Siemens S7-1200

6AV2 123-2DB03-0AX0

Introduction to PID

- Understanding Control System
- Types of Control System
    - ❑ P Control
    - ❑ PI Control
    - ❑ PID Control

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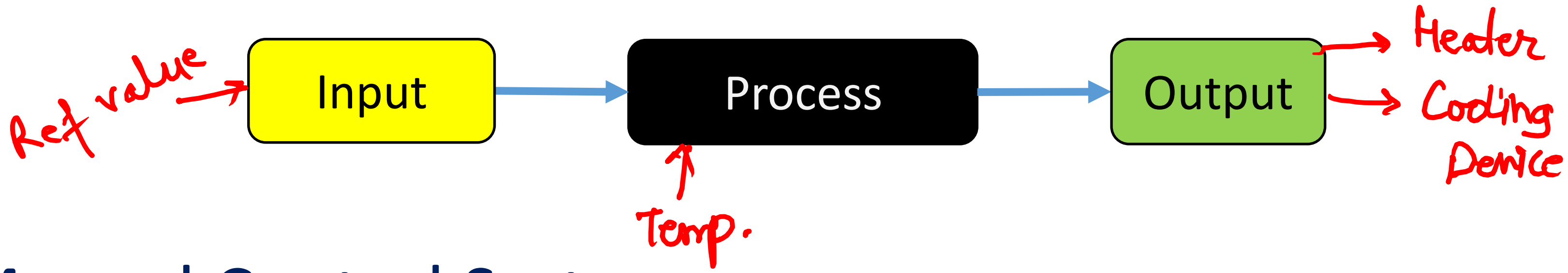
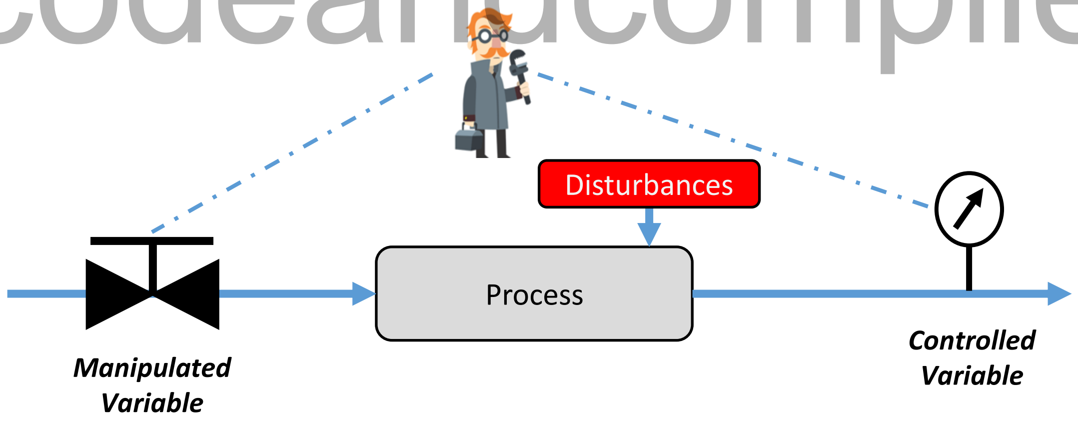
Understanding System

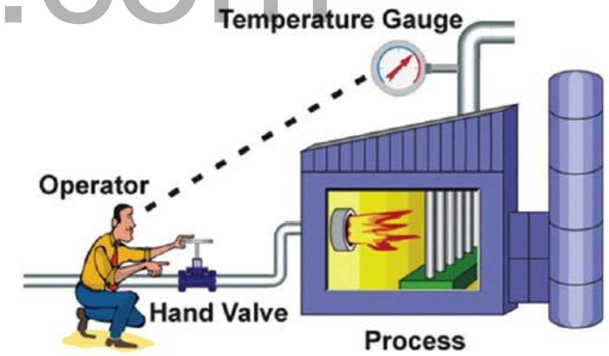
Systems have input and output flows, representing exchanges of matter, energy or information with their surroundings.



