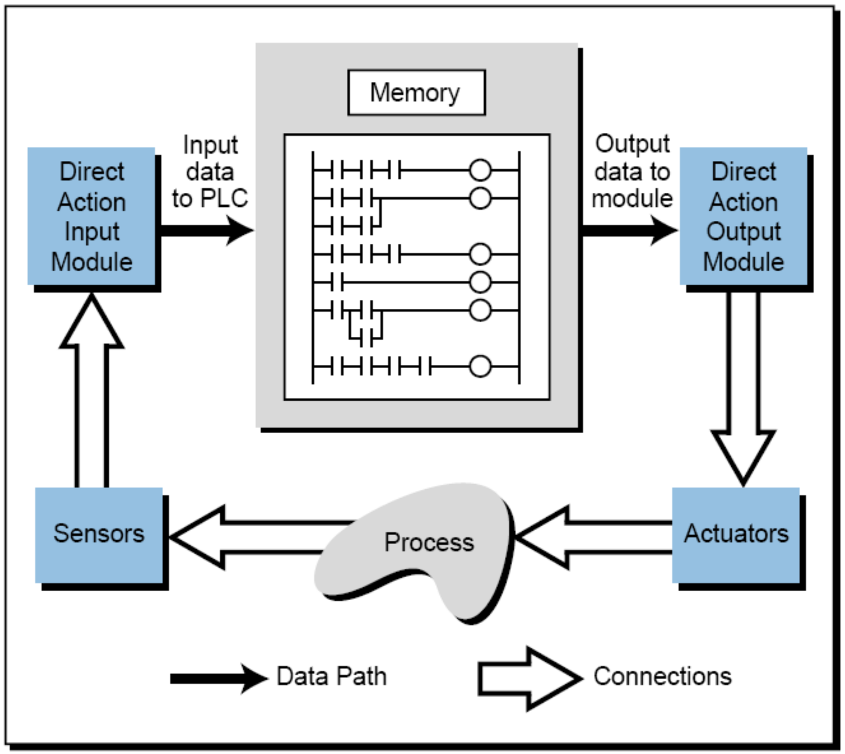
Chapter 6: Special Modules (Load cell, Thermocouple, PID, Communication, Positioning, Fuzzy Logic)

Introduction to Special Modules



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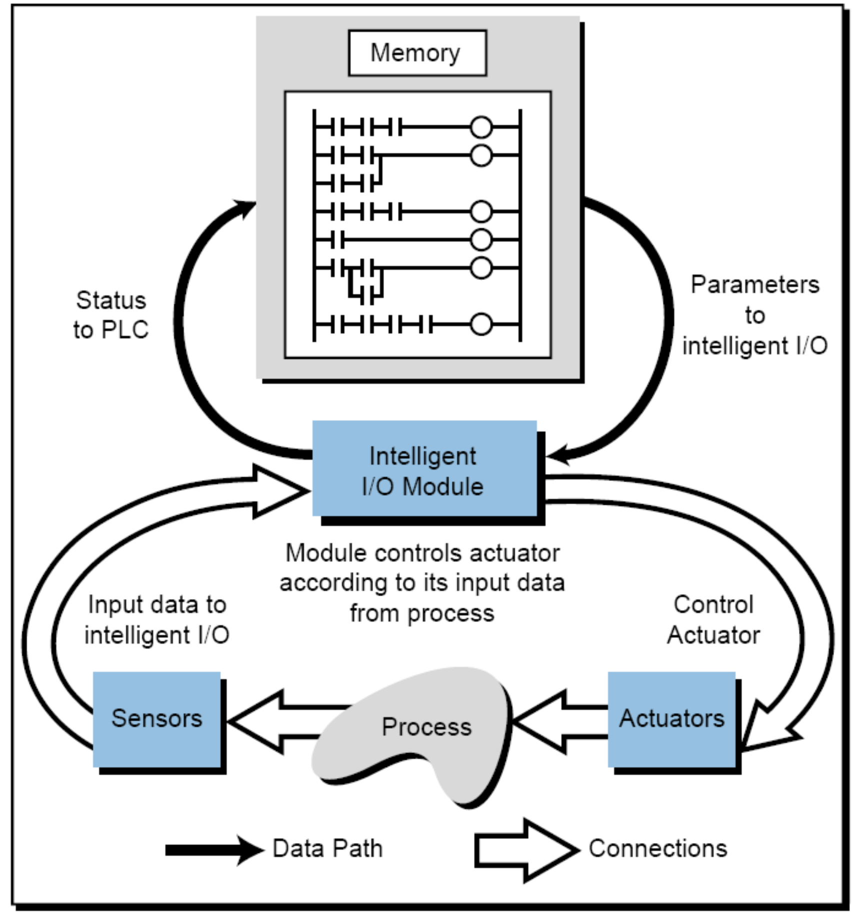
taùc ñoäng tröïc tieáp



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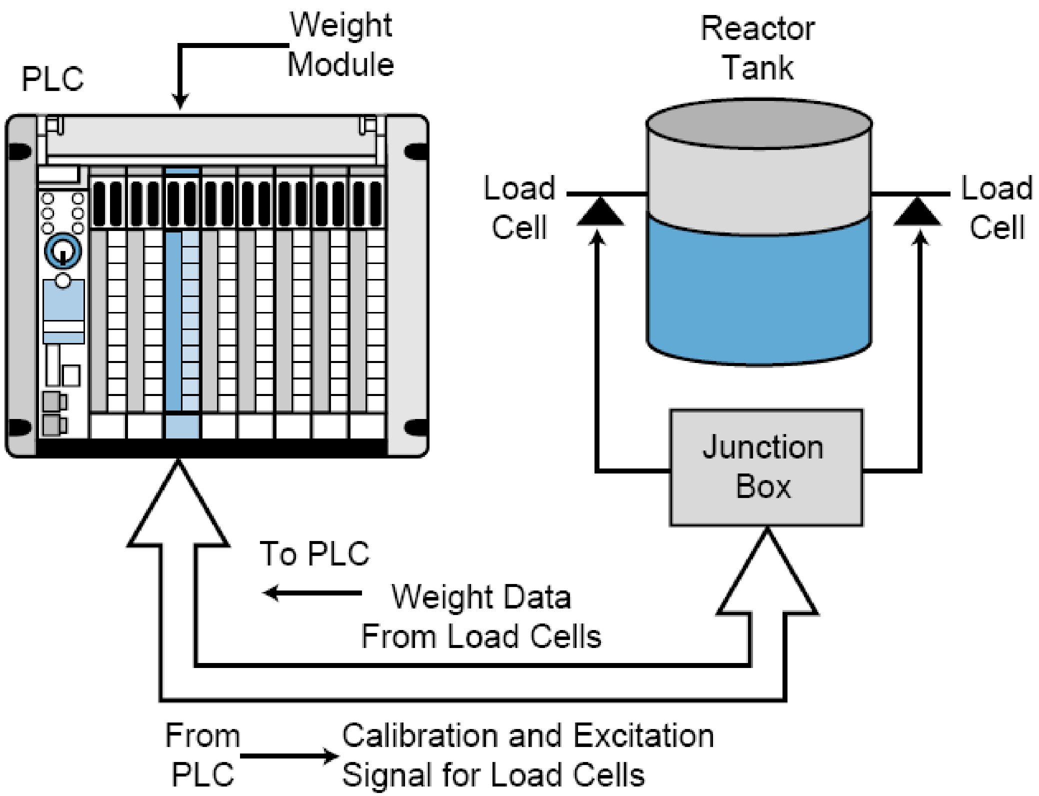
Weight input module



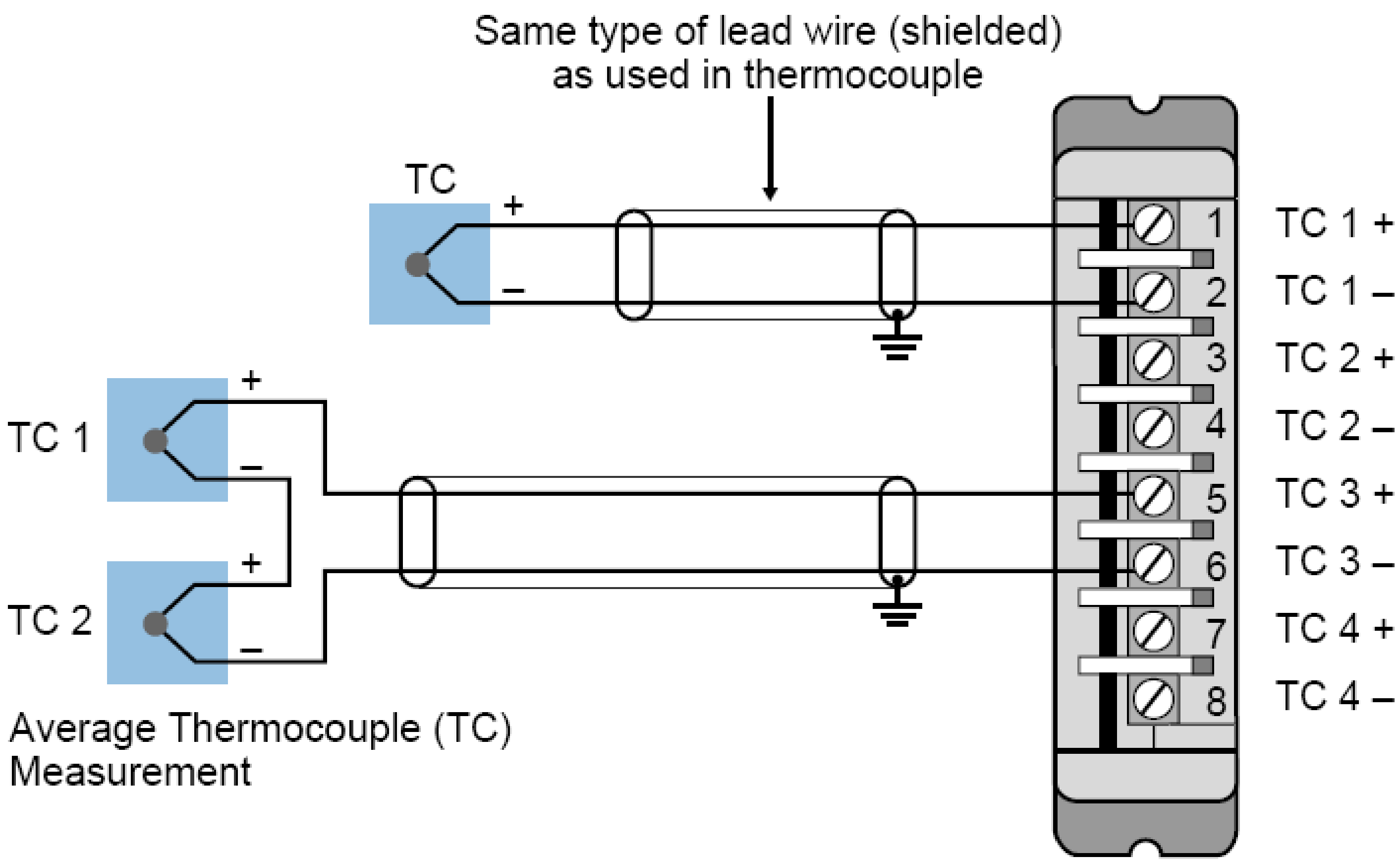
Weight input modules are special types of analog interfaces designed to read data from **load cells.**

A weight input module provides the excitation voltage for load cells, as well as the necessary software for calibrating load cell circuits. A weight module sends an excitation voltage to a load cell and reads the signal created by the weight force exerted on the cell.

Thermocouple Input Modules

- In addition to standard analog voltage/current input interfaces that can receive signals directly from transmitters, special analog input interfaces can also accept signals directly from sensing field devices. Thermocouple input modules, which accept millivolt signals from thermocouple transducers, are an example of this type of special preprocessing interface.
- Different types of thermocouple input modules are available, depending on the thermocouple used. These modules can interface with several types of thermocouples by selecting jumpers or rocker switches in the module. For example, an input module may be capable of interfacing with thermocouples of (ISA standard) type E, J, and K.

