



# 8

## PID Control Function

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In this chapter, we mainly introduce the applications of PID instructions for XC series PLC basic units, including: call the instructions, set the parameters, items to notice, sample programs etc.

### 8-1. Brief Introduction of The Functions

### 8-2. Instruction Formats

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## 8-1 . Brief Introductions of The Functions

PID instruction and auto tune function are added into XC series PLC basic units (Version 3.0 and above). Via auto tune method, users can get the best sampling time and PID parameters and improve the control precision.

The previous versions can not support PID function on basic units unless they extend analog module or BD cards. PID instruction has brought many facilities to the users.

1. The output can be data form **D** and on-off quantity **Y**, user can choose them freely when program.
2. Via auto tune, users can get the best sampling time and PID parameters and improve the control precision.
3. User can choose positive or negative movement via software setting. The former is used in heating control, the later is used in cooling control.
4. PID control separates the basic units with the expansions, this improves the flexibility of this function.

## 8-2 . Instruction Forms

### 1、 Brief Introductions of the Instructions

Execute PID control instructions with the data in specified registers.

PID control [PID]			
16 bits instruction	PID	32 bits instruction	-
Executing Condition	Normally ON/normally closed coil activates	Suitable Models	XC2、 XC3、 XC5、 XCM
Hardware Condition	V3.0 or above	Software Condition	V3.0 or above

### 2、 Operands

Operands	Usage	Type
S1	set the ID Nr. of the target value (SV)	16bits, BIN
S2	set the ID Nr. of the tested value (PV)	16 bits, BIN
S3	set the first ID Nr. of the control parameters	16 bits, BIN
D	the ID Nr. of the operation resule (MV) or output port	16 bits, BIN

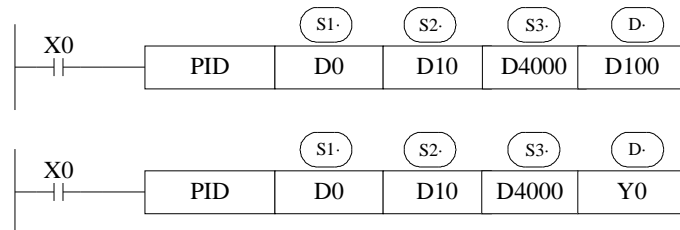
### 3、Suitable soft components

Word Type	Operands	System								Constant	Module	
		D	FD	ED	TD	CD	DX	DY	DM	DS	K/H	ID
S1												
S2												
S3												
D												

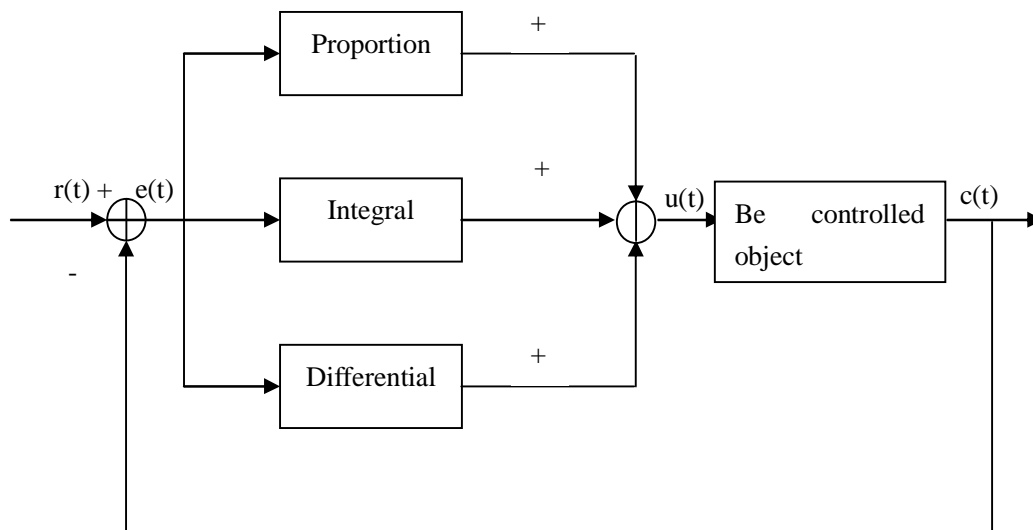
  

Bit Type	Operands	System						
		X	Y	M	S	T	C	Dnm
D								

**Functions and Actions**



- | S3~ S3+ 43 will be occupied by this instruction, so please don't use them as the common data registers.
- | This instruction executes when each sampling time interval comes.
- | To the operation result **D**, the data registers are used to store PID output values; the output points are used to output the occupy ratio in the form of ON/OFF.
- | PID control rules are shown as below:



