TECH NOTE – PID Controller

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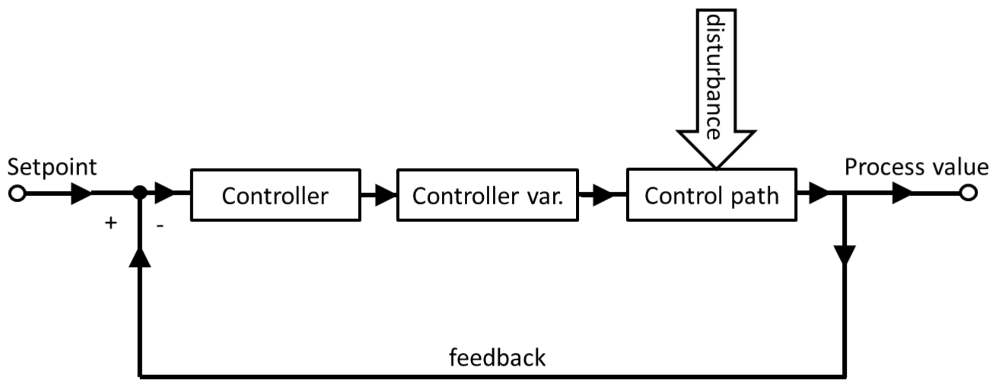
Brief description

This is an instruction for creating a PID controller with the ClipX. In this particular example a simple RC circuit first order is controlled. To demonstrate a repetitive process a periodic signal is generate by the internal signal generator of the ClipX. This signal is exemplary for any process and can be exchanged by other signals (e.g. from sensors).

Basics in control engineering

When controlling a physical value, a feedback of the process value is used to react to disturbance variables to force the actual value to follow a setpoint value. This behavior is far superior compared to a simple controller that cannot react to any changes within the system. The block diagram of a control loop is as follows:



The setpoint provides a value that is compared to the process value, the actual value. The difference between setpoint value and process value results in a control variable that affects the control path. That way disturbance values should be countered to maintain the set point value in a certain range. Besides accuracy, in practice a control loop has also to be adjusted in terms of speed and stability.
The PID controller (proportional-integral-derivative controller) consists of a P-, I-, and D-controller.
The basic characteristics of the different types are quickly pointed out below:

P-controller:
The process value is proportionally adjusted to the control variable. This adjustment is time-independent and essentially depends on the proportionality gain K_P. The control deviation is minimalized when using a relatively high proportionality factor, though results in oscillation of the system. That is why a compromise has to be found when choosing the proportionality factor. For that reason the P-controller always has a certain control deviation.
The P-controller works fast but imprecisely. As a well-known example of this is the radiator with a thermostatic valve (P controller).

I-controller:
The I-controller is capable of adjusting the process value very precisely to the setpoint by adding the time integral of the control deviation to the control variable. If the control deviation is greater than zero a balance is never achieved.
The I-controller indeed is very precise, however it takes a lot of time for the integration and therefore is quite slow.

D-controller:
By differentiating, the D-controller generates a control variable that is proportional to the gradient of the control

deviation. That way a high counterbalance for a quickly changing control deviation is possible. For the case that the control deviation is a constant value the D-controller does not provide any input because the gradient is equal zero.

ClipX settings

Calculated channels

The setpoint is defined as a constant signal. Therefore create a new calculated channel *constant signal* in the category *Mathematical Functions* and enter a value of your choice. Also define an output channel for the signal.

PID controller:

For the PID controller there is also a specific calculated channel available in the ClipX. Create a new *PID controller* in the category *Technology*. As inputs the setpoint, process value and a trigger have to be defined. As setpoint value choose the newly created constant setpoint. The process value is equal to the voltage that is applied after the RC circuit. This value is connected to channel 1 of the PX401 and is named *process value* here.

