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American National Standard

Process Instrumentation Terminology

ANSI/ISA-S51.1 — Process Instrumentation Terminology

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Preface

(This Preface is included for informational purposes and is not part of Standard S51.1.)

This Standard has been prepared as a part of the service of ISA toward a goal of uniformity in the field of instrumentation. To be of real value this document should not be static, but should be subjected to periodic review. Toward this end the Society welcomes all comments and criticisms, and asks that they be addressed to the Standards and Practices Board Secretary, ISA, 67 Alexander Drive, P.O. Box 12277, Research Triangle Park, NC 27709, Telephone 549-84111, e-mail: standards@isa.org.

The ISA Standards and Practices Department is aware of the growing need for attention to the metric system of units in general, and the International System of Units (SI) in particular, in the preparation of instrument standards. The Department is further aware of the benefits to USA users of ISA Standards of incorporating suitable references to the SI (and to the metric system) in their business and professional dealings with other countries. Towards this end this Department will endeavor to introduce SI and SI-acceptable metric units as optional alternatives to English units in all standards to the greatest extent possible.

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This committee was originally formed under the joint sponsorship of ISA and the Process Measurement and Control Section, Inc. (SAMA). Recognition is therefore given to the SAMA standard on Process Measurement and Control Terminology (PMC 20.1-1973).

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The assistance of those who aided in the preparation of this Standard, by their review of the draft and by offering suggestions toward its improvement, is gratefully acknowledged. The following have reviewed the report and served as Board of Review.

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Contents

1 Purpose

The purpose of this Standard is to establish uniform terminology in the field of process instrumentation. The generalized test procedures described in Section 5 are intended only to illustrate and clarify accuracy-related terms. It is not intended that they describe specific and detailed test procedures.

2 Scope

This Process Instrumentation Terminology Standard is intended to include many specialized terms used in the industrial process industries, to describe the use, performance, operating influences, hardware, and product qualification of the instrumentation and instrument systems used for measurement, control, or both. There are many terms and definitions relating to performance tests and environmental influences (operating conditions) as further explained in the Introductory Notes (Paragraph 3.2). Basically, this document is a guideline for vendor/user understanding when referring to product specifications, performance, and operating conditions. Process industries include chemical, petroleum, power generation, air conditioning, metallurgical, food, textile, paper, and numerous other industries.

The terms of this Standard are suitable for use by people involved in all activities related to process instrumentation; including research, design, manufacture, sales, installation, test, use and maintenance.

The Standard consists of terms selected primarily from Scientific Apparatus Makers Association (SAMA) Standard PMC20.1 and American National Standards Institute (ANSI) Standard C85.1. Additional terms have been selected from other recognized standards. Selected terms and definitions have not been modified unless there was a sufficiently valid reason for doing so. New terms have been added and defined where necessary.

This Standard is primarily intended to cover the field of analog measurement and control concepts, and makes no effort to develop terminology in the field of digital measurement and control.

3 Introduction

3.1 Italicized terms

Defined terms, where used as a part of other definitions, are set in italics to provide a ready cross reference.

3.2 Introductory notes

In defining certain performance terms, the context in which they are used has been considered. It is fitting, therefore, that the philosophy of performance evaluation on which these terms are based be explained.

Ideally, instruments should be designed for realistic operating conditions, those they are likely to meet in service, and they should be evaluated under the same conditions. Unfortunately, it is not practical to evaluate performance under all possible combinations of operating conditions. A test procedure must be used which is practical under laboratory conditions and, at the same time, will make available with a reasonable amount of effort, sufficient data on which a judgment of field performance can be made.

The method of evaluation envisioned is that of checking significant performance characteristics such as accuracy rating, dead band, and hysteresis under a set of reference operating conditions, these having a narrow range of tolerances.

Reference performance is, therefore, to be evaluated and stated in terms of reference operating conditions.

Generally, reference performance under reference operating conditions represents the "best" performance that can be expected under ideal conditions.

The effect of change in an individual operating condition, such as ambient temperature, atmospheric pressure, relative humidity, line voltage, and frequency will be determined individually throughout a range defined as normal operating conditions. These can logically be expected to be encountered above and below the values of reference operating conditions during field operation.

While this approach does not duplicate all actual conditions, where many operating variables may vary simultaneously in random fashion, it does develop data from which performance may be inferred from any given set of operating conditions.

The effect of changes in an individual operating condition, all other operating conditions being held within the reference range, is herein called operating influence. There may be an operating influence corresponding to a change in each operating condition. In some cases the effect may be negligible, while in others it may have significant magnitude.

Tabulations of operating influences will usually denote the performance quality level of a given design. Comparisons of reference performance and operating influences for instruments of a given design, or for different designs, will show clearly their relative merits and probable performance under actual operating conditions.

3.3 Operating conditions vs. performance

<u>Operating Conditions</u>	<u>Performance</u>
Reference (narrow band)	Reference (Region within which accuracy statements apply unless indicated otherwise.)
Normal (wide band)	Conditional (Region within which the influence of environment on performance is stated.)
Operative Limits (extreme band)	Indefinite (Region within which influences are not stated and beyond which damage may occur.)

3.4 Sources and references

In the preparation of this Standard of Terminology, many standards and publications sponsored by technical organizations such as ASME, IEEE, and ISA were studied by the committee in addition to those listed as principal source documents. These are listed as References.

Existing terms and definitions have been used wherever considered suitable. In many cases terms have been extracted from source documents with verbatim definitions and in such cases permission to quote from the respective source document has been obtained from the organization concerned, as indicated below. Terms defined verbatim are followed by the reference number in parenthesis. For example: (4) after a defined term indicates that this term is quoted verbatim from ANSI C85.1 "Terminology for Automatic Control."

In other cases definitions have been modified in varying degrees in conformity with current practice in process instrumentation. These have been noted in parentheses as "Ref." followed by the reference number. For example: (Ref. 8) indicates that this term is a modified definition of the referenced term in SAMA-PMC 20.1-1973 "Process Measurement and Control Terminology."

An omission or alteration of a note following a definition is not considered a modification of the definition and is not identified by the prefix, "Ref."

Principal source documents used from the many reviewed are as follows:

1) American National Standard C39.4-1966 "Specifications for Automatic Null-Balancing Electrical Measuring Instruments," published by American National Standards Institute, Inc.; Copyright 1966 by ANSI.

2) American National Standard C42.100-1972 "Dictionary of Electrical and Electronics Terms," published by the Institute of Electrical and Electronics Engineers, Inc.; Copyright 1972 by IEEE.

3) American National Standard C85.1-1963 "Terminology for Automatic Control," published by the American Society of Mechanical Engineers; Copyright 1963 by ASME.

4) SAMA Standard PMC20.1-1973 "Process Measurement and Control Terminology," published by Scientific Apparatus Makers Association, Process Measurement and Control Section, Inc.; Copyright 1973 by SAMA-PMC.

Copies of the American National Standards referred to above may be purchased from the American National Standards Institute, 1430 Broadway, New York, New York 10018. Copies of the SAMA Standard may be purchased from Process Measurement and Control Section, Inc., SAMA, 1101 16th Street, N.W., Washington, D. C. 20036.

4 Definition of terms

accuracy: In process instrumentation, degree of *conformity* of an indicated value to a recognized accepted standard value, or *ideal value*. (Ref. 4, Ref. 8)

accuracy, measured: The maximum positive and negative *deviation* observed in testing a *device* under specified conditions and by a specified procedure. See *Figure 1*.

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.

See *test procedure, Section 5.*

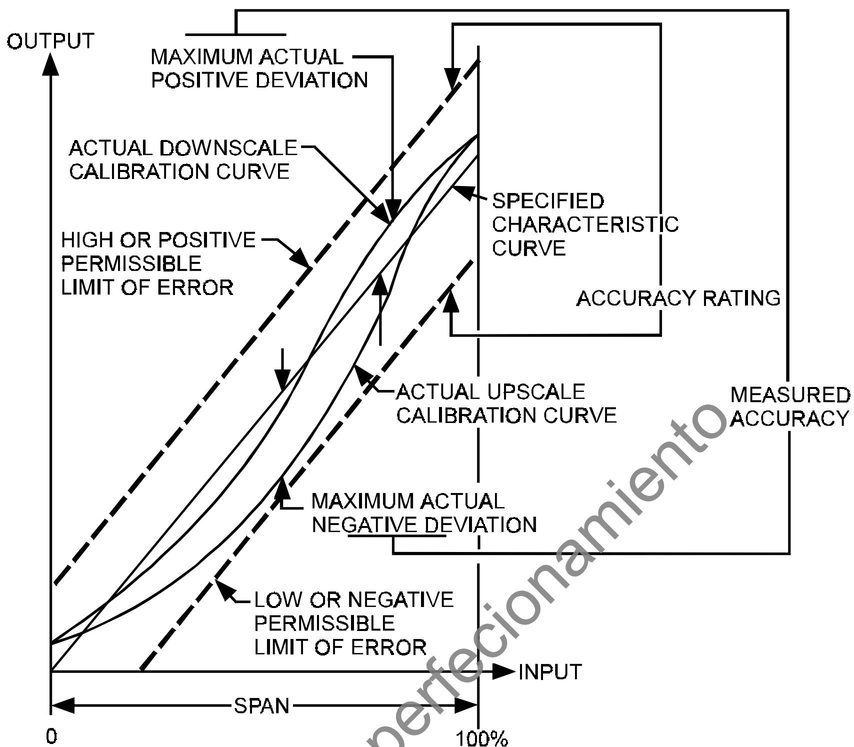

Figure 1 — Accuracy

accuracy rating: In process instrumentation, 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 ±2°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.*

adjustment, zero: Means provided in an instrument to produce a parallel shift of the input-output curve. See *zero shift.*

air conditioned area: see *area, air conditioned.*

air consumption: The maximum rate at which air is consumed by a *device* within its operating *range* during *steady-state signal* conditions.

> **NOTE:** It is usually expressed in cubic feet per minute (ft^3/min) or cubic meters per hour (m^3/h) at a standard (or normal) specified temperature and pressure. (8)

ambient pressure: see *pressure, ambient.*

ambient temperature: see *temperature, ambient.*

amplifier: In process instrumentation, a *device* that enables an *input signal* to control power from a source independent of the *signal* and thus be capable of delivering an output that bears some relationship to, and is generally greater than, the *input signal*. (3)

analog signal: see *signal, analog*.

area, air conditioned: A location with temperature at a nominal value maintained constant within narrow tolerance at some point in a specified band of typical comfortable room temperature. Humidity is maintained within a narrow specified band.

> **NOTE:** Air conditioned areas are provided with clean air circulation and are typically used for instrumentation, such as computers or other equipment requiring a closely controlled environment. (Ref. 18)

area, control room: A location with heat and/or cooling facilities. Conditions are maintained within specified limits. Provisions for automatically maintaining constant temperature and humidity may or may not be provided.

> **NOTE:** Control room areas are commonly provided for operation of those parts of a *control system* for which operator surveillance on a continuing basis is required. (18)

area, environmental: A basic qualified location in a plant with specified environmental conditions dependent on severity.

> **NOTE:** Environmental areas include: *air conditioned areas*; *control room areas*, heated and/or cooled; *sheltered areas* (*process* facilities); *outdoor areas* (remote field sites). See *specific definitions*.

area, outdoor: A location in which equipment is exposed to outdoor ambient conditions; including temperature, humidity, direct sunshine, wind and precipitation. (Ref. 18)

area, sheltered: An industrial *process* location, area, storage or transportation facility, with protection against direct exposure to the elements, such as direct sunlight, rain or other precipitation or full wind pressure. Minimum and maximum temperatures and humidity may be the same as outdoors. Condensation can occur. Ventilation, if any, is by natural means.

> **NOTE:** Typical areas are: shelters for operating instruments, unheated warehouses for storage, and enclosed trucks for transportation. (18)

attenuation: 1) A decrease in *signal* magnitude between two points, or between two frequencies. 2) The reciprocal of *gain*.

> **NOTE:** It may be expressed as a dimensionless ratio, scalar ratio, or in decibels as 20 times the $\log_{10}$ of that ratio. (Ref. 4)

auctioneering device: see *signal selector*.

automatic control system: see *control system*, *automatic*.

automatic/manual station: A *device* which enables an operator to select an automatic *signal* or a manual *signal* as the input to a controlling element. The automatic *signal* is normally the output of a *controller* while the manual *signal* is the output of a manually operated *device*.

backlash: In process instrumentation, a relative movement between interacting mechanical parts, resulting from looseness, when motion is reversed. (Ref. 4)

Bode diagram: In process instrumentation, a plot of log gain (magnitude ratio) and phase angle values on a log frequency base for a *transfer function*. See *Figure 2*. (Ref. 4, Ref. 8)

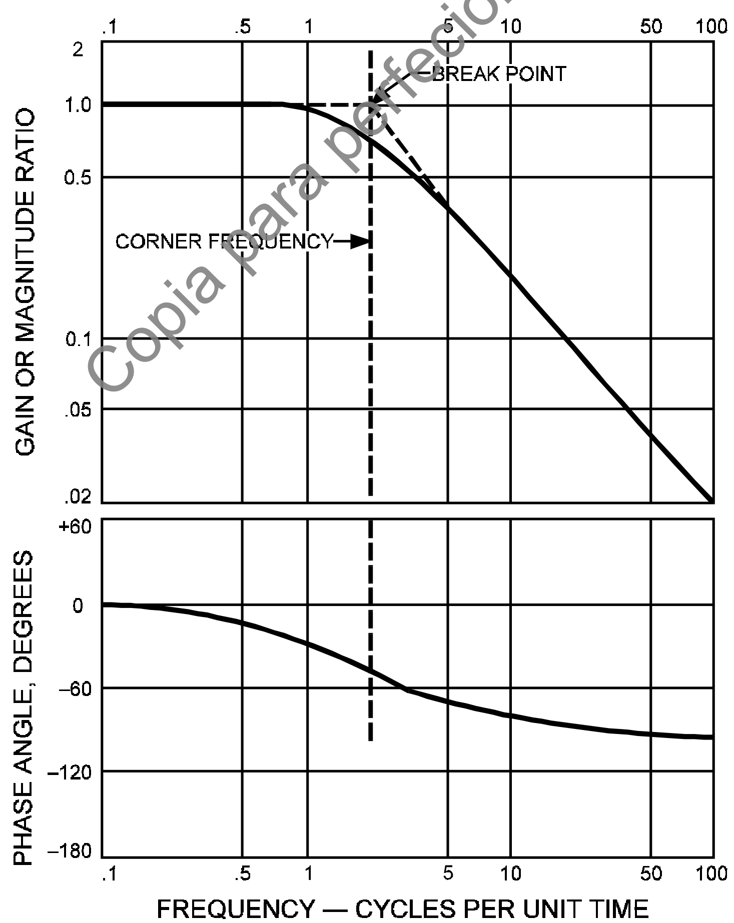

Figure 2 — Typical Bode diagram

break point: The junction of the extension of two confluent straight-line segments of a plotted curve.

> **NOTE:** In the asymptotic approximation of a log-gain vs. log-frequency relation in a Bode diagram, the value of the abscissa is called the corner frequency. See *Figure 2*. (4, 8)

calibrate: To ascertain outputs of a *device* corresponding to a series of values of the quantity which the *device* is to measure, receive, or transmit. Data so obtained are used to:

1) determine the locations at which scale graduations are to be placed;

2) adjust the output, to bring it to the desired value, within a specified tolerance;

3) ascertain the *error* by comparing the *device* output reading against a standard. (Ref. 3)

calibration curve: A graphical representation of the *calibration report*. (Ref. 11)

For example, see *Figure 30*: — *Section 5.4*

calibration cycle: The application of known values of the *measured variable* and the recording of corresponding values of *output* readings, over the *range* of the instrument, in ascending and descending directions. (Ref. 11)

calibration report: A table or graph of the measured relationship of an instrument as compared over its *range* against a standard. (Ref. 8)

For example, see *Table 3*. — *Sections 5.4 and 5.5.1*

calibration traceability: The relationship of the calibration of an instrument through a step-by-step process to an instrument or group of instruments calibrated and certified by a national standardizing laboratory. (Ref. 11)

cascade control: see *control, cascade*.

characteristic curve: A graph (curve) which shows the ideal values at *steady-state*, or an output variable of a system as a function of an input variable, the other input variables being maintained at specified constant values.

> **NOTE:** When the other input variables are treated as *parameters*, a set of characteristic curves is obtained. (Ref. 17)

closed loop: see *loop, closed*.

closed loop gain: see *gain, closed loop.*

coefficient, temperature/pressure etc.: see *operating influence.*

cold junction: see *reference junction*.

common mode interference: see *interference, common mode.*

common mode rejection: The ability of a circuit to discriminate against a *common mode voltage*.

> **NOTE:** It may be expressed as a dimensionless ratio, a scalar ratio, or in decibels as 20 times the $\log_{10}$ of that ratio.

common mode voltage: see *voltage, common mode*.

compensation: In process instrumentation, provision of a special construction, a supplemental *device*, circuit, or special materials to counteract sources of *error* due to variations in specified *operating conditions*. (Ref. 11)

compensator: A *device* which converts a *signal* into some function of it which, either alone or in combination with other *signals*, directs the *final controlling element* to reduce *deviations* in the directly controlled variable.

See Figures 10 and 11 *for application of "set point compensator" and "load compensator"*.

compliance: The reciprocal of *stiffness*.

computing instrument: see *instrument, computing*.

conformity: Of a curve, the closeness to which it approximates a specified curve (e.g., logarithmic, parabolic, cubic, etc.).