Thermocouple Input Modules



Thermocouple interface connection diagram.

RTD Input Module

- **Resistance temperature detector (RTD) interfaces** receive temperature information from RTD devices. RTDs are temperature sensors that have a wire-wound element whose resistance changes with temperature in a known and repeatable manner. An RTD in its most common form consists of a small coil of platinum, nickel, or copper protected by a sheath of stainless steel.
- These devices are frequently used for temperature sensing because of their accuracy, repeatability, and long-term stability.

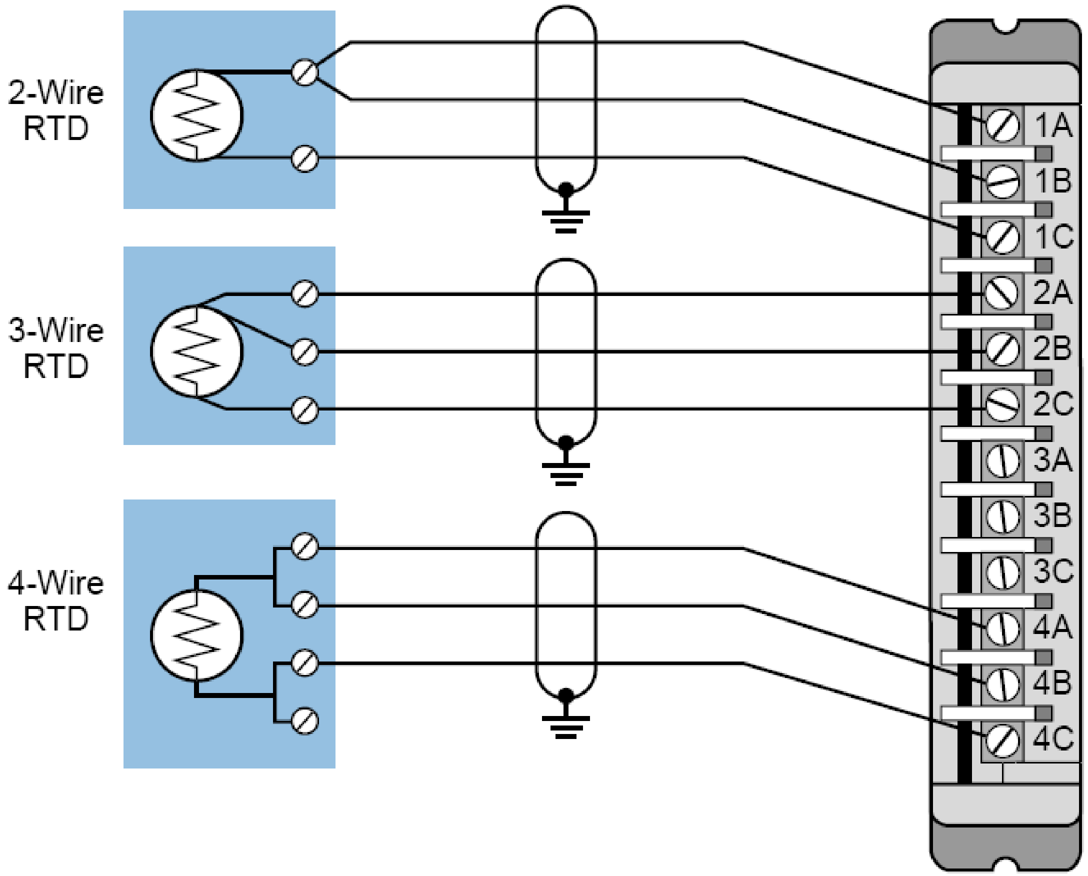
RTD Input Module

- **An RTD module converts changes in resistance into temperature values, available to the processor in either ^{0}C or ^{0}F.**

RTD Type	Resistance Rating (ohms)	Temperature Range	
Platinum	100	–200 to 850°C	–328 to 1562°F
Nickel	120	–80 to 300°C	–112 to 572°F
Copper	10	–200 to 260°C	–328 to 500°F

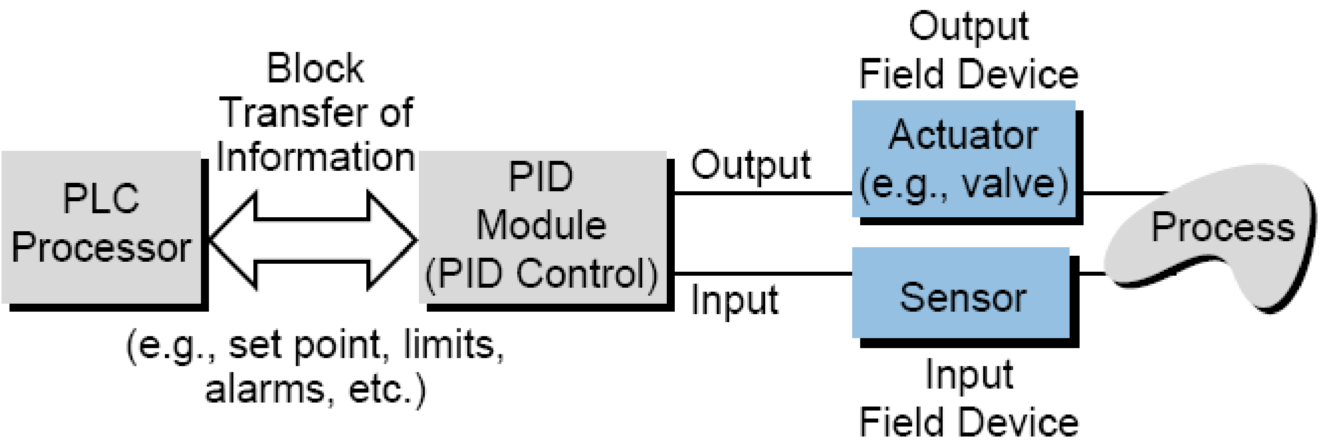
RTD Input Module

❖RTD devices are available in 2-, 3-, and 4-wire connections.



PID Modules

- **Proportional-integral-derivative (PID) interfaces** are used in process applications that require continuous closed-loop control employing the PID algorithm. These modules provide proportional, integral, and derivative control actions according to sensed parameters, such as pressure and temperature, which are the input variables to the system.



PID Modules

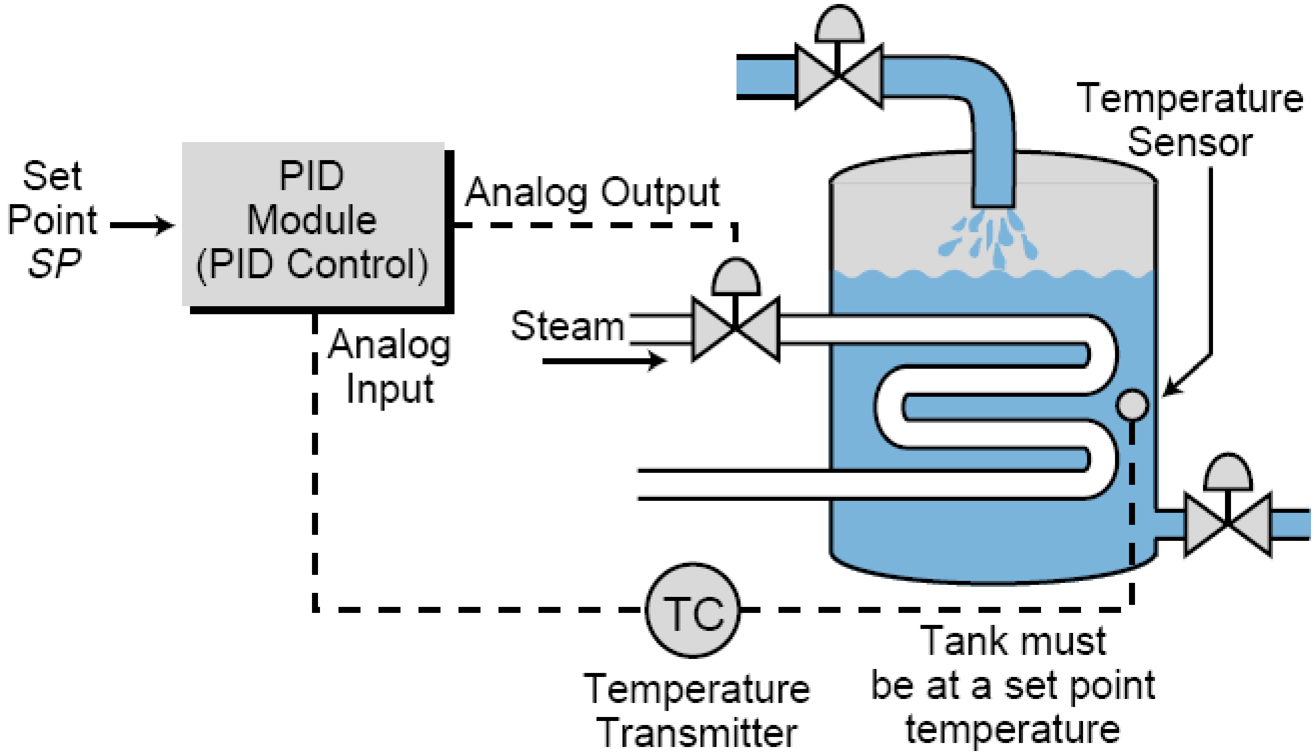
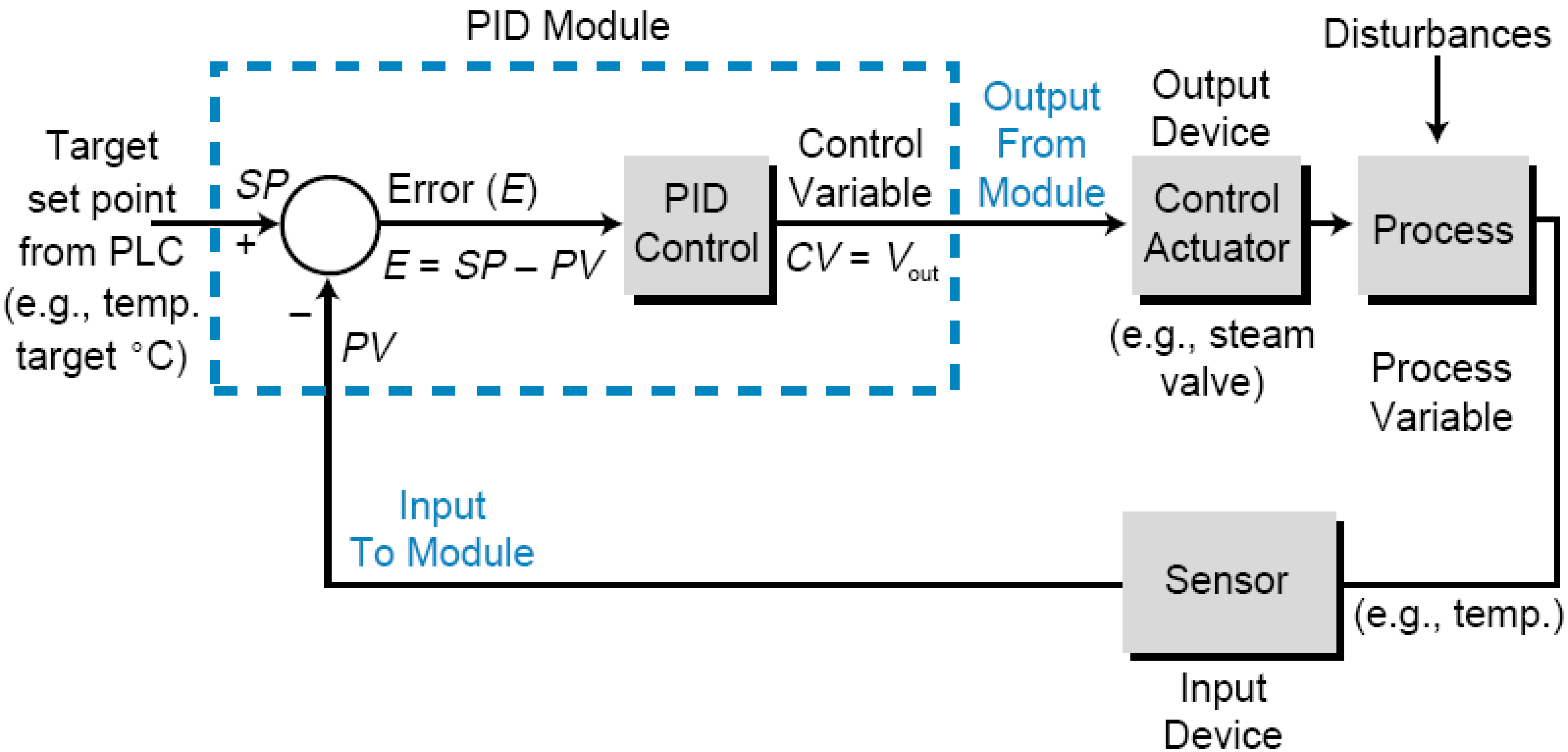


Illustration of a PID control process.

