PID Feedback Controller & IMC-PID Tunning Rules

FOPDT Process Model

$$G_p(s) = \frac{K_p.e^{-\theta s}}{T_p s + 1} \; ; K_p : Process\ Gain\ ;$$

θ : *Dead Time* T_P : *Time Constant*

PID (Real) Controller Algorithm

$$Gc(s) = K_c\left(1 + \frac{1}{T_i s} + T_d s\frac{1}{T_f s + 1}\right)$$

IMC – PID Tunning Rules

λ : *Desired Closed Loop Time Constant*

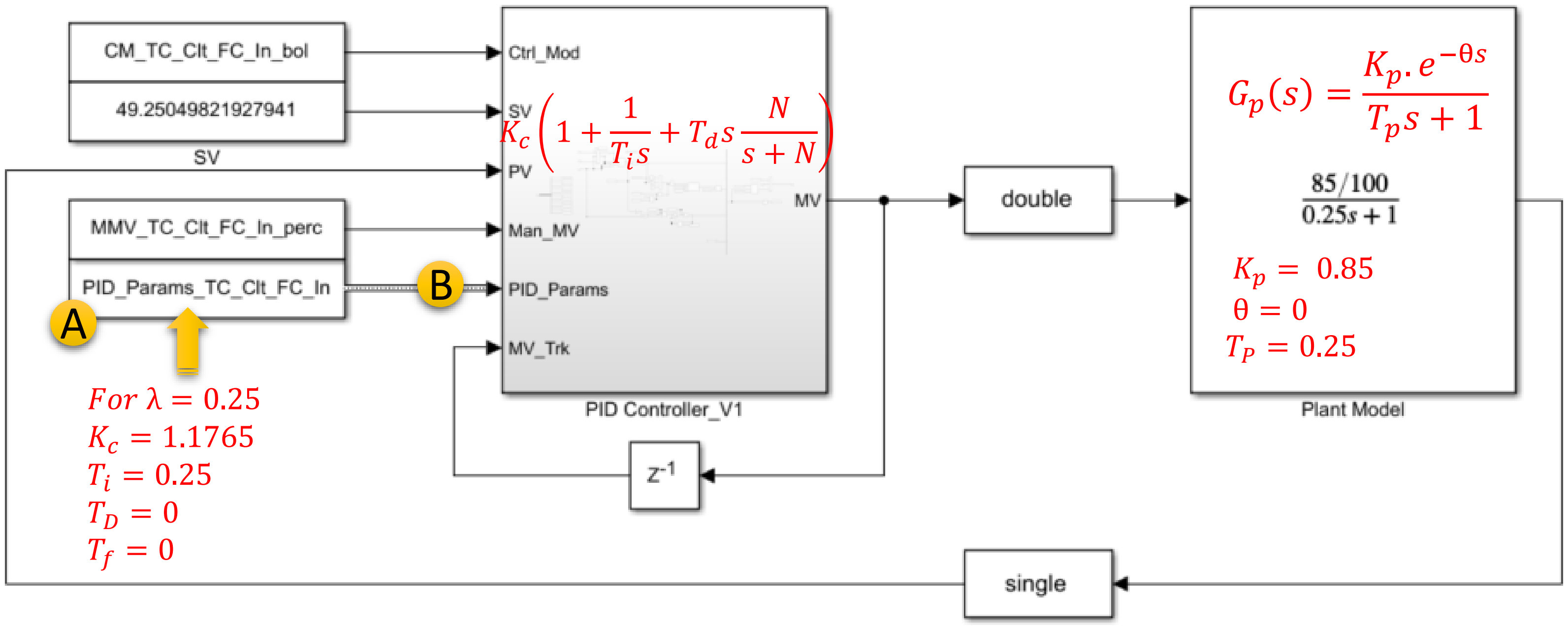
$$K_c = \frac{T_p + 0.5 * \theta}{K_p(\theta + \lambda)}$$

