Special – Purpose Concepts Dead Time

Unit 12 & Unit 13

An Overview

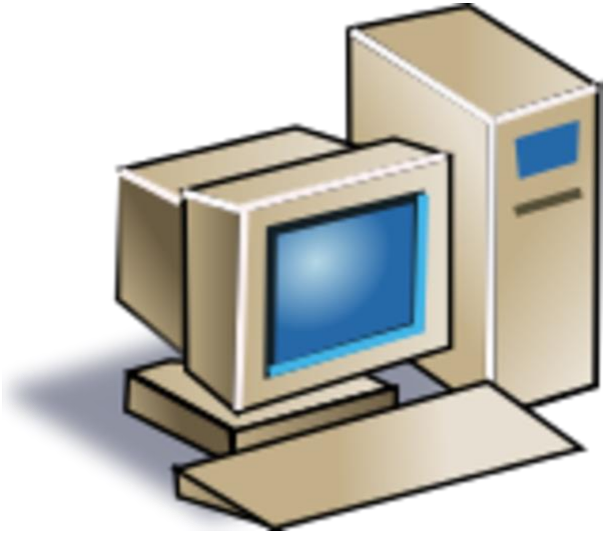
Textbook #02

Unit 12 and Unit 13 – An Overview

- Unit 12 and Unit 13 of textbook #2 contain advanced topics in control systems and is heavy in advanced mathematics.
- This lecture will be an overview of several topics within these units that should be understood and can appear on the final exam.
- Please do not get overwhelmed with the math or any of the control concepts presented in the textbook. You will not be responsible for them on any exams; however, they should be read to gain awareness.
- If there are any questions, please post the question(s) in the questions discussion topic. If needed, we can also do a live online meeting to discuss any questions you might have, individually or as a group.
- Many of these topics will be addressed in future courses within the program where there are hands-on examples to teach them.