Manual Control System

System with human interaction to control the output



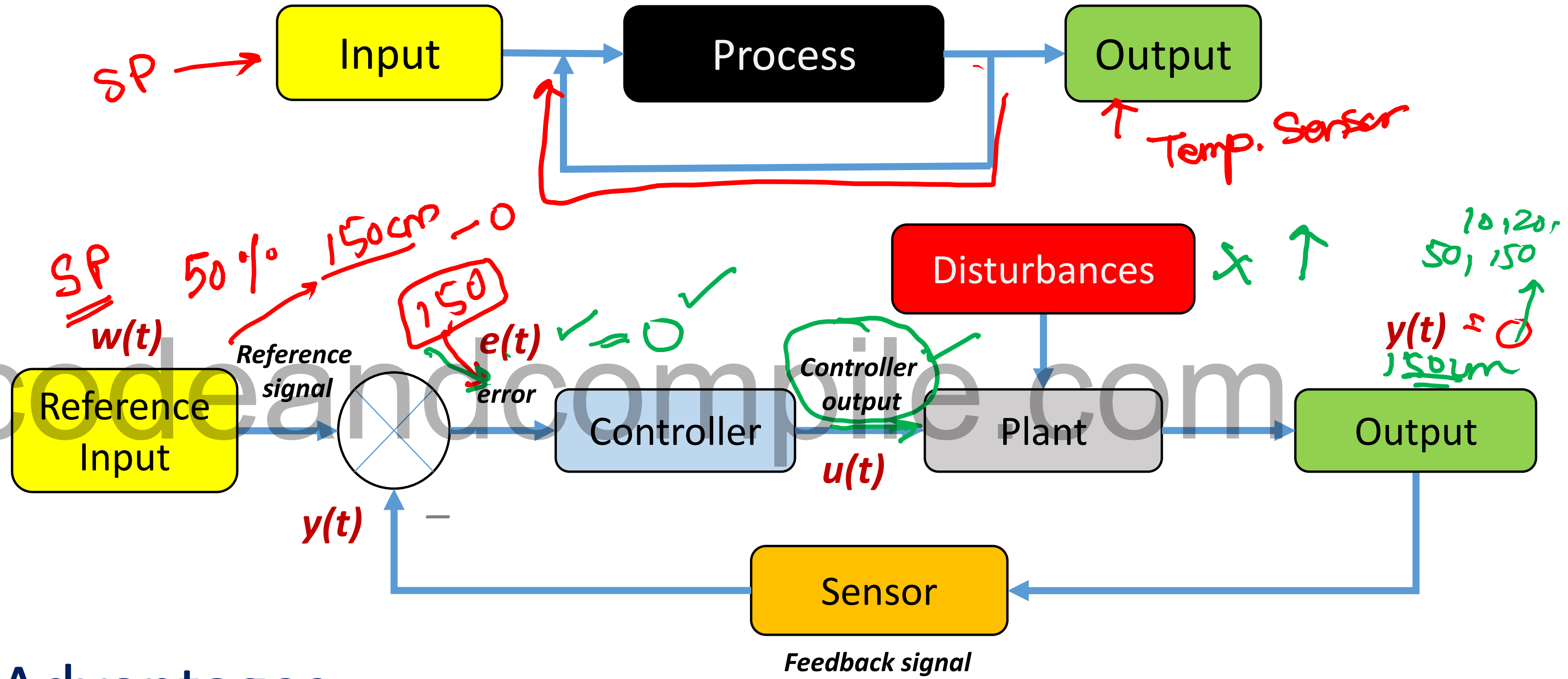


High risk involved and that's solely depends on operator

FIO Example – Liquid Level Control

Feedback Control System

Simplest way to control the system is with feedback. The sensors are installed to read the actual value and transmitted to the control hardware.



Advantages:

- Designer need not to know in advance about the disturbance which will effect the process
- More stable and reliable than open loop control system

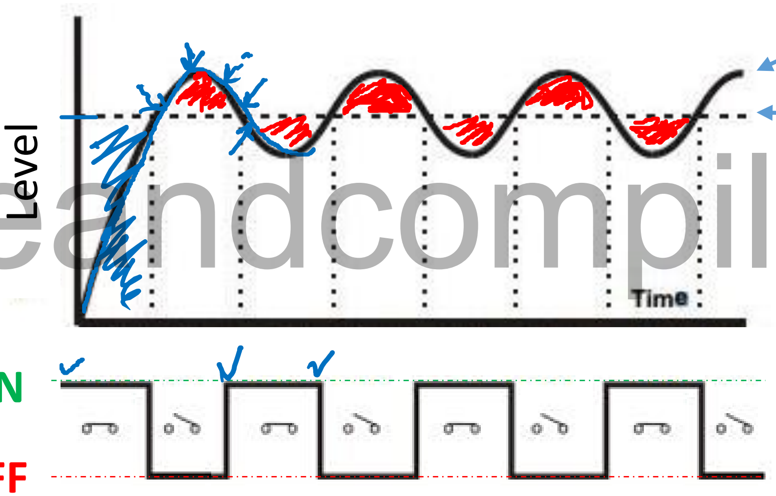
FIO Example – Liquid Level Control

ON-OFF Control or Two Position Control

- Most widely used Control system for industrial and domestic services
- Example: Home heating system, Domestic hot water heaters
- Manipulated variable quickly changes to Max. (100%) and Min. (0%) of the value.

Feedback value or Process Value

Set Point



ON

OFF

Filling Valve

Draining Valve – Manual control

ON - OFF

FIO Example – Liquid Level Control

Exercise 1

Simulate Liquid Level ON-OFF control in Factory IO via Siemens TIA

Software/Hardware used:
Software
Factory IO
Siemens TIA
Hardware
Siemens S7-1200

Task involved:

1. Calibrate the level sensor and analogue output of the environment to the range of 0 – 100%. ✓ $\boxed{0-10.0}$ × 10
2. ✓ Generate ON-OFF control algorithm in SCL
3. ✓ Display error, feedback and output on the panel