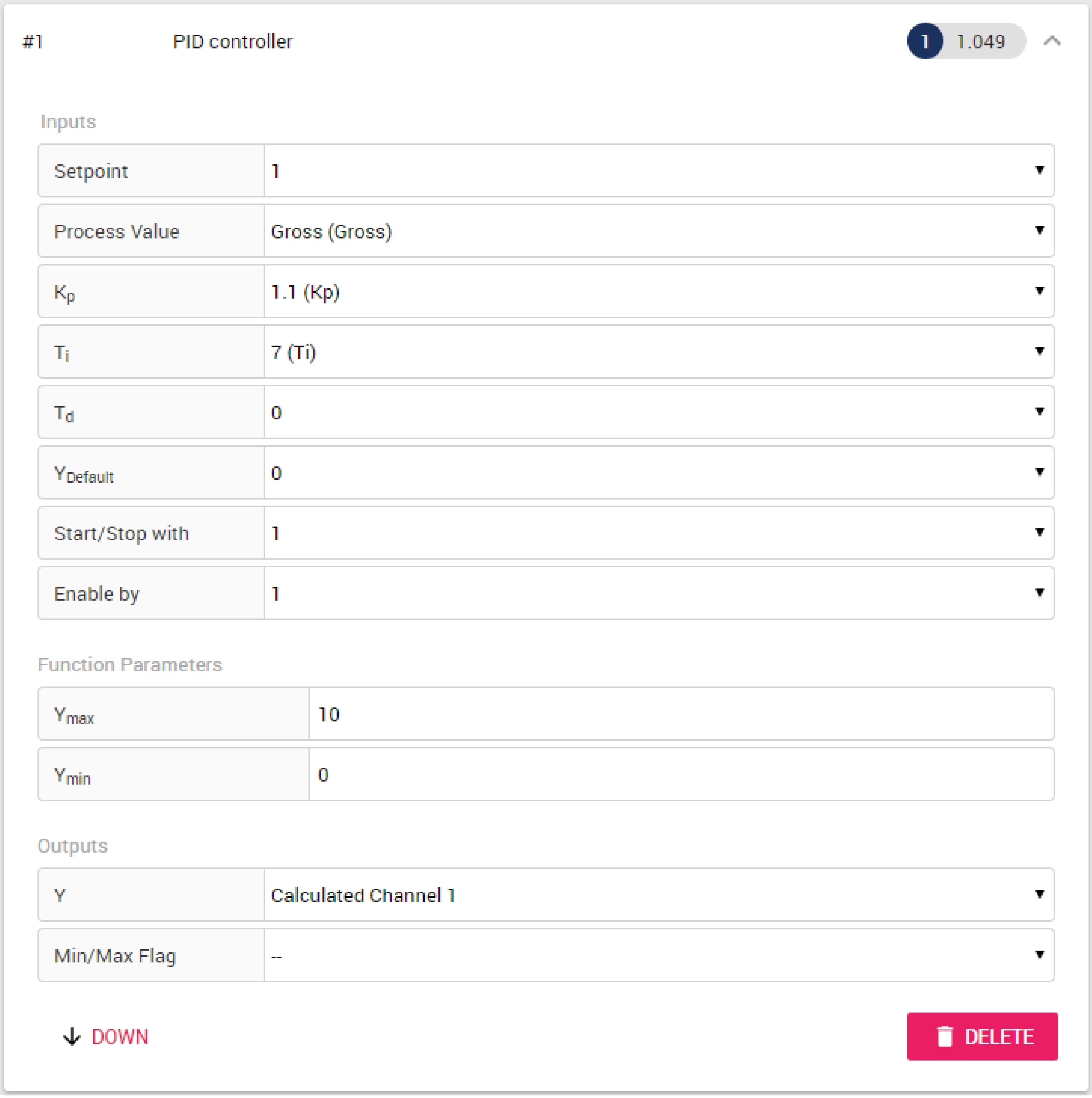
All parameters of the PID controller are shortly described here:
Kp: The proportionality-gain specifies the amplification from the P-controller
Ti [s]: The integral-time of the I-controller which is mainly depended on the time constant τ (if not used set Ti=∞; ClipX: Ti=1e38).
Td [s]: Derivative-time is the time the D-controller needs to differentiate. In this example set to 0, because no counterbalance is needed(Td=0).
Ymax und Ymin: The adjustment range, ie the maximum controller output in both directions.

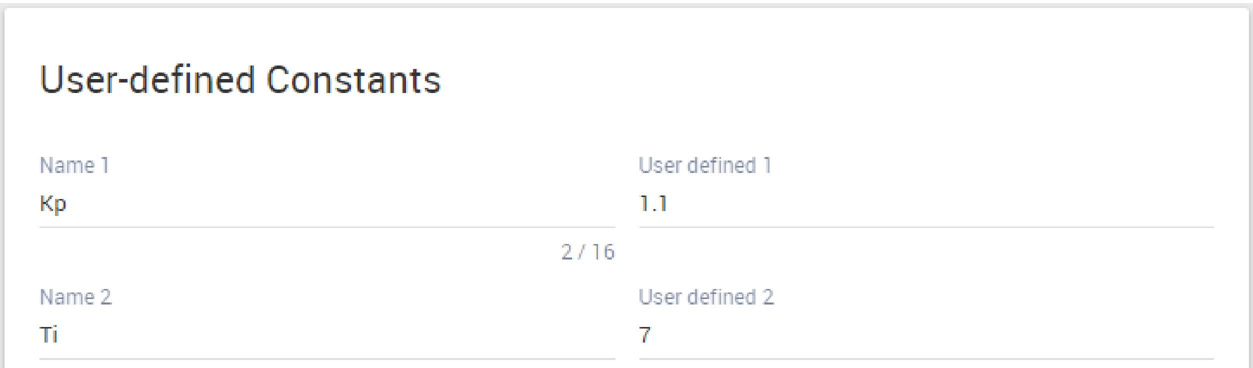
The output of the PID controller has to be finally assigned to the 10V output of the PX878. Therefore define the PID controller (here: PIDout) as source in the channel settings of the PX878. Please find the corresponding screenshot on the next page.

