CTI Workbench/Janus PID Basics

The basic idea behind a PID controller is to read a sensor, then compute the desired actuator output by calculating proportional, integral, and derivative responses and summing those three components to compute the output.

The PID controller receives the process variable (PV) and controls the manipulation variable (MV) in order to adjust the PV to match the set value (SV).

The figure below shows a typical configuration for a PID control system.
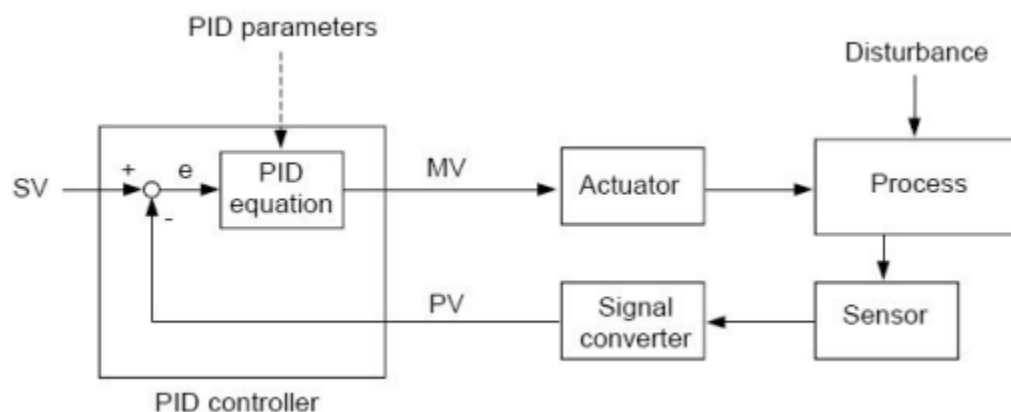
• **Process**: A physical system in which manipulating an input parameter has an effect on a measured value of the system such as temperature, pressure, flow rate, position, etc.
• **Sensor**: A detector that detects the controlled physical values. It can be a thermocouple, RTD,
pressure gauge, flow meter, etc.
• **Signal Converter**: A device that transmits a weak sensor signal to the PID controller by converting it
into the signal suited for the environment, such as 4 - 20 mA, 1 - 5 VDC, pulse train, etc.
• **Actuator**: A device that acts as an input to the process by regulating fluid or electric power according
to the Signal generated by the PID controller. It can be a control valve, thyristor, and variable speed drive, etc.
• **Process Variable (PV)**: The measured observable value of the system which is to be controlled, normally 4 - 20 mA or 1 - 5 VDC analog signals.

• **Manipulation Variable (MV)**: The PID output which controls the actuator, normally 4 - 20 mA, 1 – 5 VDC, or a time-proportional pulse.
• **Set Point Value (SV)**: The desired target for the Process Variable.
• **Error (e)**: Difference between the PV and SV at a given measurement point.
• **PID Equation**: Algorithm relating the Error, time, and PID parameters to calculate a value for MV. Controls the MV based on the magnitude of E and the PID tuning Parameters. These parameters may be more or less aggressive based on system time responses and operator preferences.

In the PLC, a PID function block and analog input/output modules are used for PID control (one PID loop). To configure two or more PID loops, two or more PID function blocks are used. The number of the PID loops configurable by one PLC is normally limited by the available number of analog inputs/outputs.
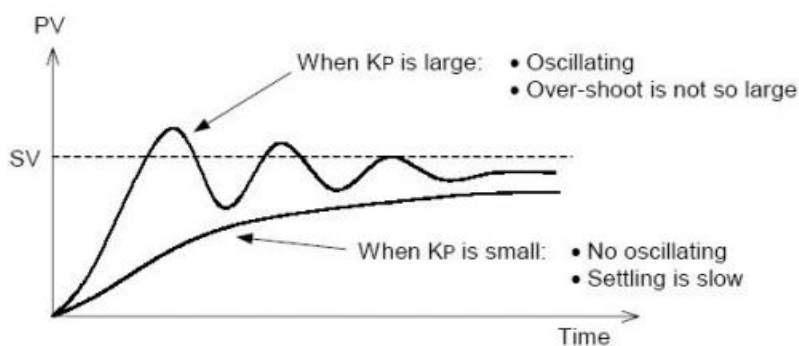
Proportional (P) Control Action
Proportional (P) control generates the MV in proportion to the error (E).
Here, the error (E) is the difference between the SV and the PV, and defined as follows:
$E = SV - PV$
In the P control action, the MV is calculated as follows:
$MV = Kp * E$