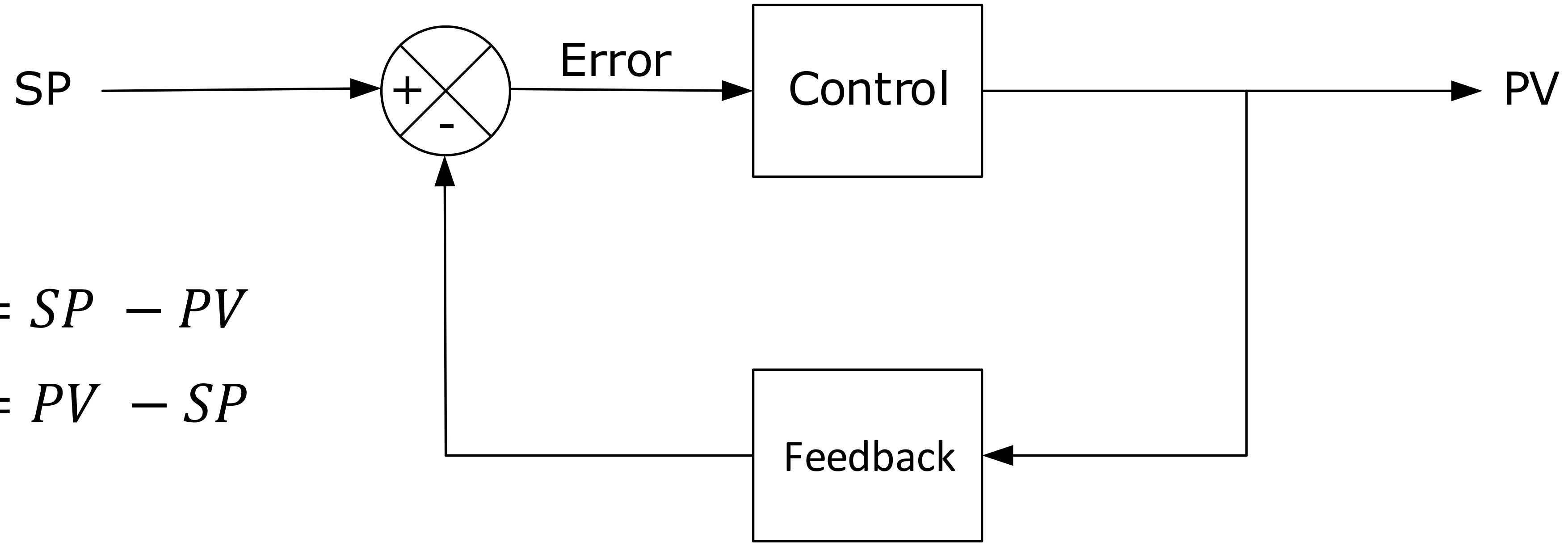
Computing Components

- Complex control systems require more complex calculation(s).
- More complex calculations require the use of a computer or Programmable Logic Controllers/Programmable Automation Controllers (PLC/PAC).



Calculations Include: Algebraic Sum/Difference

- The algebraic sum or difference of signals.
- An example: Calculating the error in the system between the set point and the process variable.



$$Error = SP - PV$$

$$Error = PV - SP$$

Calculations Include: Algebraic Product/Quotient

- The algebraic product or quotient of signals.
- An example: Applying proportional gain to a control loop.

