Introduction to Control

This module serves as a first course in process control or HVAC control for the engineering technician. The focus of this module is control loop tuning. Control loop tuning is a process of calibrating all portions of the control loop for optimum control loop response. But before we jump into tuning the loop, we must first understand:

- The process being controlled
- How to ensure the end device is properly selected
- How to ensure the sensor and transmitter are properly selected
- How to properly calibrate a transmitter
- Time elements involved in a control loop
- The three basic modes of control and how they impact the loop

Once these elements are understood, we can discuss some methods of tuning a control loop. There are numerous methods of control loop tuning ranging from trial-and-error to very sophisticated, highly mathematical procedures. In this module, we will address three methods of loop tuning.

- the Ziegler-Nichols Process Reaction Method
- the Ziegler-Nichols Closed-Loop Method
- the 'As-Found' tuning method

The first two methods are semi-formal methods while the third is a mathematically based trial-and-error method. As we will find, control loop tuning is as much an art as it is a science. No single method of loop tuning can be considered 'best'. Every process is different, every loop is different, and every controller has a different control algorithm, thus potentially requiring different approaches to tuning.

The Process

When we use the term process control, what do we mean by the term process? A process is any physical system designed to produce some desired output or action. This can range from the simplistic, such as maintaining the temperature in a kitchen oven, to the highly complex, such as the control of a cracking tower in an oil refinery. In both cases, a control loop is required to maintain the desired result. Would it surprise you to know the basic control principles for each scenario are the same?

The Control Loop

There are numerous control strategies available to maintain the desired output of a process. These include, but are not necessarily limited to:

- Programmable Logic Control
- Feedback Control
- Feedforward Control
- Ratio Control
- Cascade Control
- Model-based Control
- Smith Predictor
- Fuzzy Logic
- Neural Nets

Many of these strategies have several variations. For example, Cascade control is nothing more than two feedback control loops nested inside each other. Some of these control types can be combined. For example, it is not unusual to combine feedback and feedforward control so as to optimize control loop response for processes that require very quick response. In this module, we will only address feedback control with an introduction to cascade control. Additional coursework is necessary to delve into more sophisticated control strategies.

Control System Terminology

Unfortunately, terminology in the control industry is not standardized. In this module, we will point out the differences in semantics as may be used by different parts of the industry (i.e.: HVAC control uses slightly different terminology than process control) or as may be used by different persons depending on their training and background. Despite this lack of standardization, we still need to be aware of some of the more common terminology. Much of this terminology is defined throughout the course when it is necessary to do so. But to start off, let's build a simple control loop and define elements of that loop.

The diagrams below illustrate a room heating process where the space temperature is being maintained by regulating the flow of water through an air-water heat exchanger. A control valve regulates the flow of water through the coil. Control valve position is governed by an integral actuator, which receives the control signal from the controller. The proper output signal from the controller to the actuator is a function of the signal from the sensor as sent to the controller via