> **NOTE 1:** It is usually measured in terms of nonconformity and expressed as conformity; e.g., the maximum deviation between an average curve and a specified curve. The average curve is determined after making two or more full *range* traverses in each direction. The value of conformity is referred to the output unless otherwise stated.
>
> **NOTE 2:** As a performance specification, conformity should be expressed as *independent conformity*, *terminal-based conformity*, or *zero-based conformity*. When expressed simply as conformity, it is assumed to be *independent conformity*. (8, Ref. 4)

See *linearity.*

conformity, independent: The maximum *deviation* of the *calibration curve* (average of upscale and downscale readings) from a specified *characteristic* curve so positioned as to minimize the maximum *deviation*. See *Figure 3.* (8)

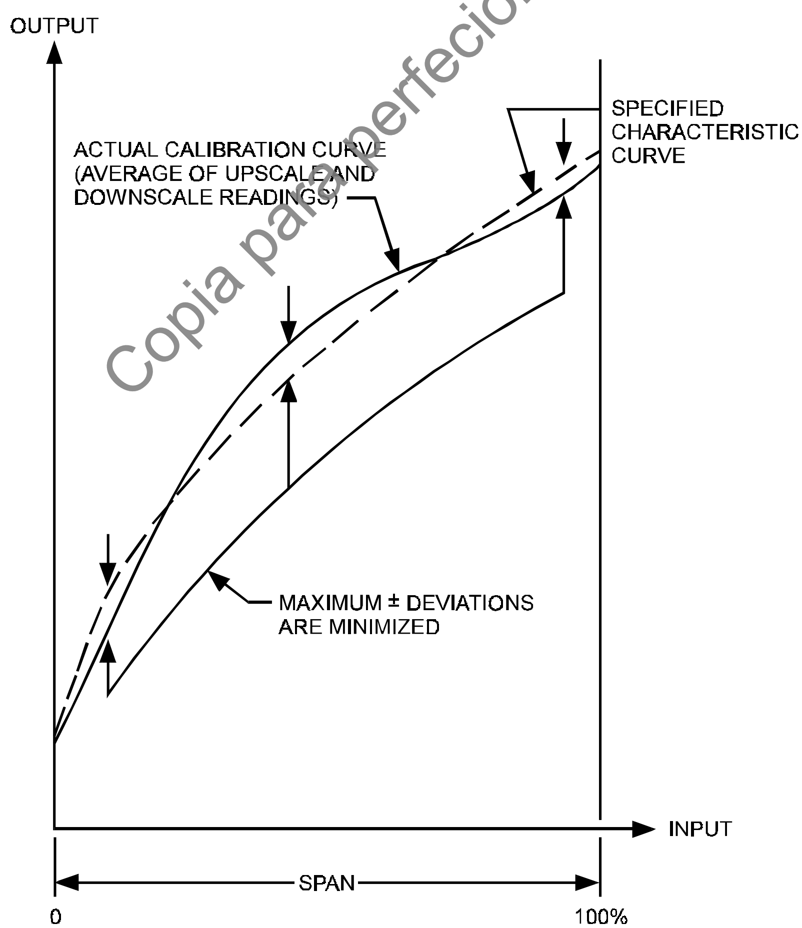

Figure 3 — Independent conformity

conformity, terminal-based: The maximum *deviation* of the *calibration curve* (average of upscale and downscale readings) from a specified *characteristic curve* so positioned as to coincide with the actual *characteristic curve* at *upper* and *lower range-values*. See *Figure 4*. (8)

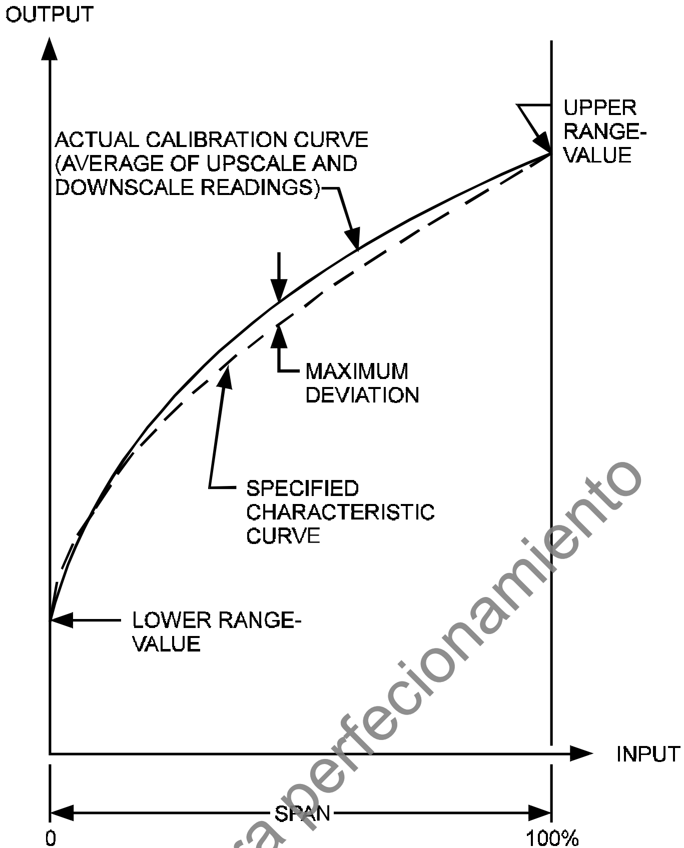

Figure 4 — Terminal-based conformity

conformity, zero-based: The maximum *deviation* of the *calibration curve* (average of upscale and downscale readings) from a specified *characteristic curve* so positioned as to coincide with the actual *characteristic curve* at the *lower range-value*. See Figure 5. (Ref. 8)

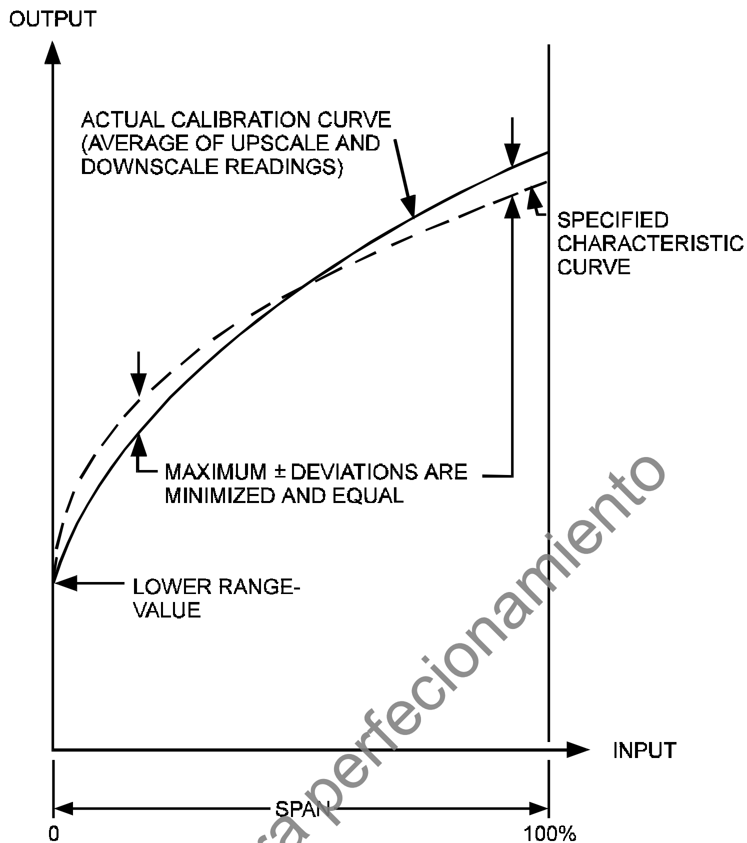

Figure 5 — Zero-based conformity

control action: Of a *controller* or of a *controlling system*, the nature of the change of the output effected by the input.

NOTE: The output may be a *signal* or a value of a *manipulated variable*. The input may be the control loop *feedback signal* when the set point is constant, an *actuating error signal*, or the output of another *controller*. (Ref. 4, Ref. 8)

control action, derivative (rate) (D): In process instrumentation, *control action* in which the output is proportional to the rate of change of the input. (8, Ref. 4)

control action, floating: In process instrumentation, *control action* in which the rate of change of the output variable is a predetermined function of the input variable.

NOTE: The rate of change may have one absolute value, several absolute values, or any value between two predetermined values. (Ref. 17 "floating action")

control action, integral (reset) (I): *Control action* in which the output is proportional to the time integral of the input, i.e., the rate of change of output is proportional to the input. See *Figure 6*.

NOTE: In the practical embodiment of integral control action, the relation between output and input, neglecting high frequency terms, is given by

$$\frac{Y}{X} = \pm \frac{I/s}{bI/s+1}, \text{ where } 0 \leqq b \ll 1$$

and

b = reciprocal of *static gain*

$I/2\pi$ = *gain crossover frequency* in hertz

s = complex variable

X = input transform

Y = output transform

I = *integral action rate* (4, 8)

See note under *control action*.

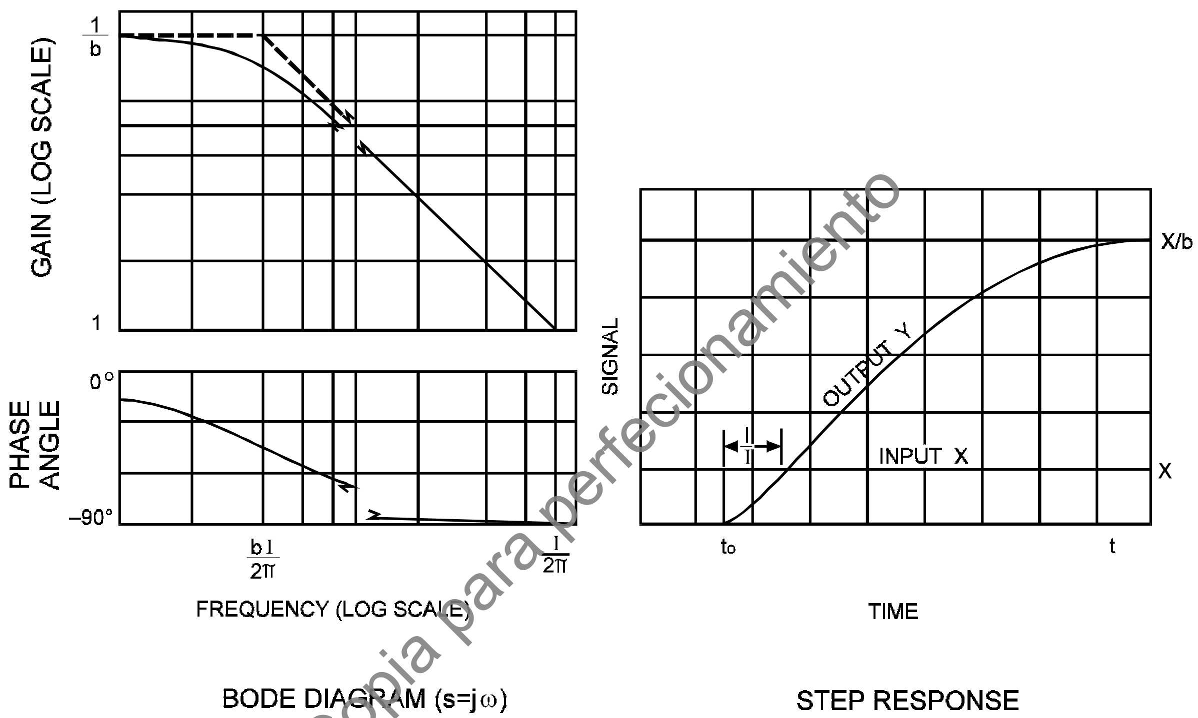

Figure 6 — Integral control action

control action, proportional (P): *Control action* in which there is a continuous linear relation between the output and the input.

NOTE: This condition applies when both the output and input are within their normal operating *range*s and when operation is at a frequency below a limiting value. (4, 8)

See note under *control action*.

control action, proportional plus derivative (rate) (PD): *Control action* in which the output is proportional to a linear combination of the input and the time rate-of-change of input. See *Figure 7*.

NOTE: In the practical embodiment of proportional plus derivative control action, the relationship between output and input, neglecting high frequency terms is,

$$\frac{Y}{X} = \pm P \frac{1 + sD}{1 + sD/a} \quad \text{, where } a > 1$$

and

a = *derivative action gain*

D = *derivative action time constant*

P = *proportional gain*

s = complex variable

X = input transform

Y = output transform (4, 8)

See note under *control action*.

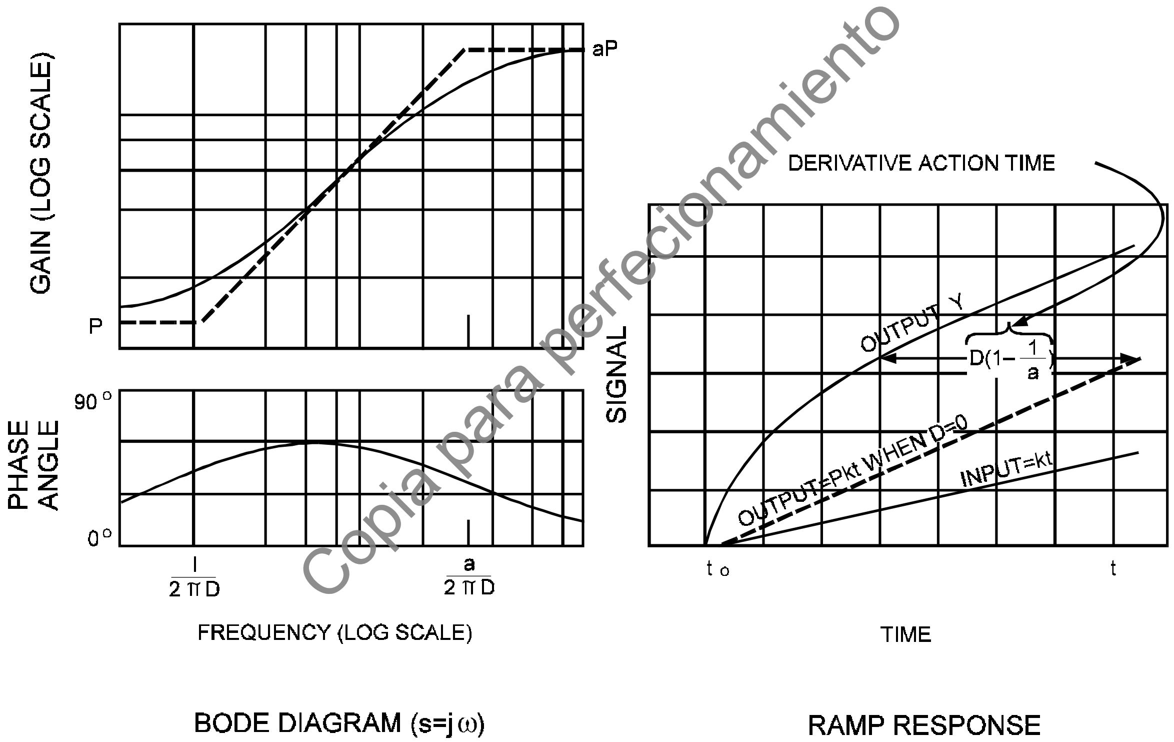

Figure 7 — Proportional plus derivative control action

control action, proportional plus integral (reset) (PI): *Control action* in which the output is proportional to a linear combination of the input and the time integral of the input. See *Figure 8*.

NOTE: In the practical embodiment of proportional plus integral control action, the relationship between output and input, neglecting high frequency terms is,

$$\frac{Y}{X} = \pm P \frac{I/s + 1}{bI/s + 1}, \text{ where } 0 \leqq b << 1$$

and

b = *proportional gain/static gain*

I = *integral action rate*

P = *proportional gain*

s = complex variable

X = input transform

Y = output transform (4, 8)

See note under *control action*.

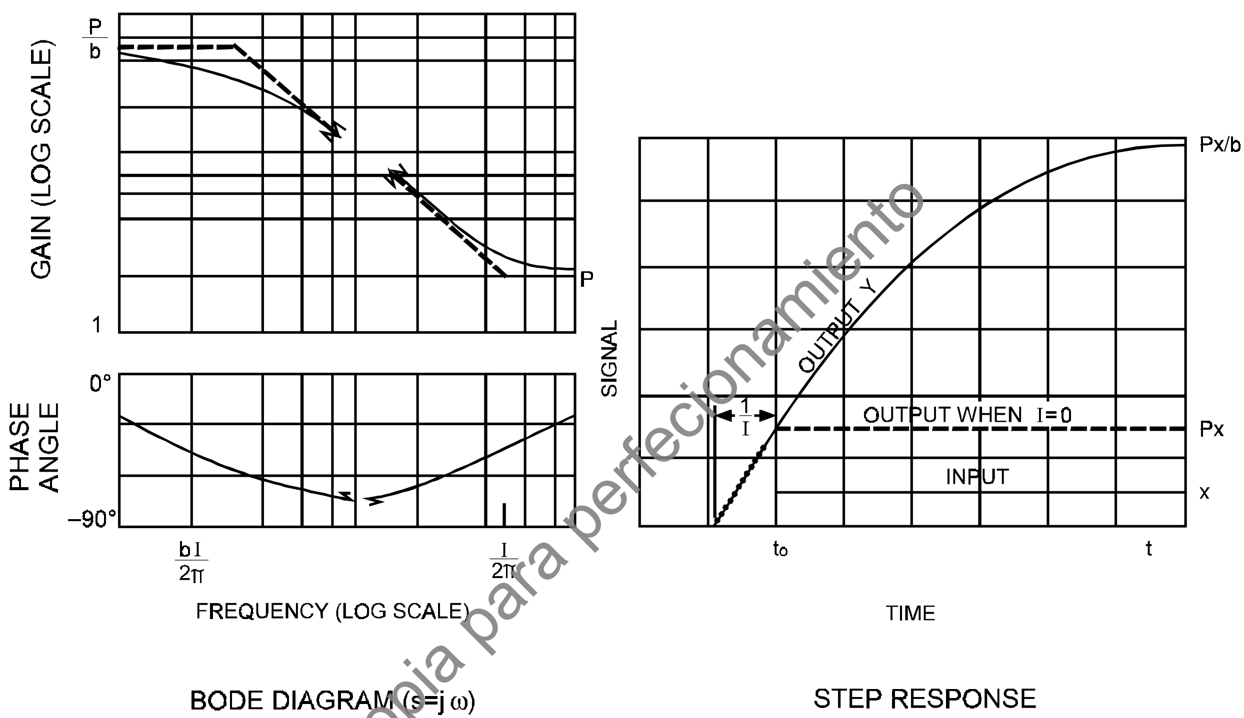

Figure 8 — Proportional plus integral control action

control action, proportional plus integral (reset) plus derivative (rate) (PID): *Control action* in which the output is proportional to a linear combination of the input, the time integral of input and the time rate-of-change of input. See *Figure 9*.

> **NOTE:** In the practical embodiment of proportional plus integral plus derivative control action, the relationship of output to input, neglecting high frequency terms, is

$$\frac{Y}{X} = \pm P \frac{I/s + 1 + Ds}{bI/s + 1 + Ds/a}, \text{ where } a > 1, 0 \leqq b << 1$$

and

a = *derivative action gain*

b = *proportional gain/static gain*

D = *derivative action time constant*

I = *integral action rate*

P = *proportional gain*

s = complex variable

X = input transform

Y = output transform (4, 8)

See note under *control action*.

