

# TEC Controller DX5100 Technical Manual

## Appendix 3

# **PID TUNING TIPS**

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## 1. CONTROLLING ALGORITHM

The block diagram of the system of automatic control with a feedback is shown in the figure below.

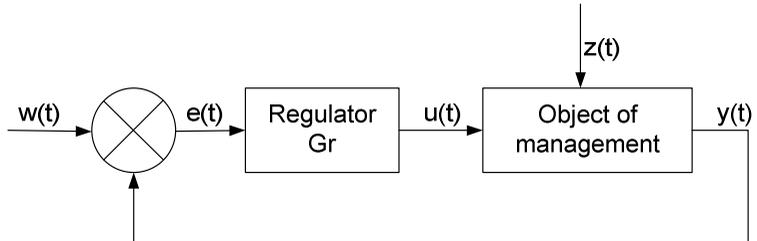


Fig.1 Block diagram of the system of automatic control with a feedback

Here  $w(t)$  is a desired value,  $y(t)$  is a target variable;  $e(t) = w(t) - y(t)$  - is a deviation of the target variable  $y(t)$  from the desired value  $w(t)$ ;  $u(t)$  is a managing influence;  $z(t)$  is an external perturbation whose influence should be reduced to minimum;

The target variable can be temperature. The purpose of the regulation can be a maintenance of the target variable equal to a desired value  $w(t)$ . For this purpose it is necessary to minimize the regulation error  $e(t)$ .

This task is solved by the automatic control  $Gr$  (Fig.1), which is described by some law of regulation  $u(t) = Gr[e(t)]$ .

The synthesis of the optimum controller giving the maximal parameters of quality of regulation is quite a complicated problem. In many cases for the manufacturing automation other simpler and widely-used types of linear controls can be applied - P-, PI- and PID-controllers.

The idealized equation of the PID-control looks like

$$u(t) = K \left[ e(t) + \frac{1}{T} \int_0^t e(\tau) d\tau + T_D \frac{de(t)}{dt} \right], \quad (1)$$

where  $K$  - transfer ratio,  $T$  - integration constant,  $T_D$  - differentiation constant.

These three parameters are chosen during the adjustment of the controller so that as to make the functioning algorithm as close to the desirable one as possible.

The described system of the automatic control is continuous, i.e. it uses continuous time. When designing a controller it is necessary to quantize the set and target variables of the controller in time with some step  $T_0$  and to transform then to the digital form with the help of analog-to-digital and digital-to-analog converters. For it the equation of the PID-control should be transformed into the differential one by replacing the derivative by a finite difference and the integral by the finite sum.

If using the method of rectangulars for the integral replacement with the finite sum we obtain:

$$u(k) = K \left[ e(k) + \frac{T_0}{T} \sum_{i=0}^k e(i-1) + \frac{T_D}{T_0} [e(k) - e(k-1)] \right], \quad (2)$$

where  $k=0, 1, \dots, \frac{t}{T_0}$  - discrete time serial number.

The shortcoming of this approach is the necessity to remember the values of deviations  $e(k)$  for all the moments of time from the beginning of the process of regulation.

This shortcoming can be removed, if a current value of managing variable  $u(k)$  is calculated by its previous value  $u(k-1)$  and a correction. For such a recurrent algorithm it is enough to subtract from equation (2) the following equation:

$$u(k-1) = K \left[ e(k-1) + \frac{T_0}{T} \sum_{i=0}^{k-1} e(i-1) + \frac{T_D}{T_0} [e(k-1) - e(k-2)] \right] \quad (3)$$

As a result we have:

$$u(k) - u(k-1) = q_0 e(k) + q_1 e(k-1) + q_2 e(k-2),$$

where

$$q_0 = K \left[ 1 + \frac{T_D}{T_0} \right],$$

$$q_1 = K \left[ 1 + 2 \frac{T_D}{T_0} - 2 \frac{T_0}{T} \right],$$

$$q_2 = K \frac{T_D}{T_0},$$

The PID coefficients stored in the in non-volatile memory of the device factors:

$K$  - proportional coefficient of PID-controller,

$2 * T_0/T$  - integral coefficient of PID-controller,

$T_D/T_0$  - differential coefficient of PID-controller.

These coefficients are set by the command 31h and can be read by the command 32h.

When coming from continuous operators to discrete ones there is an error whose value is proportional to the remainder term of the Taylor series of the function  $e(t)$ . The obtained discrete equations can be considered equivalent to the continuous ones only if the function  $e(t)$  changes little within the limits of the sampling period.

### 1.1. Sampling Period

Since the controlled value in PID regulation is temperature, the Controller applies an algorithm in which the PID sampling period is equal to the period of temperature measurement. The period of temperature measurement, in turn, depends on the number of channels of ADC involved in the measurement.

Different values of PID sampling period in correspondence to various modes of ADC operation are given in the table.

PID sampling period (~mSec)	ADC mode
460	All ADC channels are measured (by default)
287	Only 2 temperatures are measured (the choice is done by mask – the command 18h)
145	Only 1 temperature is measured (the choice is done by mask – the command 18h)
38	Only 1 temperature is measured (the choice is done by the command 17h)

A change of the sampling makes it necessary to correct the PID factors.