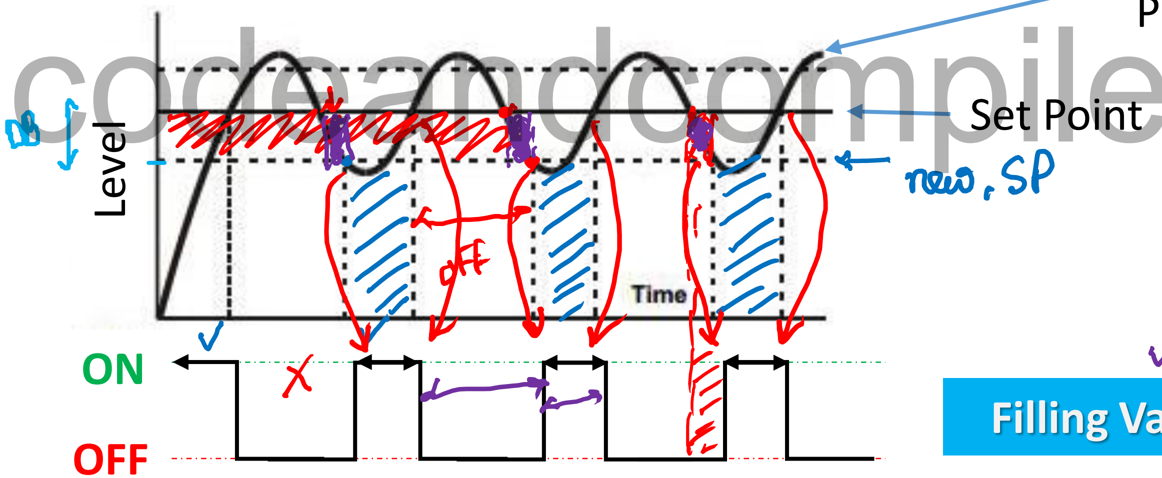
S.P > Level → Filling ON
50% 30% →
50% < 51% → " OFF

ON-OFF Control or Two Position Control with Dead band!

- ON- OFF Control without deadband undergo needless wear and tear on moving parts or contacts
- Therefore, deadband of 0.5% - 2.0% of full range is introduced. It's also known as differential gap or neutral zone
- No control action takes place when the process value is in deadzone

Basic ON-OFF Liquid Level Control with Deadband

Feedback value or Process Value



Filling Valve

Draining Valve – Manual control

ON - OFF

FIO Example – Liquid Level Control

Exercise 2

Simulate Liquid Level ON-OFF control with deadband in Factory IO via Siemens TIA

Software/Hardware used:

Software

Factory IO

Siemens TIA

Hardware

Siemens S7-1200

Task involved:

1. Read the feedback of tank by calibrating level sensor
2. Generate ON-OFF control algorithm using SCL
3. Control the deadband using independent knob
4. Display error, feedback and output on the panel

Exercise 3

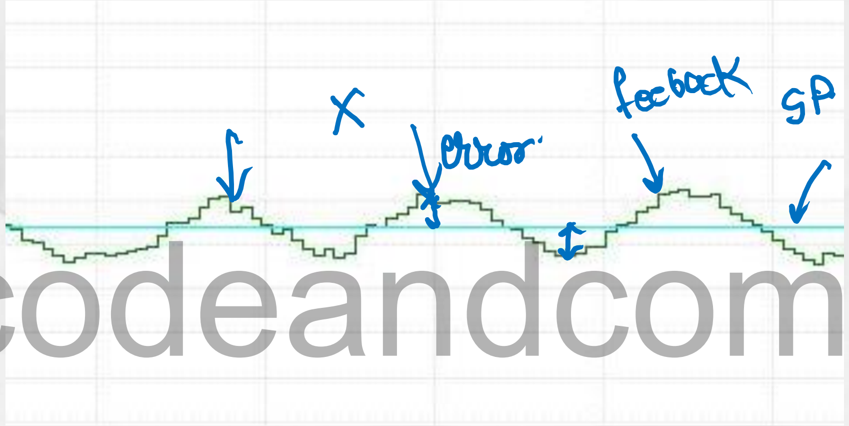
Software/Hardware used:

Software
Factory IO
Siemens TIA

Hardware
Siemens S7-1200

Paste the response curve of ON_OFF and ON_OFF Control with deadband Controller in Liquid Level control

ON/OFF Control



Digital 100% – 0%

Analogue

0 to 100
10%
20%
75%

ON/OFF Control with deadband

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  - ❑ PI Control
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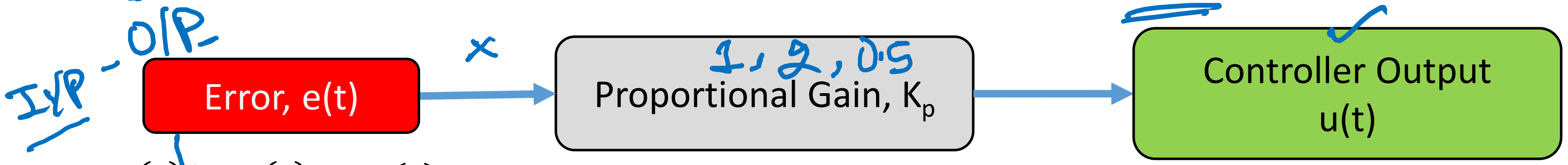
Proportional Control – Liquid Level

Gain

- Controller output is proportional to the error input signal to controller
- Typical Application: Slow change of error
- Linear relationship between Input and Output ← Stable



