Electronic Control Systems: The Basics

Controllers

The electronic controller receives a sensor signal, amplifies and/or conditions it, compares it with the setpoint, and derives a correction if necessary. The output signal typically positions an actuator. Electronic controller circuits allow a wide variety of control functions and sequences, from very simple arrangements to multiple-input circuits with several sequential outputs. Controller circuits use solid-state components, such as transistors, diodes and integrated circuits, and include the power supply and all the adjustments required for proper control.

Input Types

Electronic controllers are categorized by the type or types of inputs they accept, such as temperature, humidity, enthalpy or universal.

Temperature Controllers

Temperature controllers typically require a specific type or category of input sensors. Some have input circuits to accept RTD sensors such as BALCO or platinum elements, while others contain input circuits for thermistor sensors. These controllers have setpoint and throttling range scales labeled in degrees Fahrenheit or Celsius.

Relative Humidity Controllers

The input circuits for relative humidity controllers typically receive the sensed relative humidity signal already converted to a 0-10 V d.c. voltage, or a 4-20 mA current signal. Setpoint and scales for these controllers are in percent relative humidity.

Enthalpy Controllers

Enthalpy controllers are specialized devices that use specific sensors for inputs. In some cases, the sensor may combine temperature and humidity measurements and convert them to a single voltage to represent enthalpy of the sensed air. In other cases, individual dry-bulb temperature sensors and separate wet-bulb or relative humidity sensors provide inputs, and the controller calculates enthalpy. In typical applications, the enthalpy controller provides an output signal based on a comparison of two enthalpy measurements, indoor and outdoor, rather than on the actual enthalpy value. In other cases, the return air enthalpy is assumed constant so that only OA enthalpy is measured. It is compared against the assumed nominal return air value.

Universal Controllers

The input circuits of universal controllers can accept one or more of the standard transmitter or transducer signals. The most common input ranges are 0-10 V d.c. and 4-20 mA. Other input variations in this category include a 2-10 V d.c. and a 0-20 mA signal. Because these inputs can represent a variety of sensed variables, such as a current of 0-15 A or pressure of 0-3000 psi, the settings and scales are often expressed in percent of full scale only.

Control Modes

The control modes of some electronic controllers can be selected to suit the application requirements. Control modes include two-position, proportional and proportional-integral. Other control features include remote setpoint, the addition of a compensation sensor for reset capability, and override or limit control.

Output Control

Electronic controllers provide outputs to a relay or actuator for the final control element. The output is not dependent on the input types or control method. The simplest form of output is two-position, in which the final control element can be in one of two states. For example, an exhaust fan in a mechanical room can be turned either on or off. The most common output form, however, provides a modulating output signal which can adjust the final control device (actuator) between 0 and 100 %, such as in the control of a chilled water valve.