**KP** is called proportional gain. Generally, P control action works as follows:

With just P control, an offset (residual error) will remain. Therefore, P control is used with I control (PI control) to eliminate the offset.

Integral (I) Control Action

Integral (I) control will generate the MV in proportion to the time-integral of the error (E). While the error (E) exists, the I control will modulate the MV to eliminate the error (E). MV with I control is calculated as follows:

TI is called integral time, the unit of measure is 'seconds per repeat' When TI is large, the MV will change slowly. When TI is small, the MV will change rapidly. That is, the smaller the TI, the larger the integral gain.

When TI is too small, oscillation of PV will appear as in the figure below:
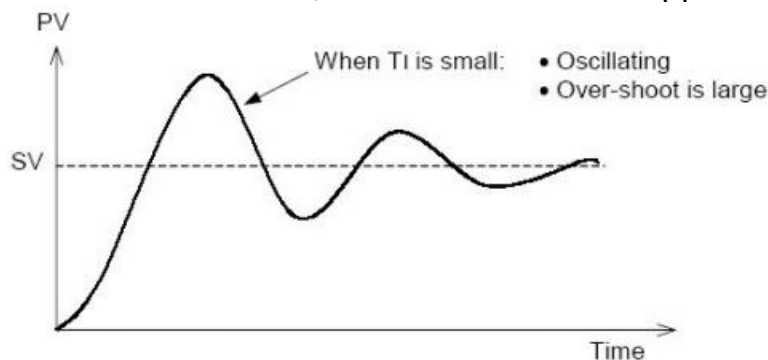
The I control is not used by itself. It is used with P (PI control) or P and D (PID control).

Derivative (D) Control Action

Derivative (D) control will generate the MV in proportion to the rate of change in the error (E). By adding D control, quick corrective action can be obtained at the beginning of an upset condition.

MV is related to the D parameter as follows:

TD is called derivative time; the unit of measure is 'repeats per second'. When TD is large, MV is relatively large for any E. That is, the larger the TD, the larger the derivative gain. If TD is 0 (zero), the D control does not function.

When TD is too large, short periodic oscillations of PV will appear:

PV

When T_D is large: • Oscillating (short period)
• Amplitude of MV is large

SV
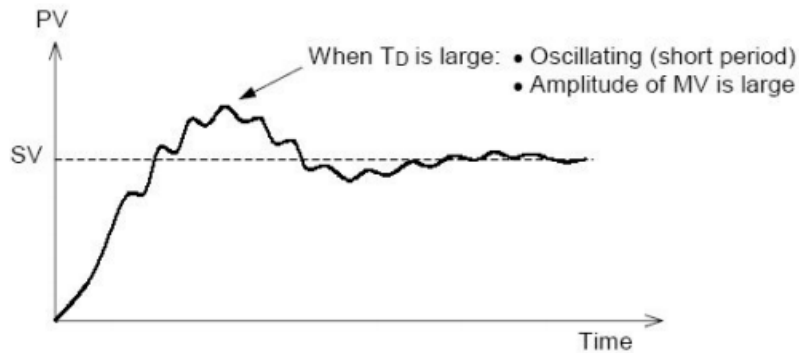
Time

The D control is not used by itself. It is used with P and I (PID control). D control is poorly suited for processes which oscillate rapidly and is seldom used in processes which have a fast response time (pressure or flow). For processes with long lag times (temperature and level), D control can reduce both the magnitude of E and the potential for large overshoots caused by a given upset condition.