$$e(t) = y(t) - w(t)$$

$$u(t) = Kpe(t)$$

$$u(t) = Kp(y(t) - w(t))$$

Terminology

$u(t) = Controller\ Output$

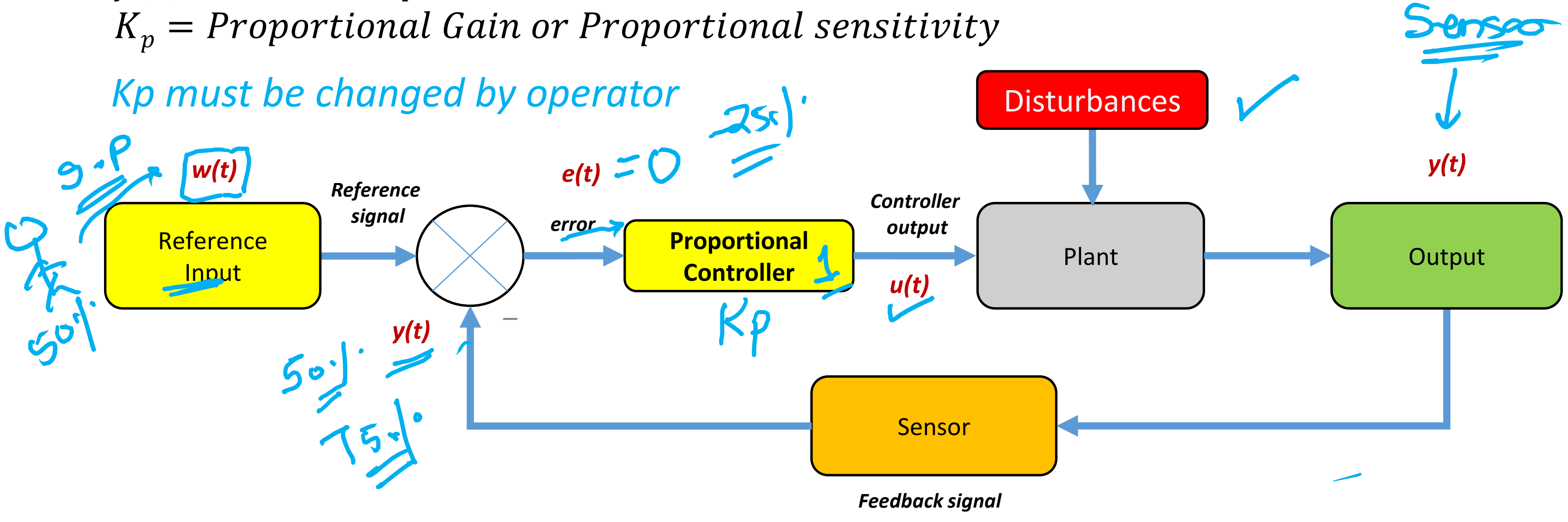
$w(t) = Input$

$e(t) = Error$

$y(t) = Plant\ Output$

$K_p = Proportional\ Gain\ or\ Proportional\ sensitivity$

Kp must be changed by operator



Proportional Control – Liquid Level

Effect of Gain, K_p

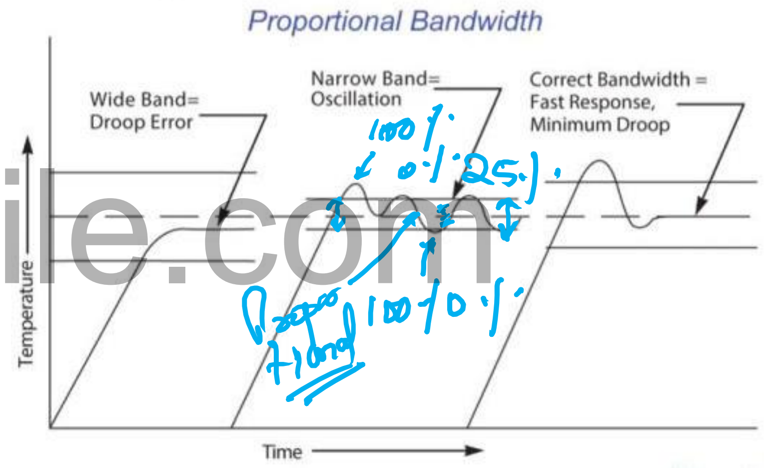
Error, e(t) → Proportional Gain, K_p → Controller Output u(t)

$$e(t) = y(t) - w(t)$$

$$\boxed{\mathrm{PB} = \frac{1}{K_p} * 100} \quad \%$$

$$u(t) = Kpe(t)$$

Proportional Gain Kp	Proportional Band, PB	Response
1	100%	
2	50%	
4	25%	
10	10%	



Proportional band is defined as the span of values of input which corresponds to full change in the output

If PB is of span, 25% = 25% of span. Example: the process controller is 0-100 units, 25% = 25 units wide. Below this 25 wide window, the process output is full ON. Above this window, the process is full OFF. Inside the 25 wide window, the process is ON or OFF a sliding analog percent.

Too wide = sluggish response. Too small = oscillations

Exercise 4

Simulate Liquid Level Proportional control in Factory IO via Siemens TIA

Software/Hardware used:

Software

Factory IO

Siemens TIA

Hardware

Siemens S7-1200

Task involved:

1. Read the feedback of tank by calibrating level sensor ✓
2. Generate Proportional control algorithm using SCL
3. Control the Proportional Gain using independent knob
4. Display error, feedback and output on the panel