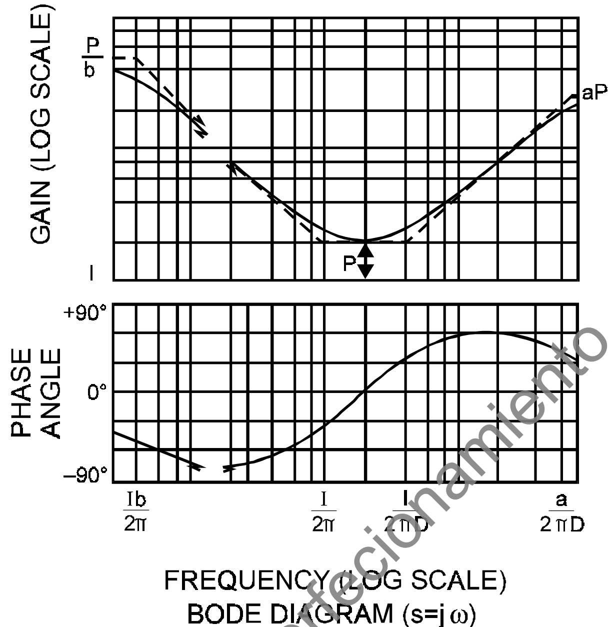

Figure 9 — Proportional plus integral plus derivative control action

control, adaptive: Control in which automatic means are used to change the type or influence (or both) of control *parameters* in such a way as to improve the performance of the *control system*. (8, Ref. 4 "control system, adaptive")

control, cascade: Control in which the output of one *controller* is the set point for another *controller.* (Ref. 8 "control action, cascade")

control center: An equipment structure, or group of structures, from which a *process* is measured, controlled and/or monitored. (Ref. 12)

control, differential gap: Control in which the output of a *controller* remains at a maximum or minimum value until the controlled variable crosses a band or gap, causing the output to reverse. The controlled variable must then cross the gap in the opposite direction before the output is restored to its original condition.

control, direct digital: Control performed by a digital *device* which establishes the *signal* to the *final controlling element*.

NOTE: Examples of possible digital (D) and analog (A) combinations for this definition are:

	feedback elements	controller	final controlling element
1.	D	D	D
2.	A	D	D
3.	A	D	A
4.	D	D	A

(Ref. 8 "control action, direct digital")

control, feedback: Control in which a *measured variable* is compared to its *desired value* to produce an *actuating error signal* which is acted upon in such a way as to reduce the magnitude of the *error*. (Ref. 8 "control action, feedback")

control, feedforward: Control in which information concerning one or more conditions that can disturb the controlled variable is converted, outside of any feedback loop, into corrective action to minimize *deviations* of the controlled variable.

NOTE: The use of feedforward control does not change system stability because it is not part of the feedback loop which determines the stability characteristics. See *Figures 10 and 11*. (Ref. 8 "control action, feedforward")

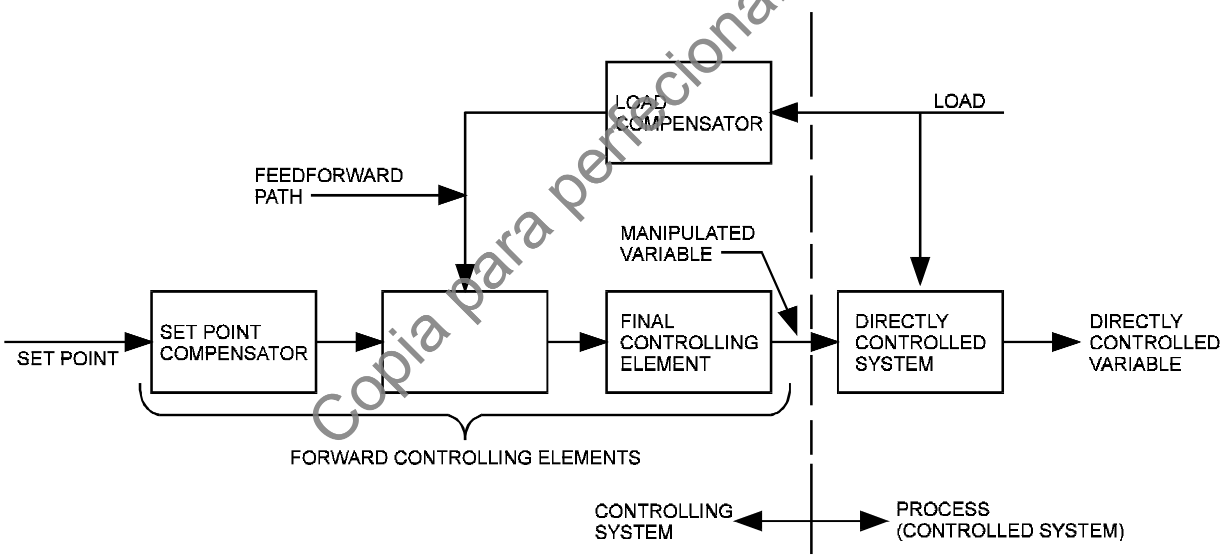

Figure 10 — Feedforward control without feedback

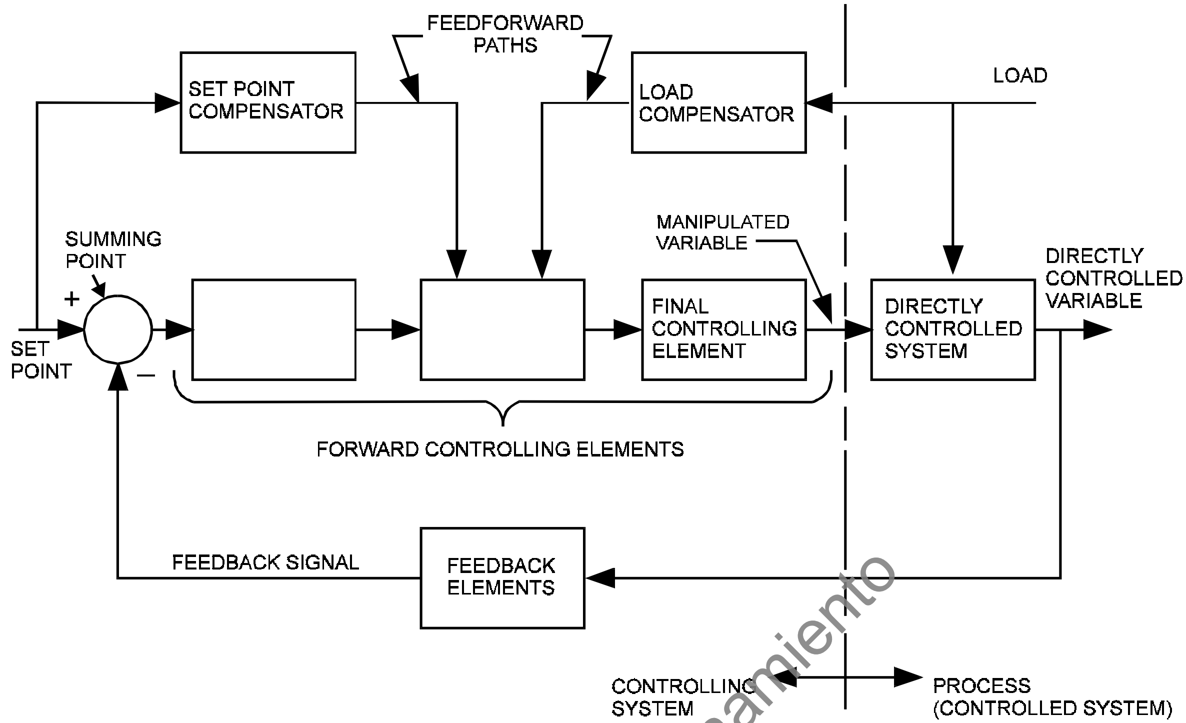

Figure 11 — Feedforward control with feedback

control, high limiting: Control in which the output *signal* is prevented from exceeding a predetermined high limiting value. (Ref. 8 "control action, high limiting")

controlled system: see *system, controlled*.

controller: A *device* which operates automatically to regulate a controlled variable.

> **NOTE:** This term is adequate for the *process* industries where the word "controller" always means "automatic controller." In some industries, "automatic" may not be implied and the term "automatic controller" is preferred. (8, Ref. 4 "automatic controller")

controller, derivative (D): A *controller* which produces *derivative control action* only.

controller, direct acting: A *controller* in which the value of the *output signal* increases as the value of the input (*measured variable*) increases. See *controller*, *reverse acting*. (Ref. 8)

controller, floating: A *controller* in which the rate of change of the output is a continuous (or at least a piecewise continuous) function of the *actuating error signal*.

> **NOTE:** The output of the *controller* may remain at any value in its operating *range* when the *actuating error signal* is zero and constant. Hence the output is said to float. When the *controller* has *integral control action* only, the mode of control has been called "proportional speed floating." The use of the term *integral control action* is recommended as a replacement for "proportional speed floating control." (8)

controller, integral (reset) (I): A controller which produces *integral control action* only.

> **NOTE:** It may also be referred to as controller, proportional speed floating. (8)

controller, multiple-speed floating: A *floating controller* in which the output may change at two or more rates, each corresponding, to a definite range of values of the *actuating error signal*. (8, Ref. 4 "control system, multiple-speed floating")

controller, multi-position: A *controller* having two or more discrete values of output. See *Figure 12*. (8)

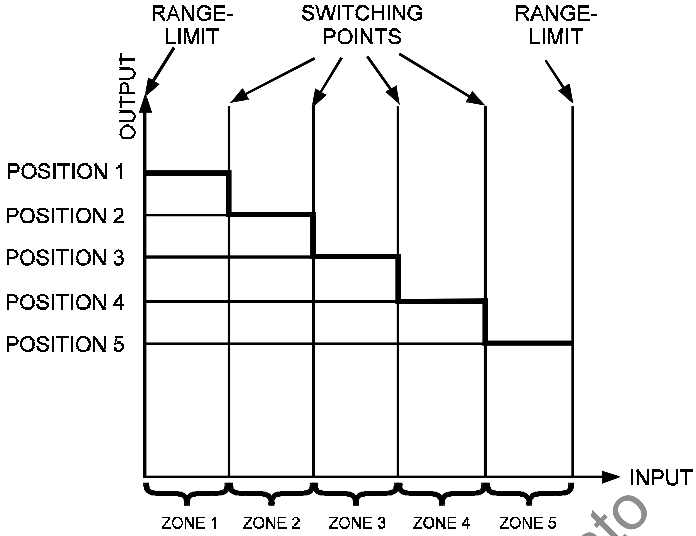

Figure 12 — Multi-position controller

controller, on-off: A *two-position controller* of which one of the two discrete values is zero. See *Figures 14 and 15*. (Ref. 8)

controller, program: A *controller* which automatically holds or changes *set point* to follow a prescribed program for a *process*.

controller, proportional (P): A *controller* which produces *proportional control action* only. (8)

controller, proportional plus derivative (rate) (PD): A *controller* which produces *proportional plus derivative (rate) control action*. (8)

controller, proportional plus integral (reset) (PI): A *controller* which produces *proportional plus integral (reset) control action*. (8)

controller, proportional plus integral (reset) plus derivative (rate) (PID): A *controller* which produces *proportional plus integral (reset) plus derivative (rate) control action.* (8)

controller, proportional speed floating: see *controller*, *integral (reset) (I)*. (8)

controller, ratio: A *controller* which maintains a predetermined ratio between two variables. (Ref. 4 "control system, ratio," Ref. 8)

controller, reverse acting: A *controller* in which the value of the *output signal* decreases as the value of the input (*measured variable*) increases. See *controller*, *direct acting*. (Ref. 8)

controller, sampling: A *controller* using intermittently observed values of a *signal* such as the *set point* signal, the *actuating error signal*, or the *signal* representing the controlled variable to effect *control action*. (8, Ref. 4 "control system, sampling")

controller, self-operated (regulator): A *controller* in which all the energy to operate the *final controlling element* is derived from the *controlled system*. (Ref. 4, Ref. 8)

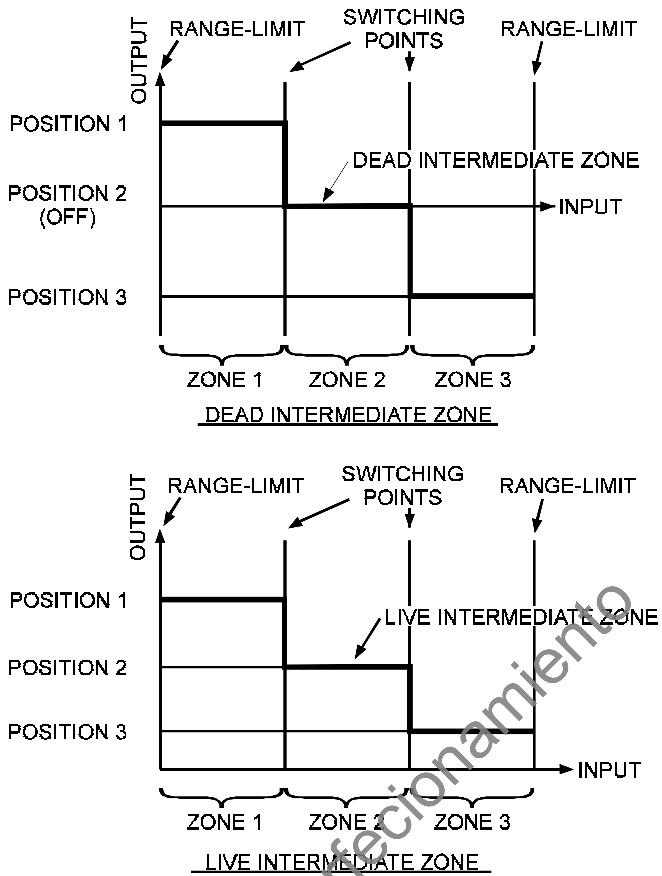

Figure 13 — Three-position controller

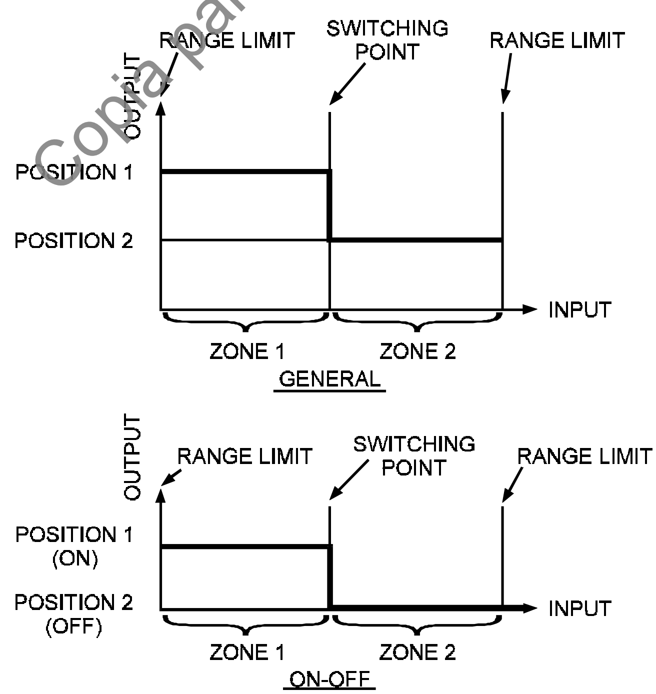

Figure 14 — Two-position controller

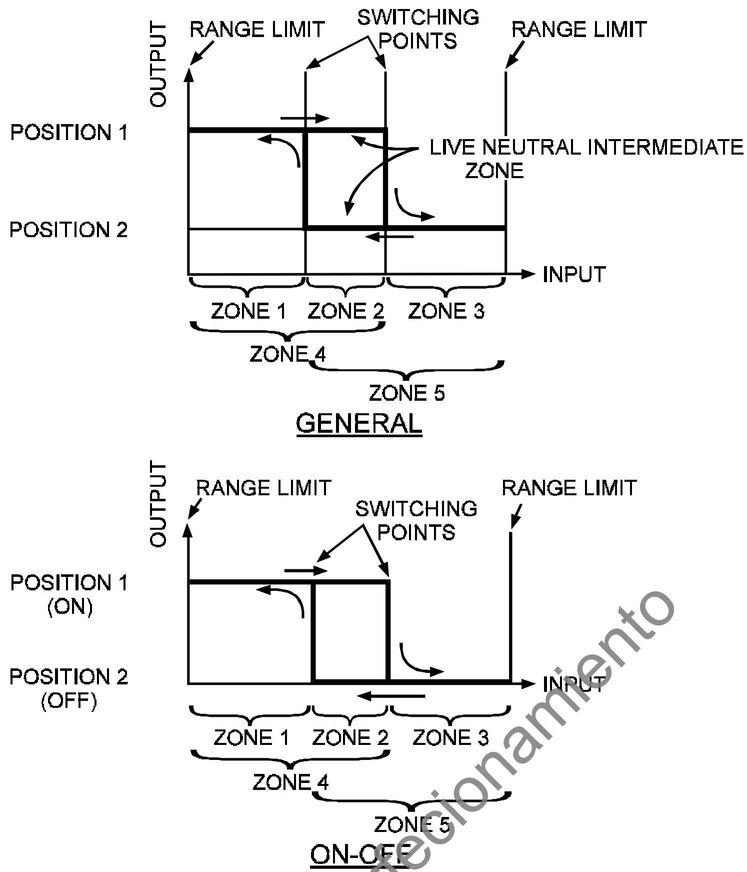

Figure 15 — Two-position controller with neutral intermediate zone

controller, single-speed floating: A *floating controller* in which the output changes at a fixed rate increasing or decreasing depending on the sign of the *actuating error signal*. See *controller, floating*.

> **NOTE:** A neutral zone of values of the *actuating error signal* in which no action occurs may be used. (Ref. 4 "control system, single speed floating," Ref. 8)

controller, three-position: A *multi-position controller* having three discrete values of output. See *Figure 13*.

