MMAN3200

Introduction to PID Controllers. Part 2

In the previous lecture we introduced the PID controller, whose dynamics is modelled as follows,

$$control(t) = K_p \cdot e(t) + K_d \cdot \frac{d}{dt} e(t) \quad + K_i \cdot \int_{t=t_0}^{t} e(\tau) \cdot d\tau$$

We analyzed the performance of the PID controller's components, in particular its derivative and integral components, based on inspecting the root locus and applying the Final Value Theorem.
An alternative interpretation, which is more intuitive, may also help to explain the reasons for justifying those components of the PID.
The derivative component has the purpose of adding a control component which is based on the predicted error. This is why in scales the derivative of the error, in place of the error itself. If the error is growing, its derivative will be positive; consequently, the derivative component of the controller will try to increase the controller output. In the opposite situation, if the error is decreasing, this controller component will try to decrease it, for reducing the overall control action.

The integral component of the PID is intended to increase the control action in cases in which a steady-state error is present. As the error is integrated, the result of the integral increases, producing a more intense control action in favor of decreasing the magnitude of that persistent error.

Limitations of the PID

The derivative component is highly sensitive to the noise which is usually present in the measurements of the system's output (The noise is usually introduced by sensors.)
To mitigate that issue a number of approaches can be applied:

1) Avoid using high derivative gains (Kd)
2) Use an estimated version of the derivative of the output value. Those estimates are provided by a process called observer or estimator (there are diverse techniques for implementing them.)
3) Introduce some low pass filter, for filtering the input which feeds the derivative component. This approach also helps to filter the aggressive transitions which may happen on the reference signal itself. (see note 1 about this approach.)

Note 1:in the provided Simulink module, for solving the tutorial about PID, the PID module shows an "unusual" derivative component,

$$C(s) = K_p \cdot \left(1 + \frac{K_i}{K_p} \cdot \frac{1}{s} + \frac{K_d}{K_p} \cdot \frac{N}{1 + N \cdot \frac{1}{s}} \right)$$

That is a version which uses a low pass filter in its derivative component, in which the factor “s” is approximated by a filtered version,

$$s \cong \frac{N}{1+N\cdot\frac{1}{s}} = \frac{N\cdot s}{s+N} = \frac{N}{s+N}\cdot s$$

In which the additional factor is a low pass filter $\frac{N}{s+N}$, i.e. it has a pole in s=-N. The higher is N, the lesser the filtering effect. That makes the derivative component to operate as a real “s” term, for a range of frequencies. If N is small, the low pass filter will be too aggressive, almost cancelling the derivative effect of the factor “s”. We will better understand this concept, after we discuss and describe systems in the frequency domain, in subsequent lectures.

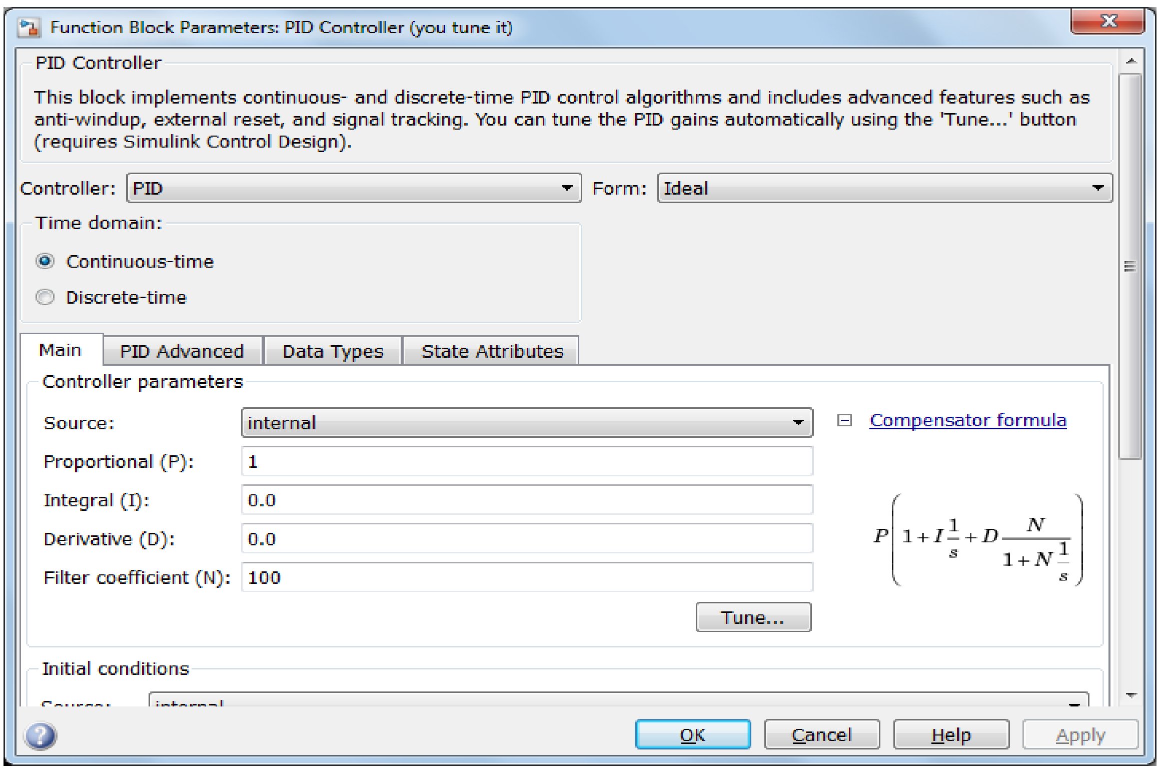

Figure 1: The PID controller block, in Simulink, showing its filtered version of the PID’s derivative component.