It is necessary to take into account that an increase of the sampling period results in the data similar to reduction of proportionality factor and, on the contrary, a reduction of sampling period is similar to increase of proportionality factor.

## 2. AUTO-PID FUNCTION

### 2.1. Introduction

The finding of optimum parameters of regulation of the given object is quite a delicate and long procedure. It is a consecutive experimental choice of parameters.

At the same time the quality of regulation of temperature depends on the optimality of the set parameters.

**Attention!** The parameters preset at the device delivery are formal and do not concern a real controlled object.

With the purpose of simplification of the PID controller optimum parameters choice in the TEC Controller DX5100 the function auto-PID is realized.

This function realizes the known Ziegler-Nichols algorithm. The user applying this function can use the obtained PID controller parameters for the subsequent accurate adjustment or apply the given parameters directly to the control of the object.

**Attention!** Before starting the auto-PID function it is necessary to set alarm limit of maximal allowable voltage of thermoelectric module.

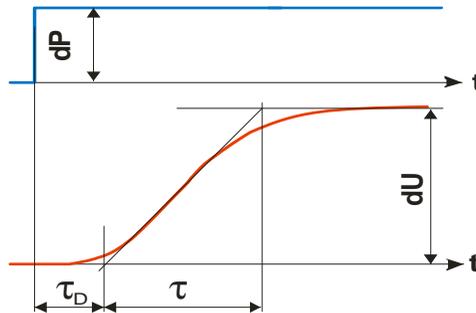
**Attention!** Nevertheless the manufacturer regards the parameters obtained with the help of the built-in auto-PID function as estimated and not quite optimum. It is recommended to check up the obtained parameters and if necessary to carry out a more accurate tuning of the PID parameters depending on the required quality of the thermal regulation.

## **2.2. Ziegler-Nichols Algorithm**

In the Controller DX5100 one of the known algorithms of an automatic finding of the PID parameters is realized.

When the object of regulation is exposed to voltage (current) of a certain value the dynamic characteristic of the object of regulation is obtained as the parameters of its transition into a stationary condition at a given influence.

The figure below illustrates the dynamics of the process and the required parameters.



The required parameters are:

- Deadtime  $\tau_D$

- Process gain  $K = \frac{\tau}{\frac{dU}{dP} \tau_D}$

The found values of the specified parameters by the Ziegler-Nichols method enable to estimate the PID parameters as:

Proportional coefficient	$1,2 \times K$
Integral coefficient	$2 \times \tau_D$
Differential coefficient	$0,5 \times \tau_D$

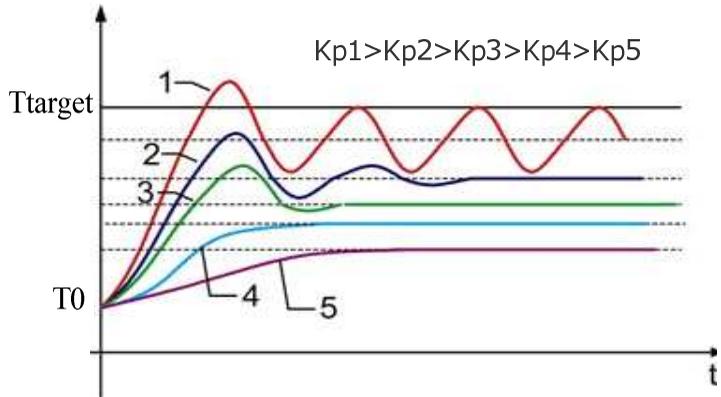
### 3. PID TUNING TIPS

The tuning quality can be estimated by different criteria: by the rate of achieving the setpoint, by the minimal overshoot, by accuracy of setpoint maintenance. The tuning quality can also be estimation by the transient process of achieving the setpoint. Recommendations for PID tuning by the form of the starting curve are given below.

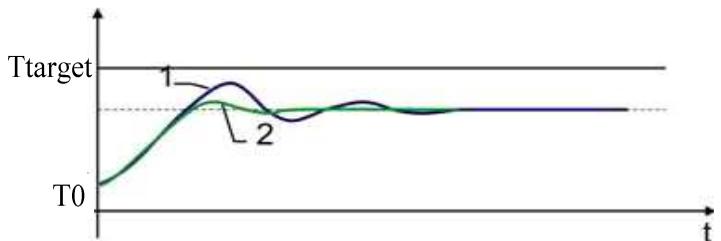
1. **Set** values of integrated and differential components equal to zero:

$$K_i=0; K_d=0$$

Modify the value of the proportional component factor so that the form of the transitive characteristic correspond that of curve 2 or 3.



2. Modify the value of the differential component factor so that the form of the transitive characteristic correspond that of curve 2.



3. The integrated component is intended to remove a residual mismatch between the temperature value achieved in the system and the setpoint. Modify the value of the proportional component factor so that the form of the transitive characteristic correspond that of curve 3.