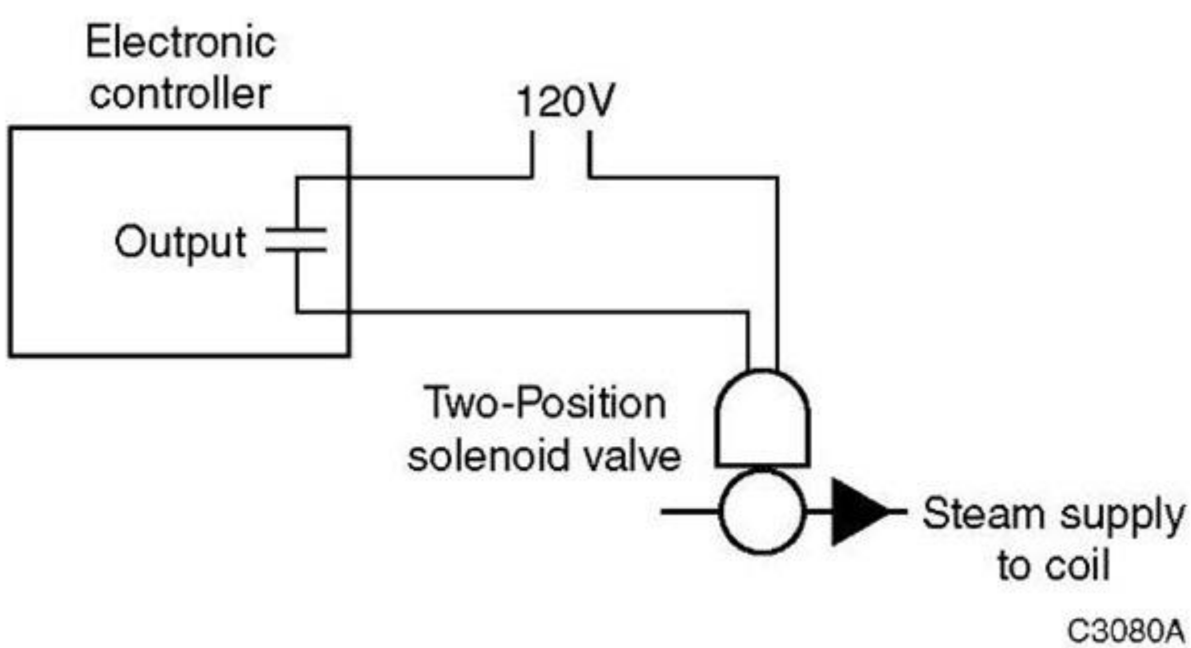

Fig. 16 Two-position control.

Output Devices

Actuators, relays, and transducers (Fig. 2) are output devices which use the controller output signal (voltage, current, or relay contact) to perform a physical function on the final control element such as starting a fan or modulating a valve. Actuators can be categorized as devices that provide two-position action or as those that provide modulating action.

Two-Position

Two-position devices such as relays, motor starters, and solenoid valves have only two discrete states. These devices interface between the controller and the final control element. For example, when a solenoid valve is energized, it allows steam to enter a coil that heats a room (Fig. 16). The solenoid valve provides the final action on the controlled media, steam. Damper actuators can also be designed to be two-position devices.

Modulating

Modulating actuators use a varying control signal to adjust the final control element. For example, a modulating valve controls the amount of chilled water entering a coil so that cool supply air is just sufficient to match the load at a desired setpoint (Fig. 17). The most common modulating actuators accept a varying voltage input of 0-10 V, or 2-10 V d.c., or a current input of 4-20 mA. Another form of actuator requires a pulsating (intermittent) or duty cycling signal to perform modulating functions. One form of pulsating signal is a Pulse Width Modulation (PWM) signal.