PID Modules



Once the module detects an error, the control loop modifies the control variable (*CV*) output to force the error to zero.

PID Modules

❖ **The control algorithms implemented by a PID module:**

$$V_{\text{out}} = K_P E + K_I \int E dt + K_D \frac{dE}{dt}$$

where:

K_P = the proportional gain

$K_I = \frac{K_P}{T_I}$, which is integral gain (T_I = reset time)

$K_D = K_P T_D$, which is derivative gain (T_D = rate time)

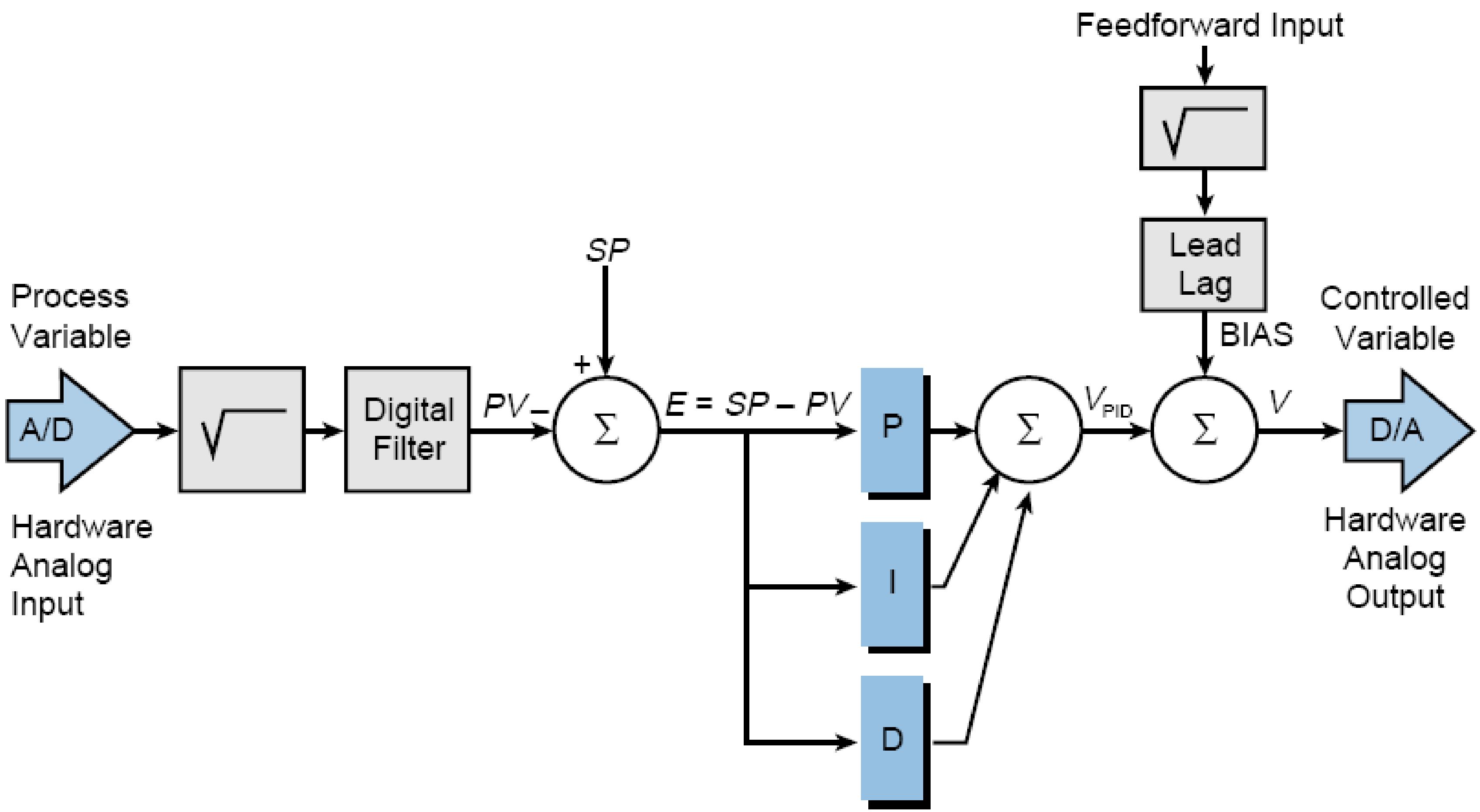
$E = SP - PV$, which is error

V_{out} = the control variable output

PID Modules

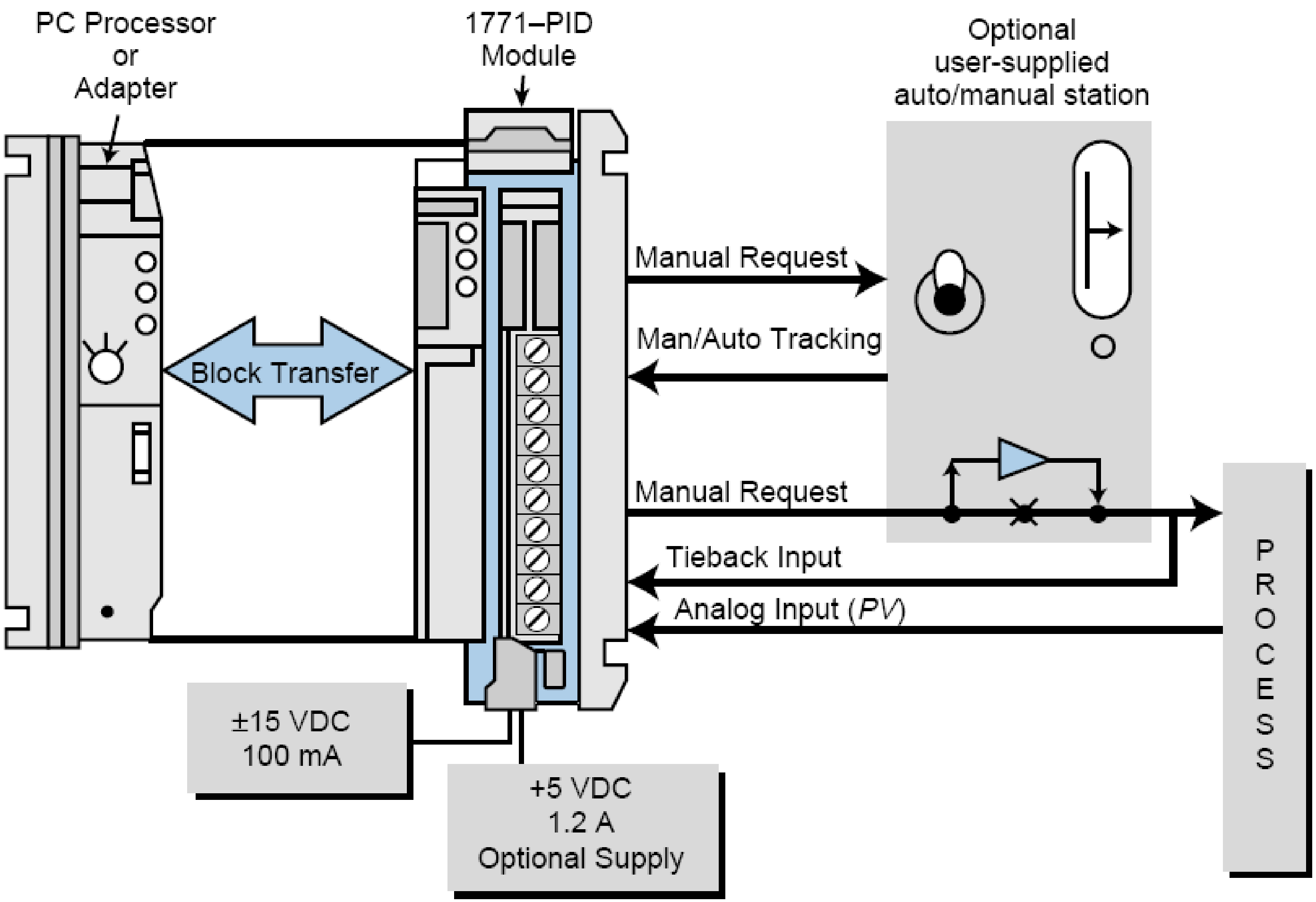
- **The PID module receives the process variable in analog form and computes the error difference between the actual value and the set point value.**
- **First, the module formulates a *proportional* control action based on an output control variable that is proportional to the instantaneous error value (*KPE*).**
- **Then, it initiates an *integral* control action (reset action) to provide additional compensation to the output control variable. This causes a change in the process variable in proportion to the value of the error over a period of time (*KI* or *KP*/*TI*).**
- **Finally, the module initiates a *derivative* control action (rate action) adding even more compensation to the control output (*KD* = *KPTD*). This action causes a change in the output control variable proportional to the rate of change of error.**
- **These three steps provide the desired control action in proportional (P), proportional-integral (PI), and proportional-integralderivative (PID) control fashion, respectively.**

PID Modules



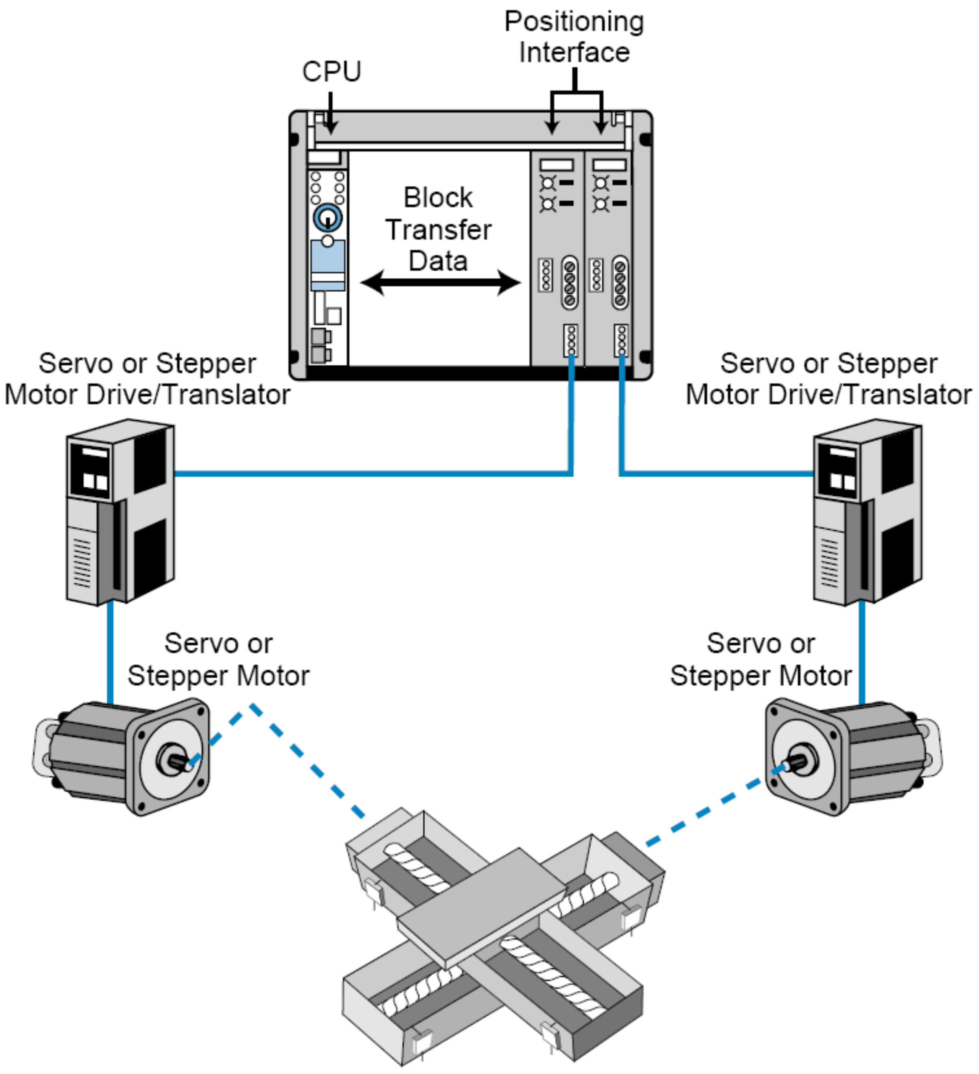
(a)