error $\Rightarrow$ s.p − feedback

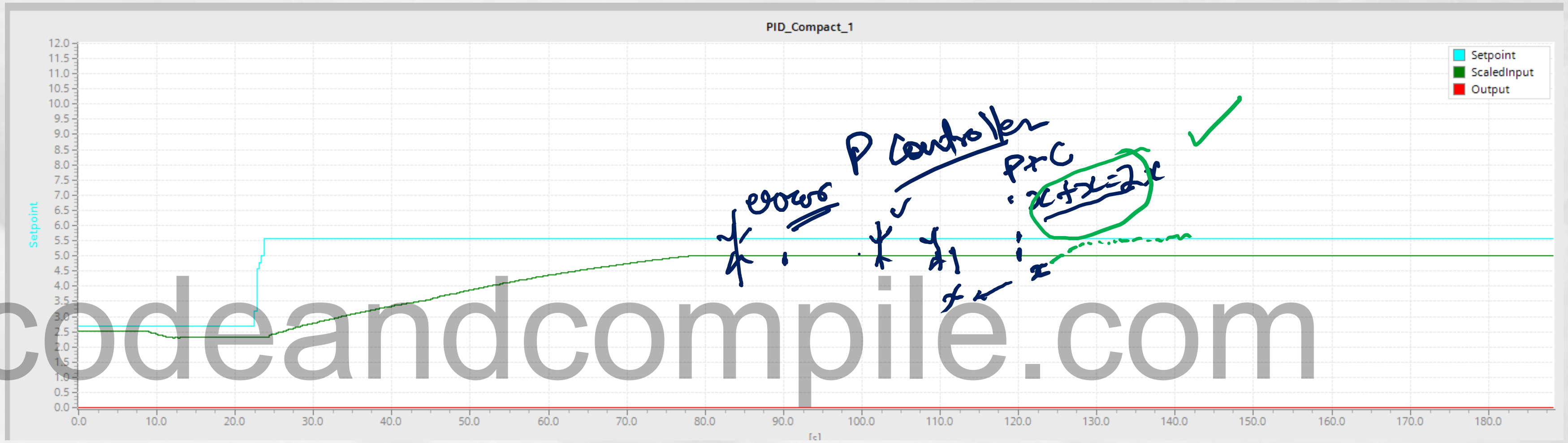
$u(t) = e(t) \cdot K_p$

filling value $= K_p \cdot (s.p - \text{feedback})$

Exercise 5

Paste the response curve of Proportional Controller in Liquid Level control

Software/Hardware used:
Software
Factory IO
Siemens TIA
Hardware
Siemens S7-1200



Conclusion

Advantage:

- Quite Simple and easiest way to control the output as there is only parameter K_p needs to be tuned.
- It also provide good stability

optimize Gain

Disadvantage:

At steady state, it has offset i.e. there is a difference at steady state between the desired value and required value (actual value)

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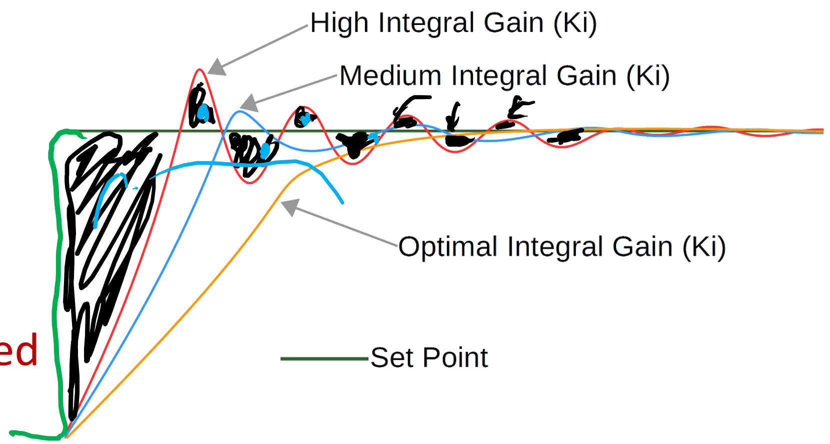
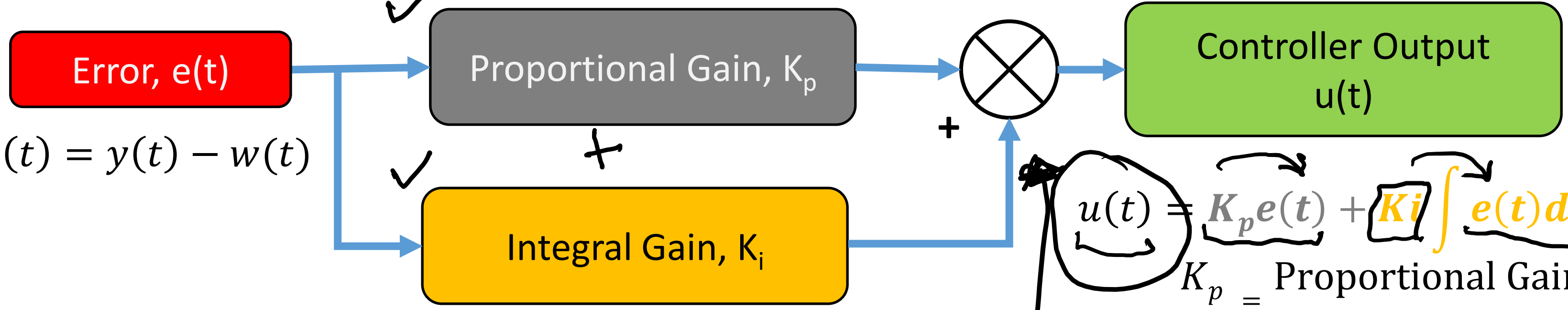
Proportional & Integral Control – Liquid Level

- Integral control is also known as Reset Control. It is an integration of error signal `e`. Integration is a continual summing. Integration of error over time means that we sum up the complete controller error history up to the present time, starting from when the controller was first switched to automatic.
- PI Controller output is proportional to the error and also changes with value of past errors. Hence it reduces steady state error





$e(t) = y(t) - w(t)$

$u(t) = K_p e(t) + \boxed{Ki} \int e(t)d(t)$

K_p = Proportional Gain

$K_i = Integral\ Gain = \frac{K_p}{T_i}$

$T_i = Integral\ Time$

$w(t) = Input$

Kp & Ki must be changed by operator

Exercise 6

Simulate Liquid Level PI (Proportional and Integral) control in Factory IO via Siemens TIA