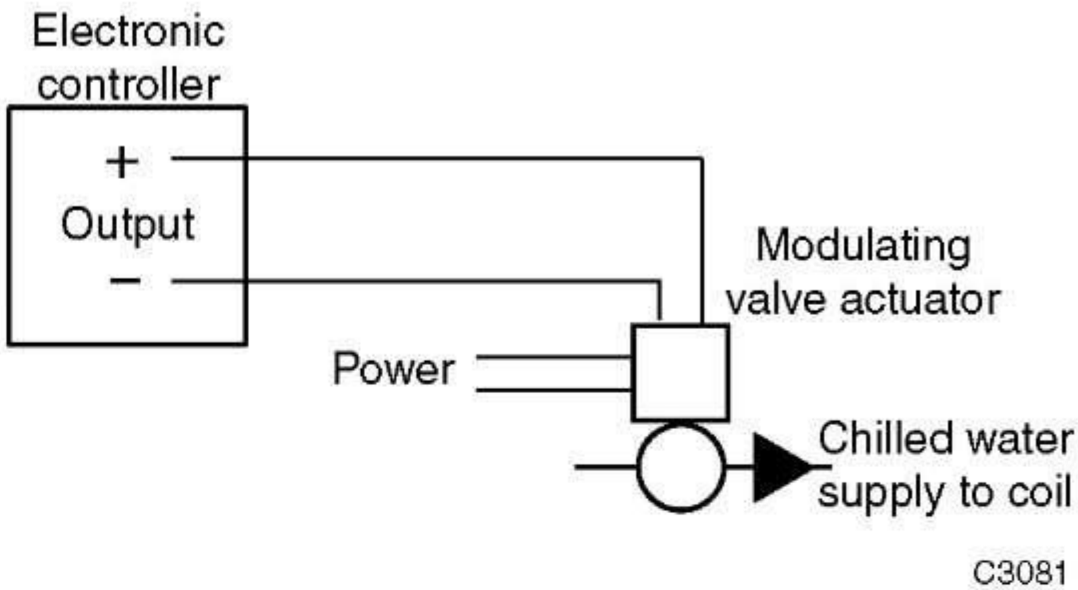

Fig. 17 Modulating control.

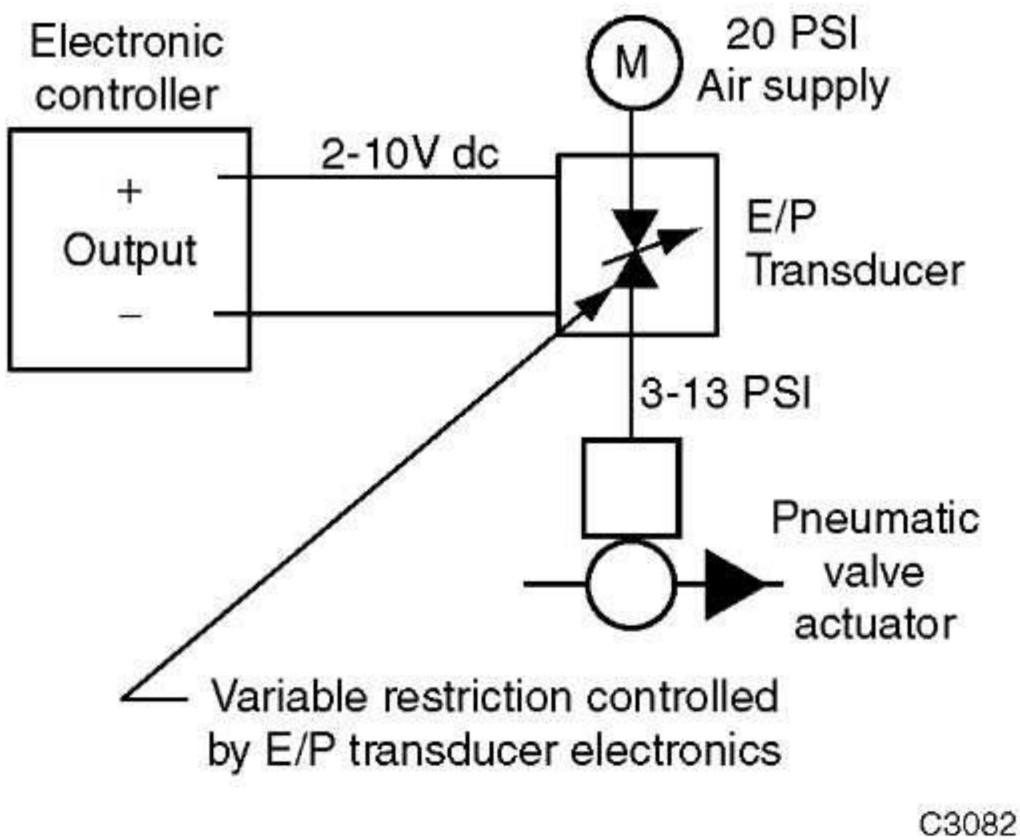

Fig. 18 Electric-to-pneumatic transducer.

Tranducer

In some applications, a transducer converts a controller output to a signal that is usable by the actuator. For example, Fig. 18 shows an Electronic-to-Pneumatic (E/P) transducer that converts a modulating 2-10 V d.c. signal from the electronic controller to a pneumatic proportional modulating 3-13 psi signal for a pneumatic actuator.