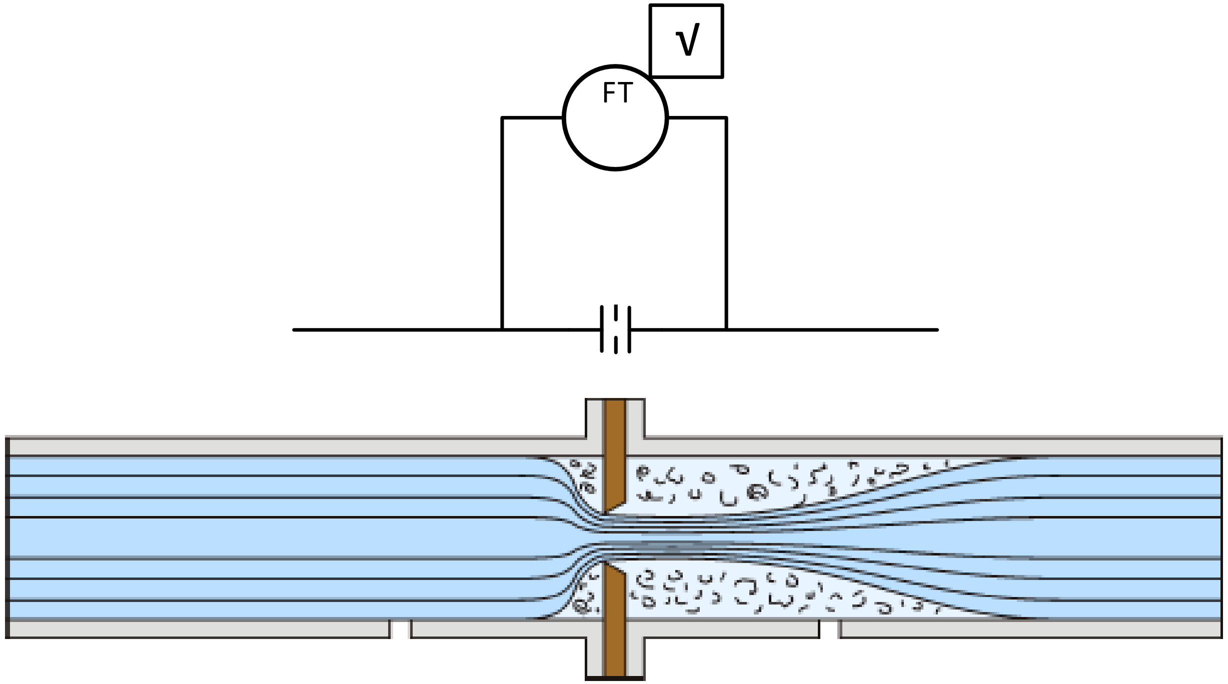
$$CV = Error \, * \, K_p$$

$$Where\text{: } K_p \; is \; Proportional \; Gain$$

Calculations Include: Square Root

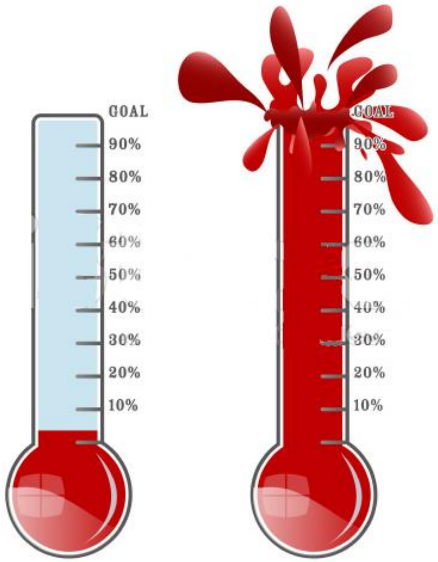
- The output signal is the square root of the input.
- An example: Square root extractors are used with flow transmitters/transducers. The equation to calculate volumetric flow rate 'Q' is related to the pressure differential measured between the high and low pressure taps of an orifice plate flow meter.

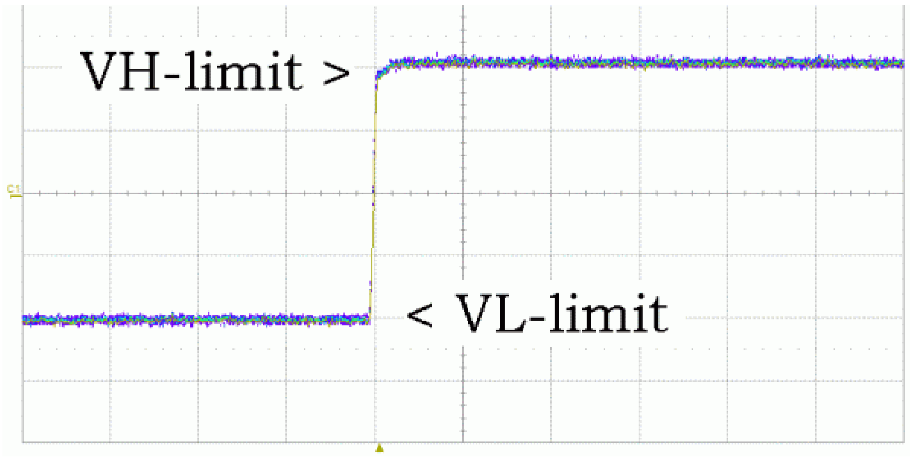