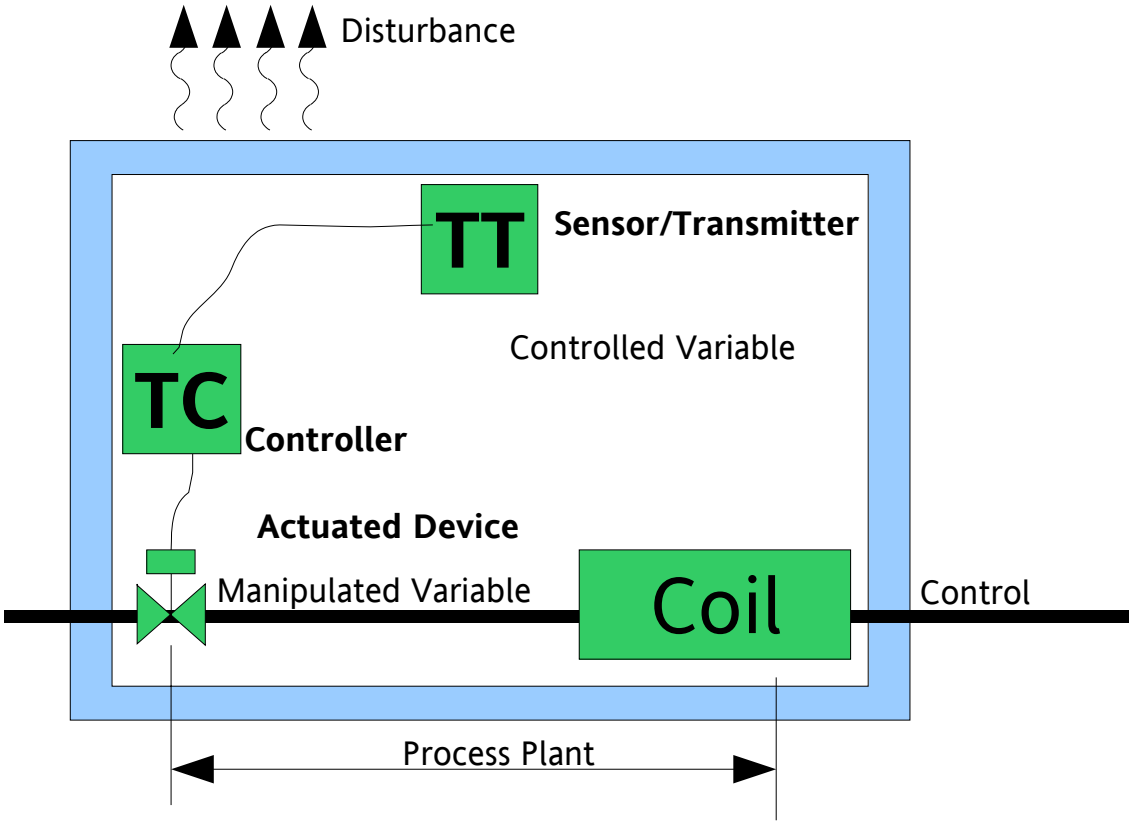

Figure 1 Closed Loop Control of Room Temperature

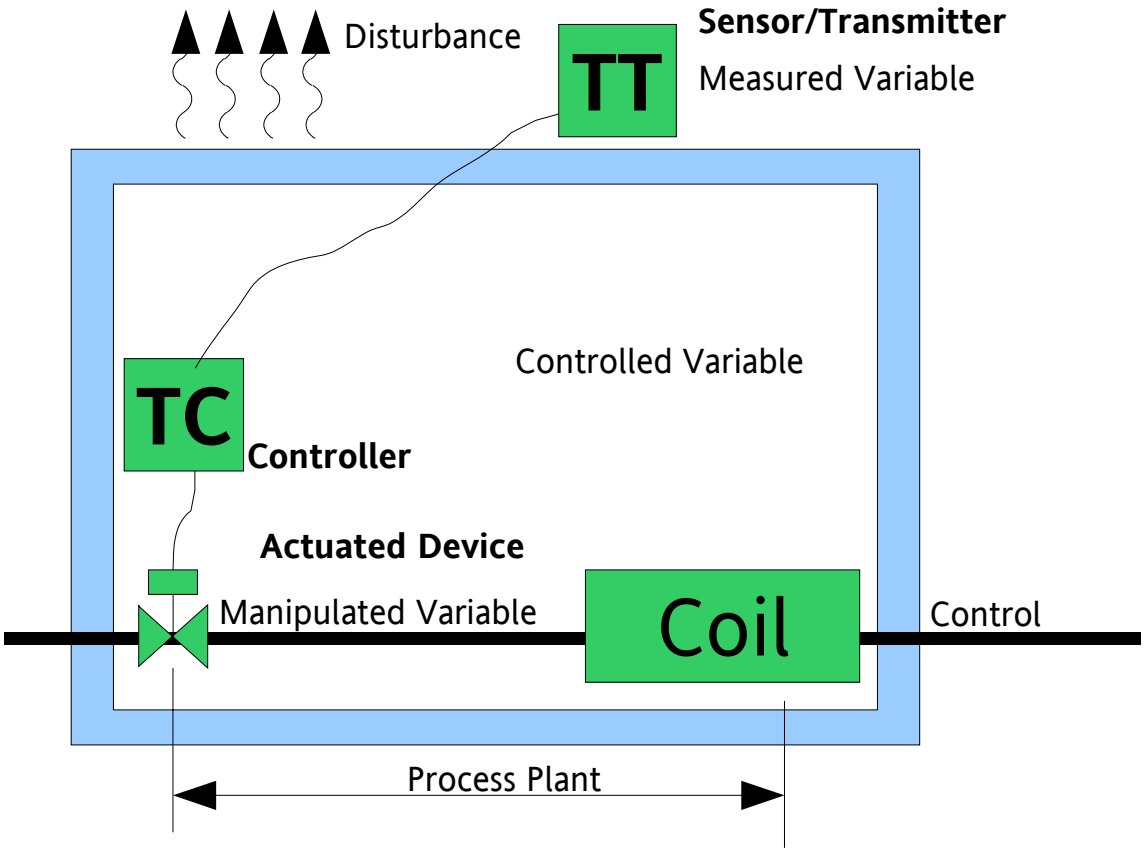

Figure 2 Open Loop Control of Room Temperature

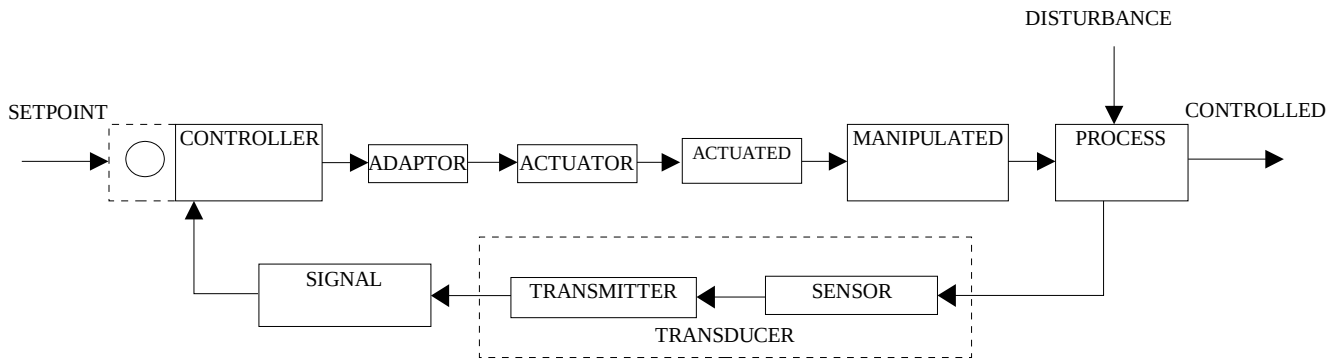

Figure 3 Block Diagram of a Closed Loop System

a signal transmitter. The first diagram indicates a simple feedback control loop. The reason it is a feedback loop is because as the value of the controlled variable changes, it's measured by a sensor that sends an appropriate control signal back to the controller. In other words, the controller measures the result of the change. The second diagram shows a simple feedforward loop. In this case, room temperature is controlled strictly based upon outdoor temperature. There is no feedback, so the controller has no information regarding the actual temperature being maintained in the space.

The first two diagrams are schematic representations of the process and the control loop. Frequently, we wish to visualize a control loop as a block diagram. This is shown in Figure 3 above. Figure 3 does show a couple of additional devices not shown in Figures 1 and 2. Based upon the diagrams above, we can define the following terms.