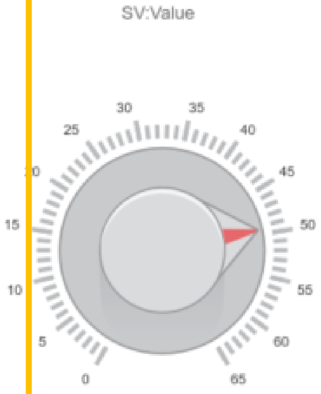
$$T_i = T_p + 0.5 * \theta$$

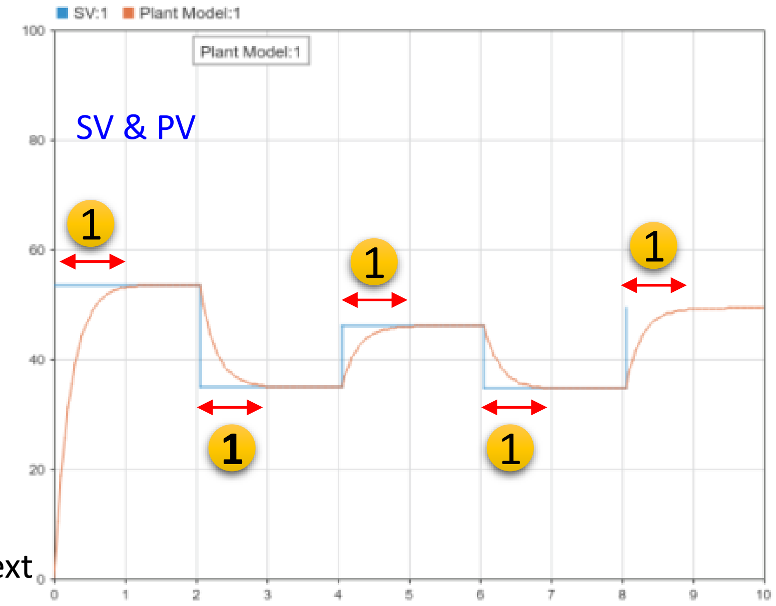
$$T_d = \frac{T_p.\theta}{2.T_p + \theta}$$

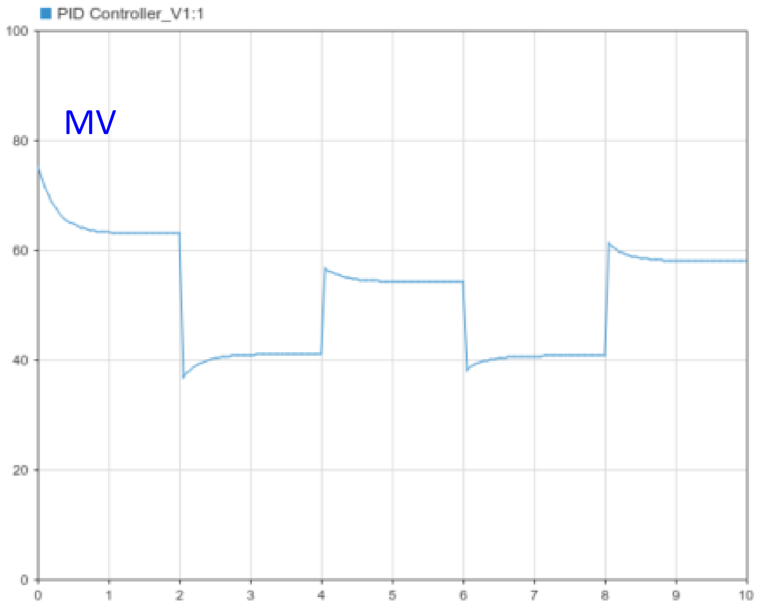
$$T_f = \frac{\theta.\lambda}{2(\theta + \lambda)}$$