$$Q = CA_T\sqrt{\frac{2\Delta P}{\rho(1-\beta^4)}}$$



Calculations Include: Finding Highest/Lowest

- Finding the highest or lowest value.
  - An example: Some times it is necessary to capture the highest or the lowest value that a variable has reached.

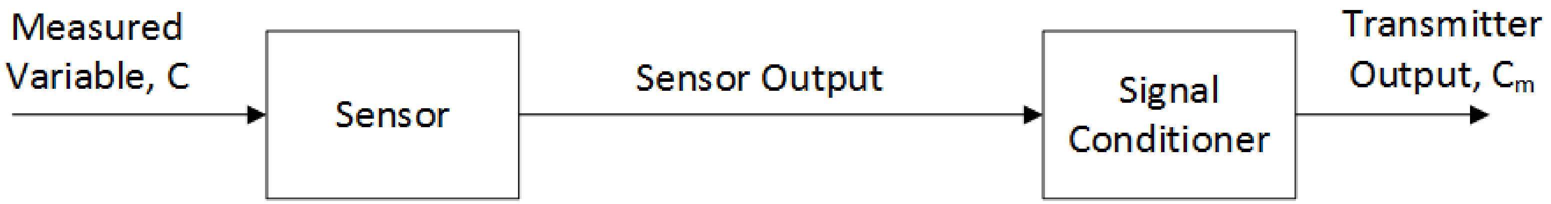




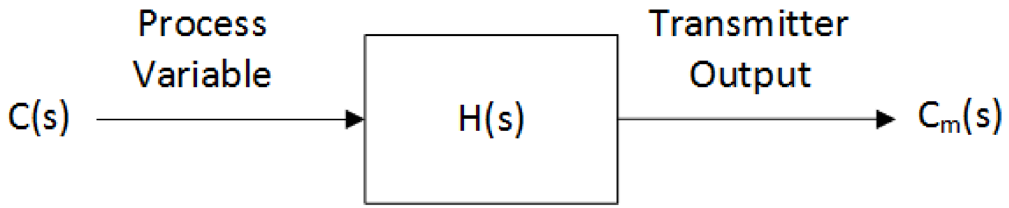
- Limiting a signal to a high or low limit.
  - An example: There might be a process where the pressure can not exceed 80 psi. A limit can be imposed so that the pressure cannot exceed the 80 psi.