PID Modules



(b)

Positioning Interfaces



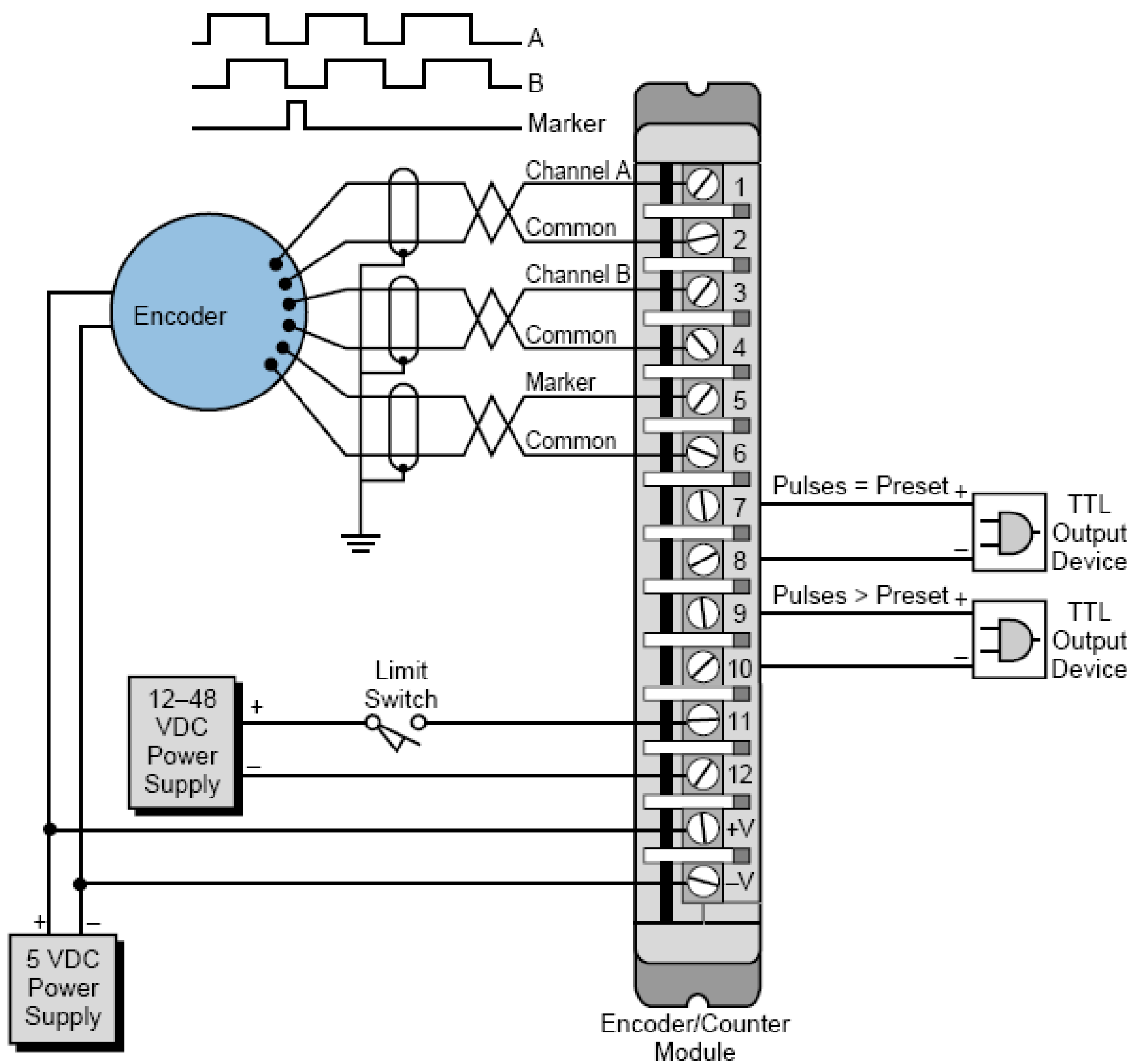
Encoder/Counter Interfaces

- **Encoder/counter modules interface encoders and high-speed counter devices with programmable controllers. This type of module operates independently of the processor and I/O scan.**
- **Applications include closed-loop positioning of machine tool axes, hoists, and conveyors, as well as cycle monitoring of high-speed machines, such as can-making equipment, stackers, and forming equipment.**
- **There are two types of encoder/counter interfaces: absolute and incremental.**
  - ***Absolute encoders* provide an angular measurement of the shaft.**
  - ***Incremental encoders* measure shaft rotation over distance by outputting a fixed number of pulses per shaftrotation.**

Encoder/Counter Interfaces

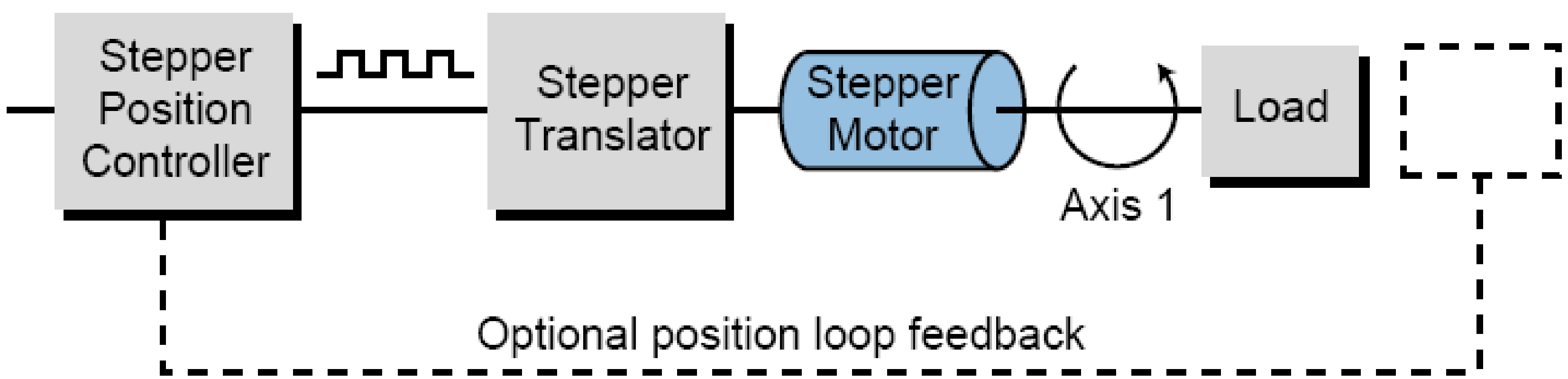
- **The communication between an encoder/counter interface and the processor is bidirectional. The module accepts the preset value and other control data from the processor and transmits values and status data to the PLC memory.**
- **The interface also lets the PLC know when the marker and limit switch are both energized, indicating a home position.**
- **Typically, the length between the module and the encoder should not exceed 50 feet, and shielded cables should be used.**

Encoder/Counter Interfaces

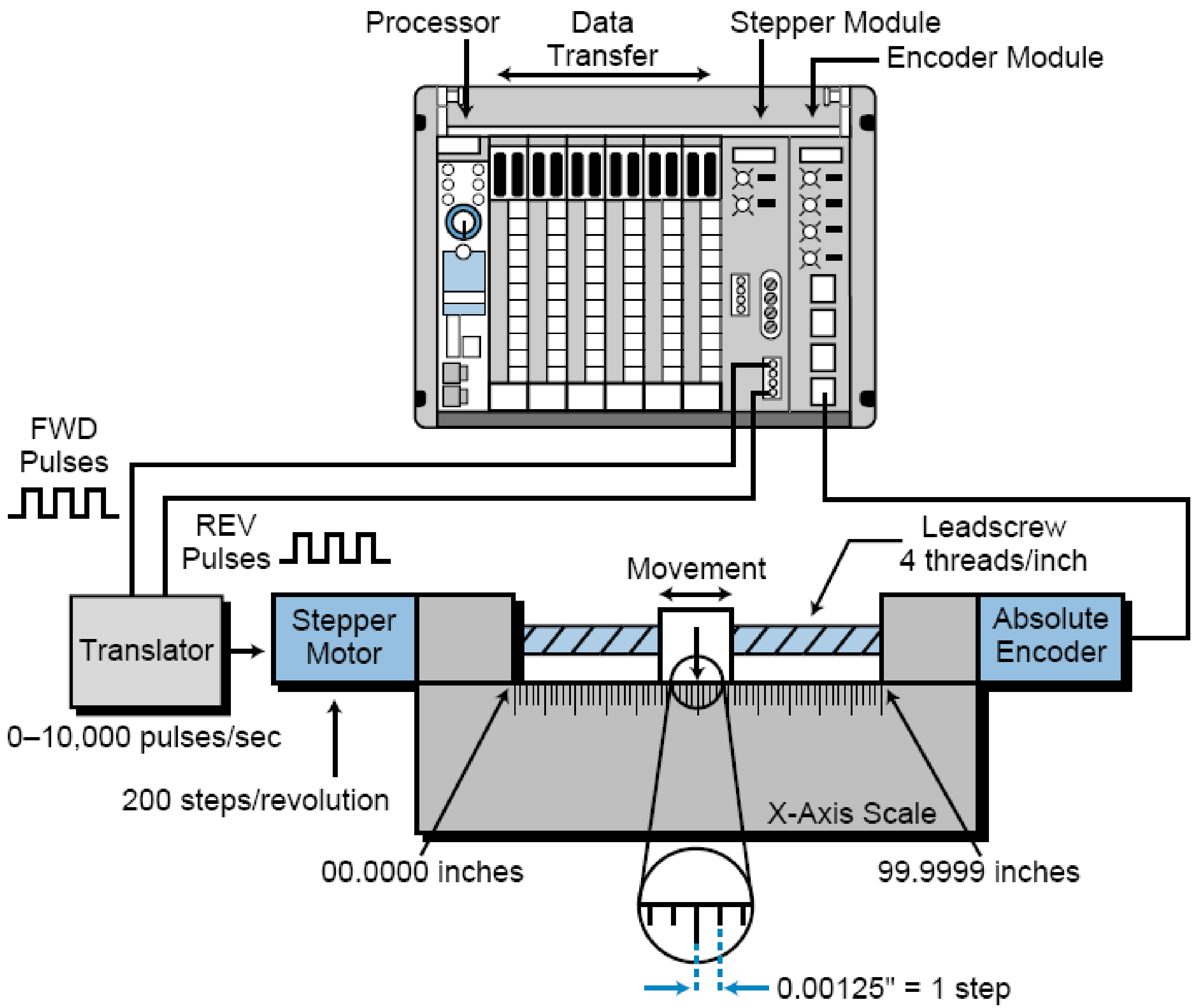


Stepper Motor Interfaces

- The motion of a stepper can be accelerated, decelerated, or maintained constantly by controlling the pulse rate output from a stepper module.
- A stepper interface generates a pulse train that is compatible with the stepper translator, indicating distance, rate, and direction commands to the motor.