Software/Hardware used:

Software
Factory IO
Siemens TIA

Hardware
Siemens S7-1200

Task involved:

1. Read the feedback of tank by calibrating level sensor
2. Generate PI control algorithm using SCL
3. Control the Proportional & Integral Gain using independent knobs
4. Display error, feedback and output on the panel

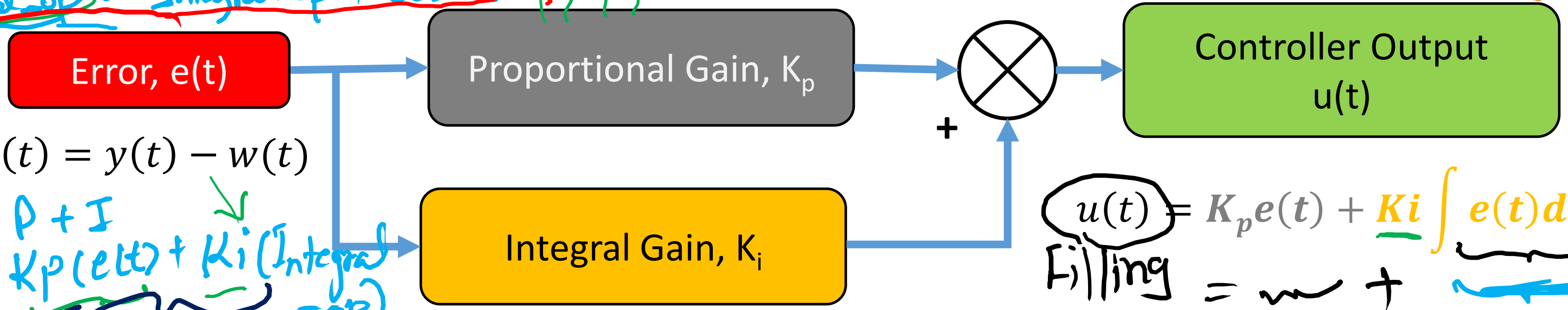
Include saturation logic & bumpless to the last code

1. Include logic to prevent saturation of controller
2. When you switch from Automatic to manual, optimize the code to have bumpless control.

Proportional & Integral Control – Liquid Level

error → i/p — feedback ✓

Integral_op := Integral_op + error ;



$$e(t) = y(t) - w(t)$$

$$u(t) = K_p e(t) + Ki \int e(t)d(t)$$

Filling = ~ +

u(t) = P + I

u(t) = Kp(e(t)) + Ki (Integral-op)

10.0 100% ← 101% 110% 200%

How to prevent Saturation (Anti-Wind up logic)? ✓

If (u(t) > 10.0)
u(t) := 10.0 ;
Integral_op := old_integral
END_IF;

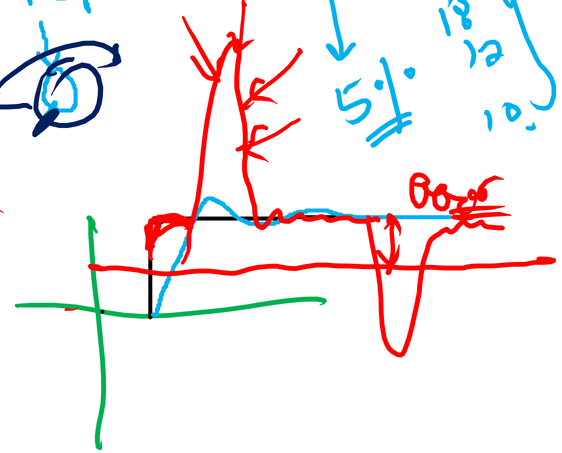
If (u(t) < 0.0)
u(t) := 0.0 ;
END_IF;

old_integral := Integral_op ;

20.0 → 5%

less meaningful

F_M



How to prevent bumps?

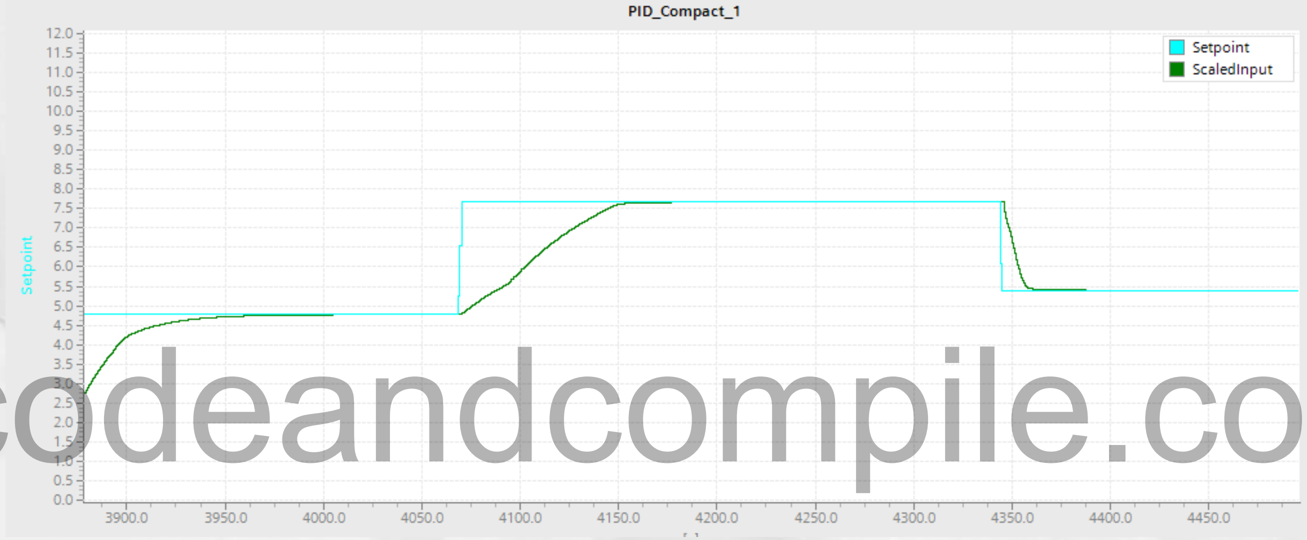
If manual := 1 ✓
u(t) := u(t)_manual ;
Integral_op := 0.0 ;
END_IF ;
ELSE u(t) := P + I

