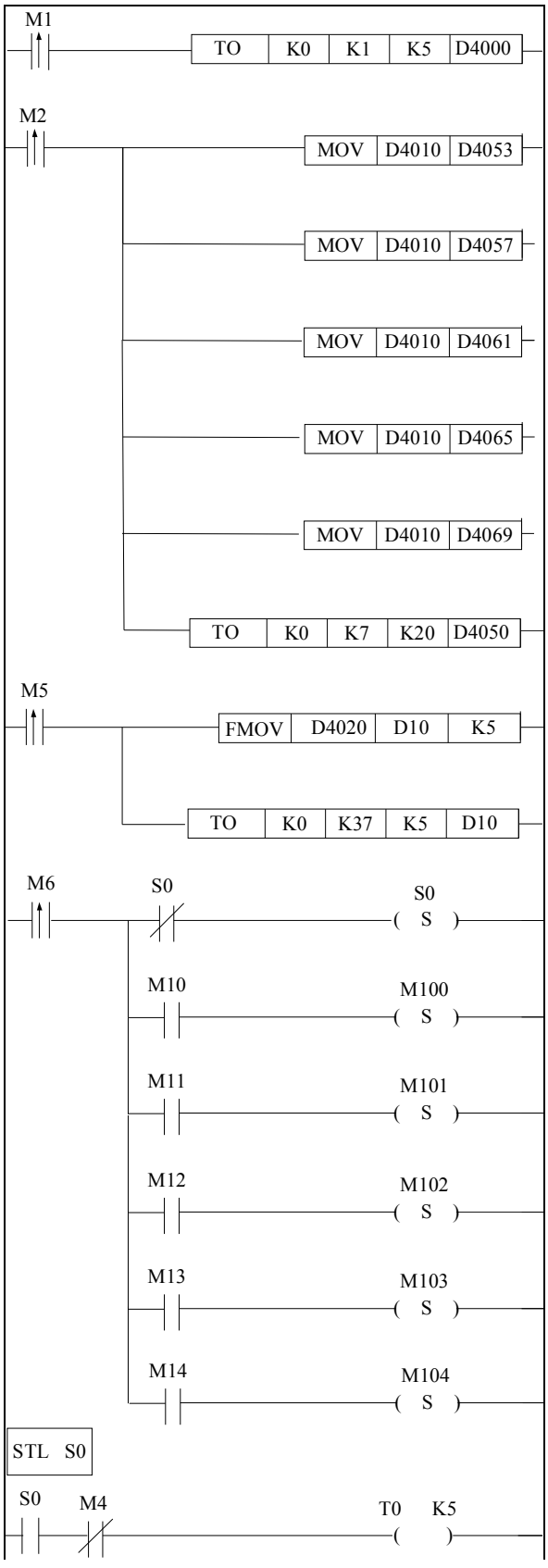
The HMI screens are as the following:







The ladder chart:



Write channel 0~4 target temperature into XC-6TCA-P address K1~K5

Move the value of D4010 to D4053, (channel 0 DIFF value)

Move the value of D4010 to D4057, (channel 1 DIFF value)

Move the value of D4010 to D4061, (channel 2 DIFF value)

Move the value of D4010 to D4065, (channel 3 DIFF value)

Move the value of D4010 to D4069, (channel 4 DIFF value)

Write the value of D4050-D4069 into K7-K26,(channel 0~4 P,I,D,DIFF value)

Write the value of D4020 to D10-D14, (ambient temperature)

Write the value of D10-D14 to K37-K41, (channel 0~4 adjust ambient temperature)

Set on M6 to enter process S0;

Set on M100 when M10 is on

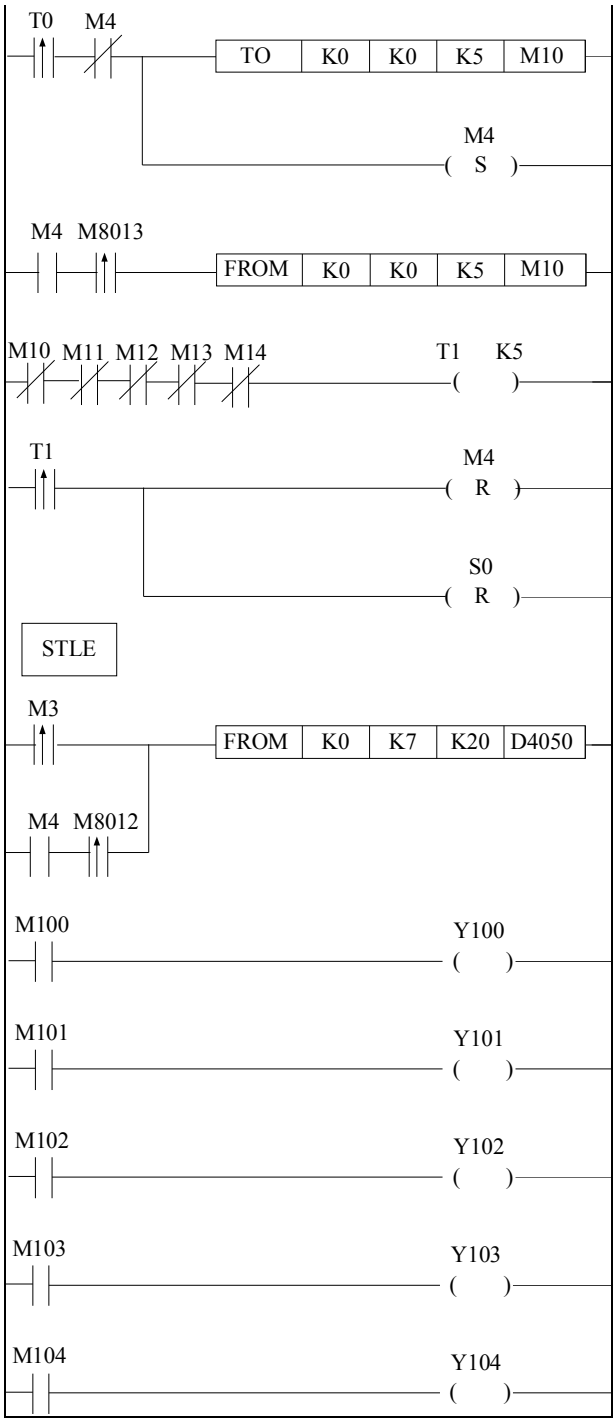
Set on M101 when M11 is on

Set on M102 when M12 is on

Set on M103 when M13 is on

Set on M104 when M14 is on

Process S0 is on, delay 5ms



Write the value of M10~M14 to K0 (self-study trigger bit)

M4 is self-study process sign bit

Read the value of K0 to M10~M14 every 1s, to see if the self-study process has been finished.

If the self-study has been finished or never begun, delay 5ms

After 5ms, reset M4.

Reset process S0

Read the P, I, D, DIFF value of channel 0~4

Read the P, I, D, DIFF value every 100ms

Open channel 0 PID control bit

Open channel 1 PID control bit

Open channel 2 PID control bit

Open channel 3 PID control bit

Open channel 4 PID control bit