Process Instrumentation Terminology

**Accuracy** - Degree of *conformity* of an indicated value to a recognized accepted standard value, or ideal value.

**Accuracy, measured** - The maximum positive and negative *deviation* observed in testing a *device* under specified conditions and by a specified procedure.
Note 1: It is usually measured as an inaccuracy and expressed as accuracy.
Note 2: It is typically expressed in terms of the measured variable, percent of span, percent of upper range-value, percent of scale length or percent of actual output reading.
Accuracy rating - A number or quantity that defines a limit that *errors* will not exceed when a *device* is used under specified *operating conditions*. See Figure 1.
Note 1: When operating conditions are not specified, *reference operating conditions* shall be assumed.
Note 2: As a performance specification, *accuracy* (or reference accuracy) shall be assumed to mean accuracy rating of the *device*, when used at *reference operating conditions*.
Note 3: Accuracy rating includes the combined effects of *conformity*, *hysteresis*, *dead band* and *repeatability* errors. The units being used are to be stated explicitly. It is preferred that a ± sign precede the number or quantity. The absence of a sign indicates a + and a - sign.

Accuracy rating can be expressed in a number of forms. The following five examples are typical:

a. Accuracy rating expressed in terms of the *measured variable*. Typical expression:
   The accuracy rating is ± 1°C, or ± 20 F.

b. Accuracy rating expressed in percent of *span*. Typical expression: The accuracy rating is ± 0.5% of span. (This percentage is calculated using scale units such as degrees F, psig, etc.)

c. Accuracy rating expressed in percent of the upper range-value. Typical expression:
   The accuracy rating is ± 0.5% of upper-range value. (This percentage is calculated using scale units such as kPa, degrees F, etc.)

d. Accuracy rating expressed in percent of scale length. Typical expression: The accuracy rating is ± 0.5% of scale length.

e. Accuracy rating expressed in percent of actual output reading. Typical expression:
   The accuracy rating is ± 1% of actual output reading.

Accuracy, reference - see accuracy, rating.

**Actuating error signal** - see signal, actuating error. adaptive control - see control, adaptive.

**Adjustment, span** - Means provided in an instrument to change the slope of the input-output curve. See span shift.
**Dead band** – The range through which an input can be varied without initiating observable response.

**Dead time** – The interval of time between initiation of an input change or stimulus and the start of the resulting observable response.

**Hysteresis** – That property of an element evidenced by the dependence of the value of the output, for a given excursion of the input, upon the history of prior excursions and the direction of the current traverse.

**Precision** – (of measurement) the extent to which repeated measurements of a standard with a given instrument yields the same result.

**Range** – The region between the limits within which a quantity is measured, received or transmitted, expressed as lower and upper values.

**Repeatability** – The closeness of agreement among a number of consecutive measurements of the output for the same value of the input under the same operating conditions, approaching from the same direction, for full range traverses.

**Transducer** - An element or device that receives information in the form of one quantity and converts it to information in the form of the same or another quantity. Note: This is a general term and definition and as used here applies to specific classes of devices such as primary element, signal transducer, and transmitter.
Transmitter - A transducer which responds to a measured variable by means of a sensing element, and converts it to a standardized transmission signal which is a function only of the measured variable.

Hysteresis and Dead band

Targets which demonstrate the difference between accuracy and repeatability. (a) Neither accurate nor repeatable. (b) Repeatable but not accurate. (c) Accurate and repeatable.
Accuracy and Repeatability

Sources of Error in Measurement

A measurement error is the difference between the measured value and the true value. This difference from the true value can be a problem of precision or accuracy.

Several sources of error exist in most instruments - non-linearity, hysteresis (e.g., gear back-lash), and sensitivity to environmental factors such as temperature, magnetic or electrical fields are a few examples. Instrument error is often magnified by the fixturing required in the measuring process. Poor electrical connection, improper fastening of mechanical linkages, and loose clamps are examples of fixturing problems. Temperature induced error, in addition to its effects on measuring instruments, affects the specimen being measured. As temperature changes, the length ($L$) of a specimen changes.