(new error)

Proportional & Integral Control – Liquid Level

Effect of Integral Gain, K_i

Paste the response curve of PI Controller in Liquid Level control



Advantage:

- Adding Integral control reduces offset

Disadvantage:

- Difficult to tune compared to Proportional controller, Now there are two parameters Proportional Gain Kp and Integral Gain Ki which are dependent to each other
- Slightly unstable than proportional control

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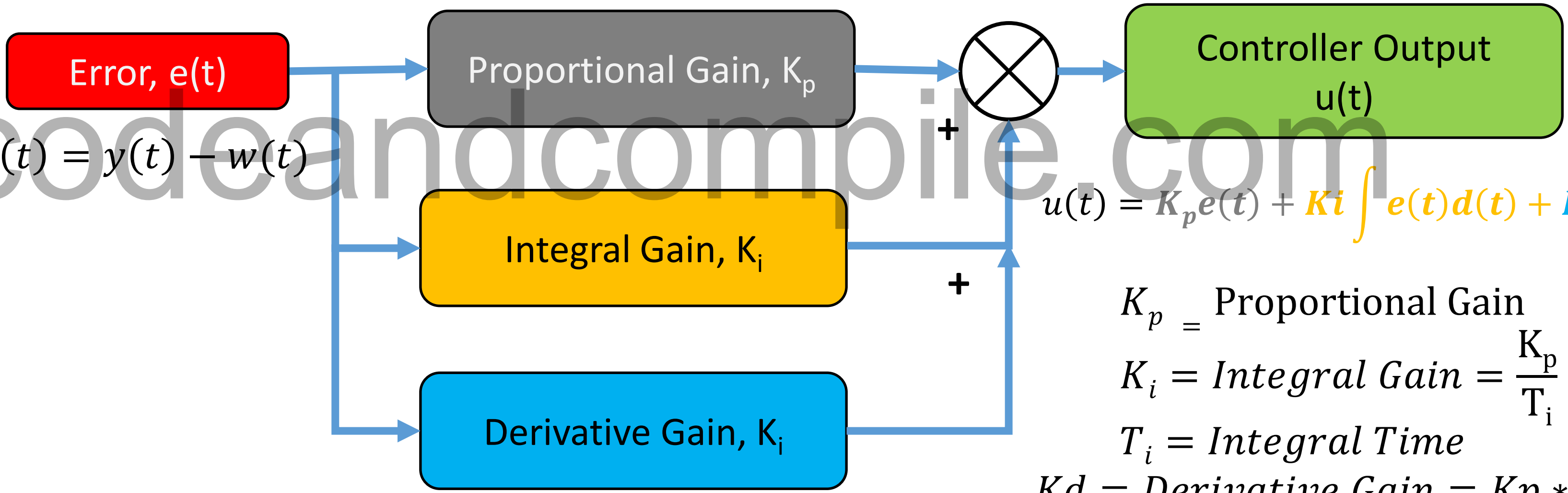
Proportional, Integral & Derivative Control – Liquid Level

- Derivative control is added to PI Control, now Derivative control is proportional to rate of change of error.
- Derivative control output is `0` if error is constant hence, it cannot be used alone. It's always used along with P or PI control
- *Derivative* acts as a brake or dampener on the control effort. The more the controller tries to change the value, the more it counteracts the effort. In our example, the variable rises in response to the setpoint change, but not as violently. As it approaches the setpoint, it settles in nicely with a minimum of overshoot. It doesn't move as quickly as the PI-only effort, but without the oscillations, the right amount of derivative action can stabilize the process variable at the setpoint sooner.
- It often requires complex tuning approach



$$e(t) = y(t) - w(t)$$

$$u(t) = K_p e(t) + Ki \int e(t)d(t) + Kd\frac{de(t)}{dt}$$

K_p = Proportional Gain

$K_i = Integral\ Gain = \frac{K_p}{T_i}$

$T_i = Integral\ Time$

$Kd = Derivative\ Gain = Kp * Td$

*Here T_d is Derivative time. It's used in situation where there is large amount of lag (slow response) in the system for example **Large temperature control problems**.*

Kp, Ki and Kd must be changed by operator

http://www.controleng.com/search/search-single-display/understanding-derivative-in-pid-control/4ea87c406e.html