Stepper Motor Interfaces



Stepper Motor Interfaces

❖ Example:

- **Suppose that the 200-step motor is operating at half-stepping conditions (400 steps per revolution) and that the leadscrew has 5 threads per inch. What are the step angle and linear displacement per step used in the system?**

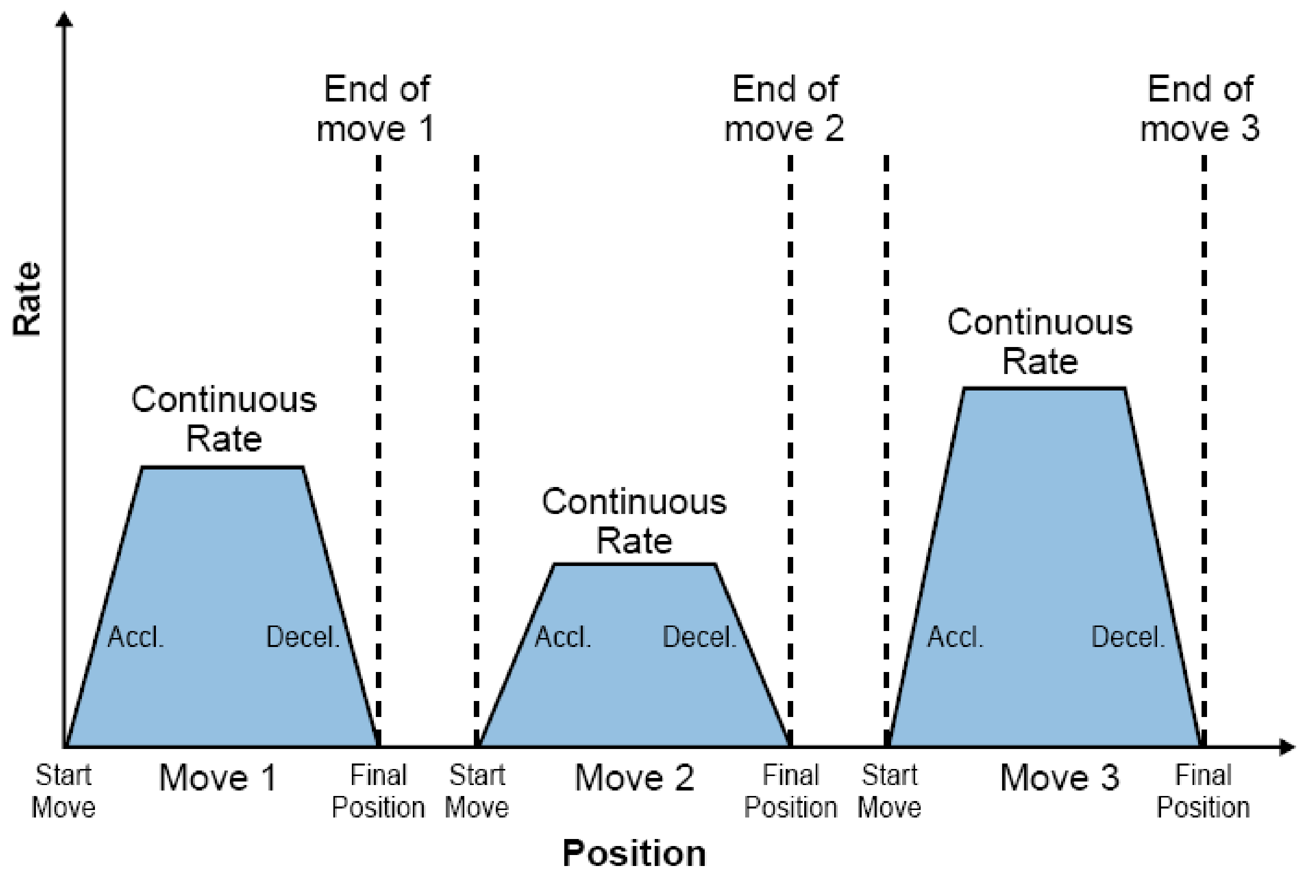
$$\text{Step angle} = \frac{360^\circ}{400} = 0.9^\circ$$

$$1'' \text{ travel} = (5 \text{ rev})(400 \text{ steps/rev}) = 2000 \text{ steps}$$

$$1 \text{ step} = \frac{1}{2000} = 0.0005 \text{ inches}$$

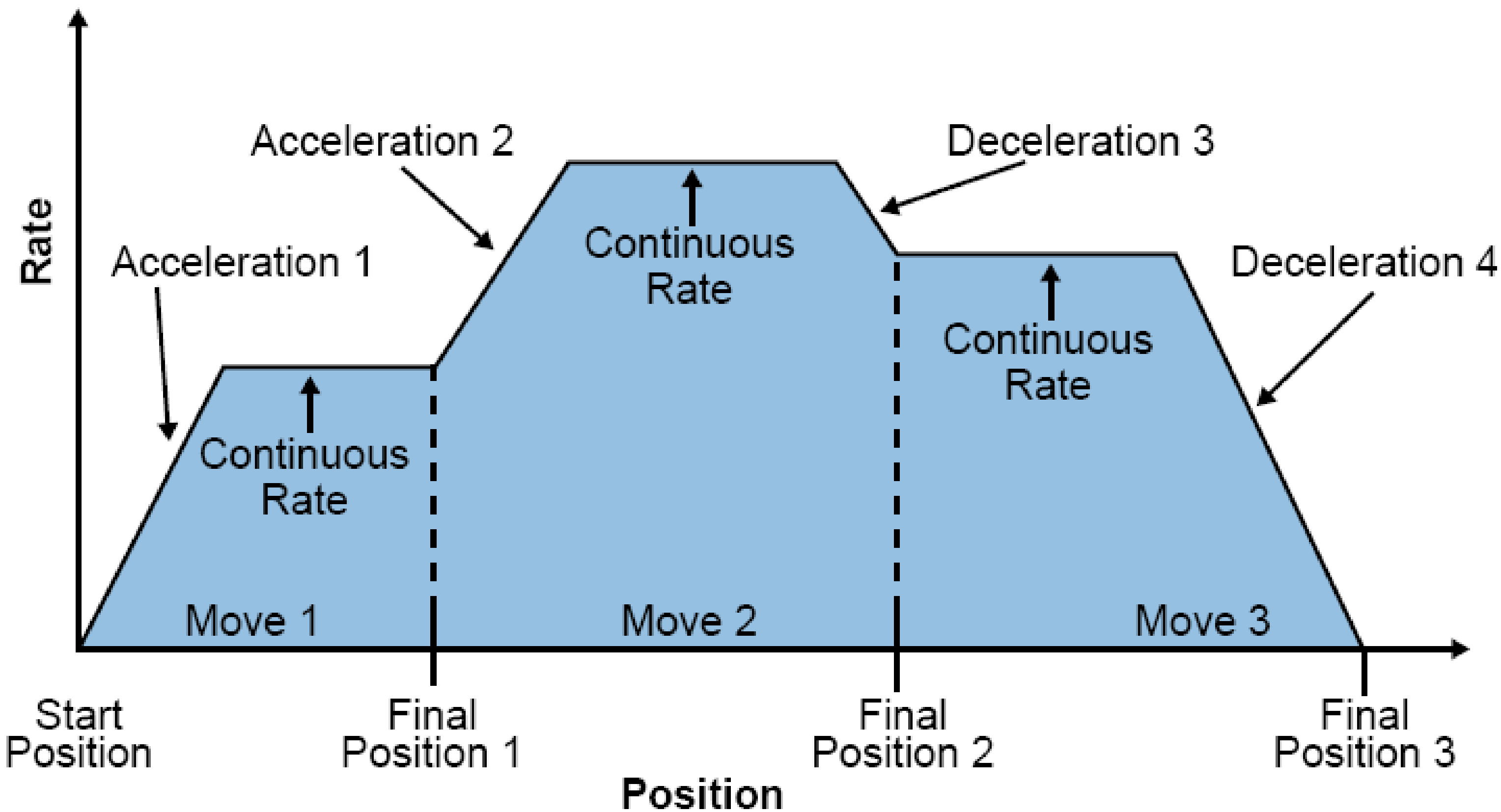
Stepper Motor Interfaces

- **Stepper motor interfaces operate in two modes: *single-step profile mode* and *continuous profile mode*.**
- ***Single-step profile mode:***