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

$$u(t) = K_p [ e(t) + 1/T_i \int e(t)dt + TD \frac{de(t)}{dt} ] \tag{1-2}$$

Here,  $e(t)$  is error,  $r(t)$  is the given value,  $c(t)$  is the actual output value,  $u(t)$  is the control value;

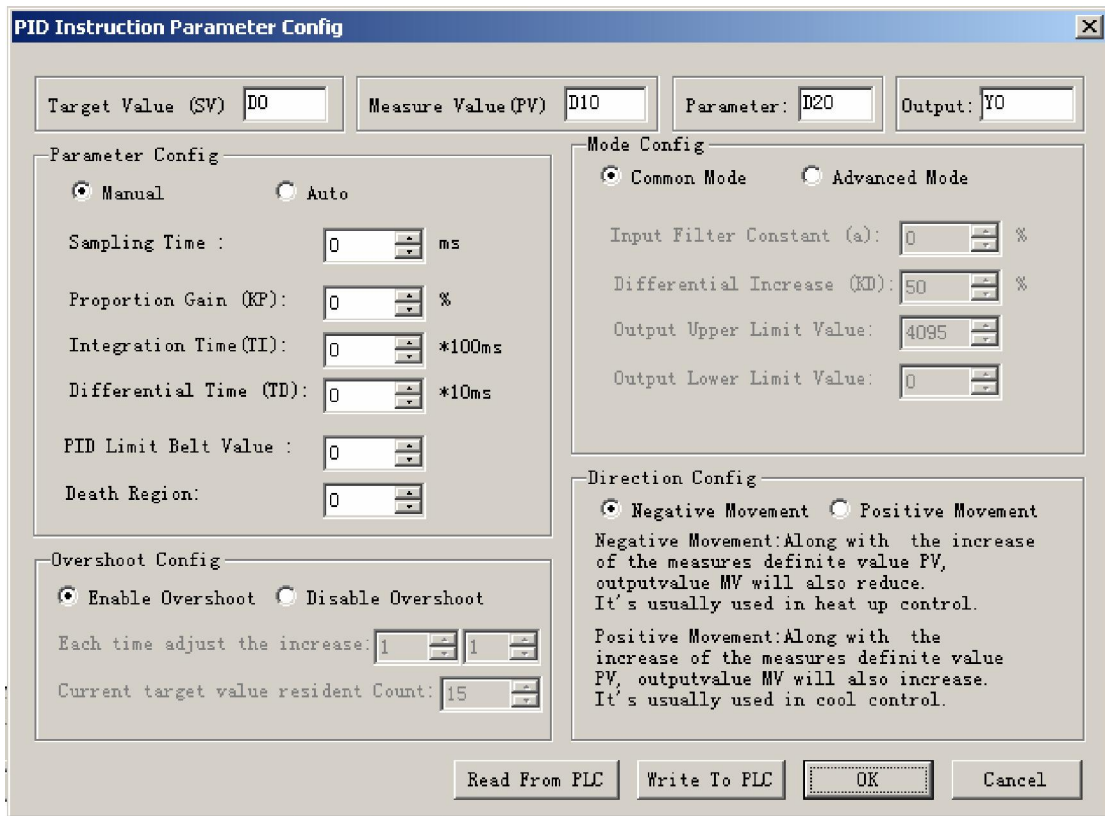
In function (1-2),  $K_p$  is the proportion coefficient,  $T_i$  is the integration time coefficient, and  $TD$  is the differential time coefficient.

The result of the operation:

1. Analog output:  $MV = \text{digital form of } u(t)$ , the default range is 0 ~ 4095.
2. Digital output:  $Y = T * [MV / \text{PID output upper limit}]$ .  $Y$  is the output's activate time within the control cycle.  $T$  is the control cycle, equals to the sampling time. PID output upper limit default value is 4095.