> **NOTE:** This is commonly achieved by selectively energizing multiplicity of circuits (outputs) to establish three discrete positions of the *final controlling element*. (Ref. 8)

controller, time schedule: A *controller* in which the *set point* or the *reference-input signal* automatically adheres to a predetermined time schedule. (8, Ref. 4)

controller, two-position: A *multi-position controller* having two discrete values of output. See *Figures 14 and 15*. (8)

controlling system: see *system, controlling*.

control, low limiting: Control in which output *signal* is prevented from decreasing beyond a predetermined low limiting value. (Ref. 8 "control action, low limiting")

control mode: A specific type of *control action* such as *proportional, integral*, or *derivative*. (8)

control, optimizing: Control that automatically seeks and maintains the most advantageous value of a specified variable, rather than maintaining it at one set value. (Ref. 4 "control action, optimizing")

control room area: see *area, control room*.

control, shared time: Control in which one *controller* divides its computation or control time among several control loops rather than by acting on all loops simultaneously. (Ref. 4 "control action, shared time")

control, supervisory: Control in which the control loops operate independently subject to intermittent corrective action, e.g., *set point* changes from an external source. (Ref. 4 "control action, supervisory")

control system: a system in which deliberate guidance or manipulation is used to achieve a prescribed value of a variable. See *Figure 16.*

NOTE: It is subdivided into a *controlling system* and a *controlled system*. (4, 8)

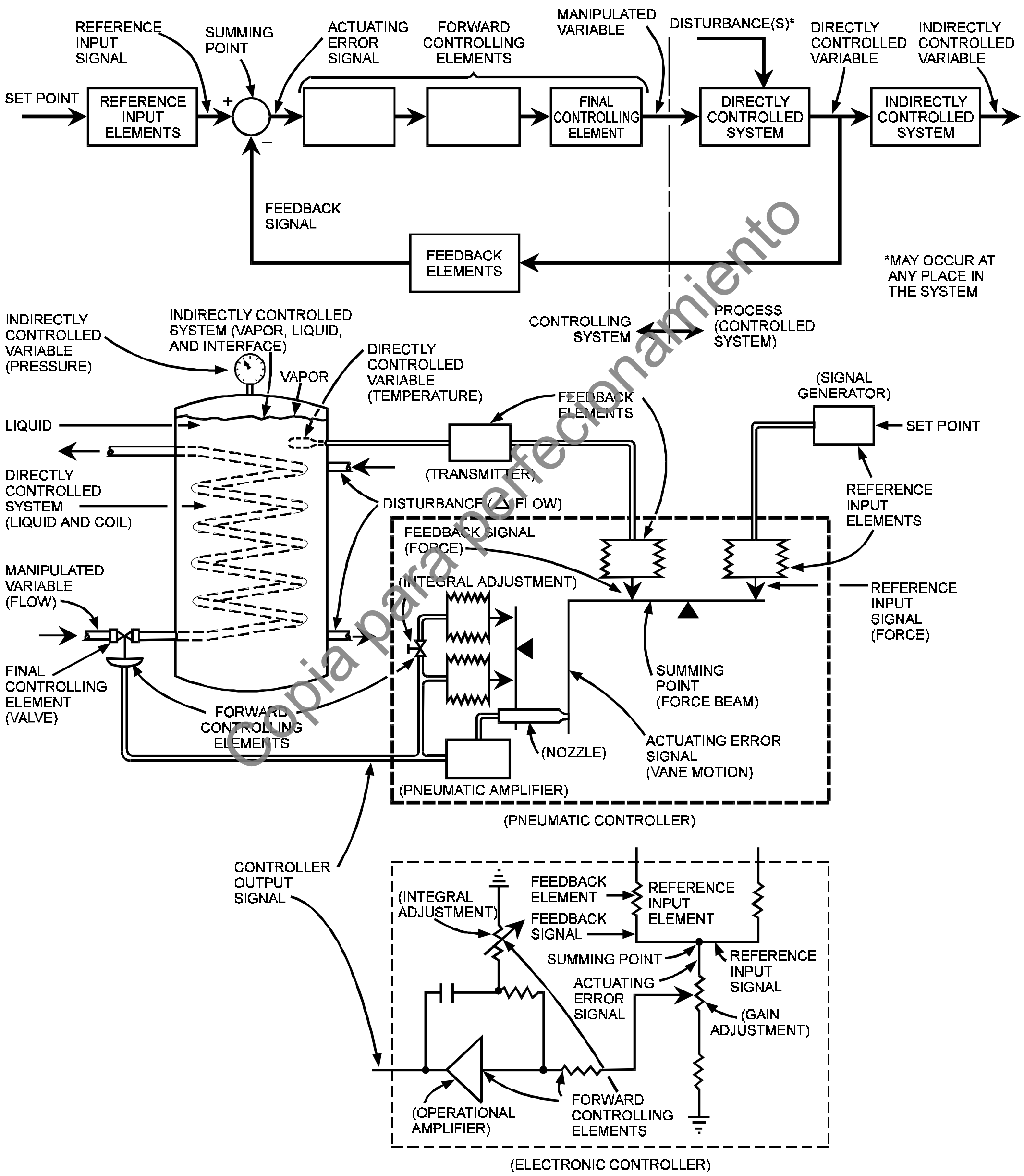

Figure 16 — Control system diagrams

control system, automatic: A *control system* which operates without human intervention. (4)

See also *control system.*

control system, multi-element (multi-variable): A *control system* utilizing *input signals* derived from two or more *process* variables for the purpose of jointly affecting the action of the *control system*.

> **NOTE 1:** Examples are *input signals* representing pressure and temperature, or speed and flow, etc. (Ref. 8)
>
> **NOTE 2:** A term used primarily in the power industry.

control system, non-interacting: a *control system* with multiple inputs and outputs in which any given input-output pair is operating independently of any other input-output pair.

control, time proportioning: *Control* in which the output *signal* consists of periodic pulses whose duration is varied to relate, in some prescribed manner, the time average of the output to the *actuating error signal*. (Ref. 4 "controller, time proportioning")

control valve: A *final controlling element*, through which a fluid passes, which adjusts the size of flow passage as directed by a *signal* from a *controller* to modify the rate of flow of the fluid. (Ref. 17 "valve")

control, velocity limiting: Control in which the rate of change of a specified variable is prevented from exceeding a predetermined limit. (Ref. 8 "control action, velocity limiting")

corner frequency: In the asymptotic form of *Bode diagram*, that frequency indicated by a *break point*, i.e., the junction of two confluent straight lines asymptotic to the log *gain* curve. (4)

correction: In process instrumentation, the algebraic difference between the *ideal value* and the indication of the *measured signal*. It is the quantity which added algebraically to the indication gives the *ideal value*.

> **NOTE:** A positive correction denotes that the indication of the instrument is less than the *ideal value*.

correction = *Ideal value*-indication.

See error. (Ref. 4, Ref. 8)

correction time: see *time, settling*.

cycling life: The specified minimum number of full scale excursions or specified partial *range* excursions over which a *device* will operate as specified without changing its performance beyond specified tolerances. (Ref. 11)

damped frequency: see *frequency, damped*.

damping: (1) (noun) The progressive reduction or suppression of oscillation in a *device* or system. (2) (adj) Pertaining to or productive of damping.

> **NOTE 1:** The response to an abrupt stimulus is commonly said to be "critically damped" when the *time response* is as fast as possible without overshoot; "underdamped" when overshoot occurs, or "overdamped" when response is slower than critical.
>
> **NOTE 2:** Viscous damping uses the viscosity of fluids (liquids or gases) to effect damping.
>
> **NOTE 3:** Magnetic damping uses the current induced in electrical conductors by changes in magnetic flux to effect damping. (Ref. 4, Ref. 8, Ref. 11)

damping factor: For the free oscillation of a second order *linear system*, a measure of *damping*, expressed (without sign) as the quotient of the greater by the lesser of a pair of consecutive swings of the output (in opposite directions) about an ultimate *steady-state* value. See *Figure 17*. (8, Ref. 4)

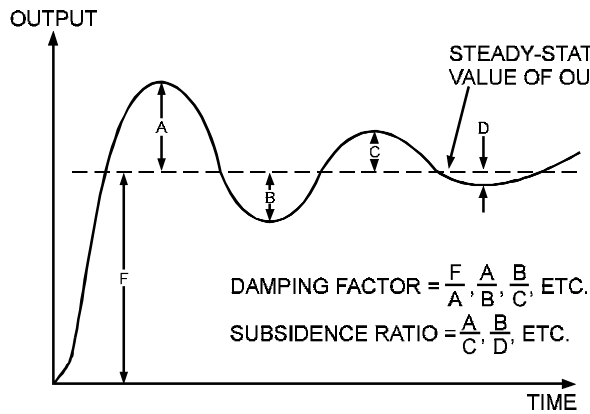

Figure 17 — Underdamped response of a system with second-order lag

damping ratio: For a *linear system* of the second order described by the differential equation

$$\frac{d^2x}{dt^2} + 2\zeta\omega_o\frac{dx}{dt} + \omega_o^2 = 0$$

the damping ratio is the value of the factor ζ.

Note: ω_o is called the angular *resonance* frequency of the system. (17)

damping, relative: For an underdamped system, a number expressing the quotient of the actual *damping* of a second-order *linear system* or *element* by its critical *damping*.

> **NOTE:** For any system whose transfer function includes a quadratic factor $s^2 + 2\zeta\omega_n s + \omega^2{}_n$, relative damping is the value of ζ, since ζ = 1 for critical damping. Such a factor has a root $-\sigma + j\omega$ in the complex s-plane, from which
>
> $$\zeta = \sigma/\omega_n = \sigma/(\sigma^2 + \omega^2)^{\frac{1}{2}} \qquad (4)$$

d controller: see *controller, derivative (D)*.

dead band: In process instrumentation, the *range* through which an *input signal* may be varied, upon reversal of direction, without initiating an observable change in *output signal*. See *Figure 18*. (Ref. 8)

> **NOTE 1:** There are separate and distinct input-output relationships for increasing and decreasing *signals* as shown in Fig. 18(b).
>
> **NOTE 2:** Dead band produces phase lag between input and output.
>
> **NOTE 3:** Dead band is usually expressed in per cent of span. (Ref. 4, Ref. 8)

See *zone, dead.*

See *test procedure, Section 5.*

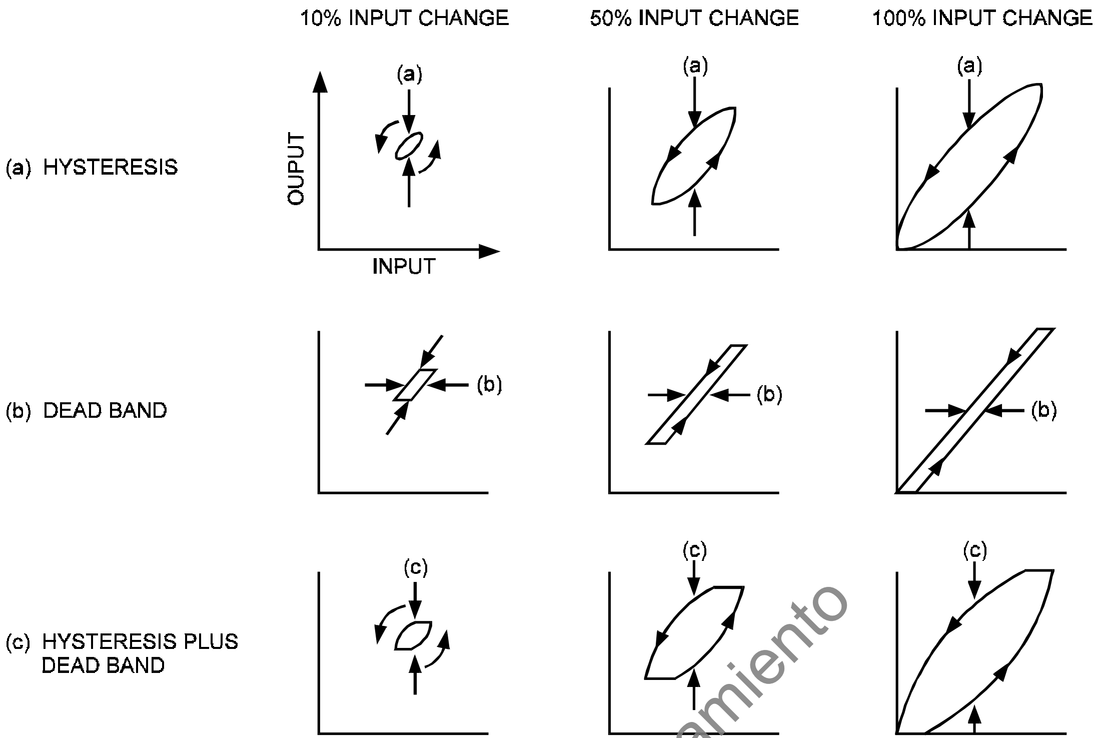

Figure 18 — Hysteresis and dead band

dead time: see *time, dead*.

dead zone: see *zone, dead*.

delay: The interval of time between a changing *signal* and its repetition for some specified duration at a downstream point of the *signal* path; the value L in the transform factor exp (–Ls). See *time, dead*. (4)

derivative action gain: see *gain, derivative action (rate gain).*

derivative action time: see *time, derivative action.*

derivative action time constant: see *time constant, derivative action.*

derivative control: see *control action, derivative (D).*

derivative control action: see *control action, derivative.*

derivative controller: see *controller, derivative.*

design pressure: see *pressure, design.*

desired value: see *value, desired.*

detector: see *transducer.* (11)

deviation: Any departure from a *desired value* or expected value or pattern. (4, 8)

deviation, steady-state: The *system deviation* after *transients* have expired. (4, 8)

See also *offset.*

deviation, system: In process instrumentation, the instantaneous value of the *directly controlled variable* minus the *set point.* (8, Ref. 4)

See also *signal, actuating error.*

deviation, transient: In process instrumentation, the instantaneous value of the *directly controlled variable* minus its *steady-state* value. (Ref. 4)

device: An apparatus for performing a prescribed function. (8)

differential gap control: see *control, differential gap.*

differential mode interference: see *interference, normal mode. (2, 8)*

digital signal: see *signal, digital.*

direct acting controller: see *controller, direct acting.*

direct digital control: see *control, direct digital.*

directly controlled system: see *system, directly controlled.*

directly controlled variable: see *variable, directly controlled.*

distance/velocity lag: A delay attributable to the transport of material or to the finite rate of propagation of a *signal*. (Ref. 4, Ref. 17)

disturbance: An undesired change that takes place in a *process* that tends to affect adversely the value of a controlled variable. (8, Ref. 4)

dither: A useful oscillation of small magnitude, introduced to overcome the effect of friction, *hysteresis,* or recorder pen clogging. See also *hunting*. (Ref. 4)

drift: An undesired change in output over a period of time, which change is unrelated to the input, environment, or load. (4)

drift, point: The change in output over a specified period of time for a constant input under specified *reference operating conditions*.

> **NOTE:** Point drift is frequently determined at more than one input, as for example: at 0%, 50% and 100% of *range*. Thus, any *drift* of zero or *span* may be calculated.

typical expression: The *drift* at mid-scale for *ambient temperature* (70 ± 2°F) for a period of 48 hours was within 0.1% of output *span*. (8)

See *test procedure, Section 5.*

droop: see *offset.*

dynamic gain: see *gain, dynamic.*

dynamic response: see *response, dynamic.*

electromagnetic interference: see *interference, electromagnetic.*

electrostatic field interference: see *interference, electromagnetic.*

element: A component of a *device* or system. (8)

element, final controlling: The *forward controlling element* which directly changes the value of the *manipulated variable*. (8, Ref. 4 "controlling element, final")

element, primary: The system *element* that quantitatively converts the *measured variable* energy into a form suitable for measurement.

> **NOTE:** For *transmitters* not used with external primary elements, the sensing portion is the primary element. (Ref. 2 "detecting means," Ref. 8)

element, reference-input: The portion of the *controlling system* which changes the *reference-input signal* in response to the *set point*. See *Figure 16.* (8, Ref. 4)

element, sensing: The *element* directly responsive to the value of the *measured variable*.

NOTE: It may include the case protecting the sensitive portion. (Ref. 8)

elements, feedback: Those *elements* in the *controlling system* which act to change the *feedback signal* in response to the *directly controlled variable*. See *Figure 16*. (Ref. 4, Ref. 8)

elements, forward controlling: Those *elements* in the *controlling system* which act to change a variable in response to the *actuating error signal*. See *Figure 16*. (Ref. 4, Ref. 8)

elevated range: see *range, suppressed-zero*. (4, Ref. 1 "Range, suppressed zero")

elevated span: see *range, suppressed-zero.*

elevated-zero range: see *range, elevated-zero.*

elevation: see *range, suppressed-zero.*

environmental area: see *area, environmental.*

environmental influence: see *operating influence.*

error: In process instrumentation, the algebraic difference between the indication and the *ideal value* of the *measured signal.* It is the quantity which algebraically subtracted from the indication gives the *ideal value*.

NOTE: A positive error denotes that the indication of the instrument is greater than the *ideal value.*

error = Indication: *ideal value*. (Ref. 2, Ref. 8)

See *correction.*

error curve: see *calibration curve.*

error, environmental: *Error* caused by a change in a specified *operating condition* from *reference operating condition*. See *operating influence*. (Ref. 8 "operating influence")

error, frictional: *Error* of a *device* due to the resistance to motion presented by contacting surfaces.

error, hysteresis: see *hysteresis.*

error, hysteretic: see *hysteresis.*

error, inclination: The change in output caused solely by an inclination of the *device* from its normal operating position. (Ref. 1 "influence, position")

error, mounting strain: *Error* resulting from mechanical deformation of an instrument caused by mounting the instrument and making all connections. See also *error*, *inclination.*

error, position: The change in output resulting from mounting or setting an instrument in a position different from that at which it was *calibrated*. See also *error*, *inclination.*

error signal: see *signal, error.*

error, span: The difference between the actual *span* and the ideal *span*.

NOTE: It is usually expressed as a percent of ideal *span*. (8)

error, systematic: An *error* which, in the course of a number of measurements made under the same conditions of the same value of a given quantity, either remains constant in absolute value and sign or varies according to a definite law when the conditions change.

error, zero: In process instrumentation, *error* of a *device* operating under specified conditions of use, when the input is at the *lower range*-*value*. (Ref. 8)

NOTE: It is usually expressed as percent of ideal *span*.

excitation: The external supply applied to a *device* for its proper operation.

NOTE: It is usually expressed as a range of supply values.

See also *excitation, maximum*. (Ref. 11)

excitation, maximum: The maximum value of excitation *parameter* that can be applied to a *device* at rated *operating conditions* without causing damage or performance degradation beyond specified tolerances. (Ref. 11)

feedback control: see *control, feedback.*

feedback elements: see *elements, feedback.*

feedback loop: see *loop, closed (feedback loop)*

feedback signal: see *signal, feedback.*

feedforward control: see *control, feedforward.*

final controlling element: see *element, final controlling.*

floating control action: see *control action, floating.*

floating controller: see *controller, floating.*

flowmeter: A *device* that measures the rate of flow or quantity of a moving fluid in an open or closed conduit. It usually consists of both a primary and a secondary *device*.

NOTE: It is acceptable in practice to further identify the flowmeter by its applied theory; as differential pressure, velocity, area, force, etc. or by its applied technology as orifice, turbine, vortex, ultrasonic, etc. Examples include turbine flowmeter, magnetic flowmeter, fluidic pressure flowmeter, etc.

flowmeter primary device: The *device* mounted internally or externally to the fluid conduit which produces a *signal* with a defined relationship to the fluid flow in accordance with known physical laws relating the interaction of the fluid to the presence of the primary *device*.

NOTE: The primary device may consist of one or more *elements* necessary to produce the primary device *signal*.

flowmeter secondary device: The *device* that responds to the *signal* from the primary *device* and converts it to a display or to an output signal that can be translated relative to flow rate or quantity.