Recomended : $\lambda > 0.2\, T_P$ & $\lambda > 1.7\theta$







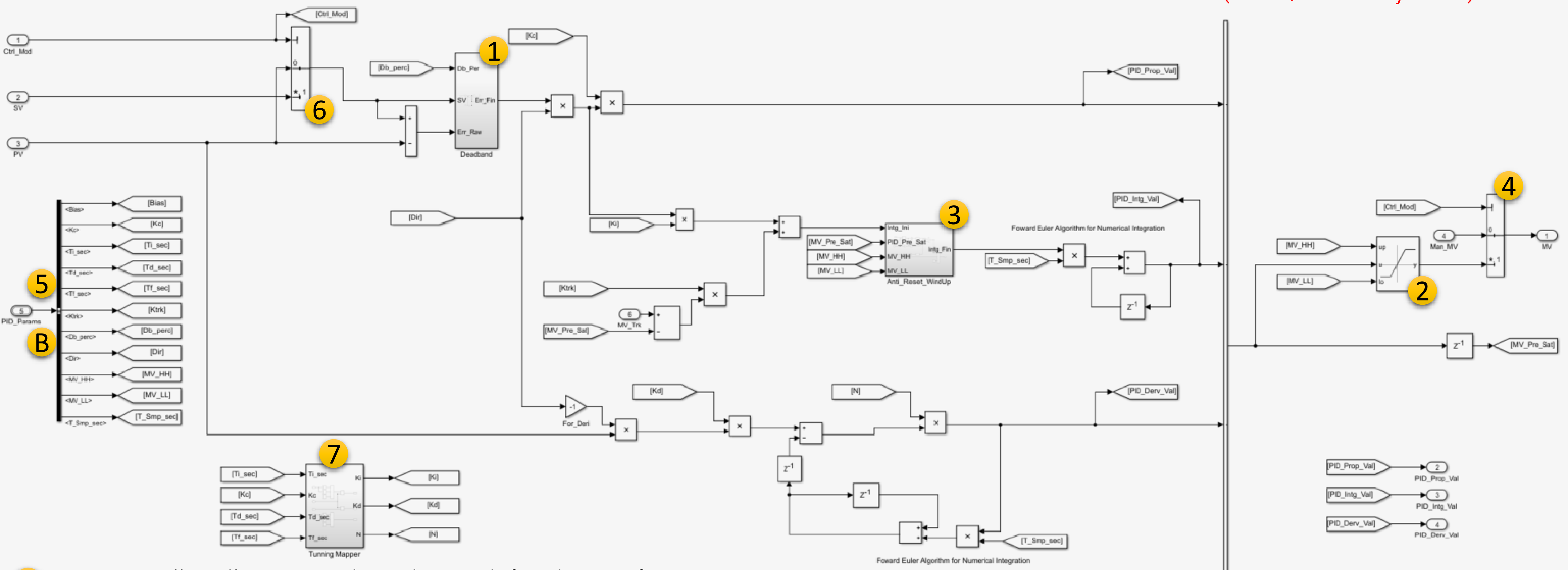


A
B
Refer Next Pages

1 *Settling time* $\sim 4\lambda =$ 1 *Sec as Closed Loop Time Constant Chosen* : $\lambda = 0.25$

Real PID Controller Implementation Simulink *(Filtered Derivative on Rate of Change of PV)*

$$G_c(s) = Bias + K_c\left(1 + \frac{1}{T_i s} + T_d s \frac{1}{T_f s + 1}\right)$$