Control deviation:

The control deviation results from the difference between process value and setpoint value. With the help of a simple adder that difference can be displayed. You can find the *adder* in the category *Mathematical Functions*.

Note: This calculated channel is optional and not necessary for the PID controller. It is only created as an information source.





Basics in control engineering

The RC circuit used consists of a 56kΩ resistor that is connected in parallel to a 120µF electrolytic capacitor. The time constant is the result of the product of the resistance and the capacitance:

$$\tau = R \cdot C$$
$$= 56\text{k}\Omega \cdot 120\mu\text{F}$$
$$= 6{,}72s$$

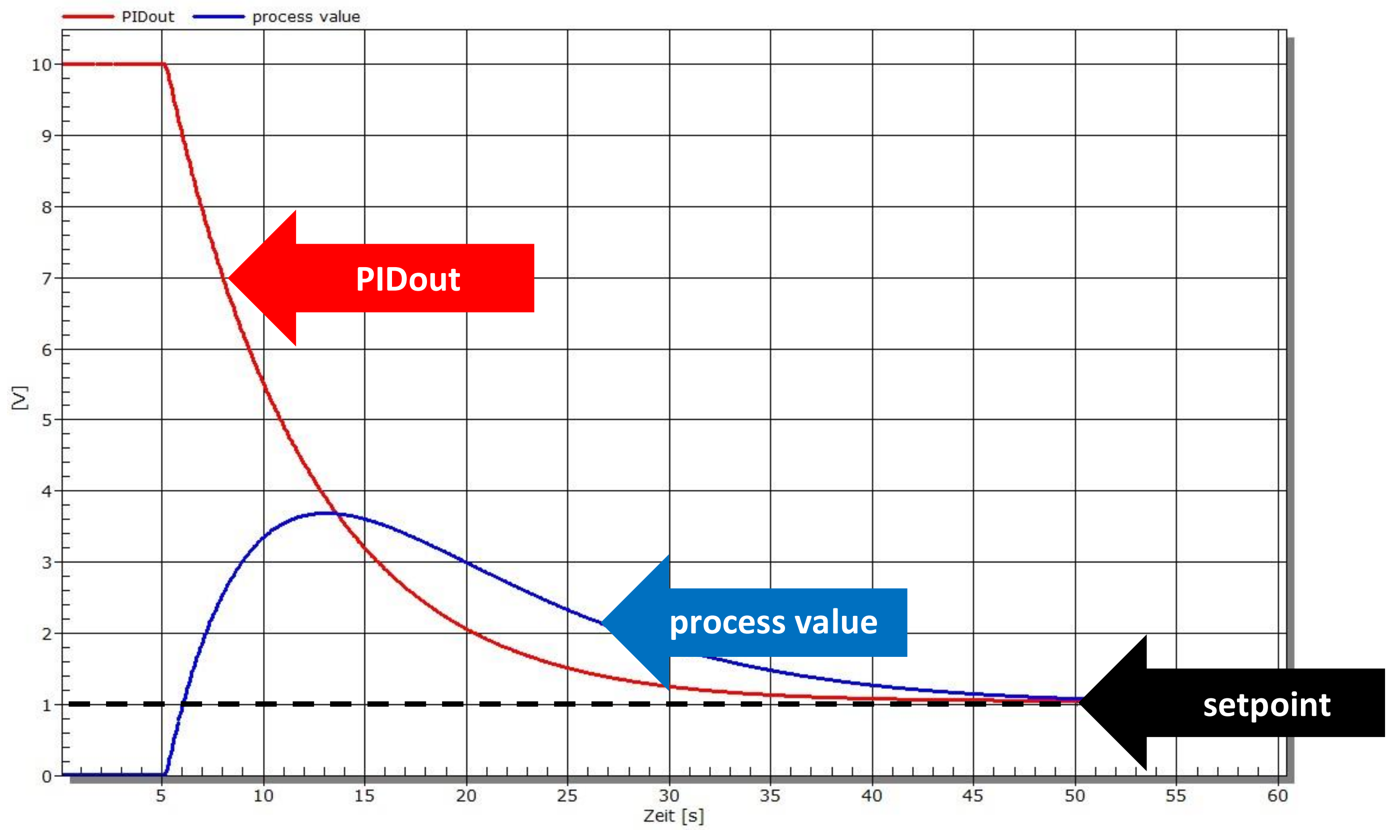
In practice a whole charging process of a capacitor (about 99%) takes approximately the time of five times the time constant:

$$t_L = 5 \cdot \tau$$
$$= 5 \cdot 6{,}72s$$
$$= 33{,}6s$$

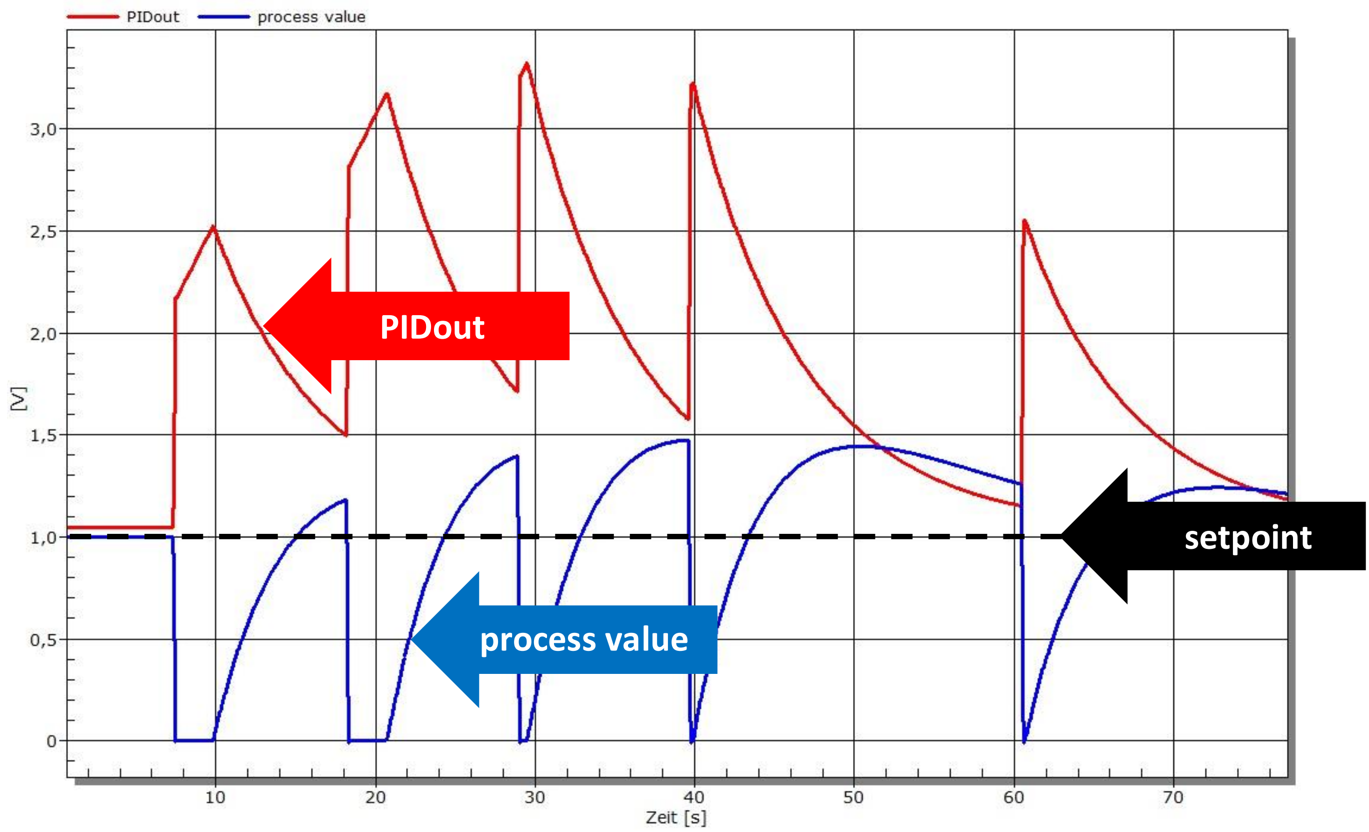
Important Note: Because the components have a certain tolerances they should be verified for sure. The usage of the correct time constant is very important for adjusting the PID-controller.