The observed $\sigma$ or standard deviation is a function of the causes contributing to the variation. The equation is:

$$\sigma_{\text{obs}} = \sqrt{\sigma_{\text{cause(a)}}^2 + \sigma_{\text{cause(b)}}^2 + \ldots + \sigma_{\text{cause(n)}}^2}$$

where $\sigma_{\text{obs}} = \text{observed variation}$

$\sigma_{\text{cause(n)}} = \text{variance of a cause}$
Response Times

Dead Time - The interval of time between initiation of an input change or stimulus and the start of the resulting observable response.

Time Constant – The value $T$ in an exponential response term $A \exp(-t/T)$ or of the transform factors $1 / (Ts + 1)$.

Rise Time – The time required for the output of a system (other than first order) to change from a small-specified percentage of steady state to a large specified percentage of steady state.
Drawings and Symbols

EFD, Engineering Flow Diagram – A drawing showing all the major engineering details of a plant or facility. This included the piping details; pipe size and specifications, insulation, vessel sizes and ratings, pump sizes and instruments. There is little to no information about the flow rates and energy transfers.

PFD, Process Flow Diagram – A drawing of a plant or facility that shows process flows, instrumentation, controls. Missing are the piping details, sizes etc. The PFD frequently has, in table form, the process and energy flows, capacity, etc. This document is used frequently used to define control strategy or basis.

Hysteresis and Dead band – Did your valve move, how much?

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Pneumatic Signal Line

Electronic Signal Line

System Link software link or manuf. system connection between functions.

Filled System Capillary Signal Line

Common Signal Line Connection Symbols
Terms Used Interchangeably for Process Control

attenuation – filtering

dead band – backlash

control interval – cycle time – execution time

delay time – dead time

derivative action – rate action

derivative time – rate time

digital filter – process variable filter – signal filter

estimator – inferential measurement – intelligent sensor

integral action – reset action

integral time – reset time

lag time – time constant

open loop gain – plant gain – process gain

open loop time constant – plant time constant – process time constant

resolution – sensitivity – sticktion – stick-slip

steady state gain – static gain

total loop dead time – system dead time – plant dead time – process dead time

upset – disturbance – load

Definitions of Process Control Terms

See ANSI/ISA-S51.1 Process Instrumentation Terminology for a comprehensive list of terms used in automation systems.

action – relative direction of change in output for a change in input (“direct” for changes in same direction and “reverse” for changes in opposite direction)

automatic mode – PID controller mode to enable its set point to be locally adjusted by the operator (also known as LOCAL and AUTO mode)

A/D – analog to digital converter typically used to convert an analog input to its digital value with a resolution of 0.05% for a 12 bit converter with one sign bit

attenuation – reduction in amplitude of an oscillation between two operating points or two frequencies as a result of smoothing by a filter time constant in the measurement or by process time constant from a mixed volume.

backlash – see dead band
**cascade mode** – secondary PID controller mode to enable its set point to be remotely adjusted by the output of a primary controller (also known as REMOTE and CAS mode).

**closed loop time constant** – time it takes for the process variable to reach 63% of its change after a time delay for a step change in the controller set point when the controller is in automatic. The controller tuning must provide a non-oscillatory response for this term to be valid. For integrating or runaway processes, the controller gain must be large enough for the control action to bend over the response within the scale range.

**controller action** – relative direction of change in controller output for a change in the controlled variable (“direct” for same direction and “reverse” for opposite direction).

**controller gain** – tuning parameter multiplier for the proportional mode (dimensionless). It is the multiplier for the integral and derivative modes in most industrial PI and PID controllers. It is the 100 percent divided by the proportional band.

**controller output** – the output of a PID controller (normally in percent for the control algorithm).

**controller tuning** – adjustment of the proportional, integral (reset), and derivative mode settings for a PID controller.

**control interval** – time interval between successive executions for digital devices (same as scan or update time and the inverse of scan rate or frequency).

**controlled variable** – a controller input to be kept at a set point. It is often a process output such as concentration, pH, pressure, temperature, or level but is normally in percent for the control algorithm.

**compression** – smallest change in value of a variable that is stored by a computer or data historian (must not exceed the repeatability of the CV or the resolution of the MV).

**cycle time** – see control interval.

**D/A** – digital to analog converter typically used to convert a digital value to an analog output with a resolution of 0.05% for a 12 bit converter with one sign bit.