1 PID Controller Idling in Dead Band Zone defined as % of SV

2 Actuator Saturation between MV High & Low Limits

3 Integral Anti Reset Wind Up in the Event of Actuator Saturation

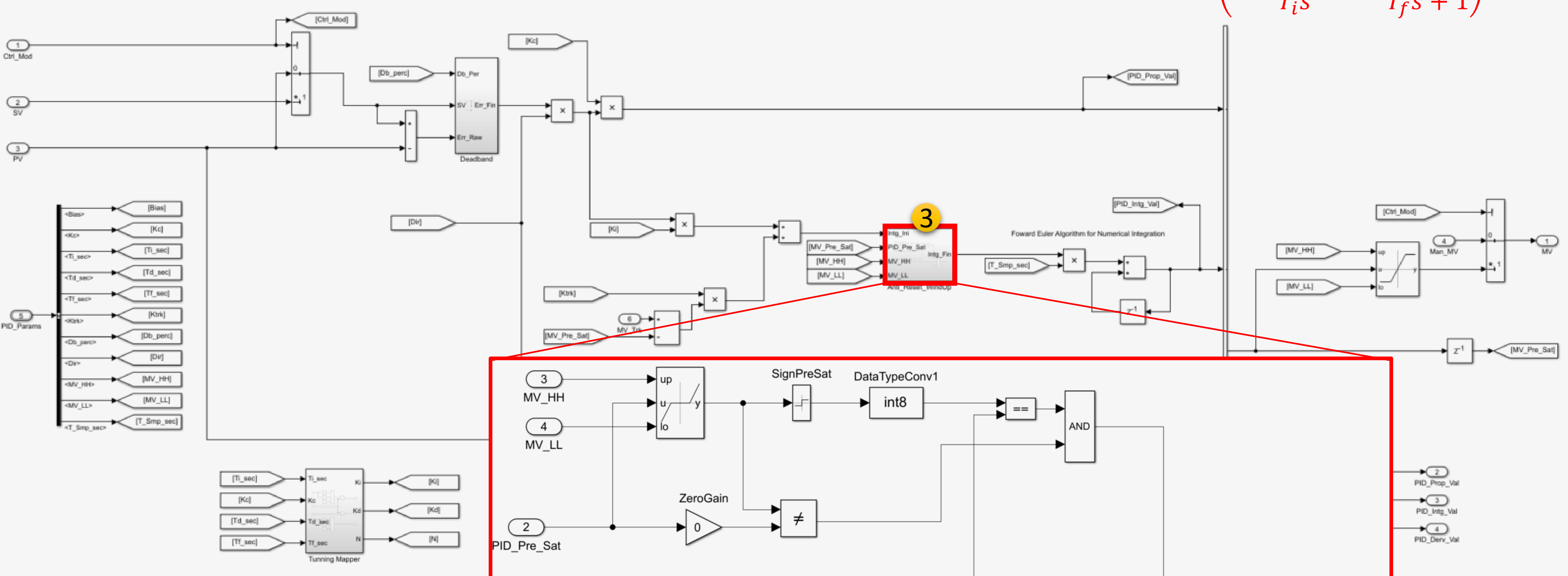
4 PID Controller Output Override in the event Controller in Manual Mode

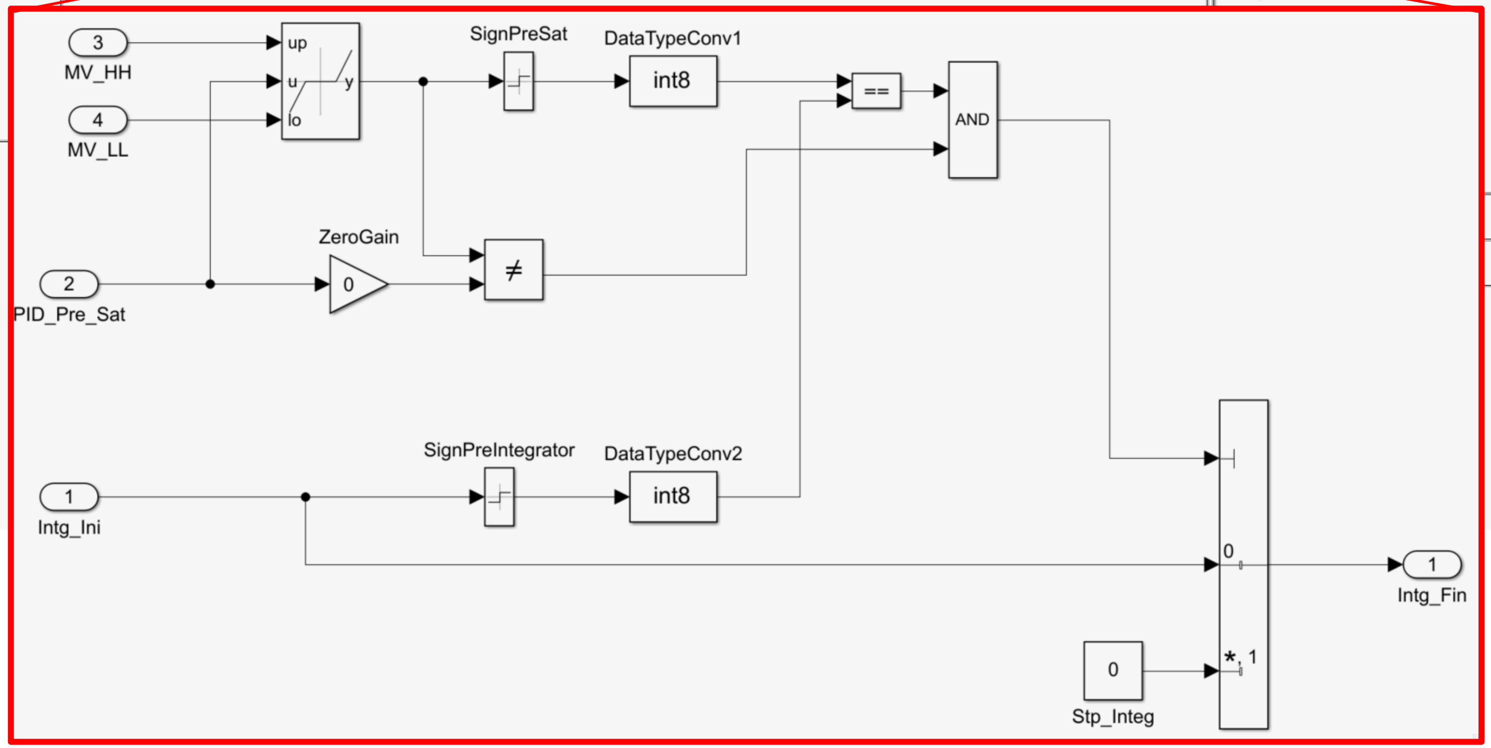
5 PID Tunning Parameters feed to the Controller via a Bus Signal PID_Params