NOTE: The secondary *device* may consist of one or more *elements* as needed to translate the primary device *signal* into standardized or nonstandardized display or transmitted units.

forward controlling elements: see *elements, forward controlling.*

frequency, damped: The apparent frequency of a damped oscillatory *time response* of a system resulting from a non-oscillatory stimulus. (4)

frequency, gain crossover: (1) On a *Bode diagram* of the *transfer function* of an *element* or system, the frequency at which the *gain* becomes unity (and its decibel value (zero). (2) Of *integral control action*, the frequency at which the *gain* becomes unity. See *Figure 6*. (4)

frequency, phase crossover: Of a *loop transfer function*, the frequency at which the phase angle reaches ±180°. (Ref. 4)

frequency response characteristic: In process instrumentation, the frequency-dependent relation, in both gain and phase, between *steady-state* sinusoidal inputs and the resulting fundamental *steady-state* sinusoidal outputs.

> **NOTE:** Frequency response is commonly plotted on a *Bode diagram*. See *Figure 2*. (Ref. 8, Ref. 4 "frequency-response characteristics")

frequency, undamped (frequency, natural):

1) Of a second-order *linear system* without *damping*, the frequency of free oscillation in radians or cycles per unit of time.

2) Of any system whose *transfer function* contains the quadratic factor $s^2 + 2z\omega_n s + \omega_n^2$ the value ω_n.

where:

s = complex variable

z = constant

ω_n = natural frequency in radians per second

3) Of a *closed-loop control system* or *controlled system,* a frequency at which continuous oscillation *(hunting)* can occur without periodic stimuli.

> **NOTE:** In *linear system*s, the undamped frequency is the phase crossover frequency. With *proportional control action* only, the undamped frequency of a *linear system* may be obtained in most cases by raising the *proportional* gain until continuous oscillation occurs. (Ref. 4, Ref. 8)

frictional error: see *error, frictional.*

gain, closed loop: In process instrumentation, the *gain* of a *closed loop* system, expressed as the ratio of the output change to the input change at a specified frequency. (8, Ref. 4)

gain, crossover frequency: see *frequency, gain crossover.*

gain, derivative action (rate gain): The ratio of maximum *gain* resulting from *proportional plus derivative control action* to the *gain* due to *proportional control action* alone. See *Figures 7 and 9. (4, 8)*

gain, dynamic: the magnitude ratio of the *steady-state* amplitude of the *output signal* from an *element* or system to the amplitude of the *input signal* to that *element* or system, for a sinusoidal *signal*. (8)

gain, loop: In process instrumentation, the ratio of the absolute magnitude of the change in the *feedback signal* to the change in its corresponding *error signal* at a specified frequency.

> **NOTE:** The *gain* of the loop *elements* is frequently measured by opening the loop, with appropriate termination. The *gain* so measured is often called the open loop gain. (8, Ref. 5)

gain (magnitude ratio): For a *linear system* or *element*, the ratio of the magnitude (amplitude) of a *steady-state* sinusoidal output relative to the causal input; the length of a phasor from the origin to a point of the transfer locus in a complex plane.

> **NOTE:** The quantity may be separated into two factors: (1) a proportional amplification often denoted as K which is frequency-independent, and associated with a dimensioned scale factor relating to the units of input and output; (2) a dimensionless factor often denoted as $G(j\omega)$ which is frequency-dependent. Frequency, conditions of operation, and conditions of measurement must be specified. A *loop gain characteristic* is a plot of log gain vs. log frequency. In nonlinear systems, gains are often amplitude-dependent. (4, 8)

gain, open loop: see *gain, loop.*

gain, proportional: The ratio of the change in output due to *proportional control action* to the change in input.

Illustration: Y = ±PX

where:

P: proportional gain

X: input transform

Y: output transform

See *proportional band.* (4, 8)

gain, static (zero-frequency gain): Of *gain* of an *element*, or *loop gain* of a system, the value approached as a limit as frequency approaches zero.

> **NOTE:** Its value is the ratio of change of *steady-state* output to a step change in input provided the output does not saturate. (4, Ref. 8)

gain, zero frequency: see *gain, static (zero-frequency gain)*

hardware: Physical equipment directly involved in performing industrial *process* measuring and controlling functions.

hazardous (classified) location: see *location, hazardous (classified).*

high limiting control: see *control, high limiting.*

hunting: An undesirable oscillation of appreciable magnitude, prolonged after external stimuli disappear.

> **NOTE:** In a *linear system,* hunting is evidence of operation at or near the stability limit; non-linearities may cause hunting of well-defined amplitude and frequency. See also *dither.* (4)

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.

> **NOTE 1:** It is usually determined by subtracting the value of *dead band* from the maximum measured separation between upscale going and downscale going indications of the *measured variable* (during a full *range* traverse, unless otherwise specified) after *transients* have decayed. This measurement is sometimes called hysteresis error or hysteretic error. See *Figure 18*.
>
> **NOTE 2:** Some reversal of output may be expected for any small reversal of input; this distinguishes hysteresis from *dead band*.

See *test procedure*, Section 5. (4)

I controller: see *controller, integral (reset) (I).*

idealized system: see *system, idealized.*

ideal value: see *value, ideal.*

impedance, input: impedance presented by a *device* to the source. (3, 8)

impedance, load: impedance presented to the output of a *device* by the load. (8, Ref. 3)

impedance, output: Impedance presented by a *device* to the load. (8, Ref. 3)

impedance, source: Impedance presented to the input of a *device* by the source. (8, Ref. 3)

inclination error: see *error, inclination.*

independent conformity: see *conformity, independent.*

independent linearity: see *linearity, ndependent.*

indicating instrument: see *instrument, indicating.*

indicator travel: The length of the path described by the indicating means or the tip of the pointer in moving from one end of the scale to the other.

> **NOTE 1:** The path may be an arc or a straight line.
>
> **NOTE 2:** In the case of knife-edge pointers and others extending beyond the scale division marks, the pointer shall be considered as ending at the outer end of the shortest scale division marks. (2, 8)

indirectly controlled system: see *system, indirectly controlled.*

indirectly controlled variable: see *variable, indirectly controlled.*

inherent regulation: see *self-regulation.*

input impedance: see *impedance, input.*

input signal: see *signal, input.*

instrumentation: A collection of instruments or their application for the purpose of observation, measurement or control.

instrument, computing: A *device* in which the output is related to the input or inputs by a mathematical function such as addition, averaging, division, integration, lead/lag, signal limiting, squaring, square root extraction, subtraction, etc.

instrument, indicating: A *measuring instrument* in which only the present value of the *measured variable* is visually indicated. (Ref. 8)

instrument, measuring: A *device* for ascertaining the magnitude of a quantity or condition presented to it. (Ref. 8)

instrument, recording: A *measuring instrument* in which the values of the *measured variable* are recorded.

> **NOTE:** The record may be either analog or digital and may or may not be visually indicated. (Ref. 8)

insulation resistance: The resistance measured between specified insulated portions of a *device* when a specified direct current voltage is applied, at *reference operating conditions* unless otherwise stated.

> **NOTE:** The objective is to determine whether the leakage current would be excessive under *operating conditions*. (Ref. 11)

insulation voltage breakdown: The voltage at which a disruptive discharge takes place through or over the surface of the insulation. (3)

integral action limiter: A *device* which limits the value of the *output signal* due to *integral control action*, to a predetermined value. (8)

integral action rate (reset rate):

1) Of *proportional plus integral* or *proportional plus integral plus derivative control action device*s: for a step input, the ratio of the initial rate of change of output due to *integral control action* to the change in *steady-state* output due to *proportional control action*.

NOTE: Integral action rate is often expressed as the number of repeats per minute because it is equal to the number of times per minute that the proportional response to a step input is repeated by the initial integral response.

2) Of *integral control action device*s: for a step input, the ratio of the initial rate of change of output to the input change. (8, Ref. 4)

integral action time constant: see *time constant, integral action.*

integral control action: see *control action, integral.*

integral controller: see *controller, integral (reset).*

interference, common mode: A form of interference which appears between measuring circuit terminals and ground. (3, 8)

interference, differential mode: see *interference, normal mode.*

interference, electromagnetic: Any spurious effect produced in the circuits or *elements* of a *device* by external electromagnetic fields.

NOTE: A special case of interference from radio transmitters is known as "Radio Frequency Interference (RFI)."

interference, electrostatic field: see *interference, electromagnetic.*

interference, longitudinal: see *interference, common mode.*

interference, magnetic field: see *interference, electromagnetic.*

interference, normal mode: A form of interference which appears between measuring circuit terminals. (2, 8)

interference, transverse: see *interference, normal mode.*

intermediate zone: see *zone, intermediate.*

intrinsically safe equipment and wiring: Equipment and wiring which are incapable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignited concentration. (14)

Laplace transform, unilateral: Of a function f(t), the quantity obtained by performing the operation

$$F(s) = \int_0^{\infty} f(t)e^{-st}dt$$

where:

F(s) = function of s

s = complex variable, $\sigma + jw$

f(t) = function of t

t = time, seconds

σ = real part of the complex variable s

j = $\sqrt{-1}$

w = angular frequency radians per second. (8, Ref. 4)

leak pressure: see *pressure, leak.*

linear system: see *system, linear.*

linearity: The closeness to which a curve approximates a straight line.

> **NOTE 1:** It is usually measured as a nonlinearity and expressed as linearity, e.g., a maximum *deviation* between an average curve and a straight line. The average curve is determined after making two or more full *range* traverses in each direction. The value of linearity is referred to the output unless otherwise stated.
>
> **NOTE 2:** As a performance specification linearity should be expressed as *independent linearity*, *terminal-based linearity* or *zero-based linearity*. When expressed simply as linearity it is assumed to be *independent linearity*.

See *conformity* (8, Ref. 4 "Linearity of a signal")

linearity, independent: The maximum *deviation* of the *calibration curve* (average of upscale and downscale readings) from a straight line so positioned as to minimize the maximum *deviation*. See *Figure 19*.

See *test procedure, Section 5.* *(Ref. 8)*

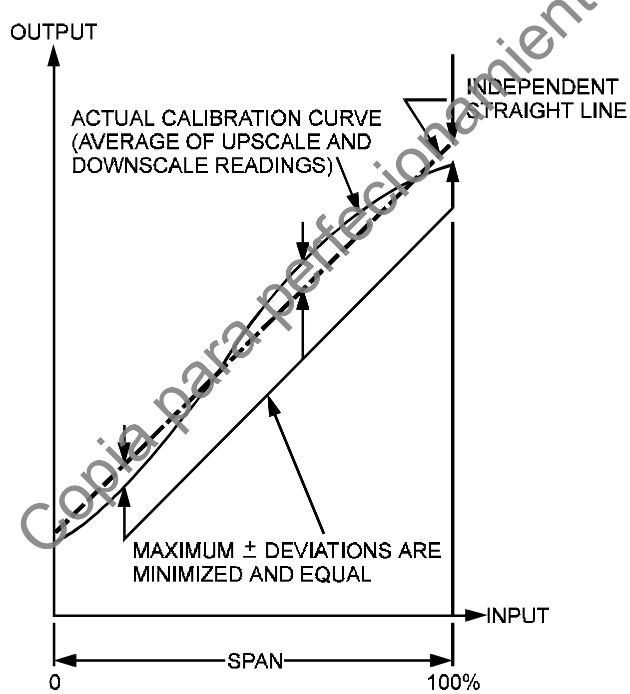

Figure 19 — Independent linearity

linearity, terminal-based: The maximum *deviation* of the *calibration curve* (average of upscale and downscale readings) from a straight line coinciding with the *calibration curve* at *upper* and *lower range-values*. See *Figure 20*.

See *test procedure, Section 5.* (Ref. 8)

linearity, zero-based: The maximum *deviation* of the *calibration curve* (average of upscale and downscale readings) from a straight line so positioned as to coincide with the *calibration curve* at the *lower range-value* and to minimize the maximum *deviation*. See *Figure 21*.

See *test procedure, Section 5.* (Ref. 8)

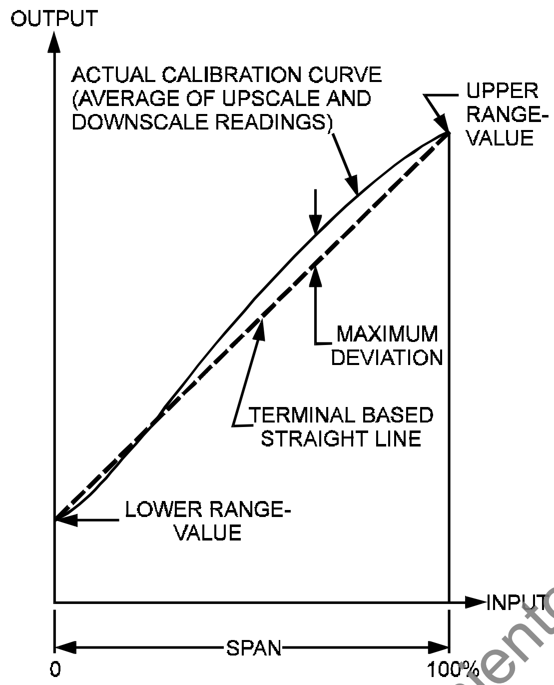

Figure 20 — Terminal-based linearity

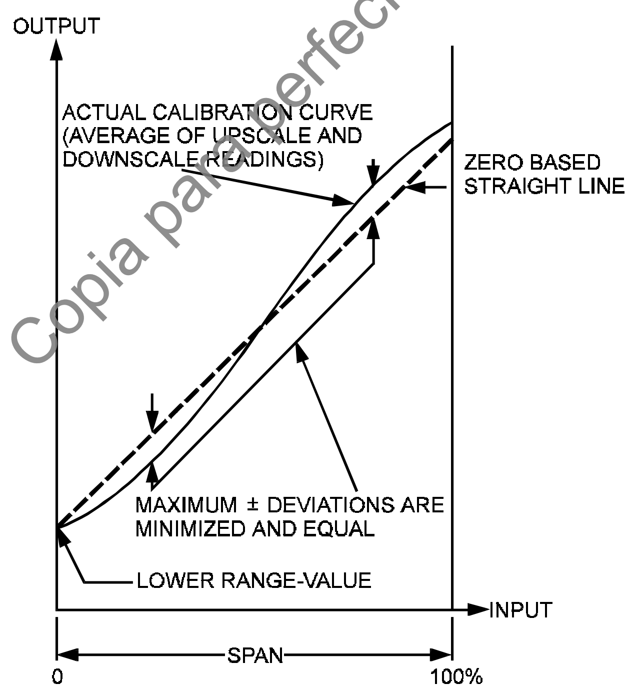

Figure 21 — Zero-based linearity

live zone: see *zone, live.*

load impedance: see *impedance, load.*

load regulation: The change in output (usually speed or voltage) from no-load to full-load (or other specified load limits). See *offset*.

> **NOTE:** It may be expressed as the percentage ratio of the change from no-load to full load divided by the no-load value. (8)

location, hazardous (classified): That portion of a plant where flammable or combustible liquids, vapors, gases or dusts may be present in the air in quantities sufficient to produce explosive or ignitable mixtures. (Ref. 9)

longitudinal interference: see *interference, common mode.*

loop, closed (feedback loop): A *signal* path which includes a forward path, a *feedback* path and a *summing point*, and forms a closed circuit. (4, 8)

loop, feedback: see *loop, closed* (*feedback loop*). (4, 8)

loop gain: see *gain, loop.*

loop gain characteristics: In process instrumentation, of a *closed loop*, the *characteristic curve* of the ratio of the change in the *return signal* to the change in the corresponding *error signal* for all real frequencies. (8)

loop, open: A *signal* path without *feedback*. (4, 8)

loop transfer function: Of a *closed loop*, the *transfer function* obtained by taking the ratio of the *Laplace transform* of the *return signal* to the *Laplace transform* of its corresponding *error signal*. (4, 8)

lower range-limit: see *range-limit, lower.*

lower range-value: see *range-value, lower.*

low limiting control: see *control, low limiting.*

magnetic field interference: see *interference, electromagnetic.*

magnitude ratio: see *gain (magnitude ratio).*

manipulated variable: see *variable, manipulated.*

maximum excitation: see *excitation, maximum.*

maximum working pressure: see *pressure, maximum working (MWP).*

measurand: see *variable, measured.*

measured accuracy: see *accuracy, measured.*

measured signal: see *signal, measured.*

measured value: see *value, measured.*

measured variable: see *variable, measured.*

measuring instrument: see *instrument, measuring.*

mechanical shock: The momentary application of an acceleration force to a device.

> **NOTE:** It is usually expressed in units of acceleration of gravity (g). (Ref. 8)

modulation: The process, or result of the process, whereby some characteristic of one wave is varied in accordance with some characteristic of another wave. (4, 8)

module: An assembly of interconnected components which constitutes an identifiable *device*, instrument, or piece of equipment. A module can be disconnected, removed as a unit, and replaced with a spare. It has definable performance characteristics which permit it to be tested as a unit.

> **NOTE:** A module could be a card or other subassembly of a larger *device*, provided it meets the requirements of this definition.

mounting position: The position of a *device* relative to physical surroundings. (8)

mounting strain error: see *error, mounting strain.*

multi-element control system: see *control system, multi-element (multi-variable).*

multi-speed floating controller: see *controller, multiple-speed floating.*

multi-position controller: see *controller, multi-position.*

multi-variable control system: see *control system, multi-element (multi-variable).*

natural frequency: see *frequency, undamped.*

neutral zone: see *zone, neutral*

noise: In process instrumentation, an unwanted component of a *signal* or variable.

> **NOTE:** It may be expressed in units of the output or in percent of output *span*.

See *interference, electromagnetic.* (Ref. 4, Ref. 8)

non-incendive equipment: Equipment which in its *normal operating condition* would not ignite a specific hazardous atmosphere in its most easily ignited concentration.

> **NOTE:** The electrical circuits may include sliding or make-and-break contacts releasing insufficient energy to cause ignition. Wiring which under normal conditions cannot release sufficient energy to ignite a specific hazardous atmospheric mixture by opening, shorting or grounding, shall be permitted using any of the methods suitable for wiring in ordinary locations.

non-interacting control system: see *control system, non-interacting.*

normal mode interference: see *interference, normal mode.*

normal mode rejection: The ability of a circuit to discriminate against a *normal mode voltage*.

> **NOTE:** It may be expressed as a dimensionless ratio, a scalar ratio, or in decibels as 20 times the $\log_{10}$ of that ratio.

normal mode voltage: see *voltage, normal mode.*

normal operating conditions: see *operating conditions, normal.*

offset: The *steady-state deviation* when the *set point* is fixed. See also *deviation*, *steady-state*.