**DDC mode** – PID controller direct digital control mode to enable its output to be adjusted by a sequence, interlock, or a computer (also known as ROUT mode).

**dead band** – minimum change in the input for a reversal of direction that will cause a change in the output (important for a control valve and a manipulated variable).

**dead time** – time it takes for the process variable to get out of the noise band after a change in the manipulated variable (same as time delay).

**delay time** – see dead time.

**derivative action** – controller output changes that are proportional to the rate of change of the error or the controlled variable (derivative mode of a PID controller).

**derivative time** – see rate time.

**digital filter** – a first order time constant in a digital device to attenuate noise.
Distributed Component Object Model (DCOM) – a protocol that enables software components to communicate directly over a network in a reliable and secure way

disturbance – a change in a process input or operating condition

dynamic gain – ratio of the output amplitude to a sinusoidal input amplitude after transients have decayed (also known as amplitude ratio and magnitude ratio)

estimator – online calculation (intelligent sensor or inferential measurement) of a process variable (e.g., composition or quality) corrected by a field or lab measurement

execution time – see control interval

feedback control – a control algorithm to reduce the error between the set point and the controlled variable (most often a PID or model predictive controller algorithm is used)

feedforward control – a computation of the manipulated variable from a measurement of the disturbance (most often corrected by a PID or model predictive controller)

filter time – time constant of a signal filter that is usually applied to the PV but can be inserted anywhere in the configuration as a function block (seconds or minutes)

filtering – see attenuation

final element – device used to adjust the manipulated variable (typically it is a control valve but it can be a variable speed drive, compressor vane, or an electrical heater)

I/P – current to pneumatic converter mounted on the valve to convert a controller output to a pneumatic signal for the actuator (often integrated with positioner)

integral action – controller output changes that are proportional to the integral of the error (integral mode of PID controller)

integral time – see reset time

integrating process – a process that ramps at a constant rate for a change in the manipulated variable when the controller is in manual if there are no disturbances

integrating process gain – per cent change in ramp rate per percent change in controller output (%/sec/%).

inferential measurement – see estimator

intelligent sensor – see estimator

limit cycle – continuous oscillation of nearly equal amplitude that persists for a variety of controller gains (caused by a resolution limit or a nonlinearity such as stick-slip and pH)

manipulated variable – variable adjusted by a controller output (most often it is a process input such as flow but it can be the set point of a process variable for cascade control) (normally in process engineering units).

manual mode – operator adjusts the controller output directly (PID algorithm is suspended but will provide a bumpless transfer to automatic, cascade, or supervisory control)
**matrix condition number** – a measure of the sensitivity of a matrix and of the ability of MPC to effectively decouple the process so that each controlled variable can be maintained at its target. Matrices that have a condition number around 1 are considered well conditioned, while those much greater than 1 are considered ill conditioned.

**model predictive control** – model based control of future trajectory of a process variable from the changes of manipulated variables (same as constrained multivariable predictive control)

**move limit** – largest change in the manipulated variable per execution of a model predictive controller (normally set large for simulation test but reduced during commissioning)

**nonlinear system** – gain, time constant, or time delay and hence controller tuning settings are not constant but a function of time, direction, operating point, or load

**OLE** – Object Linking and Editing

**OPC** – OLE for Process Control

**open loop gain** – final % change in the controller input divided by the % change in the controller output with the controller in manual for a self-regulating process. It is dimensionless steady state gain that is the product of the gains for the manipulated variable (e.g. valve gain), the process variable, (i.e. process gain), and controlled variable (e.g. measurement span). It is often simply referred to as the process gain.

**open loop time constant** – time it takes for the process variable to reach 63% of its change after its time delay for a step change in controller output when the controller is in manual. It can originate in the final element, process, or measurement. It is often simply referred to as the process time constant.