6 In Manual Mode the Error to the PID algorithm is Zero as PV is fed into SV

Real PID Controller Implementation Simulink *(Filtered Derivative on Rate of Change of PV)*

$$G_c(s) = Bias + K_c\left(1 + \frac{1}{T_i s} + T_d s\frac{1}{T_f s + 1}\right)$$



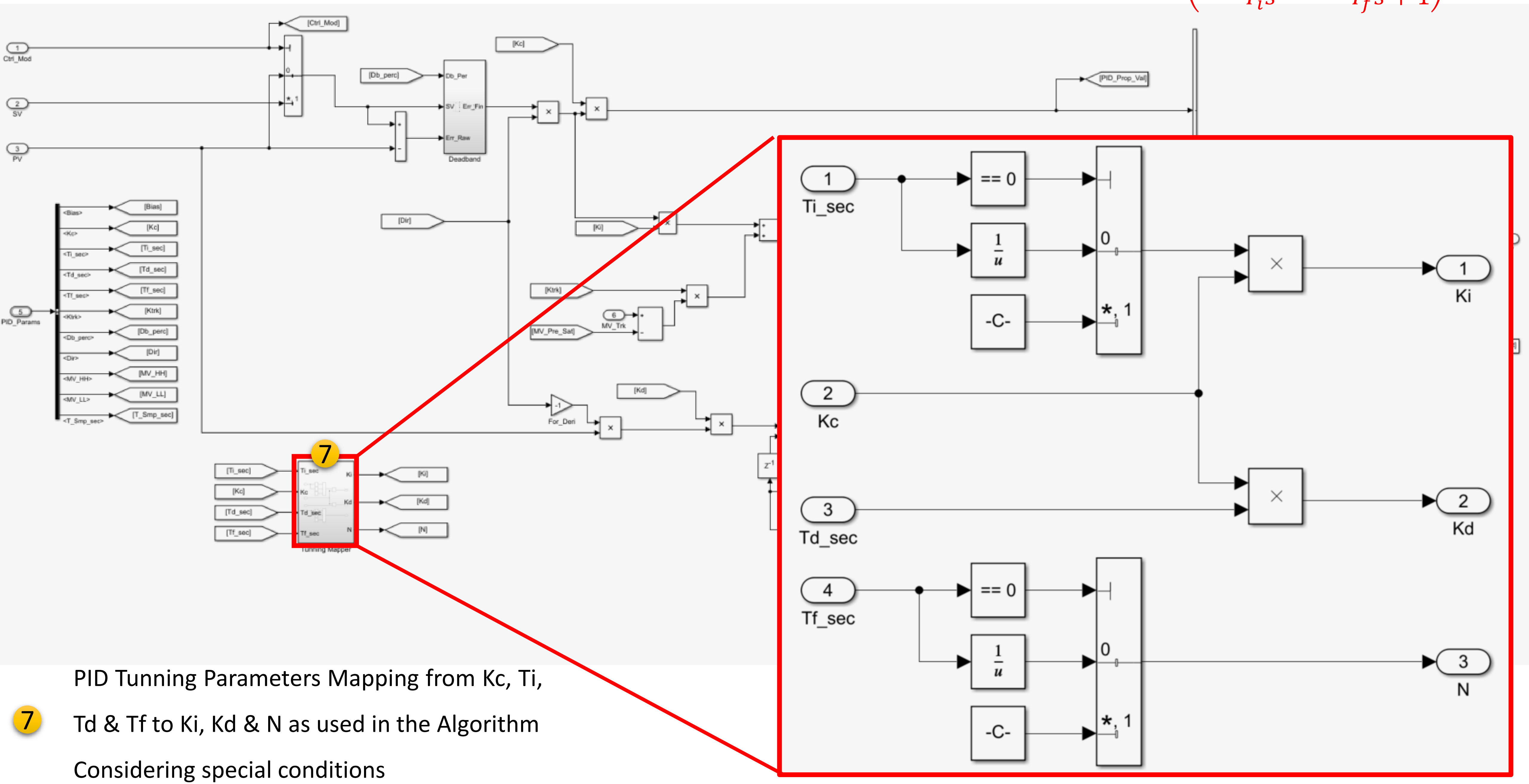


3 Integral Anti Reset Wind Up in the Event of Actuator Saturation

In the event of actuator saturation, the code will allow the current Integrator