Indicating Devices

An electronic control system can be enhanced with visual displays that show system status and operation. Many electronic controllers have built-in indicators that show power, input signal, deviation signal and output signal. Fig. 19 shows some types of visual displays. An indicator light can show on/off status or, if driven by controller circuits, the brightness of a light can show the relative strength of a signal. If a system requires an analog or digital indicating device and the electronic controller does not include this type of display, separate indicating devices can be provided.

Interface with Other Systems

It is often necessary to interface an electronic control device to a microprocessor-based building management system or other related system. An example is an interface that allows a building management system to adjust the setpoint or amount of reset (compensation) for a specific controller. Compatibility of the two systems must be verified before they are interconnected.

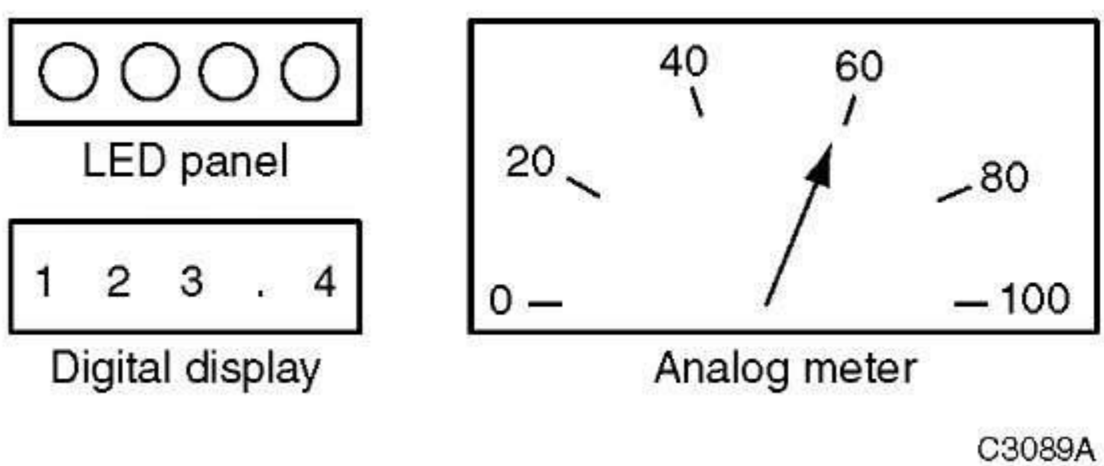

Fig. 19 Indicating devices.

ELECTRONIC CONTROLLER FUNDAMENTALS

General

The electronic controller is the basis for an electronic control system. Fig. 20 shows the basic circuits of an electronic controller including power supply, input, control and output. For greater stability and control, internal feedback correction circuits also can be included, but these are not discussed here. The circuits described provide an overview of the types and methods of electronic controllers.

Power Supply Circuit

The power supply circuit of an electronic controller provides the required voltages to the input, control, and output circuits. Most voltages are regulated DC voltages. The controller design dictates the voltages and current levels required.

All power supply circuits are designed to optimize both line and load regulation requirements within the needs and constraints of the system. Load regulation refers to the ability of the power supply to maintain the voltage output at a constant value even as the current demand (load) changes. Similarly, line regulation refers to the ability of the power supply to maintain the output load voltage at a constant value when the input (AC) power varies. The line regulation abilities or limitations of a controller are usually part of the controller specifications such as 120 V AC + 10%, -15%. The degree of load regulation involves the end-to-end accuracy and repeatability, and is usually not explicitly stated as a specification for controllers.

TYPICAL SYSTEM APPLICATIONS

Fig. 21 shows a typical air-handling system controlled by two electronic controllers, C1 and C2; sequencer S; multi-compensator M; temperature sensors T1 through T4; modulating hot- and chilled-water valves V1 and V2; and outdoor, return, and exhaust air damper actuators. The control sequence is as follows:

- **Controller C1 provides outdoor compensated,** summer/ winter control of space temperature for a heating/ cooling system which requires PI control with a low limit. Sensor T4 provides the compensation signal through multi-compensator M, which allows one outdoor temperature sensor to provide a common input to several controllers. Controller C1 modulates the hot-and chilled-water valves V1 and V2 in sequence to maintain space temperature measured by sensor T1 at a pre-selected setpoint. Sequencer S allows sequencing the two valve actuators from a single controller. Low-limit sensor T2 assumes control when the discharge air temperature drops to the control range of the low-limit setpoint. A minimum discharge air temperature is maintained regardless of space temperature.