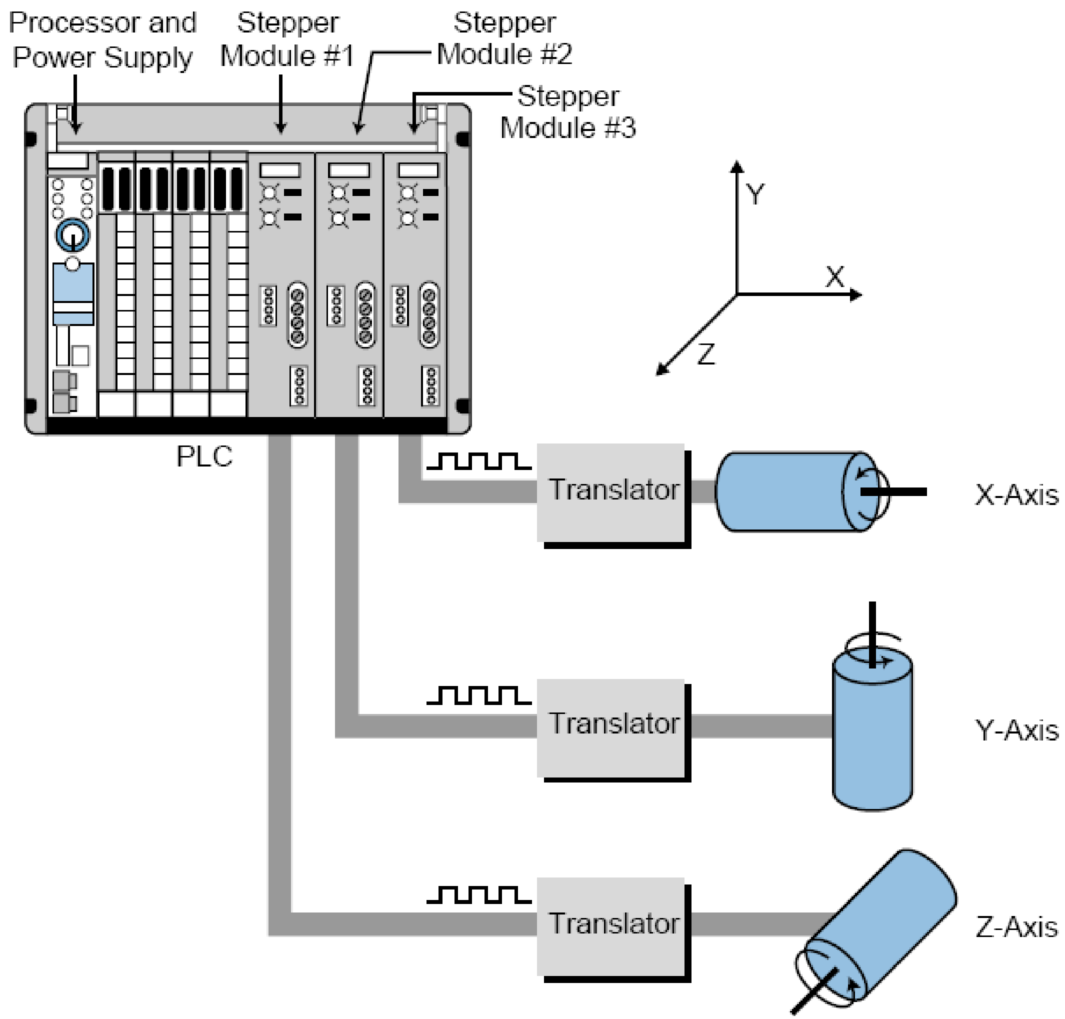


Stepper Motor Interfaces

- ***Continuous profile mode:***

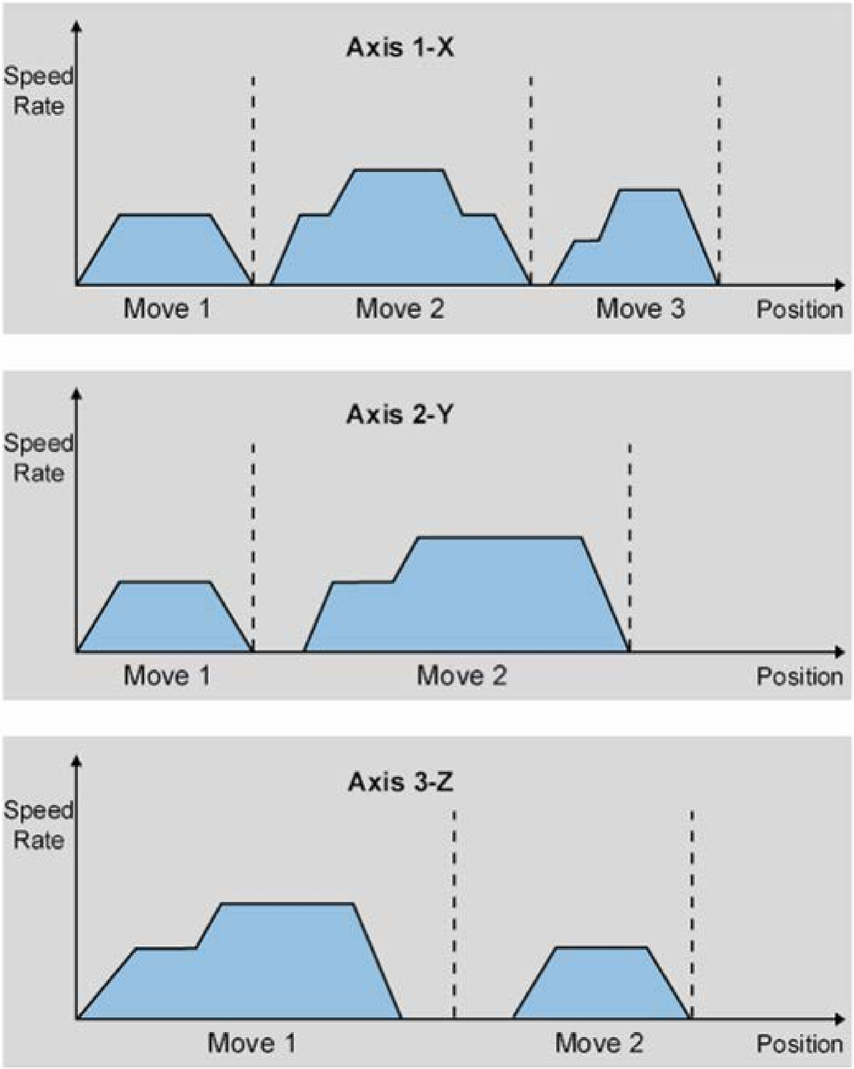


Stepper Motor Interfaces



Stepper Motor Interfaces

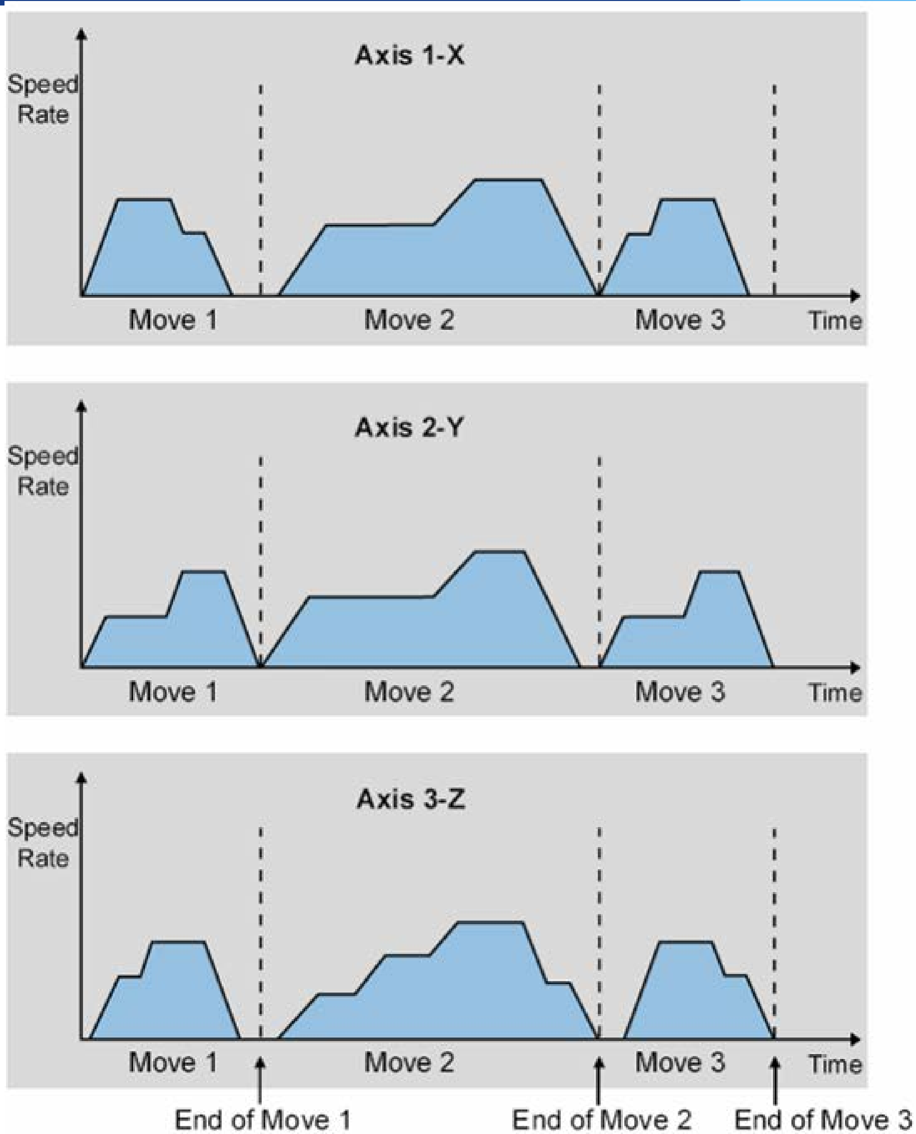
- ❖ **Each axis is independent of the other, executing its own single-step or continuous profile mode.**
- ❖ **The beginning and end of each axis motion may be different.**



(a) Independent

Stepper Motor Interfaces

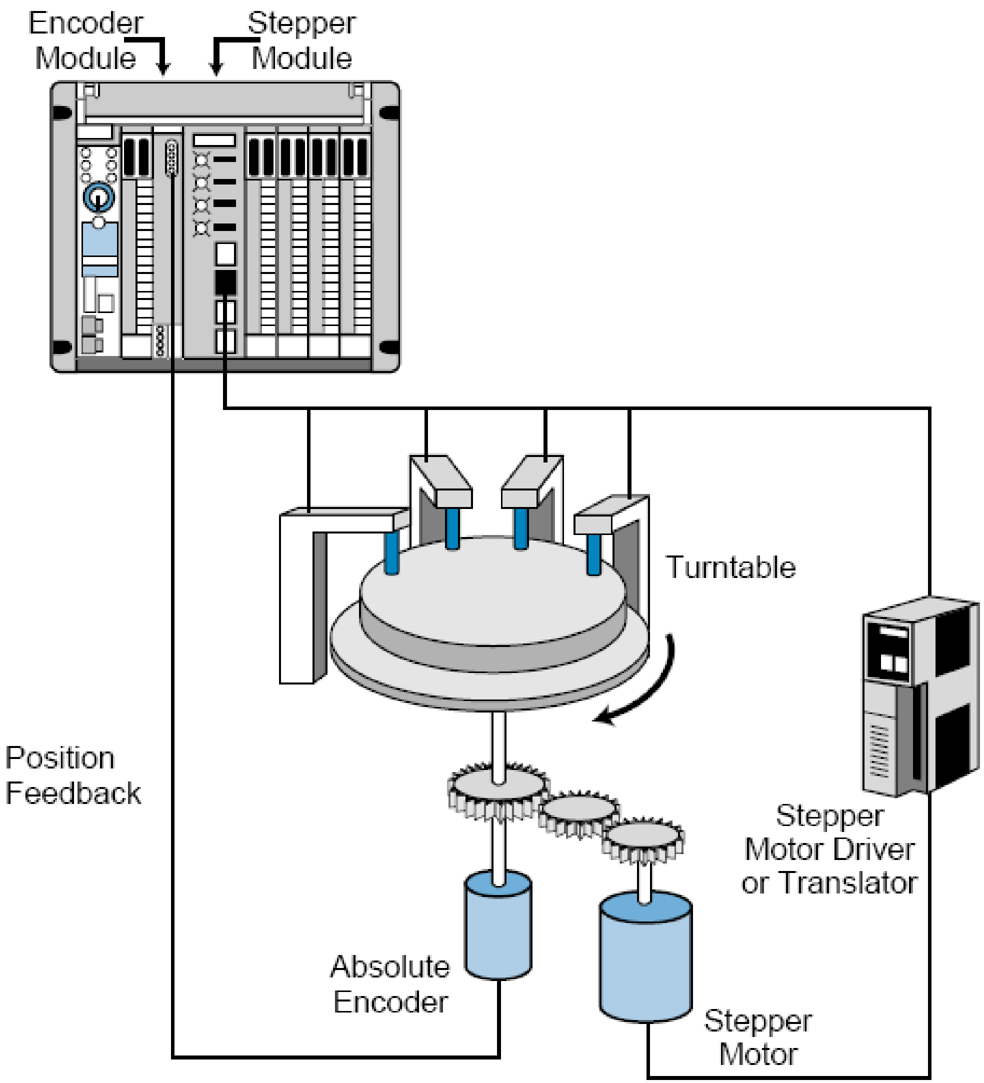
- ❖ The beginning and end of the motion commands for each axis occur at the same time.
- ❖ A profile of one of the axes may start later or end before the other axes (see Figure), but the move that follows will not occur until all axes have started and ended their motions.



(b) Synchronous

Stepper Motor Interfaces

- The use of a position/velocity feedback scheme (see Figure 8-26) can greatly improve the operation of a stepper motor control system, because this scheme provides closed-loop positioning control.