contribution if its sign can help back the pre-saturated final PID within the the Saturation limits

Real PID Controller Implementation Simulink *(Filtered Derivative on Rate of Change of PV)*

$$G_c(s) = Bias + K_c\left(1 + \frac{1}{T_i s} + T_d s\frac{1}{T_f s + 1}\right)$$

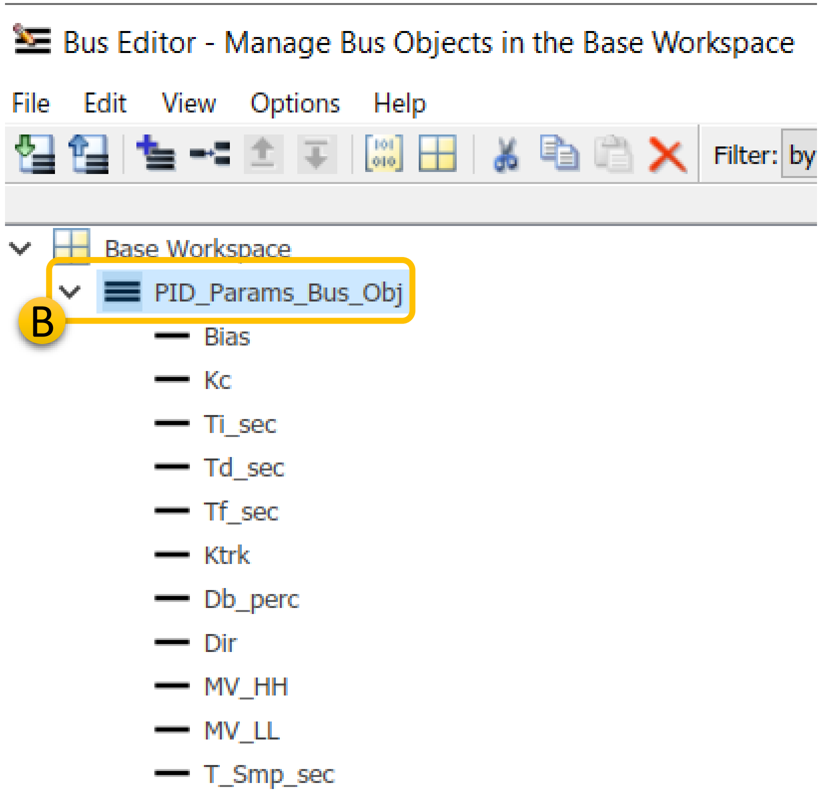


7 PID Tunning Parameters Mapping from Kc, Ti, Td & Tf to Ki, Kd & N as used in the Algorithm Considering special conditions