### 8-3 . Parameters Setting

Users can call PID instruction in XCP Pro software directly and set the parameters in the window (see graph below), for the details please refer to XCPPro user manual. Users can also write the parameters into the specified registers by MOV instructions before PID operation.



### 8-3-1 . Registers and their functions

For PID control instruction's relative parameters ID, please refer to the below table:

ID	Function	Description	Memo
S3	sampling time	32 bits without sign	Unit: ms
S3+1	sampling time	32 bits without sign	Unit: ms
S3+2	mode setting	bit0: 0: Negative; 1 Negative; bit1 ~ bit6 not usable bit7: 0: Manual PID; 1: auto tune PID bit8: 1: auto tune successful flag bit9 ~ bit14 not usable bit15: 0: regular mode; 1: advanced mode	
S3+3	Proportion Gain (Kp)	Range: 1 ~ 32767[%]	
S3+4	Integration time (TI)	0 ~ 32767[*100ms]	0 is taken as no integral.
S3+5	Differential time (TD)	0 ~ 32767[*10ms]	0 is taken as no differential.
S3+6	PID operation zone	0 ~ 32767	PID adjustment band width value.
S3+7	control death zone	0 ~ 32767	PID value keeps constant in death zone
S3+8	PID auto tune cycle varied value	full scale AD value * ( 0.3~1% )	
S3+9	PID auto tune overshoot permission	0: enable overshoot 1:disable overshoot	
S3+10	current target value adjustment percent in auto tune finishing transition stage		
S3+11	current target value resident count in auto tune finishing transition stage		
S3+12~ S3+39	occupied by PID operation's internal process		
<b>Below is the ID of advanced PID mode setting</b>			
S3+40	Input filter constant (a)	0 ~ 99[%]	0: no input filter
S3+41	Differential gain (KD)	0 ~ 100[%]	0: no differential gain
S3+42	Output upper limit value	-32767 ~ 32767	
S3+43	Output lower limit value	-32767 ~ 32767	

## 8-3-2 . Parameters Description

### | **Movement Direction:**

- ∅ Positive movement: the output value MV will increase with the increasing of the detected value PV, usually used for cooling control.
- ∅ Negative movement: the output value MV will decrease with the increasing of the detected value PV, usually used for heating control.

### | **Mode Setting**

#### ∅ Common Mode:

The parameter's register zone is from **S3** to **S3+43**, **S3** to **S3+11** needs to be set by users. **S3+12** to **S3+43+12** are occupied by the system, users can't use them.

#### ∅ Advanced Mode

The parameter's register zone is from **S3** to **S3+43**, **S3** to **(S3+11)** and **(S3+40)** to **(S3+43)** need to be set by users. **(S3+12)** to **(S3+39)** are occupied by the system, users can't use them.

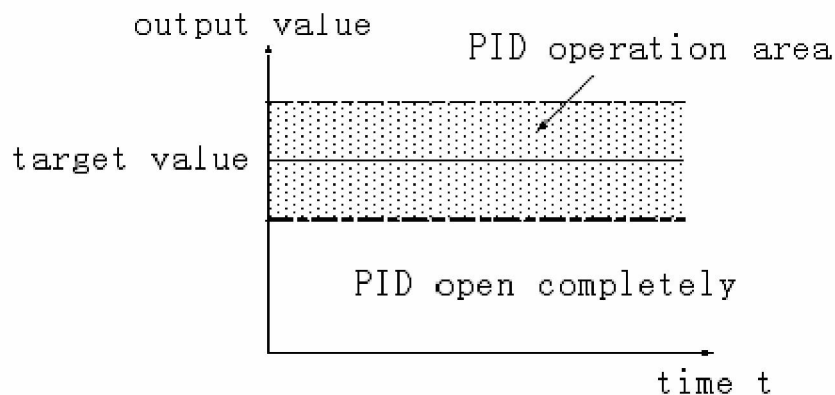
### | **Sample Time [S3]**

The system samples the current value according to certain time interval and compare them with the output value. This time interval is the sample time **T**. There is no requirement for **T** during **AD** output. **T** should be larger than one PLC scan period during port output. **T** value should be chosen among 100~1000 times of PLC scan periods.