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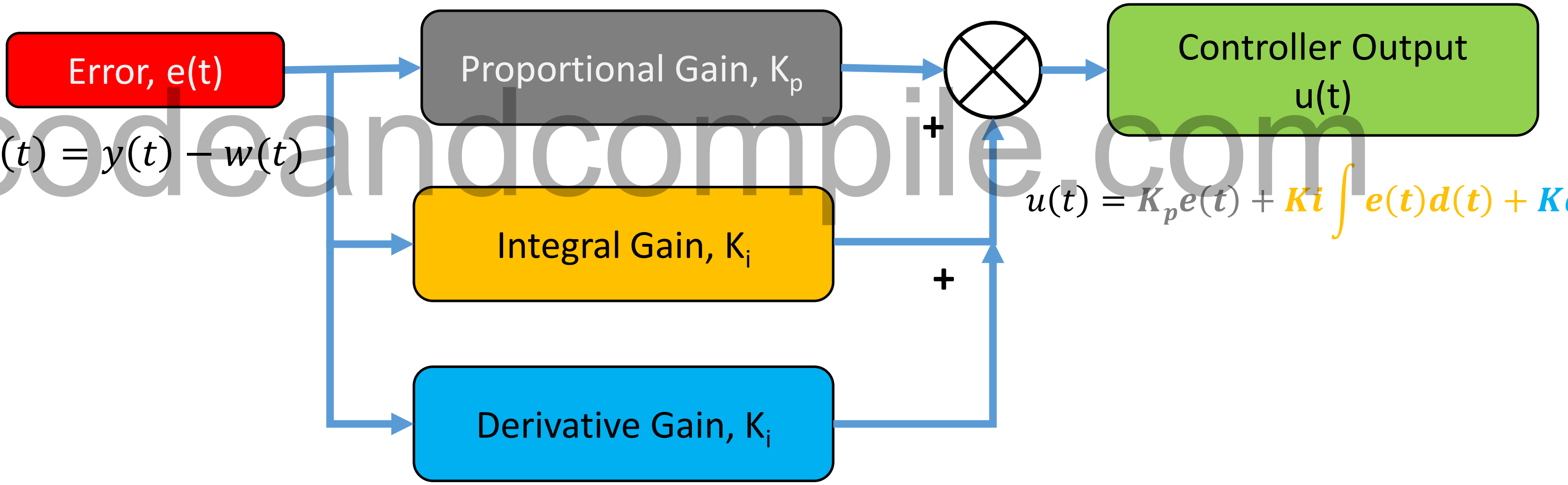


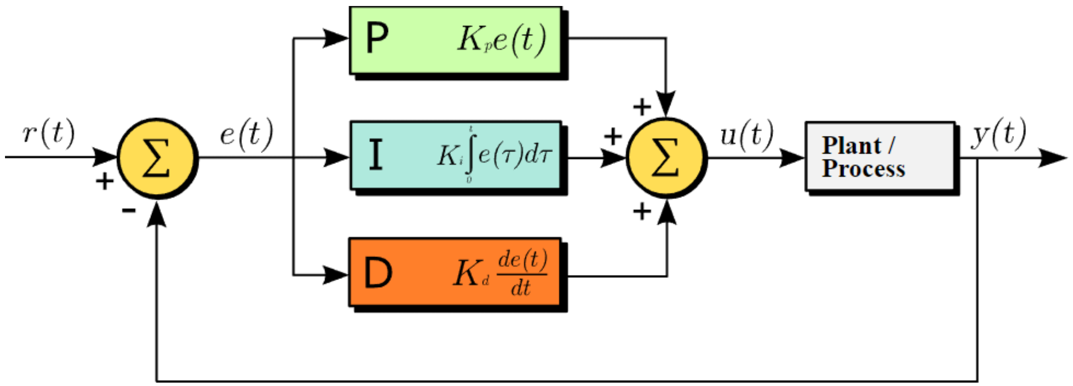
$$e(t) = y(t) - w(t)$$

$$u(t) = K_p e(t) + Ki \int e(t)d(t) + Kd\frac{de(t)}{dt}$$

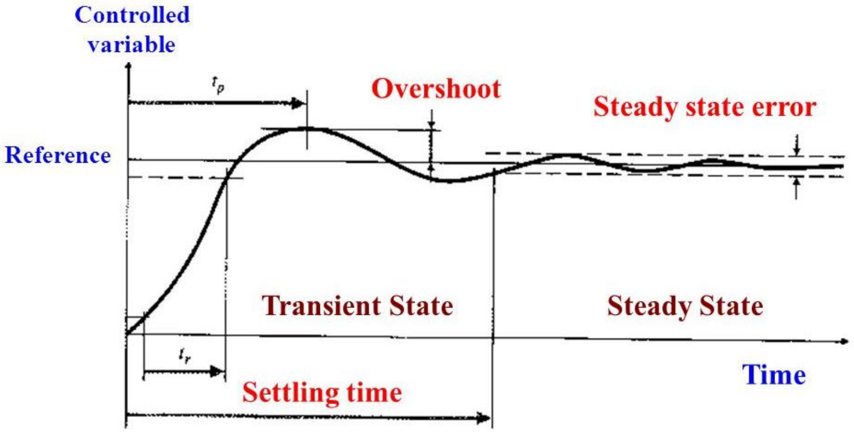
Bob Rice, Ph.D., director of solutions engineering for Control Station, sums up the three elements: "The proportional term looks at where my value is currently. Integral looks at where I've been over time, and derivative tries to predict where I'm going. Derivative tries to work opposite of where proportional and integral are trying to drive the process. P and I are trying to drive one way, and D is trying to counteract that. Derivative has its largest effect when the process is changing rapidly in one direction. The P and I terms are saying, 'Keep going.' The derivative catches it and says, 'You're going too fast. You need to slow down.'"

Proportional, Integral & Derivative Control – Liquid Level

General System model with PID Control



Typical response curve of feedback control



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