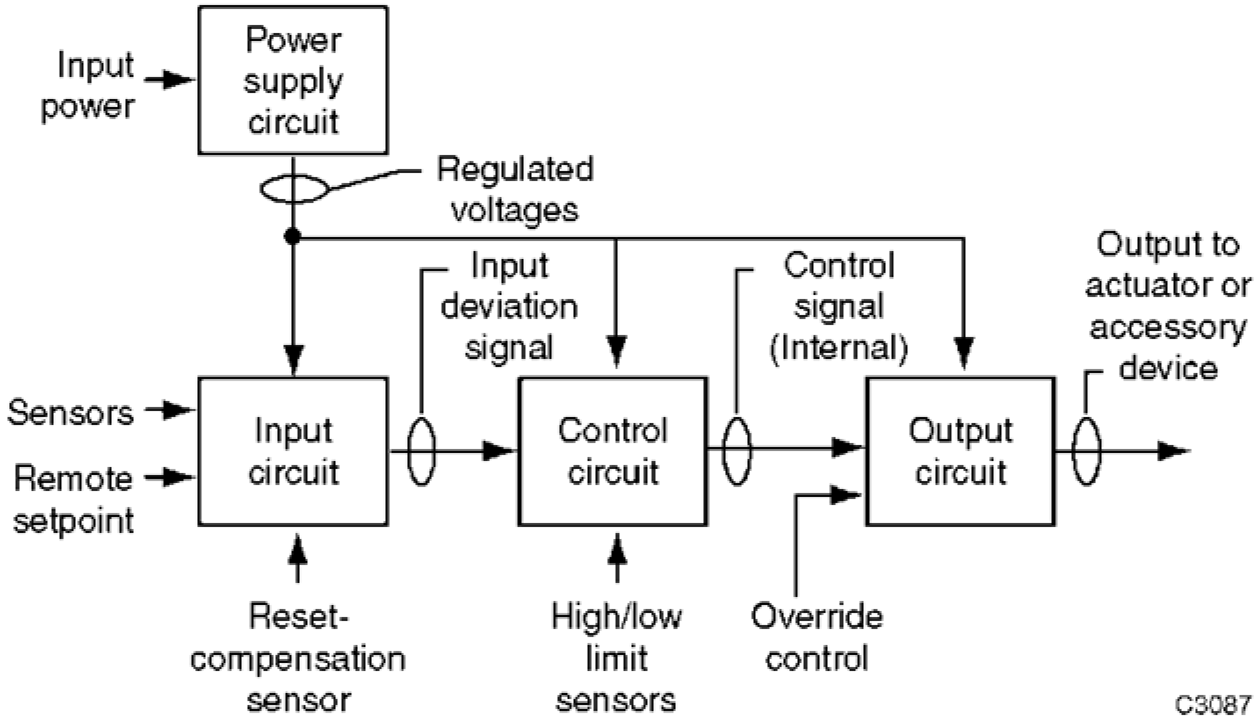

Fig. 20 Electronic controller circuits.

When the outdoor temperature is below the selected reset changeover point set on C1, the controller is in the winter compensation mode. As the outdoor air temperature falls, the space temperature setpoint is raised. When the outdoor temperature is above the reset changeover point, the controller is in the summer compensation mode. As the outdoor temperature rises, the space temperature setpoint is raised.

• **Controller C2 provides PI mixed air temperature control with economizer operation.** When the OA temperature measured by sensor T4 is below the setting of the economizer startpoint setting, the controller provides proportional control of the dampers to maintain mixed air temperature measured by sensor T3 at the selected setpoint. When the OA temperature is above the economizer startpoint setting, the controller closes the OA dampers to a preset minimum.