Actuated Device – An end device acting on the manipulated variable. In the diagrams above, this device is the control valve. However, other end devices might include variable frequency drives, solid-state relays, or silicon controlled rectifiers to name a few.

Adaptor – A transducer, relay, selector or other such device that receives a control signal and transmits it to another device. Referring to Figure 3, an adaptor might be a current to pneumatic transducer or some form of signal filtering.

Comparator – That portion of the controller that compares the feedback signal to the set point signal allowing the controller to provide a resulting biased output

Control Agent – The source of energy regulated by the actuated device. Referring to Figures 1 and 2, the control agent is the water flowing through the pipes. It is the water that carries heat energy to the coil that is transferred to the air stream passing over the coil to maintain room temperature.

Controller – A device used to compare a transmitted signal to a desired value and generate a corrective output signal to reduce the difference between these two values.

Controlled Medium – That substance (i.e.: air, water, etc.) being controlled. It is affected by the control agent as well as external disturbances. As indicated in Figures 1 and 2, the controlled medium is the air passing over the heating coil.

Controlled Variable – The engineering value of the controlled medium. The sensor measures this value. In a closed loop system, this is also the measured variable. In Figures 1 and 2 above, the controlled variable is the temperature of the air stream, the controlled medium, passing over the coil.

Closed Loop – a control loop with system feedback. The feedback is typically the value of the controlled variable. The controller compares this value with the user-supplied set point.

Disturbance – An upsetting signal, usually from an external source, that causes the control system to respond and produce a change in the controller output signal, thus producing a change in the end device. In the above examples, the disturbance shown is the heat loss through the building envelope. However, other disturbances might include people walking in and out of the room, equipment and lights being turned on or off, or perhaps a window being opened.

E/P – A type of signal conditioner used to convert an electrical voltage, typically a 1-5 V or a 210 V, to a pneumatic pressure, usually 3-15 psi. The adaptor shown in Figure 3 could be an E/P.

I/P - A type of signal conditioner used to convert an electrical current, usually 4-20 ma, to a pneumatic pressure, usually 3-15 psi. The adaptor shown in Figure 3 could be an E/P.

Manipulated Variable – That value actually regulated as a means of producing the desired result on the controlled variable. In Figures 1 and 2, the manipulated variable is the water flow rate through the coil. As flow rate is increased, heat transfer to the controlled medium is increased.

Measured Variable – In a closed loop system, the measured variable and controlled variable are the same. In an open loop system, the measured variable is the uncontrolled variable measured by a sensing element. In the open loop, when this value varies, the control system responds to the change regardless of the value of the controlled variable. Referring to Figure 2, the measured variable is the outside air temperature.

Open Loop – A control loop with no system feedback.

Process Plant – All equipment comprising the process under control. In Figures 1 and 2, this would include the piping, control valve, coil, controlled medium (air), and the control agent (the water).

Sensor – A device used to sense the condition or desired property of the controlled media. Common sensors include those used to measure temperature, humidity, pressure, flow rate, and liquid level. Other sensors might include those for analytical measurement such as pH, conductivity, turbidity, luminosity, and density to name but a few.

Set Point – The desired value of the controlled variable. The set point is usually adjusted by means of a lever, knob, keypad or some such interface mounted on the face of the controller. A set point signal may also be transmitted electrically or mechanically to the controller from a remote location.

Signal Conditioner – A device used to amplify, filter or in some way, change the characteristics of a control signal. In the examples above, the signal conditioner might be a filter to remove sensor noise from the transmitter. An I/P or E/P valve may be considered a form of signal conditioner.

System Feedback – A signal transmitted back to the controller representing the affect of the controller's response to a change in the controlled variable

Transmitter – A device comprised of a sensor and transducer housed in a common case. The terms transmitter and transducer are often used interchangeably, even though they refer to different pieces of equipment.

Transducer - A device used to convert a signal from a sensor or controller to a signal capable of being read by some receiver. The terms transmitter and transducer are often used interchangeably, even though they refer to different pieces of equipment.