**oscillation period** – time between successive peaks in any type (damped or undamped) of oscillation (the period of damped oscillations is usually larger than the ultimate period)

**penalty on error (PE)** – an MPC controlled or constraint variable tuning value that determines how much the variable is penalized for errors and violations. The higher the value, the more aggressively the controller provides feedback correction

**penalty on move (PM)** – a tuning value of an MPC manipulated variable that determines how much the manipulated variable is penalized for moving (also known as move suppression). The higher the value, the slower the moves

**positioner** – controller mounted on the valve whose set point is desired position and whose controlled variable is shaft position (also known as a digital valve controller)

**primary controller** – master or outer loop controller whose output is the set point (CAS set point) of a secondary controller in a cascade control system

**process action** – relative direction of change in process variable for a change in the manipulated variable (“direct” for same direction and “reverse” for opposite direction)

**process gain** – final change in the process variable divided by the change in the manipulated variable (commonly used as the open loop gain)

**process variable filter** – see digital filter

**process variable** – direct or inferential measurement of a variable in the process (normally in process engineering units)
**proportional action** – controller output changes that are proportional to the change in error (proportional mode of a PID controller)

**proportional band** – percent change in control error that causes a 100 percent change in controller output (%). It is equivalent to 100 percent divided by controller gain.

**rate time** – tuning parameter multiplier for the derivative mode of a PID controller (seconds)

**remote cascade** – mode where the preferred value for the controlled variable comes from model predictive control, sequence, or supervisory controller (RCAS)

**remote output** – mode where the controller algorithm is suspended and the controller output is set by a discrete action, interlock, or sequence (ROUT)

**reset time** – tuning parameter divisor for the integral mode of a PID controller (seconds per repeat). It is the inverse of the reset setting given in repeats per second

**repeatability** – short-term maximum scatter in the output for the same input approached from the same direction and at the same conditions (see reproducibility)

**reproducibility** – long-term maximum scatter in the output for the same input approached from both directions and at the same conditions (includes repeatability and drift)

**resolution** – minimum change in the input in the same direction that will cause a change in the output (important for a control valve and a manipulated variable)

**runaway process** – a process that accelerates for a change in the manipulated variable when the controller is in manual if there are no disturbances

**saturation** – controller output is at either low or high limits that are normally set to match the valve being shut and wide open, respectively (controller is effectively disabled)

**scan time** – time interval between successive scans for digital devices (same as update time or control interval and the inverse of scan rate or frequency)

**secondary controller** – slave or inner loop controller whose (CAS) set point is manipulated by the output of a primary controller in a cascade control system

**self-regulating process** – a process that decelerates and reaches a steady state for a change in the manipulated variable when the controller is in manual if there are no disturbances (no integrating or runaway response)

**sensitivity** – ratio of the steady state change in output to the change in the input (poor sensitivity is caused by poor resolution and a low steady state gain or flat curve)

**slip** – rapid movement of valve trim caused by dynamic changes in friction (the zipping past the desired position means the controller will never reach its set point)

**signal filter** – see digital filter

**smart transmitter** – transmitter with a microprocessor to compensate for changes in ambient and process conditions and to provide remote calibration and diagnostics

**steady state gain** – final change in the output of loop components (controller, valve, process, measurement) divided by the change in input (static or zero frequency gain)
**static gain** – see steady state gain

**stick** – lack of valve trim movement for a change in input signal caused by friction or an undersized actuator (major source of a valve’s resolution limit)

**time delay** – time it takes for the process variable to get out of the noise band for a change in the manipulated variable (same as dead time)

**time constant** – time it takes for the process variable to reach 63% of its change after its time delay for a step change.

**time lag** – see time constant

**time to steady state (Tss)** – the time it takes the process variable or controlled variable to reach its final value (or about 99 percent of the change in the process variable) after a change to the manipulated variable.

**tuning weight** – tuning adjustment in a model predictive controller (when applied to CV or QV it sets priority and when applied to MV it sets move suppression for stability)

**ultimate gain** – controller gain at equal amplitude oscillations for proportional only control (occurs at 180 deg phase shift and is inverse of static gain and amplitude ratio)

**ultimate period** – period of equal amplitude oscillations for proportional only control (occurs at 180 deg phase shift and is the inverse of the natural period in radians/sec)

**update time** – time interval between successive updates for digital devices (same as scan time or control interval and the inverse of scan rate or frequency)

**upset** – see disturbance

**valve action** – relative direction of change in flow for a change in the input signal to a valve (“direct or inc-open” for fail closed and “reverse” or “inc-close” for fail open)