Calculations Include: Function Generator

- The output signal is a function of the input signal; a.k.a. Function Generator.
  - An example: Assume a temperature transmitter that has a range of 250°F to 800°F. The span of the transmitter is: $800°F - 250°F = 550°F$. The transfer function of the transmitter relates its output signal to its input signal shown in the diagram and by the equation.



$$H(s) = \frac{C_m(s)}{C(s)} = \frac{K_t}{\tau_t S + 1}$$

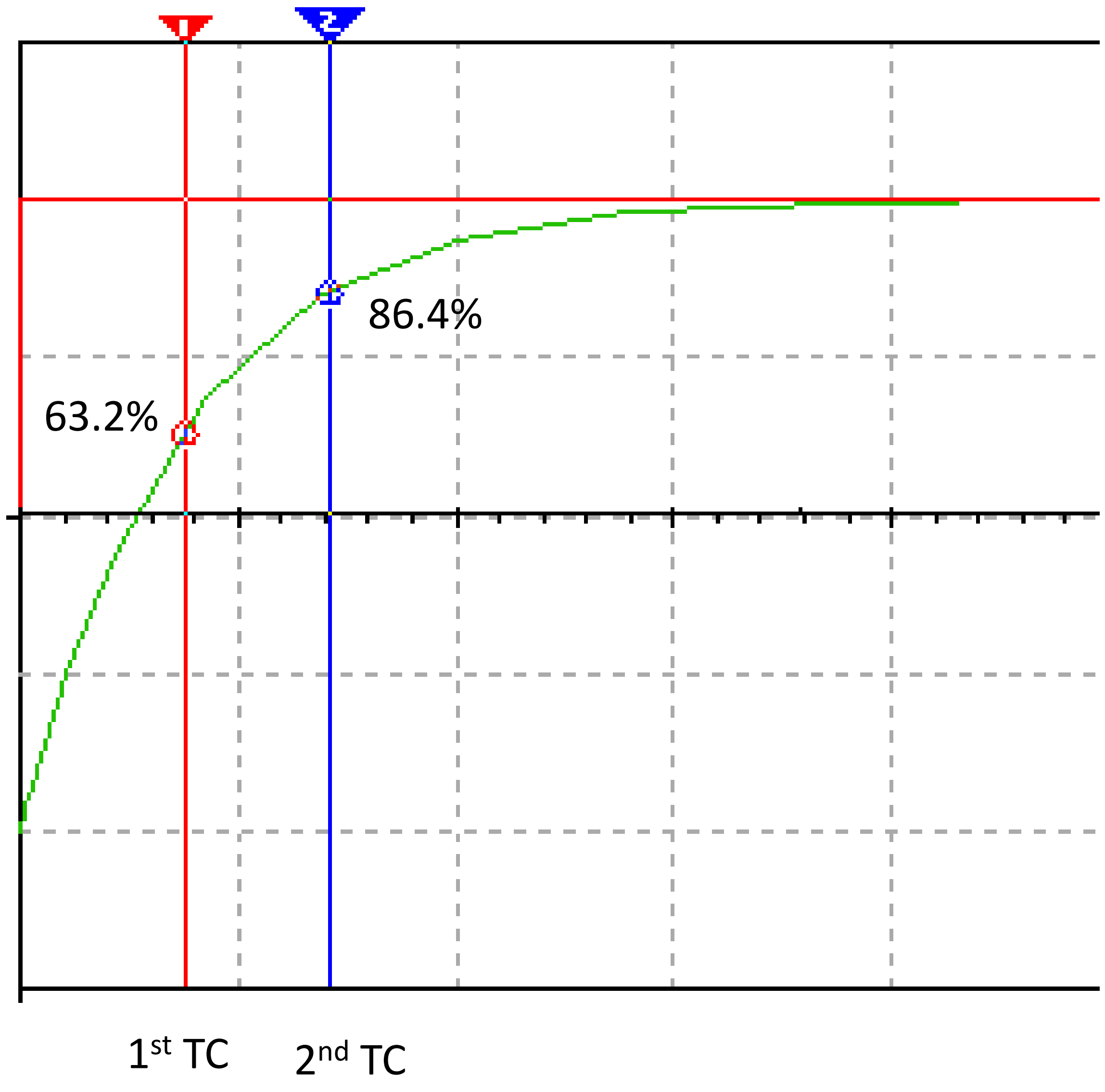


$Where\ K_t = transmitter\ gain$

$\tau_t = transmitter\ time\ contant$

Calculations Include: First Order Lag

- The output signal is the solution of a first-order differential equation in which the input signal is the forcing function (step change); a.k.a. Linear Lag or First Order Lag.
- A lag is a delay in the response of a process that represents the time it takes for a process to respond completely when there is a change in the input of the process.

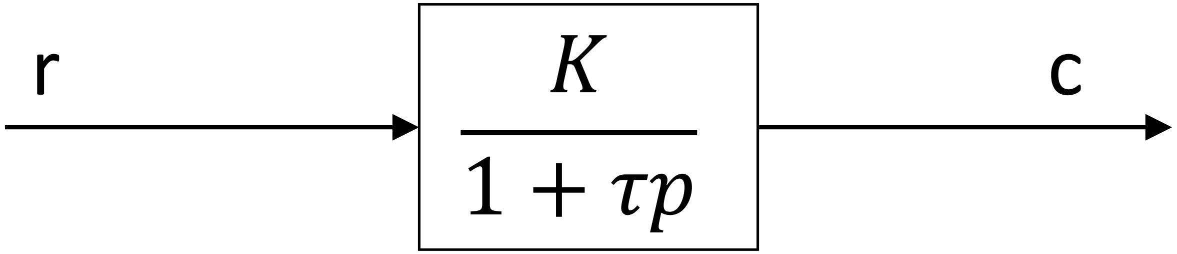


Calculations Include: First Order Lag

- First Order Lag is described by the equation:

$$\tau \frac{dc}{dt} + c = Kr$$

$$Where\ c = output, r = input, K = gain, \tau = time\ constant$$



$$where\ p\ is\ the\ Heaviside\ operator\ \frac{d}{dt}$$

Calculations Include: First Order Lag

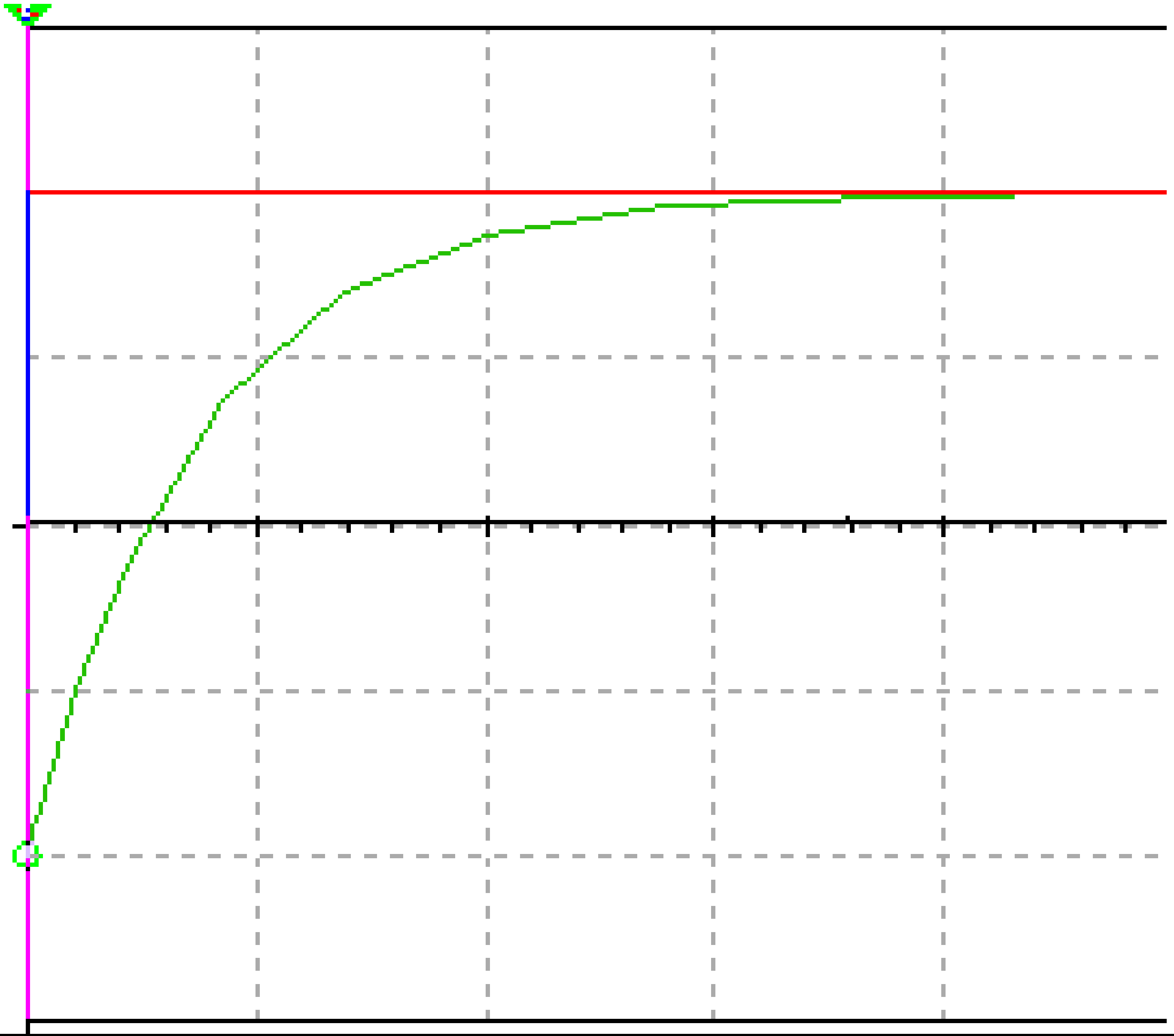
- What is a Heaviside operator?
- A Heaviside operator is Calculus.

- Don't worry…if you never had calculus, you will not have to do any. However, you should know that there is a lot of calculus in process control and you should understand what some of the terms mean.

Calculations Include: First Order Lag

- First Order Lag and the Heaviside Operator.
- The Heaviside Operator d/dt is a calculus term called a derivative.
- In process control, when a loop is tuned using Proportional Integral Derivative (PID), the derivative term is also referred to as, rate.
- Derivative (Rate) is nothing more than the rate of change of a process signal with respect to time, d/dt. Where t is time.