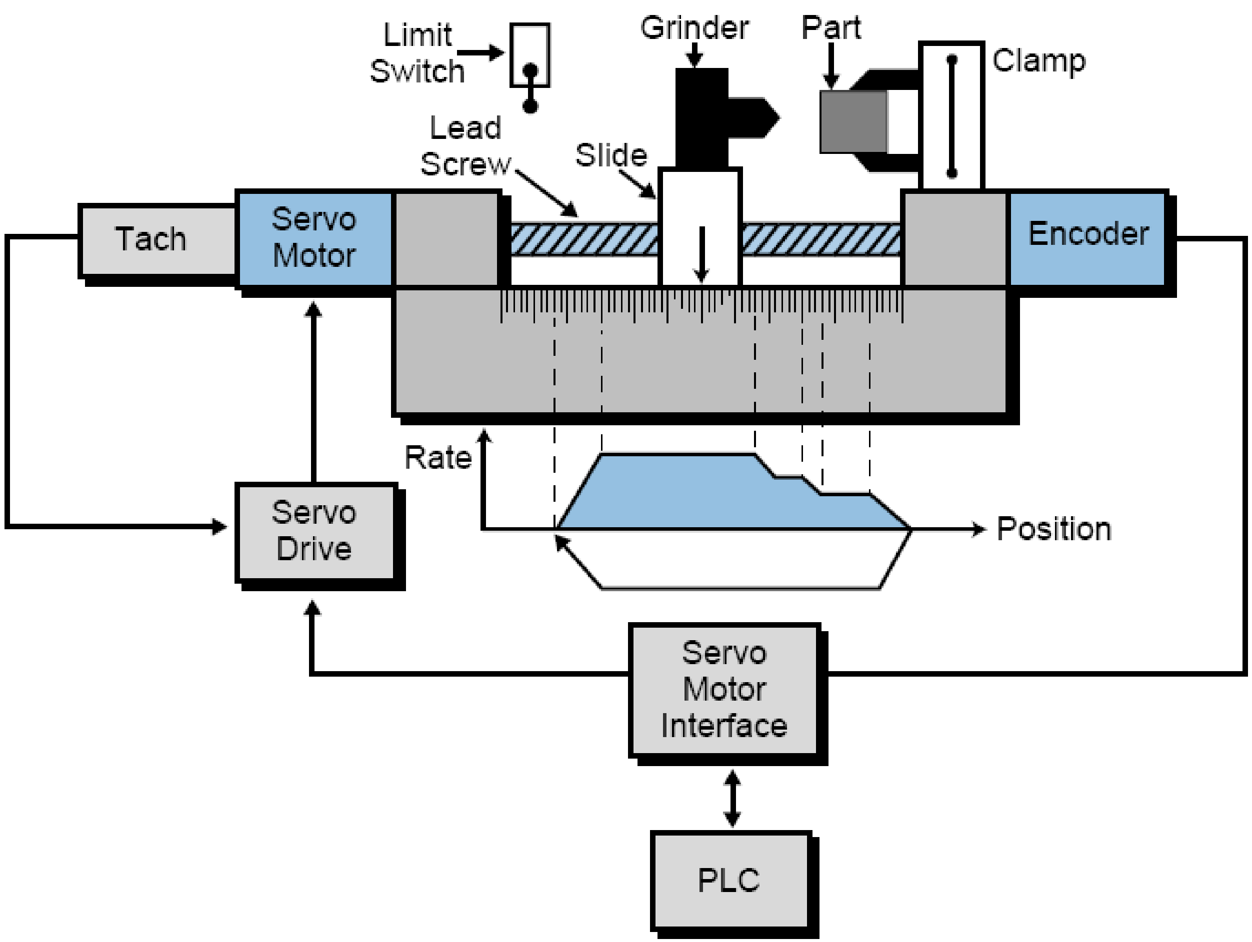


Servo Motor Interfaces

- ***Servo motor interfaces*** **are used in applications requiring control of servo motors via servo drive controllers.**
- **A servo motor is a specially designed motor that contains a permanent magnet.**
- **The speed of a servo motor can be easily varied by changing the input voltage to the motor.**
- **A servo module provides the drive controller with a ±10 VDC signal, which defines the forward and reverse speeds of the servo motor.**

Servo Motor Interfaces

- Typical applications of servo positioning include grinders, metal-forming machines, transfer lines, material-handling machines, and the precise control of servo driver valves in continuous process applications.

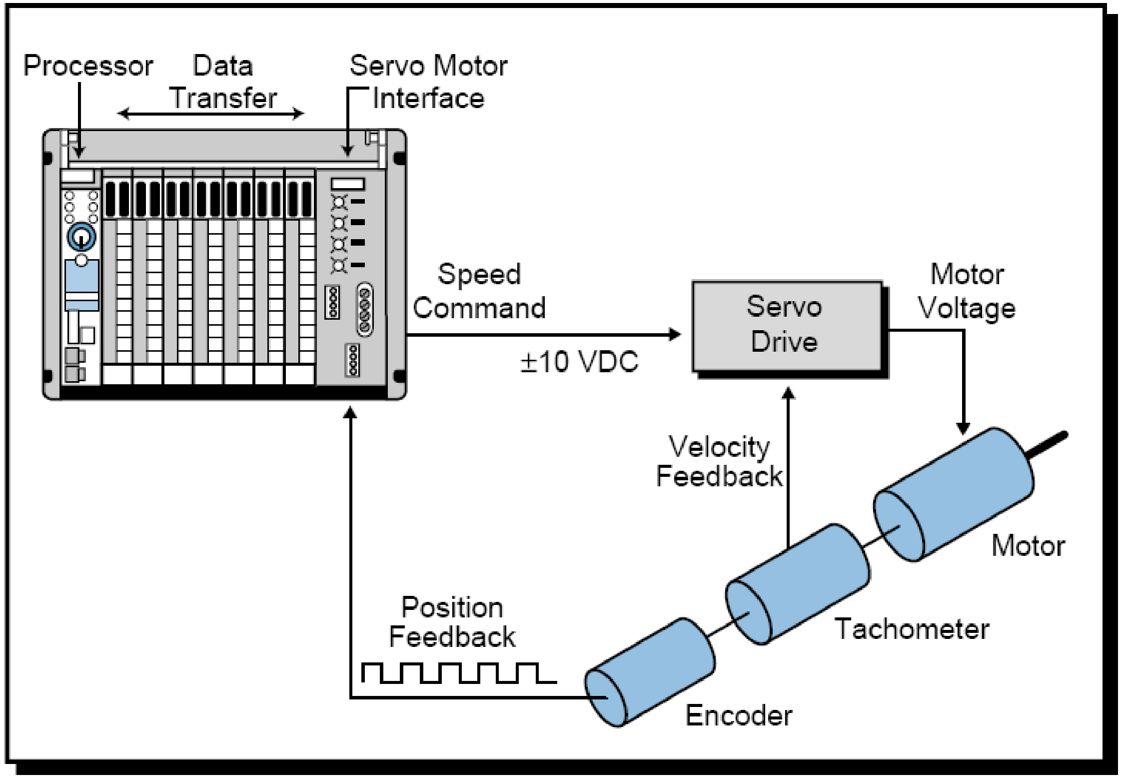


Servo Motor Interfaces

- **Servo positioning controls operate in a closed-loop system, requiring feedback information in the form of velocity or position.**
- **Servo control interfaces may receive velocity feedback in the form of a tachometer input, or positioning feedback in the form of an encoder input, or both.**
- **The feedback signal provides the module with information about the actual speed of the motor and the position of the axis.**

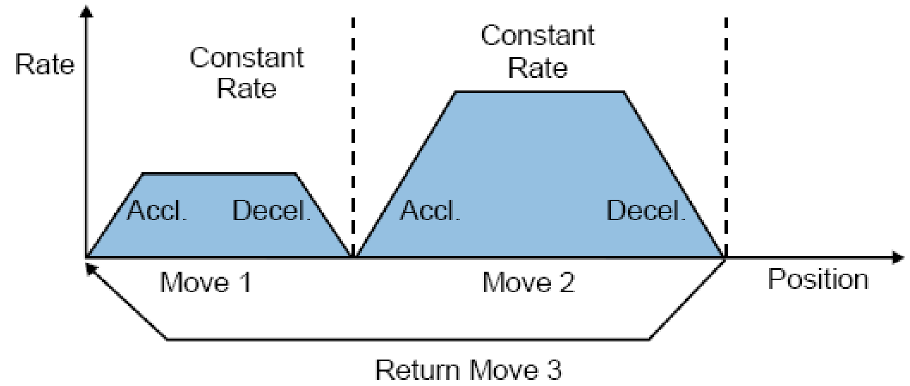
Servo Motor Interfaces

- Figure shows a servo control configuration block diagram. PLCs that have positioning control capabilities require two modules—one to implement the servo control task and one to receive feedback and close the loop.
- Some manufacturers, however, offer complete servo control for one axis in a single module.

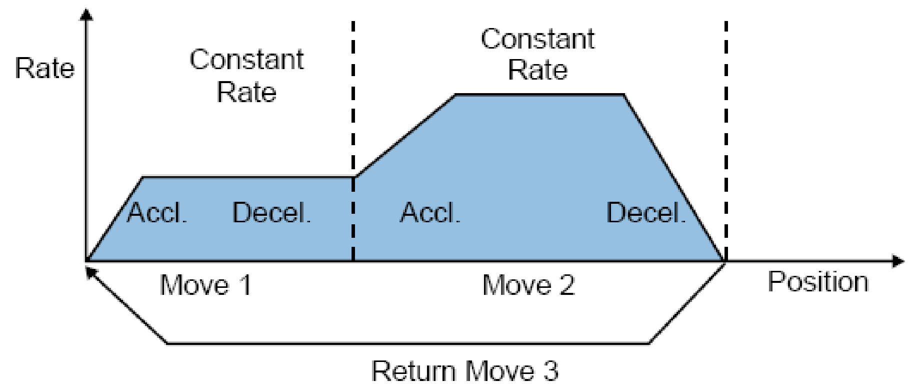


Servo Motor Interfaces

- Servo control, like stepper motor control, can occur in either single-step or continuous positioning mode.
- Depending on the manufacturer, multi-axis control can also be synchronized in either single-step or continuous mode.



(a) Single-step mode

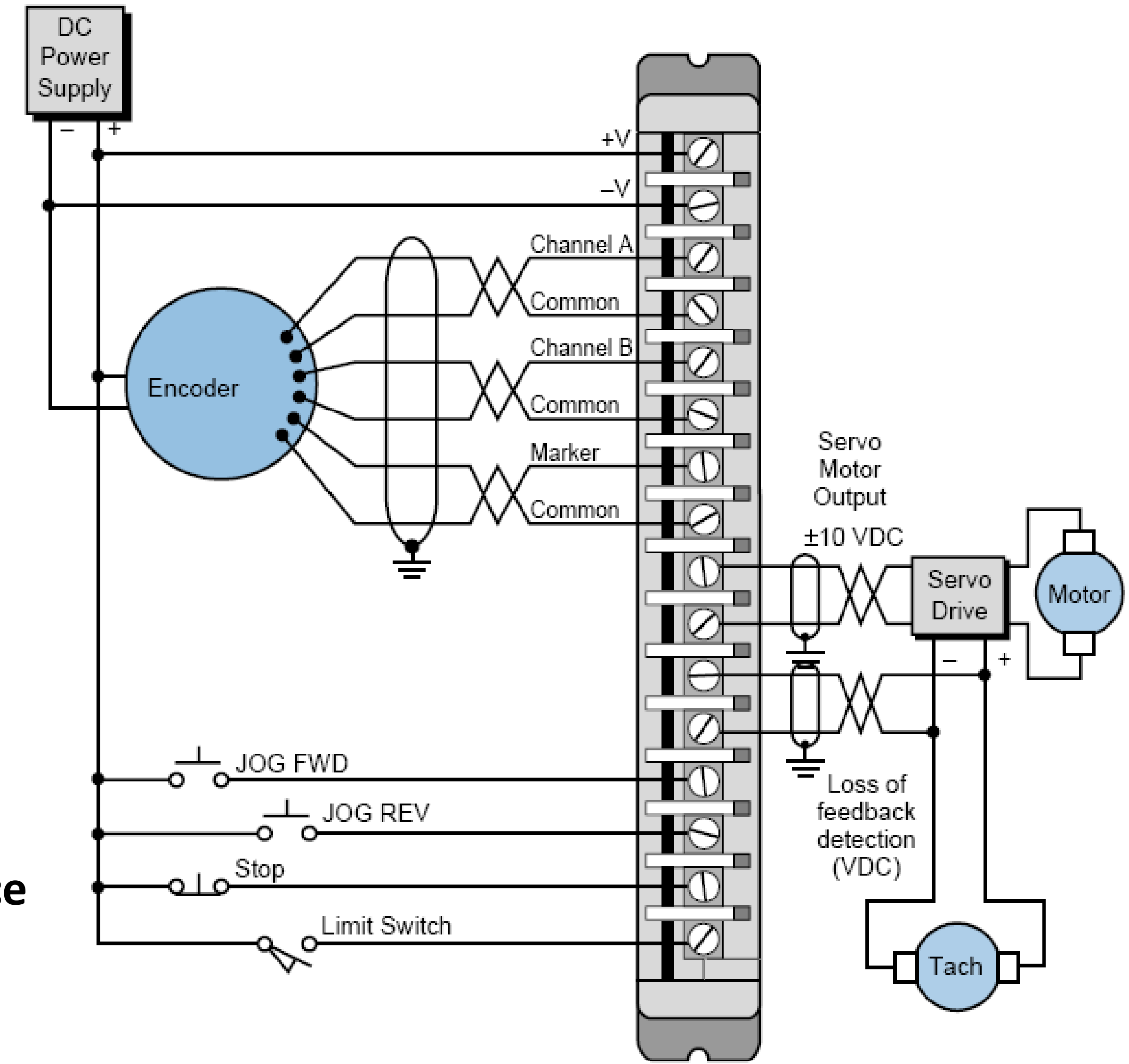


(b) Continuous mode

Servo Motor Interfaces

- **The PLC processor sends all of the move and position information, including acceleration, deceleration, and the final and feed velocities, to the servo module.**