> **NOTE:** The offset resulting from a no-load to a full-load change (or specified limits) is often called "droop" or ""*load regulation.*"

See *load regulation*. (8, Ref. 4)

on-off controller: see *controller, on-off.*

operating conditions: Conditions to which a *device* is subjected, not including the variable measured by the *device*.

Examples of *operating conditions* include: *ambient pressure*, *ambient temperature*, electromagnetic fields, gravitational force, inclination, power supply variation (voltage, frequency, harmonics), radiation, *shock* and *vibration*. Both static and dynamic variations in these conditions should be considered. (Ref. 2, Ref. 8)

operating conditions, normal: The range of *operating conditions* within which a *device* is designed to operate and for which *operating influences* are stated. See *Figure 22*. (Ref. 8)

operating conditions, reference: The range of *operating conditions* of a *device* within which *operating influences* are negligible. See Figure 22.

NOTE 1: The range is usually narrow.

NOTE 2: They are the conditions under which *reference performance* is stated and the base from which the values of *operating influences* are determined. (8)

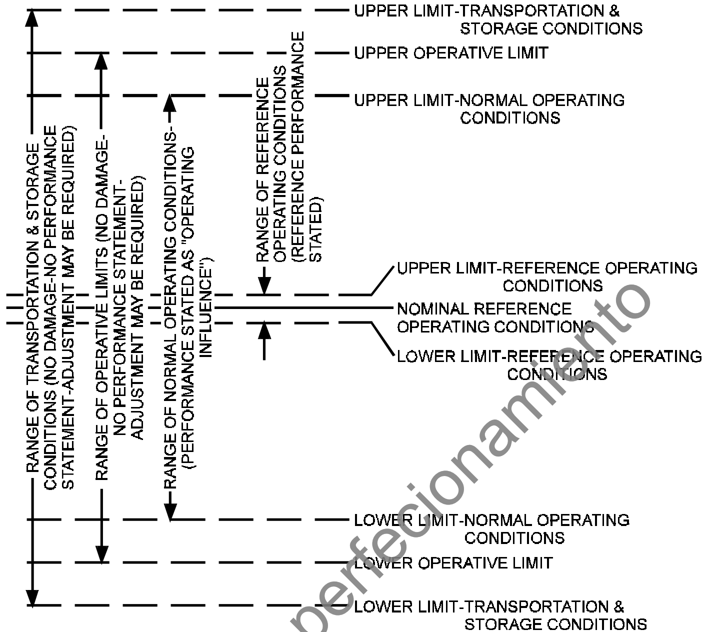

Figure 22 — Diagram of operating conditions

operating influence: The change in a performance characteristic caused by a change in a specified *operating condition* from *reference operating condition*, all other conditions being held within the limits of *reference operating conditions*.

NOTE: The specified *operating conditions* are usually the limits of the *normal operating conditions*.

Operating influence may be stated in either of two ways:

1) As the total change in performance characteristics from *reference operating condition* to another specified *operating condition*.

   Example: Voltage influence on *accuracy* may be expressed as:

   2% of *span* based on a change in voltage from reference value of 120 volts to value of 130 volts.

2) As a coefficient expressing the change in a performance characteristics corresponding to unit change of the *operating condition*, from *reference operating condition* to another specified *operating condition*.

   Example: Voltage influence on *accuracy* may be expressed as:

$$\frac{2\%\text{ of span}}{130V - 120V} = 0.2\%\text{ of span per volt}$$

NOTE: If the relation between operating influence and change in *operating condition* is linear, one coefficient will suffice. If it is non-linear, it may be desirable to state more than one coefficient such as 0.05% per volt from 120 to 125V, and 0.15% from 125 to 130V. (8, Ref. 2)

operating pressure: see *pressure, operating.*

operative limits: The range of *operating condition*s to which a *device* may be subjected without permanent impairment of operating characteristics. See *Figure 2*2.

NOTE 1: In general, performance characteristics are not stated for the region between the limits of *normal operating conditions* and the operative limits.

NOTE 2: Upon returning within the limits of *normal operating conditions*, a *device* may require adjustments to restore normal performance. (Ref. 2 "design limits," Ref. 8)

optimizing control: see *control, optimizing.*

outdoor area: see *area, outdoor.*

output impedance: see *impedance, output.*

output signal: see *signal, output.*

overdamped: see *damping.*

overrange: In process instrumentation, of a system or *element*, any excess value of the *input signal* above its *upper range value* or below its *lower range-value*. (8, Ref. 4)

overrange limit: The maximum input that can be applied to a *device* without causing damage or permanent change in performance.

overshoot: see *transient overshoot.*

parameter: A quantity or property treated as a constant but which may sometimes vary or be adjusted. (6)

P controller: see *controller, proportional.*

PD controller: see *controller, proportional plus derivative.*

pen travel: The length of the path described by the pen in moving from one end of the chart scale to the other. The path may be an arc or a straight line. (8)

phase crossover frequency: see *frequency, phase crossover.*

phase shift: (1) Of a *transfer function*, a change of phase angle with test frequency, as between points on a loop phase characteristic. (2) Of a *signal* a change of phase angle with transmission. (4)

PI controller: see *controller, proportional plus integral.*

PID controller: see *controller, proportional plus integral plus derivative.*

pneumatic delivery capability: The rate at which a pneumatic *device* can deliver air (or gas) relative to a specified output pressure change.

NOTE: It is usually determined, at a specified level of input *signal*, by measuring the output flow rate for a specified change in output pressure. The results are expressed in cubic feet per minute (ft^3/min) or cubic meters per hour (m^3/h), corrected to standard (normal) conditions of pressure and temperature.

pneumatic exhaust capability: The rate at which a pneumatic *device* can exhaust air (or gas) relative to a specified output pressure change.

NOTE: It is usually determined, at a specified level of input *signal*, by measuring the output flow rate for a specified change in output pressure. The results are expressed in cubic feet per minute (ft^3/min) or cubic meters per hour (m^3/h), corrected to standard (normal) conditions of pressure and temperature.

point drift: see *drift, point.*

position: Of a *multi-position controller*, a discrete value of the *output signal*. See Figure 12.

position error: see *error, position.*

power consumption, electrical: The maximum power used by a *device* within its operating *range* during *steady-state signal* condition.

NOTE 1: For a power factor other than unity, power consumption shall be stated as maximum volt-amperes used under the above stated condition.

NOTE 2: For a *device* operating outside of its operating *range*, the maximum power might exceed that which is experienced within the operating *range*. (Ref. 8 "Power consumption")

power factor: The ratio of total watts to the total root-mean-square (rms) volt-amperes.

$F_p = \Sigma$ watts per phase / Σ rms volt-amperes per phase = active power / apparent power

NOTE: If the voltages have the same waveform as the corresponding currents, power factor becomes the same as phasor power factor. If the voltages and currents are sinusoidal, and for polyphase circuits, form symmetrical sets, $F_p = \cos(\alpha - \beta)$. (3)

pressure, ambient: The pressure of the medium surrounding a *device*. (8)

pressure, design: The pressure used in the design of a vessel or *device* for the purpose of determining the minimum permissible thickness or physical characteristics of the parts for a given *maximum working pressure* (MWP) at a given temperature.

pressure, leak: The pressure at which some discernible leakage first occurs in a *device*.

pressure, maximum working (MWP): The maximum total pressure permissible in a *device* under any circumstances during operation, at a specified temperature. It is the highest pressure to which it will be subjected in the *process*. It is a designed safe limit for regular use.

NOTE: MWP can be arrived at by two methods: (1) Designed: by adequate design analysis, with a safety factor; (2) Tested: by rupture testing of typical samples.

See *pressure, design.*

pressure, operating: The actual pressure at which a *device* operates under normal conditions. This pressure may be positive or negative with respect to atmospheric pressure.

pressure, process: The pressure at a specified point in the *process* medium. (Ref. 8)

pressure, rupture: The pressure, determined by test, at which a *device* will burst.

NOTE: This is an alternate to the design procedure for establishing *maximum working pressure* (MWP). The rupture pressure test consists of causing the *device* to burst.

pressure, static: The *steady-state* pressure applied to a *device*; in the case of a differential pressure *device*, the *process pressure* applied equally to both connections.

pressure, supply: The pressure at the supply port of a *device*. (8)

pressure, surge: *Operating pressure* plus the increment above *operating pressure* to which a *device* may be subjected for a very short time during pump starts, valve closings, etc.

primary element: see *element, primary.*

process: Physical or chemical change of matter or conversion of energy, e.g., change in pressure, temperature, speed, electrical potential, etc.

process control: The regulation or manipulation of variables influencing the conduct of a *process* in such a way as to obtain a product of desired quality and quantity in an efficient manner.

process measurement: The acquisition of information that establishes the magnitude of *process* quantities.

process pressure: see *pressure, process.*

process temperature: see *temperature, process.*

program controller: see *controller, program.*

proportional band: The change in input required to produce a full *range* change in output due to *proportional control action*.

> **NOTE 1:** It is reciprocally related to *proportional gain*.
>
> **NOTE 2:** It may be stated in input units or as a percent of the input *span* (usually the indicated or recorded input *span*).

The preferred term is *proportional gain.*

See *gain, proportional*. (8)

proportional control action: see *control action, proportional.*

proportional controller: see *controller, proportional.*

proportional gain: see *gain, proportional.*

proportional plus derivative control action: see *control action, proportional plus derivative.*

proportional plus derivative controller: see *controller, proportional plus derivative.*

proportional plus integral control action: see *control action, proportional plus integral.*

proportional plus integral controller: see *controller, proportional plus integral.*

proportional plus integral plus derivative control action: see *control action, proportional plus integral plus derivative.*

proportional plus integral plus derivative controller: see *controller, proportional plus integral plus derivative.*

proportional plus rate control action: see *control action, proportional plus derivative.*

proportional plus rate controller: see *controller, proportional plus derivative.*

proportional plus reset control action: see *control action, proportional plus integral.*

proportional plus reset controller: see *controller, proportional plus integral.*

proportional plus reset plus rate control action: see *control action, proportional plus integral plus derivative.*

proportional plus reset plus rate controller: see *controller, proportional plus integral plus derivative.*

proportional speed floating controller: see *controller, integral*

ramp response: see *response, ramp.*

ramp response time: see *time, ramp response.*

range: The region between the limits within which a quantity is measured, received, or transmitted, expressed by stating the *lower* and *upper range-values*.

NOTE 1: For example:

a) 0 to 150°F

b) –20 to +200°F

c) 20 to 150°C

NOTE 2: Unless otherwise modified, input *range* is implied.

NOTE 3: The following compound terms are used with suitable modifications in the units: *measured variable range*, *measured signal range*, indicating scale range, chart scale range, etc. See *Tables 1 and 2*.

NOTE 4: For multi-range *device*s, this definition applies to the particular range that the *device* is set to measure. (3, 8)

range, elevated-zero: A *range* in which the zero value of the *measured variable*, *measured signal*, etc., is greater than the *lower range-value*. See *Table 1*.

NOTE 1: The zero may be between the *lower* and *upper range-values*, at the *upper range-value*, or above the *upper range-value*.

NOTE 2: Terms *suppression, suppressed range* or *suppressed span* are frequently used to express the condition in which the zero of the *measured variable* is greater than the *lower range-value*. The term "elevated-zero range" is preferred. (Ref. 8)

range-limit, lower: The lowest value of the *measured variable* that a *device* can be adjusted to measure.

NOTE: The following compound terms are used with suitable modifications to the units: *measured variable* lower range-limit, *measured signal* lower range-limit, etc. See *Tables 1 and 2*. (Ref. 8)

range-limit, upper: The highest value of the *measured variable* that a *device* can be adjusted to measure.

NOTE: The following compound terms are used with suitable modifications to the units: *measured variable* upper range-limit, *measured signal* upper range-limit, etc. See *Tables 1 and 2*. (Ref. 8)

range, suppressed-zero: A *range* in which the zero value of the *measured variable* is less than the *lower range* value. (Zero does not appear on the scale.) See *Table 1.*

NOTE 1: For example: 20 to 100

NOTE 2: Terms *elevation*, *elevated range* or *elevated span* are frequently used to express the condition in which the zero of the *measured variable* is less than the *lower range-value*. The term "suppressed-zero range" is preferred. (Ref. 2, Ref. 8)

range-value, lower: The lowest value of the *measured variable* that a *device* is adjusted to measure.

NOTE: The following compound terms are used with suitable modifications to the units: *measured variable* lower range-value, *measured signal* lower range-value, etc. See *Tables 1 and 2.* (Ref. 8)

Table 1 — Illustrations of the use of range and span terminology

TYPICAL RANGES	NAME	RANGE	LOWER RANGE-VALUE	UPPER RANGE-VALUE	SPAN	SUPPLEMENTARY DATA
0 +100	—	0 to 100	0	+100	100	—
20 +100	SUPPRESSED ZERO RANGE	20 to 100	20	+100	80	SUPPRESSION RATIO = 0.25
–25 0 +100	ELEVATED ZERO RANGE	–25 to +100	–25	+100	125	—
–100 0	ELEVATED ZERO RANGE	–100 to 0	-100	0	100	—
–100 –20	ELEVATED ZERO RANGE	–100 to –20	-100	-20	80	—

range-value, upper: The highest value of the *measured variable* that a *device* is adjusted to measure.

> **NOTE:** The following compound terms are used with suitable modifications to the units: *measured variable* upper range-value, *measured signal* upper range-value, etc. See *Tables 1 and 2*. (Ref. 8)

rate: see *control action, derivative.*

rate control action: see *control action, derivative.*

rate gain: see *gain, derivative action.*

ratio controller: see *controller, ratio.*

recording instrument: see *instrument, recording.*

reference accuracy: see *accuracy rating.*

reference-input element: see *element, reference-input.*

reference-input signal: see *signal, reference-input.*

reference junction: That thermocouple junction which is at a known or reference temperature.

> **NOTE:** The *reference junction* is physically that point at which the thermocouple or thermocouple extension wires are connected to a *device* or where the thermocouple is connected to a pair of lead wires, usually copper. (Ref. 7)

reference junction compensation: A means of counteracting the effect of temperature variations of the reference junction, when allowed to vary within specified limits.

reference operating conditions: see *operating conditions*, *reference*.

reference performance: Performance attained under *reference operating conditions*.

> **NOTE:** Performance includes such things as *accuracy, dead band, hysteresis*, *linearity, repeatability*, etc. (8)

Table 2 — U.S.A. domestic units: Illustrations of the use of the terms "measured variable" and "measured signal"

TYPICAL RANGES	TYPE OF RANGE	RANGE	LOWER RANGE–VALUE	UPPER RANGE–VALUE	SPAN
(1) THERMOCOUPLE 0 2000°F TYPE K T/C	MEASURED VARIABLE	0 to 2000°F	0°F	2000°F	2000°F
–0.68 +44.91 mV	MEASURED SIGNAL	–0.68 to +44.91 mV	–0.68 mV	+44.91 mV	45.59 mV
0 20 x100=°F	SCALE AND/OR CHART	0 to 2000°F	0°F	2000°F	2000°F
(2) FLOWMETER 0 10 000 lb/h	MEASURED VARIABLE	0 to 10 000 lb/h	0 lb/h	10 000 lb/h	10 000 lb/h
0 100 in H_2O	MEASURED SIGNAL	0 to 100 in H_2O	0 in H_2O	100 in H_2O	100 in H_2O
0 10 x1000=lb/h	SCALE AND/OR CHART	0 to 10 000 lb/h	0 lb/h	10 000 lb/h	10 000 lb/h
(3) TACHOMETER 0 500 rpm	MEASURED VARIABLE	0 to 500 rpm	0 rpm	500 rpm	500 rpm
0 5V	MEASURED SIGNAL	0 to 5V	0V	5V	5V
0 80 ft/s	SCALE AND/OR CHART	0 to 80 ft/s	0 ft/s	80 ft/s	80 ft/s

regulator: see *controller, self-operated (regulator).*

relative damping: see *damping, relative.*

reliability: The probability that a *device* will perform its objective adequately, for the period of time specified, under the *operating conditions* specified. (Ref. 4)

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. See *Figure 23*.

> **NOTE:** It is usually measured as a non-repeatability and expressed as *repeatability* in percent of *span*. It does not include *hysteresis*.

See *test procedure, Section 5*. (8, Ref. 2)

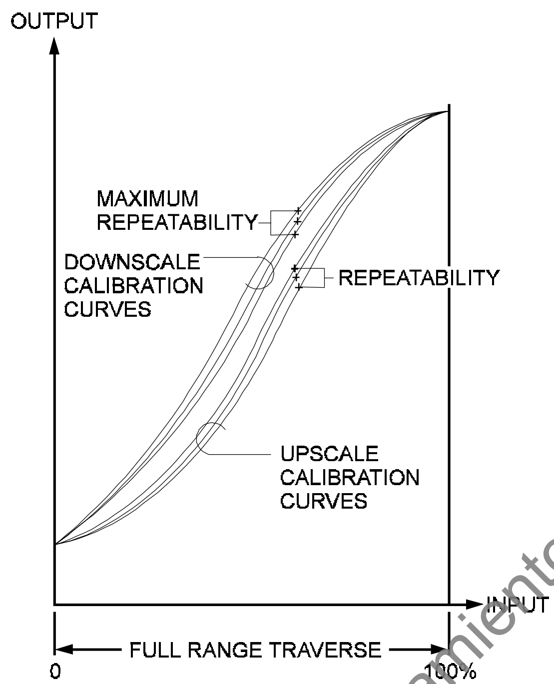

Figure 23 — Repeatability

reproducibility: In process instrumentation, the closeness of agreement among repeated measurements of the output for the same value of input made under the same *operating conditions* over a period of time, approaching from both directions.

> **NOTE 1:** It is usually measured as a nonreproducibility and expressed as reproducibility in percent of *span* for a specified time period. Normally, this implies a long period of time, but under certain conditions the period may be a short time during which *drift* may not be included.
>
> **NOTE 2:** Reproducibility includes *hysteresis*, *dead band*, *drift* and *repeatability*.
>
> **NOTE 3:** Between repeated measurements the input may vary over the *range* and *operating conditions* may vary within *normal operating conditions*.

