# IDC Technologies' Tech Brief
## *(Instrumentation)*

# Tuning of PID Controllers
# in both
# Open and Closed Loop Control Systems

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## *Acknowledgements*

**IDC Training expresses its sincere thanks to all those who freely made available their expertise in preparing this manual.**

## Objectives

As a result of studying this section, and after having completed the relevant exercises, the student should be able to:

- Apply the procedures for open and closed loop tuning.
- Calculate the tuning constants according to Ziegler & Nichols.

## Objectives of Tuning

There are often many and sometimes contradictory objectives, when tuning a controller in a closed loop control system. The following list contains the most important objectives for tuning of a controller:

### Minimization of the Integral of the Error

The objective here is to keep the area enclosed by the two curves, the Set Point (SP) and Process Variable (PV) trends; to a minimum. This is the aim of tuning, using the methods developed by Ziegler and Nichols.

### Minimization of the Integral of the Error Squared

It is possible to have a small area of error but an unacceptable deviation of PV from SP for a start time. In such cases special weight must be given to the magnitude of the deviation of PV from SP. Since the weight given is proportional to the magnitude of the deviation, the weight is multiplied by the error. This gives us error squared (error squared = error * weight). Many modern controllers with automatic and continuous tuning work on this basis.

### Fast Control

In most cases fast control is a principle requirement from an operational point of view,

### Minimum Wear and Tear of Controlled Equipment

A valve or servo system for instance should not be moved unnecessarily frequently, fast or into extreme positions. In particular, the effects of noise, excessive process disturbances and unrealistically fast control have to be considered here.

### No Overshoot on Start Up

The most critical time for overshoot is the time of start up of a system. If we control an open tank, we do not want the tank to overflow as a result of overshoot of the level. More dramatically, if we have a closed tank, we do not want the tank to burst. Similar considerations exist everywhere, where danger of some sort exists. A situation of a tank having a maximum permissible pressure that may not be exceeded under any circumstances is an example here.

*Note: Start Up is not the equivalent of a change of Setpoint.*

### Minimizing the Effect of Known Disturbances

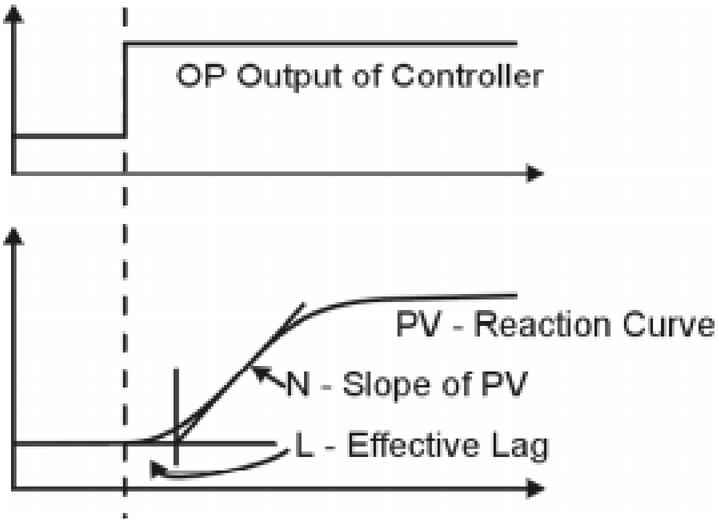
If we can measure disturbances, we may have a chance to control these before the effect of them becomes apparent. See Feed Forward Control for an example of an approach to this problem. Two approaches to tuning of a loop will be briefly discussed here.

## Reaction Curve Method of Tuning (Ziegler Nichols) – Open Loop

If we know the exact value of the effective lag of an industrial process, we are in a position to find the appropriate frequency matching the 180 degree phase shift. This means that we can calculate the critical frequency based on the effective lag. We can then compute the optimum tuning constants.

Ziegle and Nichols have done just this and came up with formulas for optimum tuning. The optimum tuning obtained with these formulas is aimed at minimizing the integral of the error term (minimum area of error). It does not take into account the magnitude of the error. The optimum tuning constants are based on a process with a small dead time and a first order lag.

The steps of open loop tuning (Reaction Curve Method) are as follows:



### 1. Place the Controller in Manual Mode

If the control is in Manual Mode, we will be sure that we have an open loop in which the controller's action has no influence whatsoever. This is because we are not interested in the controller's behavior, but are interested in the process's reaction curve only.

### 2. Make a Step Change to the OP Value

If we make a step change to the output value of the controller, then we expect an appropriate reaction curve of the PV, which is the reaction of the process. We must have enough process knowledge to know by how much we can change the output value of the controller without danger to the process itself.

## 3. Calculation of Tuning Constants

Observe the reaction of the process. We cannot calculate the tuning constants before we have analyzed the curve using a few common sense considerations. If we have a value of 0 for L, then we know there is no stability problem at all. This means that the tuning formulas which deal with a stability problem, do not make sense if there is not stability problem.

## 4. Calculation of Tuning Constants

We obtain different tuning constants with different combinations of control modes.

### *P-Control:*

Kc = OP% / (N * L)

### *PI-Control:*

Kc = 0.9 * (OP% / (N * L)
T(int) = 3 * L

### *PID-Control:*

Kc = 1.2 * (OP% / (N * L)
T(int) = 2 * L
T (der) = 0.5 * L