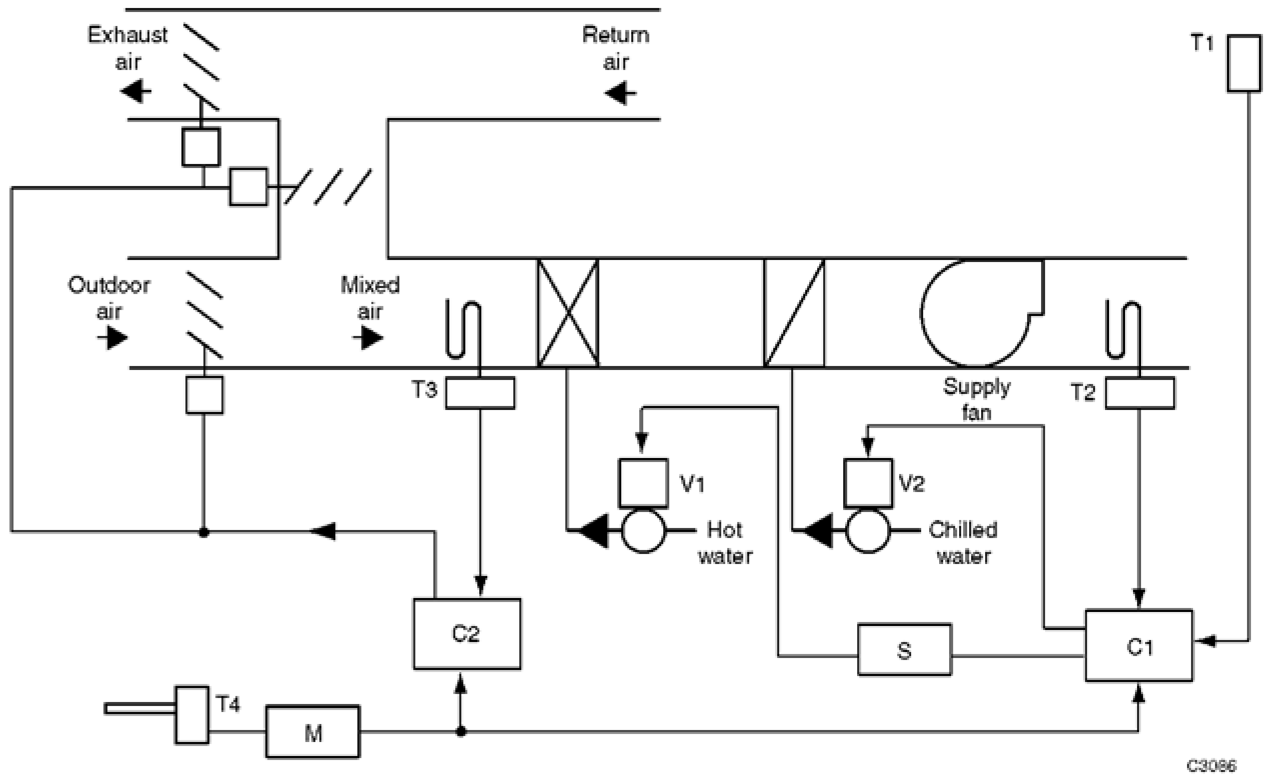

Fig. 21 Typical application with electronic controllers.

ADDITIONAL DEFINITIONS

Authority (reset authority or compensation authority). A setting that indicates the relative effect a compensation sensor input has on the main setpoint (expressed in percent).

Compensation change-over. The point at which the compensation effect is reversed in action and changes from summer to winter or vice versa. The percent of compensation effect (authority) may also be changed at the same time.

Control Point. The actual value of a controlled variable (setpoint plus or minus offset).

Deviation. The difference between the setpoint and the value of the controlled variable at any moment. Also called “offset.”

Direct acting. A direct-acting controller increases its output signal on an increase in input signal.

Electric control. A control circuit that operates on line or low voltage, and uses a mechanical means, such as a temperature-sensitive bimetal or bellows, to perform control functions, such as actuating a switch or positioning a potentiometer. The controller signal usually operates or positions an electric actuator, although relays and switches are often controlled.