See *test procedure, Section 5.* (8)

reset control action: see *control action, integral (reset).*

reset rate: see *integral action rate.*

resolution: The least interval between two adjacent discrete details which can be distinguished one from the other. (4)

resonance: Of a system or *element*, a condition evidenced by large oscillatory amplitude, which results when a small amplitude of periodic input has a frequency approaching one of the natural frequencies of the driven system. (4, 8)

response, dynamic: The behavior of the output of a *device* as a function of the input, both with respect to time. (8, Ref. 2)

response, ramp: The total (transient plus *steady-state*) *time response* resulting from a sudden increase in the rate of change from zero to some finite value of the input stimulus. (Ref. 4 "response, ramp-forced")

response, step: The total (*transient* plus *steady-state*) *time response* resulting from a sudden change from one constant level of input to another. (4 "response, step-forced")

response, time: An output expressed as a function of time, resulting from the application of a specified input under specified *operating conditions*. See *Figure 24.* (4, 8)

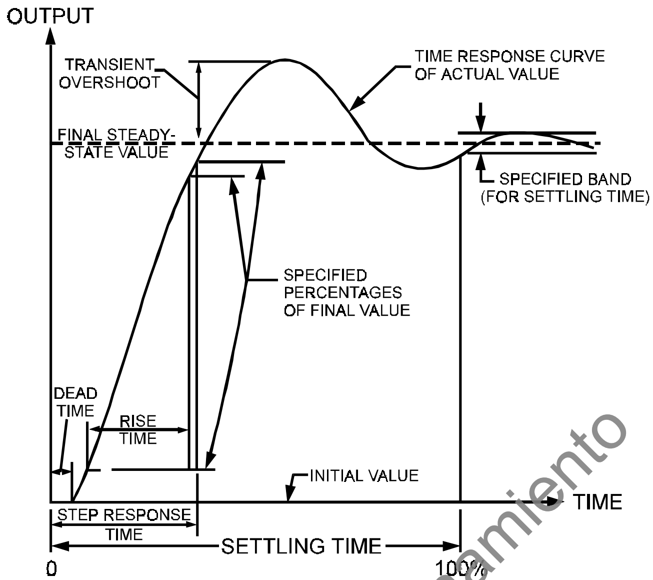

Figure 24 — Typical time response of a system to a step increase of input

return signal: see *signal, return.*

reverse acting controller: see *controller, reverse acting.*

rise time: see *time, rise.*

rms value: see *value, rms.*

rupture pressure: see *pressure, rupture.*

sampling controller: see *controller, sampling.*

sampling period: The time interval between observations in a periodic sampling *control system*. (4, 8)

scale factor: The factor by which the number of scale divisions indicated or recorded by an instrument should be multiplied to compute the value of the *measured variable*. (Ref. 8)

> **NOTE:** Deflection factor is a more general term than scale factor in that the instrument response may be expressed alternatively in units other than scale divisions. (Ref. 3)

self-heating: Internal heating resulting from electric energy dissipated within a *device*. (Ref. 11)

self-operated controller: see *controller, self-operated (regulator).*

self-regulation (inherent regulation): The property of a *process* or machine which permits attainment of equilibrium, after a *disturbance*, without the intervention of a *controller*. (4)

sensing element: see *element, sensing.*

sensing element elevation: The difference in elevation between the *sensing element* and the instrument.

> **NOTE:** The elevation is considered positive when the *sensing element* is above the instrument. (8)

sensitivity: The ratio of the change in output magnitude to the change of the input which causes it after the *steady-state* has been reached.

> **NOTE 1:** It is expressed as a ratio with the units of measurement of the two quantities stated. (The ratio is constant over the *range* of a linear *device*. For a nonlinear *device* the applicable input level must be stated.)
>
> **NOTE 2:** Sensitivity has frequently been used to denote the *dead band*. However, its usage in this sense is deprecated since it is not in accord with accepted standard definitions of the term. (8, Ref. 4)

sensor: see *transducer*. (11)

servomechanism: An automatic *feedback control device* in which the controlled variable is mechanical position or any of its time derivatives. (Ref. 4)

set point: An input variable which sets the desired value of the controlled variable.

> **NOTE 1:** The input variable may be manually set, automatically set, or programmed.
>
> **NOTE 2:** It is expressed in the same units as the controlled variable. (8, Ref. 4 "command")

settling time: see *time, settling.*

shared time control: see *control, shared time.*

sheltered area: see *area, sheltered.*

signal: In process instrumentation, physical variable, one or more *parameters* of which carry information about another variable (which the signal represents). (17)

signal, actuating error: In process instrumentation, the *reference-input signal* minus the *feedback signal*. See *Figure 16*.

See also *deviation, system*. (8, Ref. 4 "signal, actuating")

signal amplitude sequencing (split ranging): Action in which two or more *signals* are generated or two or more *final controlling elements* are actuated by an *input signal*, each one responding consecutively, with or without overlap, to the magnitude of that *input signal*. See *Figure 25*. (8)

signal, analog: A *signal* representing a variable which may be continuously observed and continuously represented.

signal converter: see *signal transducer.*

signal, digital: Representation of information by a set of discrete values in accordance with a prescribed law. These values are represented by numbers.

signal, error: In a *closed loop*, the *signal* resulting from subtracting a particular *return signal* from its corresponding *input signal*.

See also *signal, actuating error*. (4, 8)

signal, feedback: In process instrumentation, the *return signal* which results from a measurement of the *directly controlled variable.* See *Figure 16*. (8, Ref. 4)

signal, feedforward: see *control, feedforward.*

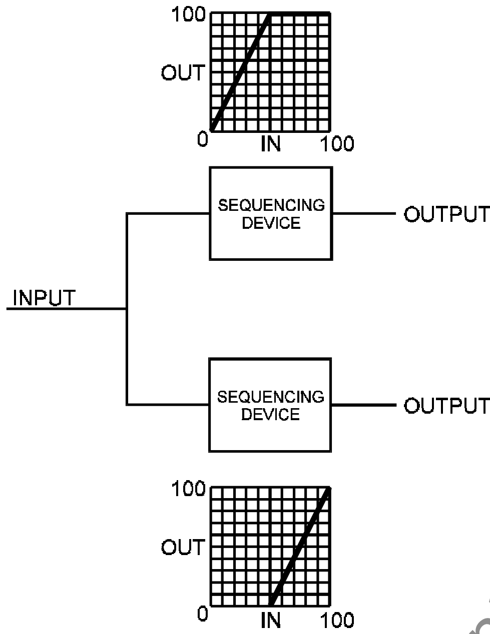

Figure 25 — Signal amplitude sequencing

signal, input: A *signal* applied to a *device*, *element* or system. (8, Ref. 4)

signal, measured: The electrical, mechanical, pneumatic or other variable applied to the input of a *device*. It is the analog of the *measured variable* produced by a *transducer* (when such is used.)

Example 1: In a thermocouple thermometer, the measured signal is an emf which is the electrical analog of the temperature applied to the thermocouple.

Example 2: In a *flowmeter*, the measured signal may be a differential pressure which is the analog of the rate of flow through the orifice.

Example 3: In an electric tachometer system, the measured signal may be a voltage which is the electrical analog of the speed of rotation of the part coupled to the tachometer generator.

See *variable, measured*. (8, Ref. 2)

signal, output: A *signal* delivered by a *device*, *element* or system. (8, Ref. 4)

signal, reference-input: One external to a control loop, serving as the standard of comparison for the *directly controlled variable*. See *Figure 16*. (4, 8)

signal, return: In a *closed loop*, the *signal* resulting from a particular *input signal*, and transmitted by the loop and to be subtracted from the *input signal*. See also *signal*, *feedback*. (4, 8)

signal selector: A *device* which automatically selects either the highest or the lowest *input signal* from among two or more *input signals*.

NOTE: This *device* is sometimes referred to as a signal auctioneer. (Ref. 8 "auctioneering device")

signal to noise ratio: Ratio of *signal* amplitude to *noise* amplitude.

NOTE: For sinusoidal and non-sinusoidal *signals*, the amplitude may be peak or rms and should be so specified. (Ref. 8)

signal transducer (signal converter): A *transducer* which converts one standardized transmission *signal* to another. (Ref. 8)

single speed floating controller: see *controller, single speed floating.*

source impedance: see *impedance, source.*

span: The algebraic difference between the *upper* and *lower range-values*.

NOTE 1: For example:

Range 0 to 150°F, *Span* 150°F

Range –20 to 200°F, *Span* 220°F

Range 20 to 150°C, *Span* 130°C

NOTE 2: The following compound terms are used with suitable modifications to the units: *measured variable span*, *measured signal span*, etc.

NOTE 3: For multi-range *devices*, this definition applies to the particular *range* that the *device* is set to measure. See *Tables 1 and 2*. (8, Ref. 3)

span adjustment: see *adjustment, span.*

span error: see *error, span.*

span shift: Any change in slope of the input-output curve. See *Figure 26*.

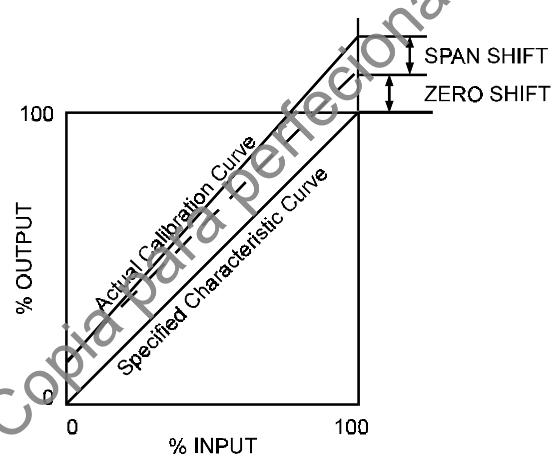

Figure 26 — Shift, span and zero

split ranging: see *signal amplitude sequencing (split ranging).*

static friction: see *stiction***.**

static gain: see *gain, static.*

static pressure: see *pressure, static.*

steady-state: A characteristic of a condition, such as value, rate, periodicity, or amplitude, exhibiting only negligible change over an arbitrary long period of time.

NOTE: It may describe a condition in which some characteristics are static, others dynamic. (8, Ref. 4)

steady-state deviation: see *deviation, steady-state.*

step response: see *response, step.*

step response time: see *time, step response.*

stiction (static friction): Resistance to the start of motion, usually measured as the difference between the driving values required to overcome static friction upscale and downscale. (4)

stiffness: In process instrumentation, the ratio of change of force (or torque) to the resulting change in deflection of a spring-like *element*.

> **NOTE:** Stiffness is the opposite of compliance.

subsidence: see *damping*, also *subsidence ratio*.

subsidence ratio: In process instrumentation, the ratio of the peak amplitudes of two successive oscillations of the same sign measured from an ultimate *steady-state* value, the numerator representing the first oscillation in time. See *Figure 17*. (Ref. 16)

summing point: Any point at which *signals* are added algebraically. See *Figure 16.* (4, 8)

supervisory control: see *control, supervisory.*

supply pressure: see *pressure, supply.*

suppressed range: see *range, elevated-zero.*

suppressed span: see *range, elevated-zero.*

suppressed-zero range: see *range, suppressed-zero.*

suppression: see *range, elevated-zero.*

suppression ratio: (of a *suppressed-zero range*): the ratio of the *lower range-value* to the *span*.

> **NOTE:** For example:
>
> *Range* 20 to 100,
>
> Suppression Ratio = $\frac{20}{80} = 0.25$
>
> See *Table 1.* (8, Ref. 2)

surge pressure: see *pressure, surge.*

switching point: A point in the input *span* of a *multi-position controller* at which the *output signal* changes from one *position* to another. See *Figure 12*. (8)

systematic error: see *error, systematic.*

system, control: see *control system.*

system, controlled: The collective functions performed in and by the equipment in which the variable(s) is (are) to be controlled.

> **NOTE:** Equipment as embodied in this definition should be understood not to include any automatic control equipment. (Ref. 8 "process")

system, controlling: (1) Of a *feedback control system*, that portion which compares functions of a *directly controlled variable* and a *set point*, and adjusts a *manipulated variable* as a function of the difference. It includes the *reference-input elements*; *summing point*; *forward* and *final controlling elements*, and *feedback elements* (including *sensing element*). (2) Of a *control system* without *feedback*, that portion which manipulates the *controlled system*. (Ref. 4, Ref. 8)

system deviation: see *deviation, system.*

system, directly controlled: The body, *process*, or machine directly guided or restrained by the *final controlling element* to achieve a prescribed value of the *directly controlled variable*. (4, 8)

system, idealized: An imaginary system whose *ultimately controlled variable* has a stipulated relationship to a specified *set point*.

NOTE: It is a basis for performance standards. (8, Ref. 4)

system, indirectly controlled: The portion of the *controlled system* in which the *indirectly controlled variable* is changed in response to changes in the *directly controlled variable*.

See *Figure 16*. (Ref. 4, Ref. 8)

system, linear: One of which the *time response* to several simultaneous inputs is the sum of their independent *time responses*.

NOTE: It is represented by a linear differential equation, and has a *transfer function* which is constant for any value of input within a specified *range*. A system not meeting these conditions is described as "nonlinear." (Ref. 4)

tapping: see *dither.*

temperature, ambient: The temperature of the medium surrounding a *device*.

NOTE 1: For *device*s which do not generate heat this temperature is the same as the temperature of the medium at the point of *device* location when the *device* is not present.

NOTE 2: For *device*s which do generate heat this temperature is the temperature of the medium surrounding the *device* when it is present and dissipating heat.

NOTE 3: Allowable ambient temperature limits are based on the assumption that the *device* in question is not exposed to significant radiant energy sources. (8)

temperature, process: The temperature of the *process* medium at the *sensing element*. (8)

terminal-based conformity: see *conformity, terminal-based.*

terminal-based linearity: see *linearity, terminal-based.*

thermal shock: An abrupt temperature change applied to a *device*. (8)

three-position controller: see *controller, three-position.*

time constant: In process instrumentation, the value T in an exponential response term A exp (–t/T) or in one of the transform factors

$$1 + sT,\ 1 + j\omega T,\ 1/(1 + sT),\ 1/(1 + j\omega T)\ .$$

where:

s = complex variable

t = time, seconds

T = time constant

$j = \sqrt{-1}$

ω = angular velocity, radians per second.

NOTE: For the output of a first-order system forced by a step or an impulse, T is the time required to complete 63.2% of the total rise or decay; at any instant during the process, T is the quotient of the instantaneous rate of change divided into the change still to be completed. In higher order systems, there is a time constant for each of the first-order components of the *process*. In a *Bode diagram*, break points occur at $\omega = 1/T$. (Ref. 4, Ref. 8)

time constant, derivative action: Of *proportional plus derivative control action*, a *parameter* the value of which is equal to $1/2\pi f_d$ where f_d is the frequency (in hertz) on a *Bode diagram* of the lowest frequency gain corner resulting from *derivative control action*. (4,8)

time constant, integral action: (1) Of *proportional plus integral control action*, a *parameter* whose value is equal to $1/2\pi f_i$ where f_i is the frequency (in hertz) on a *Bode diagram* of the highest frequency gain corner resulting from *integral control action*. (2) It is the reciprocal of *integral action rate*.

NOTE: The use of integral action rate is preferred. (8, Ref. 4)

time, correction: see *time, settling.*

time, dead: The interval of time between initiation of an input change or stimulus and the start of the resulting observable response. See *Figure 24*. (Ref. 4, Ref. 8)

time, derivative action: In *proportional plus derivative control action*, for a unit ramp *signal* input, the advance in time of the *output signal* (after *transients* have subsided) caused by *derivative control action*, as compared to the *output signal* due to *proportional control action* only. (Ref. 5, Ref. 8)

time proportioning control: see *control, time proportioning.*

time, ramp response: The time interval by which an output lags an input, when both are varying at a constant rate. (4, Ref. 3 "response time, ramp-forced")

time response: see *response, time.*

time, rise: The time required for the output of a system (other than first order) to change from a small specified percentage (often 5 or 10) of the *steady-state* increment to a large specified percentage (often 90 to 95), either before or in the absence of overshoot. See *Figure 24*.

NOTE: If the term is unqualified, response to a unit step stimulus is understood; otherwise the pattern and magnitude of the stimulus should be specified. (Ref. 4, Ref. 8)

time schedule controller: see *controller, time schedule.*

time, settling: The time required, following the initiation of a specified stimulus to a system, for the output to enter and remain within a specified narrow band centered on its *steady-state* value. See *Figure 24*.

NOTE: The stimulus may be a step impulse, ramp, parabola, or sinusoid. For a step or impulse, the band is often specified as ±2%. For nonlinear behavior both magnitude and pattern of the stimulus should be specified. (8, Ref. 4)

time, step response: Of a system or an *element*, the time required for an output to change from an initial value to a large specified percentage of the final *steady-state* value either before or in the absence of overshoot, as a result of a step change to the input. See *Figure 24.*

NOTE: Usually stated for 90, 95 or 99 percent change.

See "*time constant*" for use of 63.2% value. (Ref. 4 "time response", Ref. 8)

transducer: An *element* or *device* which 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 *device*s such as *primary element*, *signal transducer*, *and transmitter*.

See *primary element, signal transducer,* and *transmitter*. (Ref. 4, Ref. 8)

transfer function: A mathematical, graphical, or tabular statement of the influence which a system or *element* has on a *signal* or action compared at input and at output terminals. (4, 8)

transient: In process instrumentation, the behavior of a variable during transition between two *steady-states*. (17)

transient deviation: see *deviation, transient.*

transient overshoot: The maximum excursion beyond the final *steady-state* value of output as the result of an input change. (Ref. 8)

transient overvoltage: A momentary excursion in voltage occurring in a *signal* or supply line of a *device* which exceeds the maximum rated conditions specified for that *device*.

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*. (Ref. 8)

transportation and storage conditions: The conditions to which a *device* may be subjected between the time of construction and the time of installation. Also included are the conditions that may exist during shutdown. See *Figure 22*.

> **NOTE:** No permanent physical damage or impairment of operating characteristics shall take place under these conditions, but minor adjustments may be needed to restore performance to normal. (8)

transverse interference: see *interference, normal mode.*

two-position controller: see *controller, two-position.*

ultimately controlled variable: see *variable, ultimately controlled.*

undamped frequency: see *frequency, undamped.*

underdamped: see *damping.*

upper range-limit: see *range-limit, upper.*

upper range-value: see *range-value, upper.*

value, desired: In process instrumentation, the value of the controlled variable wanted or chosen.

> **NOTE:** The desired value equals the *ideal value* in an *idealized system*. (8)

value, ideal: In process instrumentation, the value of the indication, output or *ultimately controlled variable* of an idealized *device* or system.

> **NOTE:** It is assumed that an ideal value can always be defined even though it may be impossible to achieve. (8)

value, measured: The numerical quantity resulting, at the instant under consideration, from the information obtained by a measuring *device*. (Ref. 16)

value, rms (root-mean-square value): The square root of the average of the squares of the instantaneous values.

NOTE: rms value = $\left[\frac{1}{T} \int_{t_o}^{t_o + T} \cdot x^2 dt \right]^{1/2}$

where:

x is the instantaneous value,

t_o is any value of time,

T is the observation period (4)

variable, directly controlled: In a control loop, the variable the value of which is sensed to originate a *feedback signal*. (4, 8)

variable, indirectly controlled: A variable which does not originate a *feedback signal*, but which is related to, and influenced by, the *directly controlled variable*. (4, 8)

variable, manipulated: A quantity or condition which is varied as a function of the *actuating error signal* so as to change the value of the *directly controlled variable*. (4, 8)

variable, measured: A quantity, property, or condition which is measured.