A

```
% PID Tuning Parameters
PID_Params_TC_Clt_FC_In.Bias = single(0);
PID_Params_TC_Clt_FC_In.Kc = single(1.17);
PID_Params_TC_Clt_FC_In.Ti_sec = single(0.25);
PID_Params_TC_Clt_FC_In.Td_sec = single(0);
PID_Params_TC_Clt_FC_In.N = single(0);
PID_Params_TC_Clt_FC_In.Ktrk = single(0);
PID_Params_TC_Clt_FC_In.Db_perc = single(0);
PID_Params_TC_Clt_FC_In.Dir = single(1);
PID_Params_TC_Clt_FC_In.MV_HH = single(100);
PID_Params_TC_Clt_FC_In.MV_LL = single(0);
PID_Params_TC_Clt_FC_In.T_Smp_sec = single(0.05);
```

Typical Structure ex *'PID_Param_TC_Clt_FC_In'* Based Initialization via M File of the PID Tunning Parameters loaded on the Workspace.



Typical Bus declaration for *'PID_Param_Bus_Obj'* as input declaration PID Controller Block.

To be loaded on the workspace

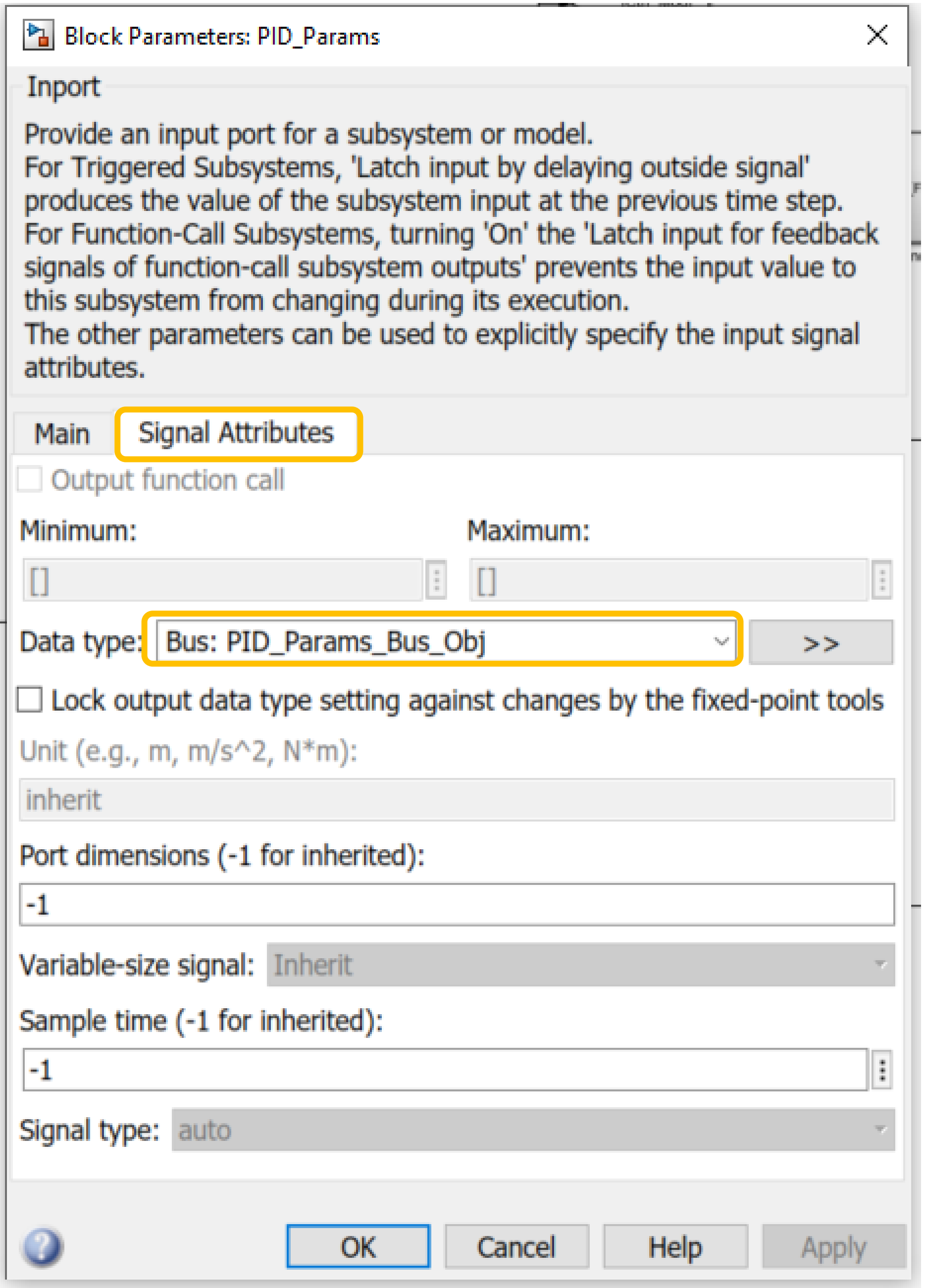


Table 7.2 PID Tuning Parameters for First-Order + Time Delay Processes

Controller	k_c	τ_I	τ_D	τ_F	Notes
PID	$\dfrac{\tau_p+\frac{\theta}{2}}{k_p(\theta+\lambda)}$	$\tau_p+\frac{\theta}{2}$	$\dfrac{\tau_p\theta}{2\tau_p+\theta}$	$\dfrac{\theta\lambda}{2(\theta+\lambda)}$	(1)
PID	$\dfrac{\tau_p+\frac{\theta}{2}}{k_p(\lambda+\frac{\theta}{2})}$	$\tau_p+\frac{\theta}{2}$	$\dfrac{\tau_p\theta}{2\tau_p+\theta}$	—	(2)
PI	$\dfrac{\tau_p}{k_p\lambda}$	τ_p	—	—	(3)
Improved PI	$\dfrac{\tau_p+\frac{\theta}{2}}{k_p\lambda}$	$\tau_p+\frac{\theta}{2}$	—	—	(4)

$$g_p(s) = \frac{k_p\, e^{-\theta s}}{\tau_p s + 1}$$