### | **PID Operation Zone [S3+6]**

PID control is entirely opened at the beginning and close to the target value with the highest speed (the defaulted value is 4095), when it entered into the PID computation range, parameters **Kp**, **Ti**, **TD** will be effective.

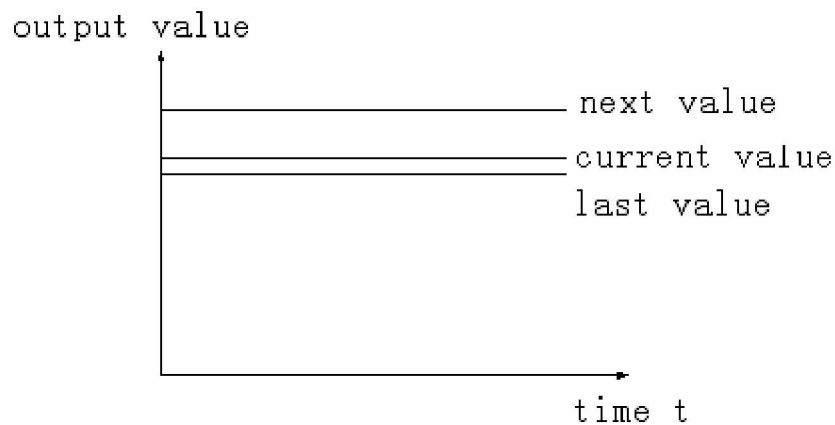
See graph below:



If the target value is 100, PID operation zone is 10, then the real PID's operation zone is from 90 to 110.

### | **Death Region [S3+7]**

If the detected value changed slightly for a long time, and PID control is still in working mode, then it belongs to meaningless control. Via setting the control death region, we can overcome this condition. See graph below:



Suppose: we set the death region value to be 10. Then in the above graph, the difference is only 2 comparing the current value with the last value. It will not do PID control. The difference is 13 (more than death region 10) comparing the current value with the next value, this difference value is larger than control death region value, it will do the PID control with 135.

#### 8-4 . Auto Tune Mode

If users do not know how to set the PID parameters, they can choose auto tune mode which can find the optimal control parameters (sampling time, proportion gain **Kp**, integral time **Ti**, differential time **TD**) automatically.

Auto tune mode is suitable for these objectives: temperature, pressure; not suitable for liquid level and flow.

Users can set the sampling cycle to be 0 at the beginning of the auto tune process then modify the value manually in terms of practical needs after the auto tune process is completed.

Before doing auto tune, the system should be under the no-control steady state. Take the temperature for example, the detected temperature should be the same as the environment temperature.

To enter the auto tune mode, please set bit7 of (**S3+ 2**) to be 1 and turn on PID working condition.

If bit8 of (**S3+ 2**) turn to 1, it means the auto tune is successful.

PID auto tune period value [**S3+ 8**]

Set this value in [**S3+ 8**] during auto tune.

This value decides the auto tune performance, in a general way, set this value to be the AD result corresponding to one standard detected unit. The default value is 10. The suggested setting range:

**full-scale AD result × 0.3 ~ 1%.**

User don't need to change this value. However, if the system is interfered greatly by outside, this value should be increased modestly to avoid wrong judgment for positive or negative movement.

If this value is too large, the PID control period (sampling time) got from the auto tune process will be too long. As the result do not set this value too large.

1: if users have no experience, please use the defaulted value 10, set PID sampling time ( control period ) to be 0ms then start the auto tune.

#### I PID auto tune overshooting permission setting [S3+ 9]

If set 0, overshooting is permitted, the system can study the optimal PID parameters all the time. But in self-study process, detected value may be lower or higher than the target value, safety factor should be considered here.

If set 1, overshooting is not permitted. For these objectives which have strict safety demand such as pressure vessel, set [S3+ 9] to be 1 to prevent from detected value seriously over the target value. In this process, if [S3+ 2] bit8 changes from 0 to 1, it means the auto tune is successful and the optimal parameters are got; if [S3+ 2] is always 0 until [S3+ 2] bit7 changes from 1 to 0, it means the auto tune is completed but the parameters are not the best and need to be modified by users.