Electronic control. A control circuit that operates on low voltage and uses solid-state components to amplify input signals and perform control functions, such as operating a relay or providing an output signal to position an actuator. Electronic devices are primarily used as sensors. The controller usually furnishes fixed control routines based on the logic of the solid-state components.

Electronic controller. A solid-state device usually consisting of a power supply, a sensor amplification circuit, a process/comparing circuit, an output driver section, and various components that sense changes in the controlled variable and derive a control output which provides a specific control function. In general, adjustments such as setpoint and throttling range necessary for the process can be done at the controller via potentiometers and/or switches.

Final control element. A device such as a valve or damper that changes the value of the manipulated variable. The final control element is positioned by an actuator.

Integral action (I). An action in which there is a continuous linear relationship between the amount of increase (or decrease) on the output to the final control element and the deviation of the controlled variable to reduce or eliminate the deviation or offset.

Limit sensor. A device which senses a variable that may be other than the controlled variable and overrides the main sensor at a preset limit.

Main sensor. A device or component that measures the variable to be controlled.

Negative (reverse) reset. A compensating action in which a decrease in the compensation variable has the same effect as an increase in the controlled variable. For example, in a heating application, as the outdoor air temperature decreases, the control point of the controlled variable increases. Also called "winter reset or compensation."

Offset. A sustained deviation between the control point and the setpoint of a proportional control system under stable operating conditions. Also called "deviation."

Positive (direct) reset. A compensating action in which an increase in the compensation variable has the same effect as an increase in the controlled variable. For example, in a cooling application, as the OA temperature increases, the control point of the controlled variable increases. Also called "summer reset or compensation."

Proportional band (throttling range). In a proportional controller, the control point range through which the controlled variable must pass to drive the final control element through its full operating range. Proportional band is expressed in percent of the main sensor span. A commonly used equivalent is "throttling range," which is expressed in values of the controlled variable.

Proportional control (P). A control algorithm or method in which the final control element moves to a position proportional to the deviation of the value of the controlled variable from the setpoint.

Proportional-integral (PI) control. A control algorithm that combines the proportional (proportional response) and integral or deviation control algorithms. Integral action tends to correct the offset resulting from proportional control. Also called “proportional plus reset” or “two-mode” control.

Remote setpoint. A means for adjusting the controller setpoint from a remote location, in lieu of adjusting it at the controller itself. The means of adjustment may be manual with a panel or space mounted potentiometer, or automatic when a separate device provides a signal (voltage or resistive) to the controller.

Reset control. A process of automatically adjusting the control point of a given controller to compensate for changes in a second measured variable such as outdoor air temperature. For example, the hot deck control point is reset upward as the outdoor air temperature decreases. Also known as “compensation control.”

Reset sensor. The system element which senses a variable other than the controlled variable and resets the main sensor control point. The amount of this effect is established by the authority setting.

Reverse acting. A reverse-acting controller decreases its output signal on an increase in input signal.

Setpoint. The value on the controller scale at which the controller is set, such as the desired room temperature set on a thermostat. The setpoint is always referenced to the main sensor (not the reset sensor).

Throttling range. In a proportional controller, the control point range through which the controlled variable must pass to move the final control element through its full operating range. Throttling range is expressed in values of the controlled variable such as temperature in degrees Fahrenheit, relative humidity in percent, or pressure in pounds per square inch. A commonly used equivalent is “proportional band,” which is expressed in percent of sensor span for electronic controls.

Transducer. A device that converts one energy form to another. It amplifies (or reduces) a signal so that the output of a sensor or transducer is usable as an input to a controller or actuator. A transducer can convert a pneumatic signal to an electric signal (P/E transducer) or vice versa (E/P transducer), or it can convert a change in capacitance to an electrical signal.

Transmitter. A device that converts a sensor signal to an input signal usable by a controller or display device.

CONCLUSION

Basic automatic electronic control systems are extremely important to provide desirable operational features of energy-using equipment and systems. Proper control is critical to achieving functional performance, as well as energy-efficient performance in equipment, buildings and processes.