Servo Motor Interfaces



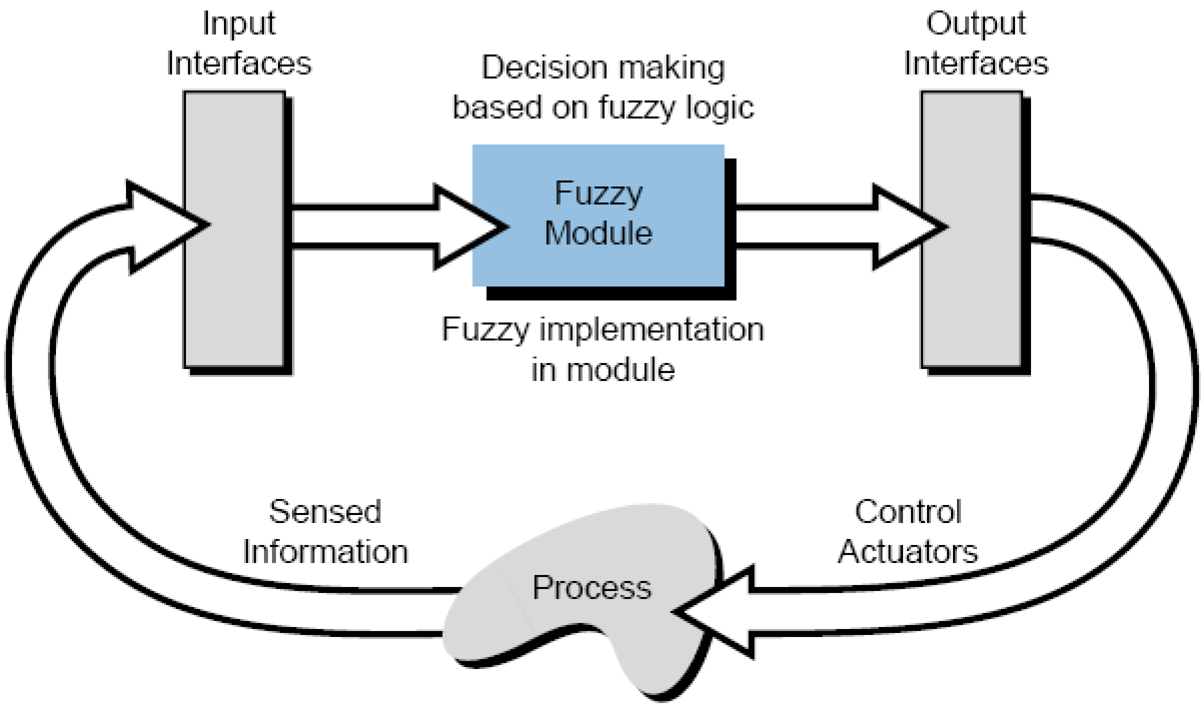
Servo motor interface connection diagram

Servo Motor Interfaces

- **When servo interfaces are used for positioning control, the feedback resolution provided by the system is a key issue.**
- **For example, if an interface uses a leadscrew (a rotational-to-linear motion translator) for axis displacement and an encoder to provide a feedback signal to the servo module, the user must know the leadscrew pitch, the number of encoder pulses per revolution, and the multiplier value in the encoder section of the interface.**

Fuzzy Logic Interfaces

- Offered by a few PLC manufacturers, provide a way of implementing fuzzy logic algorithms in PLCs. Fuzzy logic algorithms analyze input data to provide control of a process.

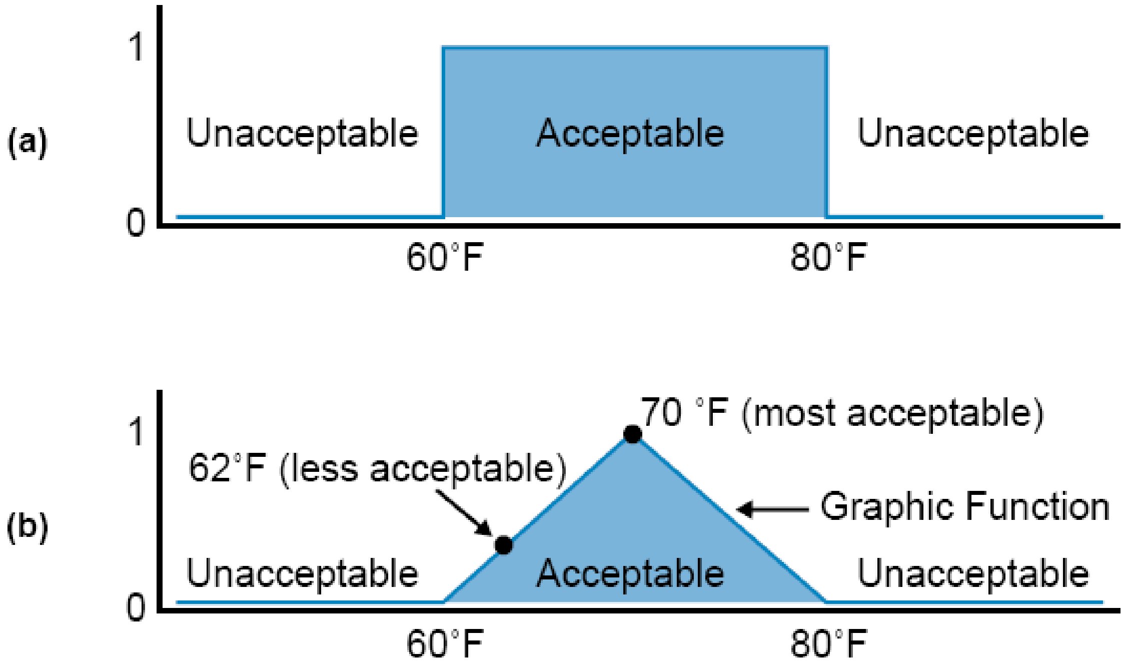


Fuzzy Logic Interfaces

- Fuzzy logic modules are an integral part of the advanced capabilities of today's programmable controllers. They help to bridge the gap between the discrete and analog decision-making functions of a PLC. In essence, fuzzy logic modules allow PLCs to "reason," letting them interpret data in an analog-type form instead of just as ON or OFF.
- The "reasoning" capabilities of fuzzy modules allow them to provide finetuned control of analog processes, as well as nonlinear and time-variant processes, like tension and position control.

Fuzzy Logic Interfaces

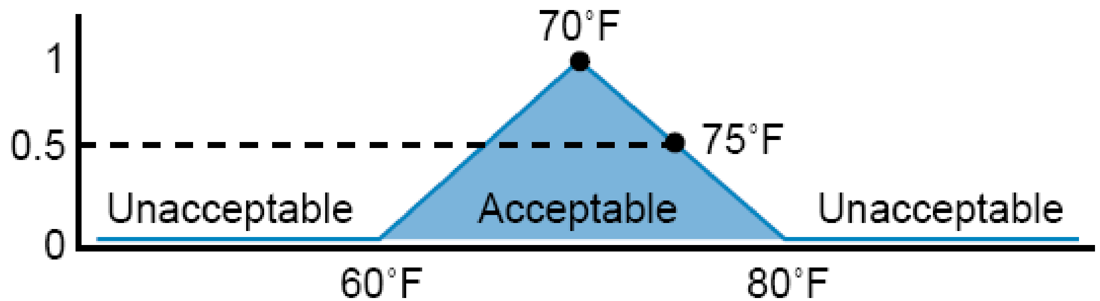
- **Fuzzy logic modules can provide this type of human-like judgment.**



Temperature sensing in (a) a normal PLC and (b) a PLC with fuzzy logic capabilities.

Fuzzy Logic Interfaces

- **Fuzzy logic modules work with other modules to input and output process information according to fuzzy control algorithms.**
- **These algorithms are based on user-programmed *rules*, which are formed by *IF conditions* and *THEN actions*. A fuzzy module analyzes its inputs according to the IF conditions and then outputs control data according to the corresponding THEN action.**

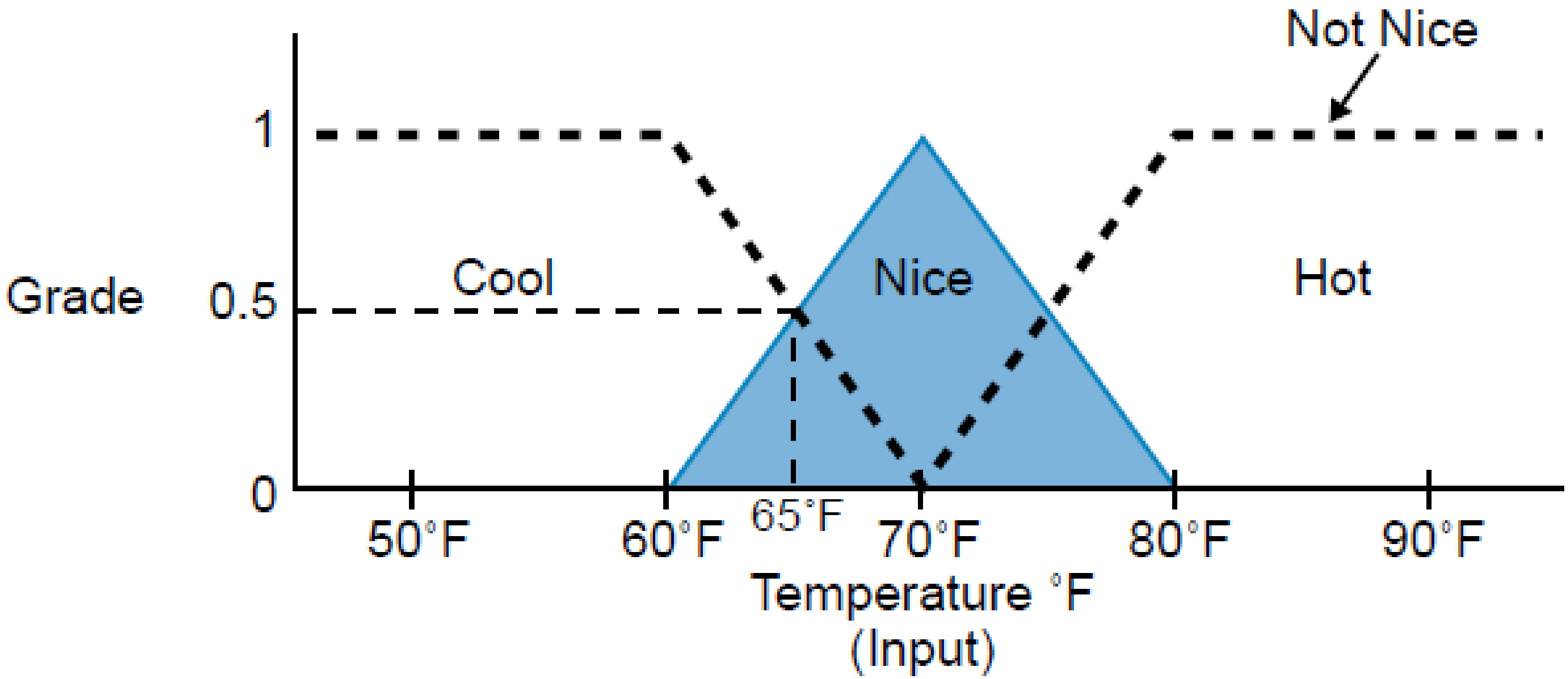


IF the temperature equals 75°F
THEN turn the output's controlling element a little clockwise

Fuzzy Logic Interfaces

- Fuzzy logic control is even more practical when multiple rules exist. For example, a fuzzy I/O module may receive data from a field device measuring the input process temperature, as well as from a field device measuring the outside environmental temperature.
- In this case, the module could combine two rules to determine a more precise acceptability level, resulting in a more precise output action.
- For example, IF the input temperature is 75^0F and IF the outside environmental temperature is 70^0F, THEN the acceptability level is 0.63, so turn the control element a little less (perhaps 8 degrees) clockwise.

Fuzzy Logic Interfaces



A reading of 65°F will have a grade of 0.5 nice temperature (50%) and 0.5 cool temperature (50%).