#### I Every adjustment percent of current target value at auto tune process finishing transition stage [S3+10]

This parameter is effective only when [S3+ 9] is 1.

If doing PID control after auto tune, small range of overshooting may be occurred. It is better to decrease this parameter to control the overshooting. But response delay may occur if this value is too small. The defaulted value is 100% which means the parameter is not effective. The recommended range is 50~80%.

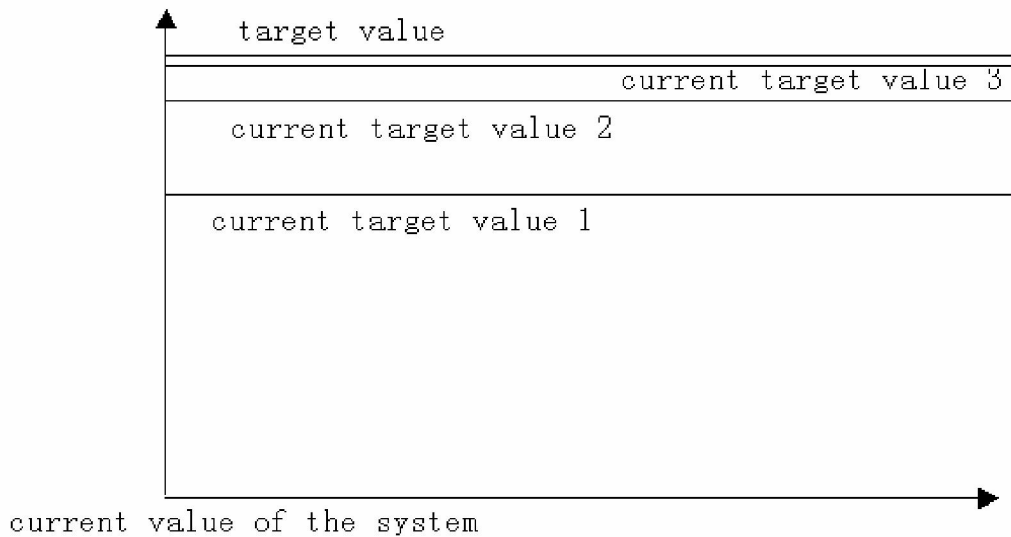
### **Cutline Explanation:**

Current target value adjustment percent is 2/3 ( $S3 + 10 = 67\%$ ), the original temperature of the system is 0 °C, target temperature is 100 °C, the current target temperature adjustment situation is shown as below:

Next current target value = current target value + (final target value – current target value ) × 2/3;

So the changing sequence of current target is 66 °C, 88 °C, 96 °C, 98 °C, 99 °C, 100 °C.





- | The stay times of the current target value at auto tune process finishing transition stage **[S3+11]**

This parameter is valid only when **[S3+9]** is 1;

If entering into PID control directly after auto tune, small range of overshoot may occur. It is good for preventing the overshoot if increasing this parameter properly. But it will cause response lag if this value is too large. The default value is 15 times. The recommended range is from 5 to 20.

## 8-5 . Advanced Mode

Users can set some parameters in advanced mode in order to get the better effect of PID control. Enter into the advanced mode, please set **[S3+2]** bit 15 to be 1, or set it in the XCP Pro software.

- | Input Filter constant

It will smooth the sampling value. The default value is 0% which means no filter.

- | Differential Gain

The low pass filtering process will relax the sharp change of the output value. The default value is 50%, the relaxing effect will be more obviously if increasing this value. Users do not need to change it.

- | Upper-limit and lower-limit value

Users can choose the analog output range via setting this value.