Graphical presentation

Charging curve of the capacitor



Interference by shortly discharging the capacitor



Determine control parameters

First Ziegler-Nichols method

The method of Ziegler and Nichols is a heuristic procedure to determine the control parameters proportionality-gain (K_p), integral-time (T_i) and derivative-time (T_d).
The approach is pretty easy: First the two parameters proportionality gain(K_p) and derivative-time(T_d) of the PID controller are set to zero and the integral-time(T_i) is set to ∞ (ClipX: T_i=1e38). Then the proportionality gain(K_p) of the P-controller is increased until the stability limit of the system is reached. At that maximum amplitude K_u the system oscillates with constant amplitude. With the parameters K_u and the period of oscillation T_u the parameters of the PID controller are now adjusted.

1. Z-N tuning	K_p	T_i	T_d
P controller	0.5 K_u	-	-
PI controller	0.45 K_u	0.85 T_u	-
PD controller	0.55 K_u	-	0,15 T_u
PID classic Ziegler-Nichols	0.6 K_u	0.5 T_u	0.125 T_u
PID Pessen Integral rule	0.7 K_u	0.4 T_u	0.15 T_u
PID Some Overshoot	0.33 K_u	0.5 T_u	0.33 T_u
PID No Overshoot	0.2 K_u	0.5 T_u	0.33 T_u

Second Ziegler-Nichols method

In the second approach the controlling path is approximated as transfer element first order with dead time ($PT1T_t$-element). The stationary amplification K_s, the time constant T and the dead time T_t have to be known. Those can be found out by approximation with the help of the step function response, so that the following can be applied:

$T = T_g$ und $T_t = T_u$.

2. Z-N tuning	K_p	T_i	T_d
P controller	$\frac{1}{K_s} \cdot \frac{T}{T_t}$	-	-
PI controller	$0.9 \cdot \frac{1}{K_s} \cdot \frac{T}{T_t}$	$3.33 \cdot T_t$	-
PID controller	$\frac{1}{K_s} \cdot \frac{T}{T_t}$	$2 \cdot T_t$	$0.5 \cdot T_t$

Hint: Classic Z-N tuning is designed for countering disturbances fast and quickly and therefore results in some overshoot. Furthermore the control parameters have to be determined experimentally at the uncontrolled process, which is the reason to be very careful that it takes no damage.

Chien, Hrones and Reswick tuning rules

The method of Chien, Hrones and Reswick can be used for control paths of a higher order and is an advancement of the second Ziegler-Nichols method. The differentiation into periodic and aperiodic controlling as well as the separated settings for set-point-value and disturbance-value are beneficial.
The parameters stationary amplification K_s, time constant T and dead time T_t have to be known and can also be found out with the step function response, if the process is suitable for that.
The calculation is as shown in the table.

Chien, Hrones and Reswick tuning		Aperiodic			Periodic (20% overshoot)		
		K_p	T_i	T_d	K_p	T_i	T_d
P controller	Disturbance	$0.3 \cdot \frac{T_g}{T_u \cdot K_s}$	-	-	$0.7 \cdot \frac{T_g}{T_u \cdot K_s}$	-	-
	FÜHRUNG	$0.3 \cdot \frac{T_g}{T_u \cdot K_s}$	-	-	$0.7 \cdot \frac{T_g}{T_u \cdot K_s}$	-	-
PI controller	Disturbance	$0.6 \cdot \frac{T_g}{T_u \cdot K_s}$	$4 \cdot T_u$	-	$0.7 \cdot \frac{T_g}{T_u \cdot K_s}$	$2.3 \cdot T_u$	-
	FÜHRUNG	$0.35 \cdot \frac{T_g}{T_u \cdot K_s}$	$1.2 \cdot T_g$	-	$0.6 \cdot \frac{T_g}{T_u \cdot K_s}$	$1 \cdot T_g$	-
PID controller	Disturbance	$0.95 \cdot \frac{T_g}{T_u \cdot K_s}$	$2.4 \cdot T_u$	$0.42 \cdot T_u$	$1.2 \cdot \frac{T_g}{T_u \cdot K_s}$	$2 \cdot T_u$	$0.42 \cdot T_u$
	FÜHRUNG	$0.6 \cdot \frac{T_g}{T_u \cdot K_s}$	$1 \cdot T_g$	$0.5 \cdot T_u$	$0.95 \cdot \frac{T_g}{T_u \cdot K_s}$	$1.35 \cdot T_g$	$0.47 \cdot T_u$

Disclaimer

These examples are for illustrative purposes only. They cannot be used as the basis for any warranty or liability claims.