Calculations Include: Derivative Function



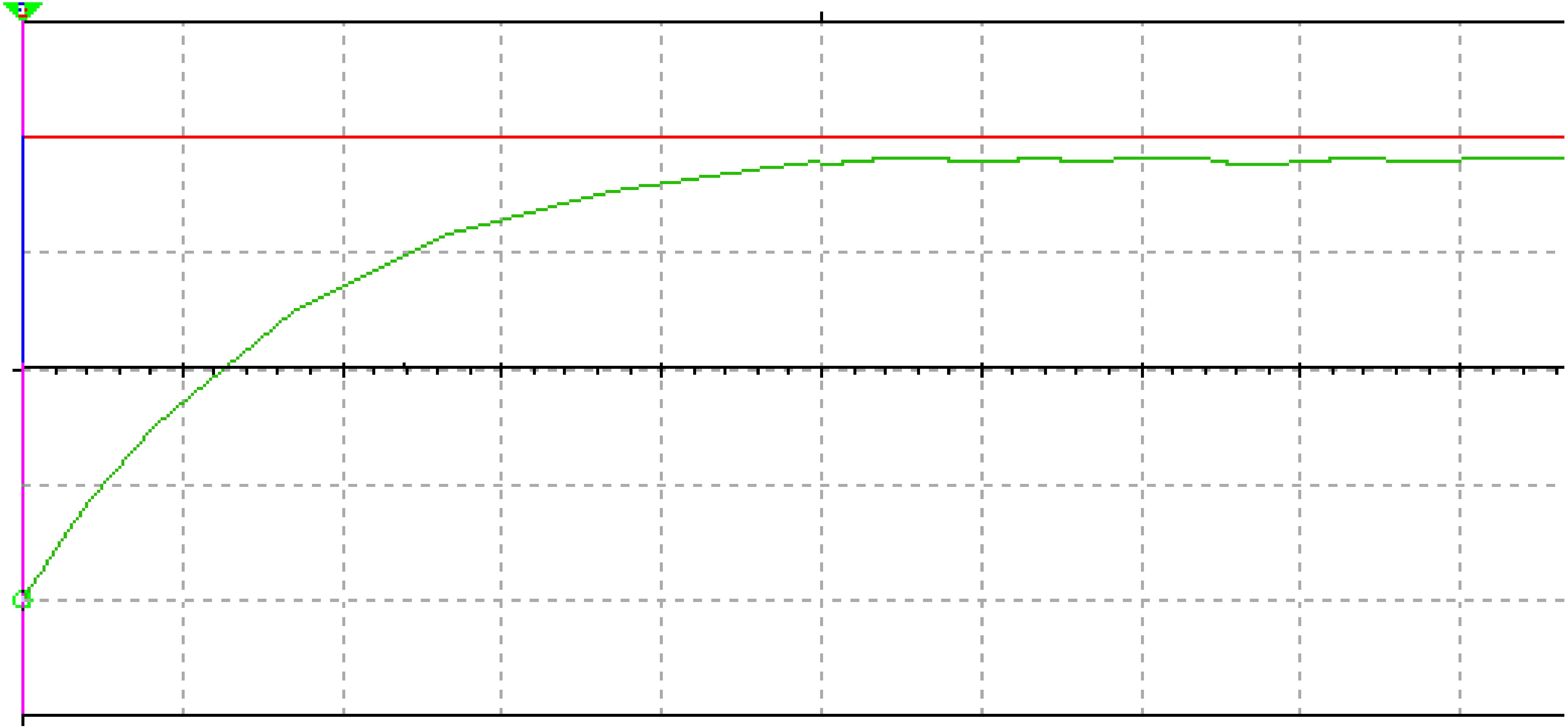
Calculations Include: Integral Function

- An output or input signal that is the time integral of the other, a.k.a. integrator (Integral) or totalizer.
- Integral is another calculus term and is the ‘I’ term in a PID control loop.
- The integral portion is used to change the output of a process by an amount proportional to an error over time. It can be represented mathematically by:

$$E + \frac{1}{T_i}\int_0^t E\,dt$$

$$Where\ E\ is\ the\ error, T_i\ is\ time\ and\ \int_0^t Edt\ is\ an\ integral\ of\ error\ over\ time$$