Default value: lower- limit output= 0

Upper -limit= 4095

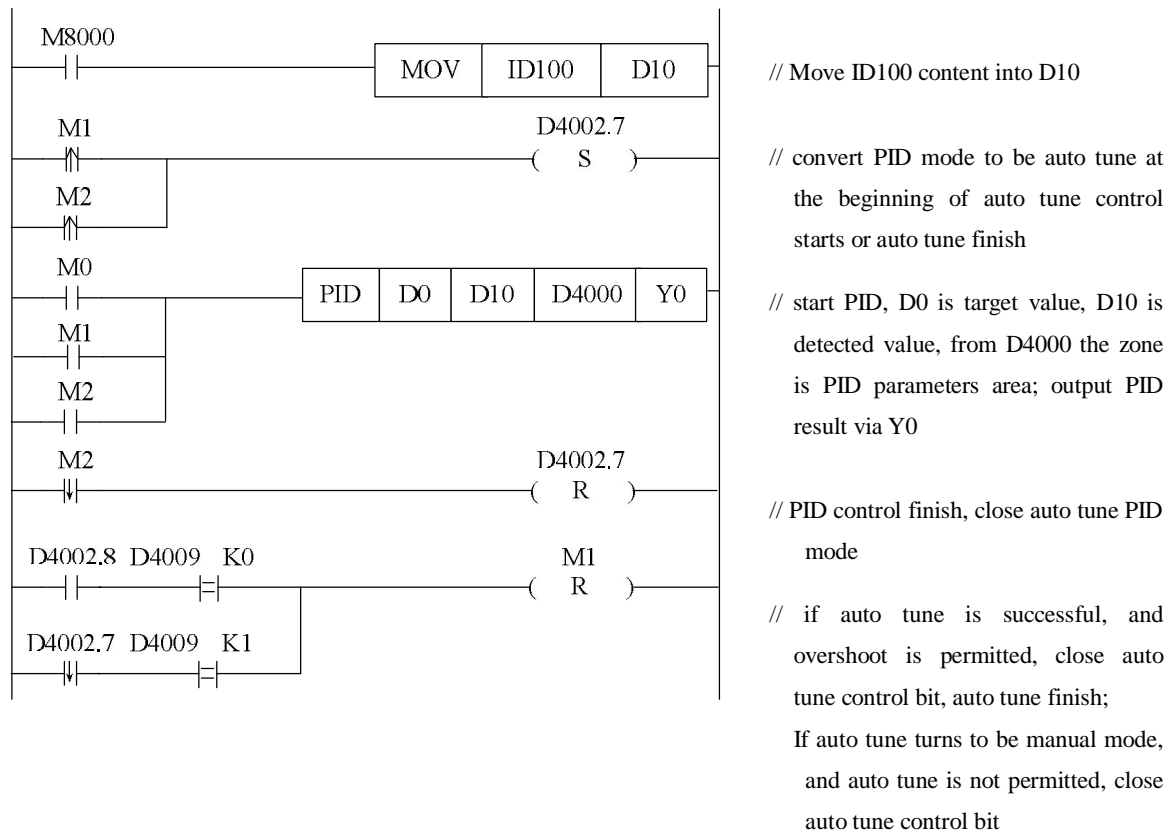
## 8-6 . Application Outlines

- l Under the circumstances of continuous output, the system whose effect ability will die down with the change of the feedback value can do self-study, such as temperature or pressure. It is not suitable for flux or liquid level.
- l Under the condition of overshoot permission, the system will get the optimal PID parameters from self-study.
- l Under the condition of overshoot not allowed, the PID parameters got from self-study is up to the target value, it means that different target value will produce different PID parameters which are not the optimal parameters of the system and for reference only.
- l If the self-study is not available, users can set the PID parameters according to practical experience. Users need to modify the parameters when debugging. Below are some experience values of the control system for your reference:

□ Temperature system:  
 P (%) 2000 ~ 6000, I (minutes) 3 ~ 10, D (minutes) 0.5 ~ 3  
 □ Flux system: P (%) 4000 ~ 10000, I (minutes) 0.1 ~ 1  
 □ Pressure system: P (%) 3000 ~ 7000, I (minutes) 0.4 ~ 3  
 □ Liquid level system: P (%) 2000 ~ 8000, I (minutes) 1 ~ 5

## 8-7 . Program Example

PID Control Program is shown below:



Soft components function comments:

D4000.7: auto tune bit

D4002.8: auto tune successful sign

M0: normal PID control

M1: auto tune control

M2: enter into PID control after auto tune