Note that these same processes often act as mechanical integrator and the I tuning parameter can actually stimulate a worsening of the overshoot or oscillation problem.

Example Workbench PID Loop in Ladder

R2 ——| AUTO |——(Eno)——|

```
                          ExamplePID
                    ┌──────────────────────┐
                    │ AUTO          PID  Eno│
              PV ──│ Pv          Xout│── Xout
              SP ──│ Sp            ER│── ER
     Xout_Manual ──│ Xout_Manu Xout_P│── Xout_P
              KP ──│ Kp        Xout_I│── Xout_I
              TI ──│ Ti        Xout_D│── Xout_D
              TD ──│ Td      Xout_HLM│──                Xout_HLM
              TS ──│ Ts      Xout_LLM│──                Xout_LLM
            XMIN ──│ XMIN          │
            XMAX ──│ XMAX          │
      ──| I_SEL |──│ I_SEL         │
  ──| INT_HOLD |──│ INT_HOLD      │
    ──| I_ITL_ON |──│ I_ITL_ON      │
        I_ITLVAL ──│ I_ITLVAL      │
   DEADBAND_ERR ──│ DEADB_...     │
             FFD ──│ FFD           │
                    └──────────────────────┘
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Xout_HLM ──( )──
Xout_LLM ──( )──
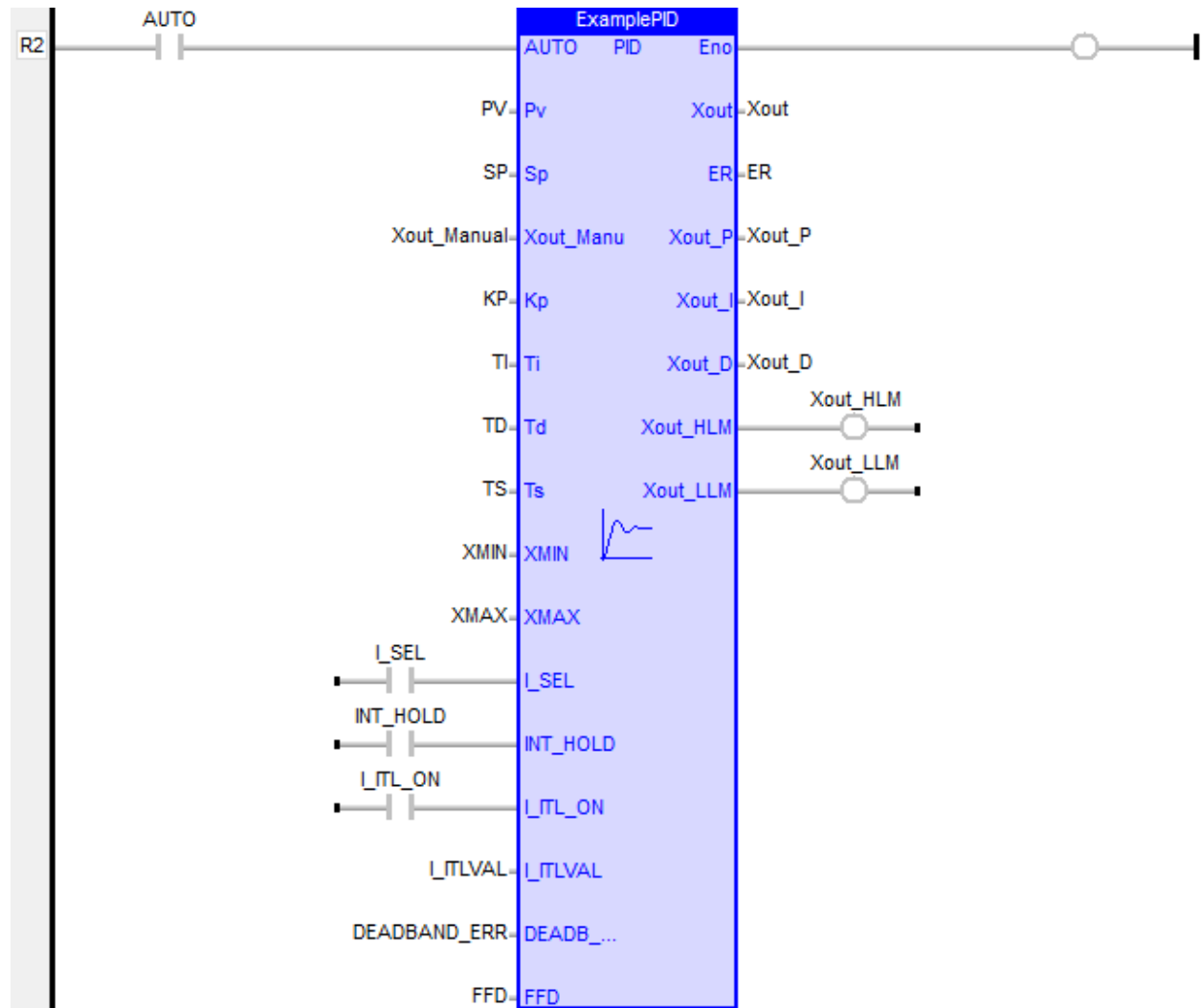
IEC PID Implementation
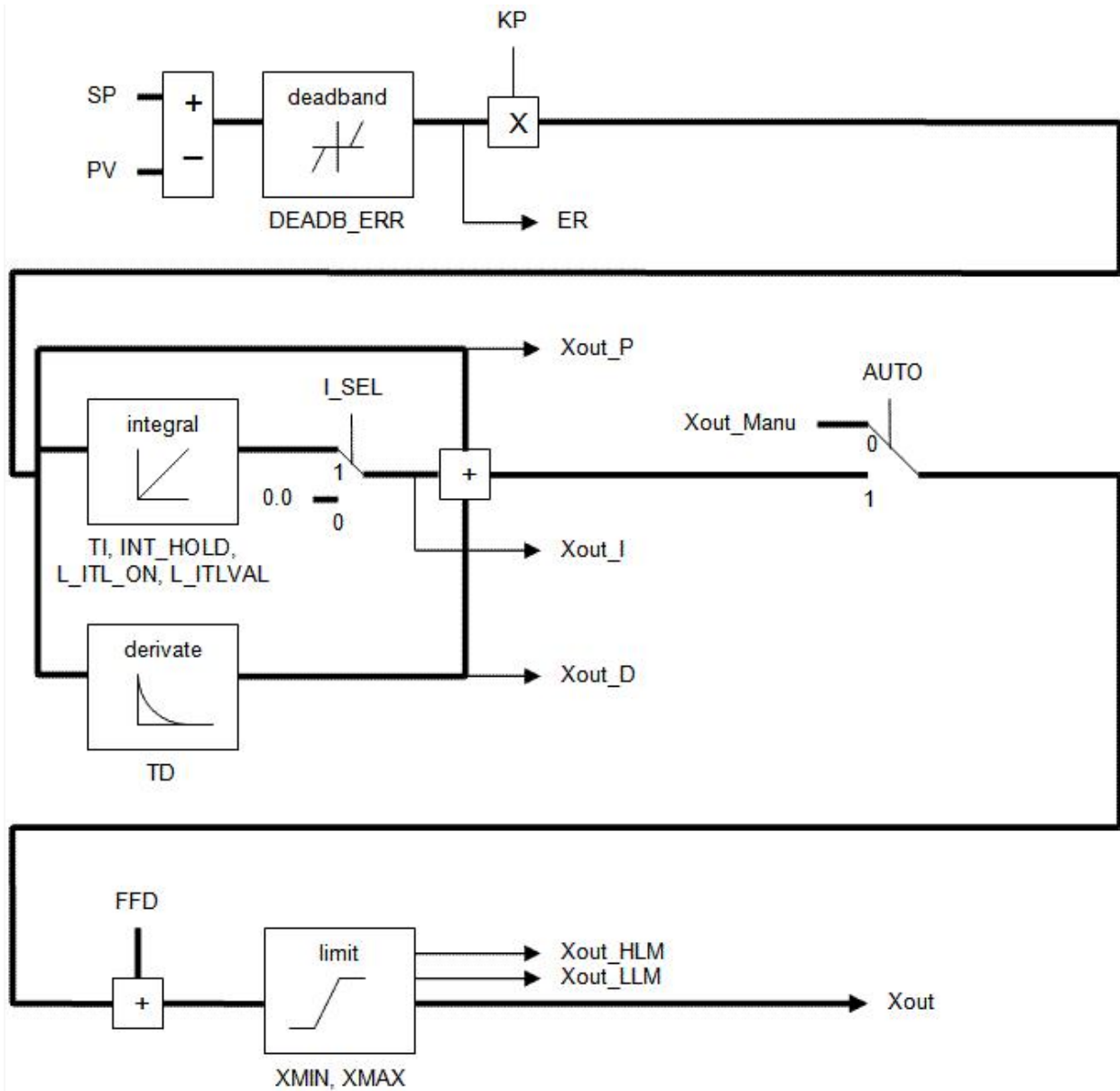
The PID instruction in IEC 61131-3 Mode is supported in Ladder Diagram (LD), Function Block Diagram (FBD), and Structured Text (ST) programming languages.

Workbench PID Input and Output Definitions.

Input Operand	Data Type	Description
AUTO	BOOL	TRUE = normal mode - FALSE = manual mode.
PV	REAL	Process value
SP	REAL	Set point
Xout Manual	REAL	Output value in manual mode
KP	REAL	Proportional gain.
TI	REAL	Integration factor
TD	REAL	Derivation factor
TS	TIME	Sampling period, must be > than PLC cycle time
XMIN	REAL	Minimum allowed output value
XMAX	REAL	Maximum output value
I_SEL	BOOL	FALSE, the integrated value is ignored.
INT_HOLD	BOOL	TRUE, the integrated value is frozen
I_ITL_ON	BOOL	TRUE, the integrated value is reset to I_ITLVAL
I_ITLVAL	REAL	Reset value for integration when I_ITL_ON is TRUE
DEADB_ERR	REAL	Hysteresis on PV.
FFD	REAL	Disturbance value on output
Xout	REAL	Output command value (Manipulation Value)
ER	REAL	Last calculated error