Calculations Include: Integral Function



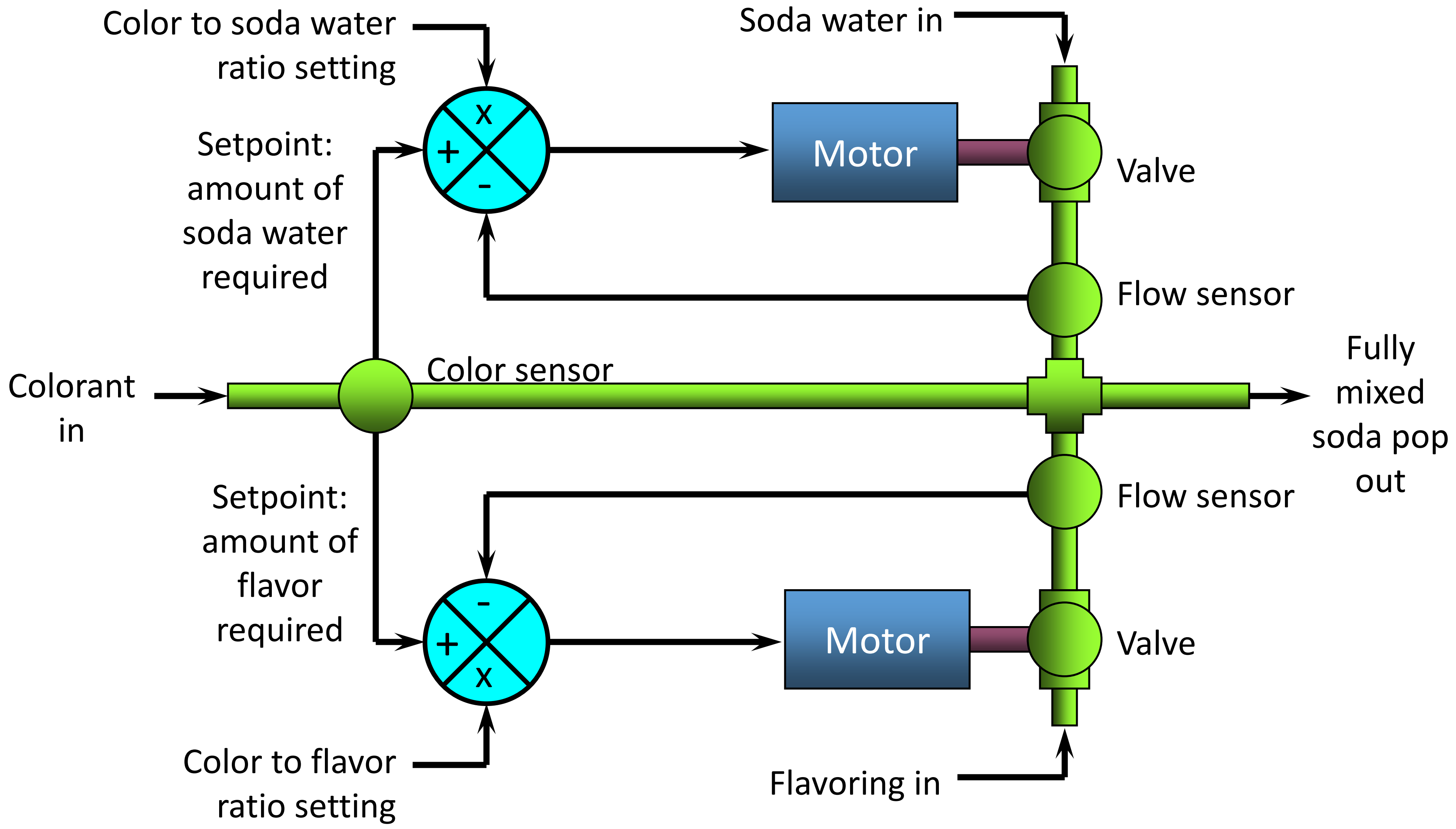
Calculations Include: Lead-Lag Control

- Lead-Lag is an advanced topic control method that will be addressed in another course. The output of this type of control system is defined using a differential equation:

$$output = K\left(\frac{1+\tau_1 p}{1+\tau_2 p}\right)input$$

$$Where: K = Gain, \tau_1 = Lead\ time\ constant,$$
$$\tau_2 = Lag\ time\ constant, p = \frac{d}{dt}$$

Ratio Control



Ratio Control

A control strategy used to control a secondary flow to the predetermined fraction, or flow ratio, of a primary flow.

Other Control Systems (Advanced Topics)

- Override Control
- Selective Control
- Duplex or Split-Range Control
- Auto-Selector or Cutback Control

Unit 13 – Dead Time Control

- Please read through Unit 13 so that you are familiar with the terminology.
- It is an advanced control concept and can be defined in several ways and have many applications.
- For the most part, Dead Time is:
  - The amount of time between a change in input and the start of the resulting response to that input.
  - It is a definite delay that is deliberately placed between two related actions to avoid overlap that could permit a particular event to take place before it should.