$$g_c(s) = k_c\left[\frac{\tau_I\tau_D s^2 + \tau_I s + 1}{\tau_I s}\right]\left[\frac{1}{\tau_F s + 1}\right]$$

(1) With an "all-pass" factorization and semi-proper q(s). Recommended $\lambda > 0.25\theta$.

(2) Without an "all-pass" factorization and improper q(s). Recommended $\lambda > 0.8\theta$.

(3) With zero-order Padé approximation ($e^{-\theta s} \approx 1$). Recommended $\lambda > 1.7\theta$.

(4) With the approximation $\dfrac{k_p e^{-\theta s}}{\tau_p s + 1} \approx \dfrac{k_p}{(\tau_p + \frac{\theta}{2})s+1}$. Recommended $\lambda > 1.7\theta$.

In all cases it is recommended that $\lambda > 0.2\,\tau_p$.

PID Feedback Controller & IMC-PID Tunning Rules

Reference : https://rpi.edu/dept/chem-eng/WWW/faculty/bequette/courses/cpc/IMC_PID.pdf

```
% Process Model Input Parameters

Kp=0.85; % Process Gain in respective Units  = [PV MV^-1]
Tp=0.25; % Process Time Constant in Sec
Tdt=0; % Process Dead Time in Sec

% Controller Design Parameter
Lbd = 0.25; % Process Control Closed Loop Desired Time Constant in Sec
% Recomended Lambda should be > 0.2 times Process Time Constant & > 0.8 times Process Dead Time

% Computed Controller Parameters

Kc = (Tp+0.5*Tdt)/(Kp*(Tdt+Lbd)) % Controller Gain in respective Units ie [MV PV^-1]

Kc = 1.1765

Ti = Tp+0.5*Tdt % Controller Integral Time in Secs

Ti = 0.2500

Td = Tp*Tdt/(2*Tp+Tdt) % Controller Derivative Time in Secs

Td = 0

Tf = Tdt*Lbd/(2*(Tdt+Lbd)) % Derivative Filter Time Constant in sec

Tf = 0
```