Xout_P	REAL	Last calculated proportional value
Xout_I	REAL	Last calculated integrated value
Xout_D	REAL	Last calculated derived value.
Xout_HLM	BOOL	TRUE if the output value is saturated to XMIN
Xout_LLM	BOOL	TRUE if the output value is saturated to XMAX

XMIN and XMAX are required inputs for the PID instruction to function and when used with the FFD disturbance value can scale output. If Xout is saturated to either limit, the Integration output is frozen. If the PID loop is set to manual mode, Xout is set to Xout_Manu + FFD.

IEC PID PWM Output Implementation

R2

PID_Auto ─┤ ├─

PID_Loop
AUTO	PID	Eno

PV ─ Pv ── Xout ─ Xout

SP ─ Sp ── ER ─ ER

Xout_Manual ─ Xout_Ma... ── Xout_P ─ Xout_P

KP ─ Kp ── Xout_I ─ Xout_I

TI ─ Ti ── Xout_D ─ Xout_D

TD ─ Td ── Xout_HLM ──( )── Xout_HLM

TS ─ Ts ── Xout_LLM ──( )── Xout_LLM

XMIN ─ XMIN

XMAX ─ XMAX

I_SEL ─┤ ├─ I_SEL

I_HOLD ─┤ ├─ INT_HOLD

I_ITL_ON ─┤ ├─ I_ITL_ON

I_ITLVAL ─ I_ITLVAL

DEADBAND ─ DEADB_...

FFD ─ FFD

Slot01_CH1_Pulse_En... ──( )──

En / Eno

Xout ─ IN1 ── Q ─ PWM_Out

100 ─ IN2

En any_to_udint Eno

PWM_Out ─ IN ── Q ─ Slot01_CH1_ON_Duty...