Interactive Process PID Control Tuner

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URL: http://www.che.utexas.edu/course/che360/documents/tuner/Process_Tuner.html

The Process PID control tuner provides the open and closed-loop process system responses for a continuous process model (G) with a continuous PID controller (G_c). The Process model can be characterized by the numerator and denominator polynomial coefficients of the process transfer function model. Delay time (τ_D) can be specified to the process transfer function. The PID controller tuning parameters are the control gain (K_c), integral action (τ_I) and derivative action (τ_D). The PID controller has also the derivative action-filter parameter that attenuates the effect of the derivative action in the closed loop response, and makes the controller transfer function realizable.

The continuous process transfer function is denoted by G:

$$G = \frac{Y(s)}{U(s)} = \frac{\sum_{i=0}^{m} b_i s^i}{\sum_{j=0}^{n} a_j s^j} e^{-st_d} = \frac{b_m s^m + b_{m-1} s^{m-1} + \cdots b_0}{a_n s^n + a_{n-1} s^{n-1} + \cdots a_0} e^{-st_d} \qquad \text{(Eq.4.40)}$$

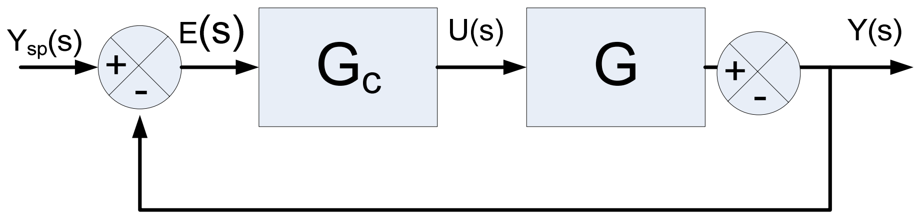
The tuner **open loop** response represents the response of $G(s)$ to a step in $U(s)$. The adjustable step size represents the magnitude of the input step, i.e., $u(t > 0)$. The diagram below illustrates the open loop block representation:

The PID controller structure is given by:

$$G_c = \frac{U(s)}{E(s)} = K_c \left(1 + \frac{1}{\tau_I s} + \frac{\tau_D s}{1 + \alpha s} \right) \qquad \text{(Eq.8.14)}$$

Note that this PID structure resembles the parallel form except for the incorporation of the derivative filter. The closer α gets to zero, the more the equation above will resemble Eq. 8.14 of Seborg et al. (2004). Making α=0 can result in G_c G_p having a numerator polynomial order greater than or equal to the denominator for a first order plus time delay process.

The **closed loop** diagram:



is represented by the following transfer function:

$$G_{cl} = \frac{Y(s)}{Y_{sp}(s)} = \frac{G_c G}{1 + G_c G}$$

where the sub-index "cl" stands for "closed loop". The response for the closed loop transfer function is obtained in the process PID Control Tuner when the case "Closed Loop" is chosen. The closed loop input step is applied to the Set-point, $Y_{sp}(s)$, instead of the process input, U(s). This structure represents the closed loop servo problem as the controller is used to make the process output follow a set-point change. The comparator symbol '$\otimes$' shown in the block diagram compares the set-point to the process output, Y(s). The difference is the error E(s), which is the input to the PID controller. This control configuration is a feedback structure, as the process output is brought to the input side of the diagram and compared against the set-point.

The PID controller parameters are adjusted to obtain a desired closed-loop response. The three main parameters used are the controller gain (K_c), the integral time (τ_I) and the derivative time (τ_D). The main objective of the PID controller is to bring the process output as close as possible to the set-point in a reasonable amount of time. That also means it brings the error $e(t)$ close to zero in a reliable and prompt manner.

A controller tends to be more aggressive when a slight change in the error $e(t)$ triggers a considerable change in its output $u(t)$. Moreover, the larger the magnitude of K_c, the more aggressive is the controller. The gain K_c and the process transfer function gain should have the same sign when no other block element besides the controller and the process is placed between the error $e(t)$ and the output signal $y(t)$, as is the case of the diagram shown above.

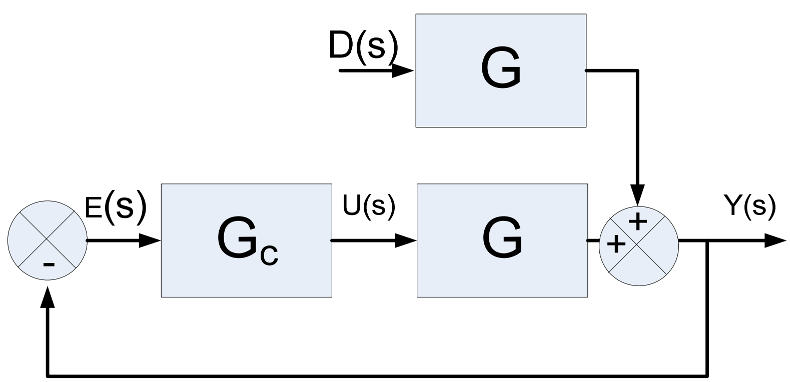
Why can the process gain sign be either positive or negative? Sometimes the process output increases when the input increases - positive process gain, like when more fuel flow increases the temperature of the combustion chamber. In other situations the process output decreases when its input increases. This is the case of using cooling water to control the temperature. As cold water flow increases, the process temperature decreases.

Integral action is important to eliminate the steady state error, also known as offset. In other words, the controller will always tend to eliminate the offset when integral action is active. In the case of integral time, note in Eq. 8.14 that its reciprocal is used in the controller expression. Therefore, the larger the value of τ_I, there is less influence by integral action. $\tau_I = \infty$ eliminates the integral action term in the controller. For practical purposes, in the PID control tuner, when $\tau_I = 0$, it is considered as if the integral action is not present in the controller.

Derivative action is rarely used as the controller output responds to changes in its input derivative (de/dt). Some problems in the implementation of the derivative action arise when $y(t)$ is noisy. Noisy signals tend to change the derivative value quite often. Because $e(t) = y_{sp}-y(t)$, if the output derivative changes, the error derivative will also change drastically. This effect will propagate the noise to process components like valves and actuators.

Now you are ready to use the Process PID Control Tuner to determine the best tuning parameters for your PID controller. Some performance specification of the closed loop response are based on the settling time (time that it is necessary for the output to be within 5% of the set-point based on the output response span), or the response overshoot (deviation measured from the set-point line). Figures 5.9 and 5.10 in Seborg et al. illustrate the different closed loop performance specifications.

If you configure a PID controller to bring the process output back to its original set-point in the presence of a disturbance, you are considering the regulator instead of the servo problem. The regulator problem is represented in the following diagram:



and its respective closed loop transfer function is given by:

$$G_{cl} = \frac{Y(s)}{D(s)} = \frac{G}{1 + G_c G}$$

where $D(s)$ represents the load or disturbance. Note that the output $Y(s)$ is the addition of two signals. Typical regulator problem example is the presence of wild flows in a mixing process. A tank process could be mixing a manipulated flow $U(s)$ and a wild flow $D(s)$. The controller main task consists of adjusting the manipulated flow $U(s)$ in order to reject the fluctuations in the tank concentration $Y(s)$ due to changes in the disturbance or perturbation flow $D(s)$.

Most PID tuning rules apply for the servo as well as for the regulator problem. Note that the closed loop transfer function denominator is the same regardless of type of problem being considered.