> **NOTE 1:** It is sometimes referred to as the measurand.
>
> **NOTE 2:** Common measured variables are temperature, pressure, rate of flow, thickness, speed etc. (Ref. 8)

variable, ultimately controlled: the variable whose control is the end purpose of the *automatic control system*.

velocity limit: A limit which the rate of change of a specified variable may not exceed. (Ref. 8)

velocity limiting control: see *control, velocity limiting.*

vibration: A periodic motion or oscillation of an *element*, *device*, or system.

> **NOTE 1:** Vibration is caused by any excitation which displaces some or all of a particular mass from its position of equilibrium. The resulting vibration is the attempt of the forces, acting on and within the mass, to equalize.
>
> **NOTE 2:** The amplitude and duration of any vibration is dependent on the period and amplitude of the excitation and is limited by the amount of *damping* present.

voltage, common mode: A voltage of the same polarity on both sides of a differential input relative to ground. See *Figure 27*.

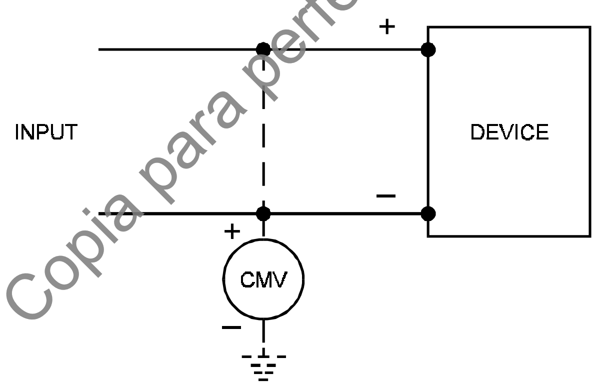

Figure 27 — Common mode voltage

voltage, normal mode: A voltage induced across the input terminals of a *device*. See *Figure 28*.

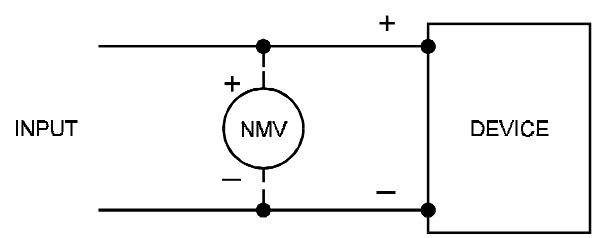

Figure 28 — Normal mode voltage

warm-up period: The time required after energizing a *device* before its rated performance characteristics apply. (8)

zero adjustment: see *adjustment, zero.*

zero-based conformity: see *conformity, zero-based.*

zero-based linearity: see *linearity, zero-based.*

zero elevation: For an *elevated-zero range*, the amount the *measured variable* zero is above the *lower range-value*. It may be expressed either in units of the *measured variable* or in percent of *span*. (8)

zero error: see *error, zero.*

zero frequency gain: see *gain, zero frequency.*

zero shift: In process instrumentation, any parallel shift of the input-output curve. See *Figure 26*.

zero suppression: For a *suppressed-zero range*, the amount the *measured variable* zero is below the *lower range-value*. It may be expressed either in units of the *measured variable* or in percent of *span*. (8)

zone: *On a multi-position controller*, the *range* of input values between selected switching points or any *switching point* and range-limit. See *Figure 12*. (8)

zone, dead: (1) For a *multi-position controller*, a *zone* of input in which no value of output exists. It is usually intentional and adjustable. See *Figure 13*. (Ref. 8) (2) a predetermined *range* of input through which the output remains unchanged, irrespective of the direction of change of the *input signal*. See *Figure 29*.

The notes apply to Definition (2) only.

NOTE 1: There is but one input-output relationship, as shown in Fig. 29.

NOTE 2: Dead zone produces no phase lag between input and output.

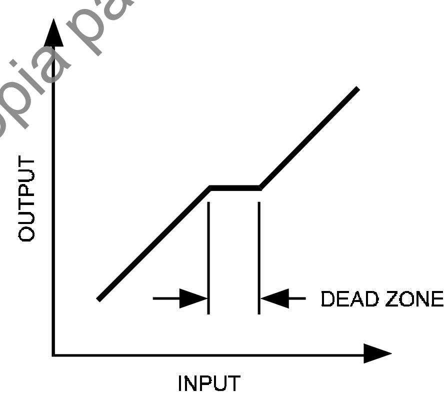

Figure 29 — Dead zone

zone, intermediate: Any *zone* not bounded by a range-limit. (8)

zone, live: A *zone* in which a value of the output exists. (8)

zone, neutral: A predetermined *range* of input values in which the previously existing output value is not changed. See *Figure 15*. (Ref. 4)

5 Test procedures

5.1 Scope and Purpose

The purpose of the test procedures, as described herein, is to illustrate and clarify accuracy related terms. It is intended only that the procedures indicate a generalized method of test.

The test procedures that follow are for the following terms:

accuracy measured
dead band
drift point
hysteresis
linearity, independent
linearity, terminal-based
linearity, zero-based
repeatability
reproducibility

5.2 Introduction

Tests described are for determination of static performance characteristics, not dynamic characteristics. When relating performance characteristics such as values of *accuracy* to values of other terms such as *linearity*, *hysteresis*, *dead band*, and *repeatability*, equivalent units must be used.

The *accuracy rating* of the reference measuring means that relates to the characteristics being tested shall preferably be no greater than one tenth the tolerance allowed on the test device, but in any case not greater than one third the allowed tolerance.

Example: *dead band*

Test *device*, allowed *dead band* 0.2%

Measuring *device*, preferred *dead band* 0.02%

Measuring *device*, allowed *dead band* 0.06%

When the *accuracy rating* of the reference measuring means is one tenth or less than that of the *device* under test, the *accuracy rating* of the reference measuring means may be ignored. When the *accuracy rating* of the reference measuring means is one third or less but greater than one tenth that of the *device* under test, the *accuracy rating* of the reference measuring means shall be taken into account.

The *device* under test and the associated test equipment shall be allowed to stabilize under *steady-state operating conditions*. All testing shall be done under these conditions. Those *operating conditions* which would influence the test shall be observed and recorded. Where the performance characteristic being determined requires *reference operating conditions*, the conditions of test shall be maintained at *reference operating conditions*.

The number of test points to determine the desired performance characteristic of a *device* should be distributed over the *range*. They should include points at or near (within 10%) the *lower* and *upper range-values*. There should not be less than five points and preferably more. The number and location of these test points should be consistent with the degree of exactness desired and the characteristic being evaluated.

Prior to recording observations the *device* under test shall be exercised by a number of full range traverses in each direction.

At each point being observed the input shall be held steady until the *device* under test becomes stabilized at its apparent final value.

Tapping or vibrating the *device* under test is not allowed unless the performance characteristic under study requires such action.

5.3 Calibration Cycle

Maintain test conditions and precondition the test device as indicated in the introduction. Observe and record output values for each desired input value for one full range traverse in each direction starting near mid-range value. The final input must be approached from the same direction as the initial input. Apply the input in such a way as to not overshoot each input value.

5.4 Calibration Curve

For the purpose of the following test procedures, the *calibration curve* will be prepared as a "deviation plot." Determine the difference between each observed output value and its corresponding ideal output value. This difference is the *deviation* and may be expressed as a percent of ideal output *span.* The *deviation* is plotted versus input or ideal output. Figure 30 illustrates percent *deviation* plotted versus percent input. A positive *deviation* denotes that the observed output value is greater than the ideal output value.

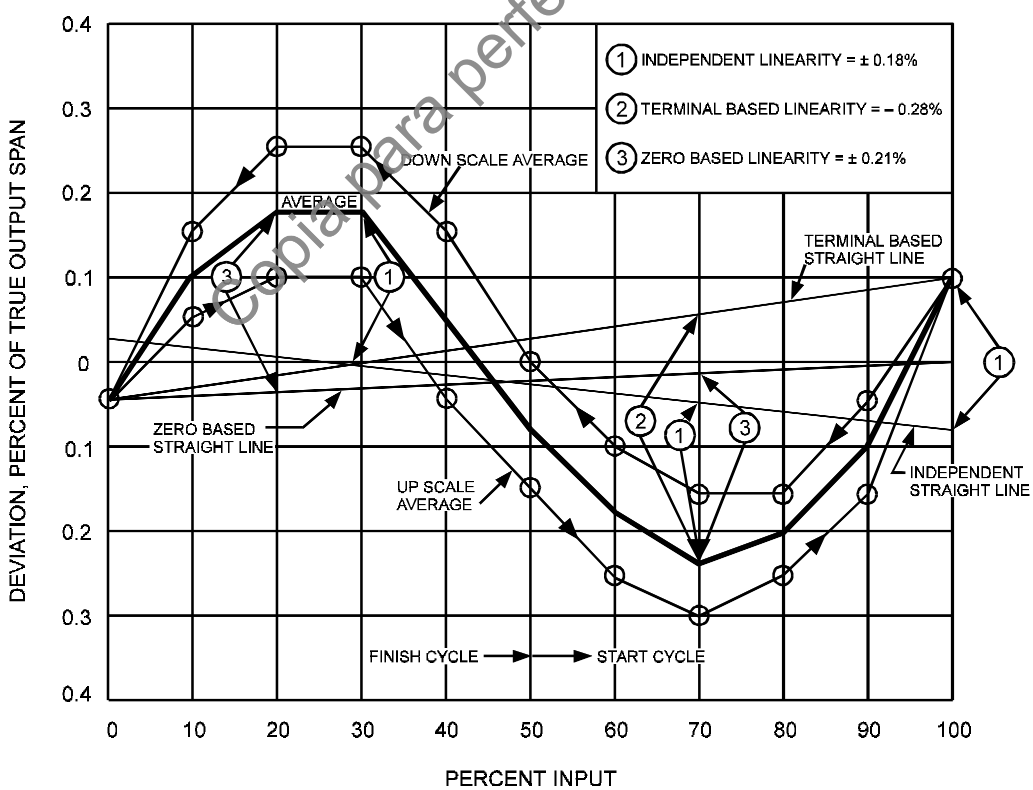

Figure 30 — Calibration curve (of data from table 3)

5.5 Test Procedures

5.5.1 accuracy, measured: *Measured accuracy* may be determined from the *deviation* values (Table 3) of a number of calibration cycles. It is the greatest positive and negative *deviation* of the recorded values (from both an upscale and a downscale output traverse) from the reference or zero *deviation* line. *Measured accuracy* may be expressed as a plus and minus percent of ideal output *span*.

Example: The *measured accuracy* is +0.26%, to –0.32% of output *span*.

5.5.2 dead band: Maintain test conditions and precondition the test *device* as indicated in the introduction and proceed as follows:

1) Slowly vary (increase or decrease) the input to the *device* being tested until a detectable output change is observed.
2) Observe the input value.
3) Slowly vary the input in the opposite direction (decrease or increase) until a detectable output change is observed.
4) Observe the input value.

The increment through which the *input signal* is varied (difference between steps 2 and 4) is the *dead band*. It is determined from a number of cycles (steps 1 thru 4). The maximum value is reported. The *dead band* should be determined at a number of points to make certain that the maximum *dead band* has been observed.

Dead band may be expressed as a percent of input *span*.

Example: The *dead band* is 0.10% of input span.

5.5.3 drift point: Maintain test conditions and precondition the test *device* as indicated in the introduction and proceed as follows:

1) Adjust the input to the desired value without overshoot and record the output value.

NOTE: The test *device* should be permitted to warm up (if required) before recording the initial output value.

2) Maintain a fixed *input signal* and fixed *operating conditions* for the duration of the test.
3) At the end of the specified time interval observe and record the output value.

In evaluating the results of this test it is presumed that *dead band* is either negligible or of such a nature that it will not affect the value of *drift*.

Point drift is the maximum change in recorded output value observed during the test period. It is expressed in percent of ideal output *span* for a specified time period.

Example: The point drift is 0.1% of output *span* for a 24 hour test.

5.5.4 hysteresis: *Hysteresis* results from the inelastic quality of an *element* or *device*. Its effect is combined with the effect of *dead band*. The sum of the two effects may be determined directly from the *deviation* values (Table 3) of a number of test cycles, and is the maximum difference between corresponding upscale and downscale outputs for any single test cycle. *Hysteresis* then is determined by subtracting the value of *dead band* from the corresponding value of *hysteresis* plus *dead band* for a given input. The maximum difference is reported.

The difference may be expressed as a percent of ideal output *span*.

Example: The hysteresis is 0.12% of output span.

Table 3 — Calibration report (see figure 30)

INPUT	ERROR										
	UP ACTUAL	DOWN ACTUAL	UP ACTUAL	DOWN ACTUAL	UP ACTUAL	DOWN ACTUAL	UP ACTUAL	UP AVERAGE	DOWN AVERAGE	UP AVERAGE	AVERAGE ERROR
%	%	%	%	%	%	%	%	%	%	%	%
0		–0.04		–0.05		–0.06			–0.05		–0.05
10		+0.14	+0.04	+0.15	+0.05	+0.16	+0.06		+0.15	+0.05	+0.10
20		+0.23	+0.08	+0.26	+0.09	+0.26	+0.13		+0.25	+0.10	+0.175
30		+0.24	+0.09	+0.25	+0.10	+0.26	+0.11		+0.25	+0.10	+0.175
40		+0.13	–0.07	+0.15	–0.04	+0.17	–0.04		+0.15	–0.05	+0.05
50	–0.18	–0.02	–0.16	+0.01	–0.13	+0.01	–0.13	–0.15	0	–0.15	–0.075
60	–0.27	–0.12	–0.25	–0.10	–0.23	–0.08		–0.25	–0.10		–0.175
70	–0.32	–0.17	–0.30	–0.16	–0.28	–0.12		–0.30	–0.15		–0.225
80	–0.27	–0.17	–0.26	–0.15	–0.22	–0.13		–0.25	–0.15		–0.20
90	–0.16	–0.06	–0.15	–0.05	–0.14	–0.04		–0.15	–0.05		–0.10
100	+0.09		+0.11		+0.10			+0.10			+0.10

Measured Accuracy = +0.26%
–0.32%
Hysteresis plus Dead Band = +0.22%
Repeatability = 0.05%

Note: Accuracy of reference measuring means was not considered in the determination of the average error.

5.5.5 linearity, independent: *Independent linearity* may be determined directly from the *calibration* curve, (Figure 30) using the following procedure:

1) Plot a *deviation* curve which is the average of corresponding upscale and downscale output readings.

2) Draw a straight line through the average *deviation* curve in such a way as to minimize the maximum *deviation*. It is not necessary that the straight line be horizontal or pass through the end points of the average *deviation* curve.

Independent linearity is the maximum *deviation* between the average *deviation* curve and the straight line. It is determined from the *deviation* plots of a number of calibration cycles. It is measured in terms of independent nonlinearity as a plus or minus percent of ideal output *span*.

Example: The ideal *independent linearity* is ±0.18% of output *span*.

> **NOTE:** The average *deviation* curve is based on the average of corresponding upscale and downscale readings. This permits observation of *independent linearity* independent of *dead band* or *hysteresis*. This concept assumes that if no *hysteresis* or *dead band* were present the *deviation* curve would be a single line midway between upscale and downscale curves.

5.5.6 linearity, terminal-based: *Terminal-based linearity* may be determined directly from the *calibration curve* (Figure 30) using the following procedure:

1) Plot a *deviation* curve which is the average of corresponding upscale and downscale output readings.

2) Draw a straight line such that it coincides with the average *deviation* curve at the *upper range-value* and the *lower range-value*.

Terminal-based linearity is the maximum *deviation* between the average *deviation* curve and the straight line. It is determined from the *deviation* plots of a number of calibration cycles. It is measured in terms of terminal based nonlinearity as a plus and minus percent of ideal output *span*.

Example: The *terminal-based linearity* is 0.28% of output *span*.

> **NOTE:** The average *deviation* curve is based on the average of corresponding upscale and downscale readings. This permits observation of *terminal-based linearity* independent of *dead band* or *hysteresis.* This concept assumes that if no *hysteresis* or *dead band* were present, the *deviation* curve would be a single line midway between upscale and downscale readings.

5.5.7 linearity, zero-based: *Zero-based linearity* may be determined directly from the calibration curve (Figure 30) using the following procedure:

1) Plot a *deviation* curve which is the average of corresponding upscale and downscale output readings.

2) Draw a straight line such that it coincides with the average *deviation* curve at the *lower range-value* (zero) and minimizes the maximum deviation.

Zero-based linearity is the maximum *deviation* between the average *deviation* curve and the straight line. It is determined from the *deviation* plots of a number of calibration cycles. It is measured in terms of zero-based linearity as a plus or minus percent of ideal output *span*.

Example: The *zero-based linearity* is ±0.21% of output *span*.

> **NOTE:** The average *deviation* curve is based on the average of corresponding upscale and downscale readings. This permits observation of *zero-based linearity* independent of *dead band* or *hysteresis*. This concept assumes that if no *hysteresis* or *dead band* were present, the *deviation* curve would be a single line midway between upscale and downscale readings.

5.5.8 repeatability: *Repeatability* may be determined directly from the *deviation* values (Table 3) of a number of calibration cycles. It is the closeness of agreement among a number of consecutive measurements of the output for the same value of input approached from the same direction. Fixed *operating conditions* must be maintained.

Observe the maximum difference in percent *deviation* for all values of output considering upscale and downscale curves separately. The maximum value from either upscale or downscale curve is reported.

Repeatability is the maximum difference in percent *deviation* observed above and is expressed as a percent of output *span.*

Example: The *repeatability* is 0.05% of output *span*.

5.5.9 reproducibility

1) Perform a number of calibration cycles as described in Section 5.3.

2) Prepare a calibration curve based on the maximum difference between all upscale and downscale readings for each input observed. The *deviation* values are determined from the number of calibration cycles performed for step 1 above. See *Section 5.4*.

3) Maintain the test device in its regular operating condition, energized and with an *input signal* applied.

4) At the end of the specified time repeat steps 1 and 2.

The test *operating conditions* may vary over the time interval between measurements providing they stay within the *normal operating conditions* of the test *device*. Tests under step 4 above must be performed under the same *operating conditions* that existed for the initial tests.

Reproducibility is the maximum difference between recorded output values (both upscale and downscale) for a given input value. Considering all input values observed, the maximum difference is reported. The difference is expressed as a percent of output *span* per specified time interval.

Example: The *reproducibility* is 0.2% of output *span* for a 30 day test.

6 References

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