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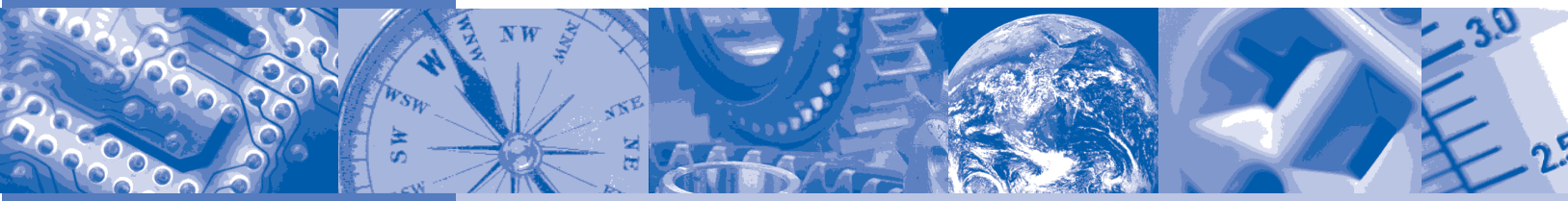

Process Instrumentation Terminology

Reaffirmed 26 May 1995

ISA–The Instrumentation, Systems, and Automation Society

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ANSI/ISA-51.1-1979 (R1993), Process Instrumentation Terminology

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Preface

This Preface is included for informational purposes and is not part of ANSI/ISA-51.1-1979 (R1993).

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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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.

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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

Operating Conditions	Performance
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.)

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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.*

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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.*

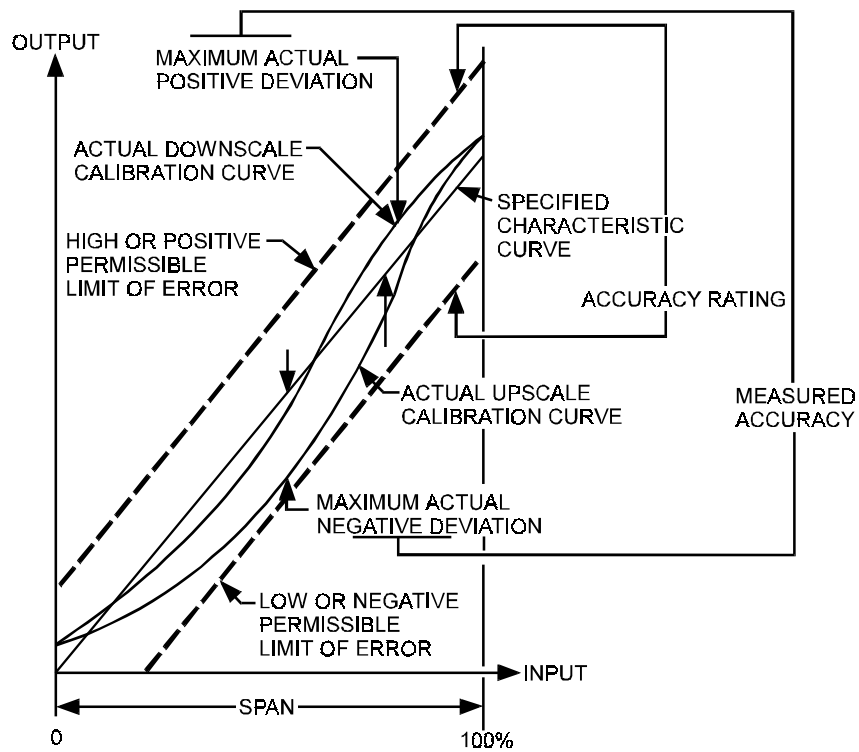

Figure 1 — Accuracy

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.)

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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)

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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)

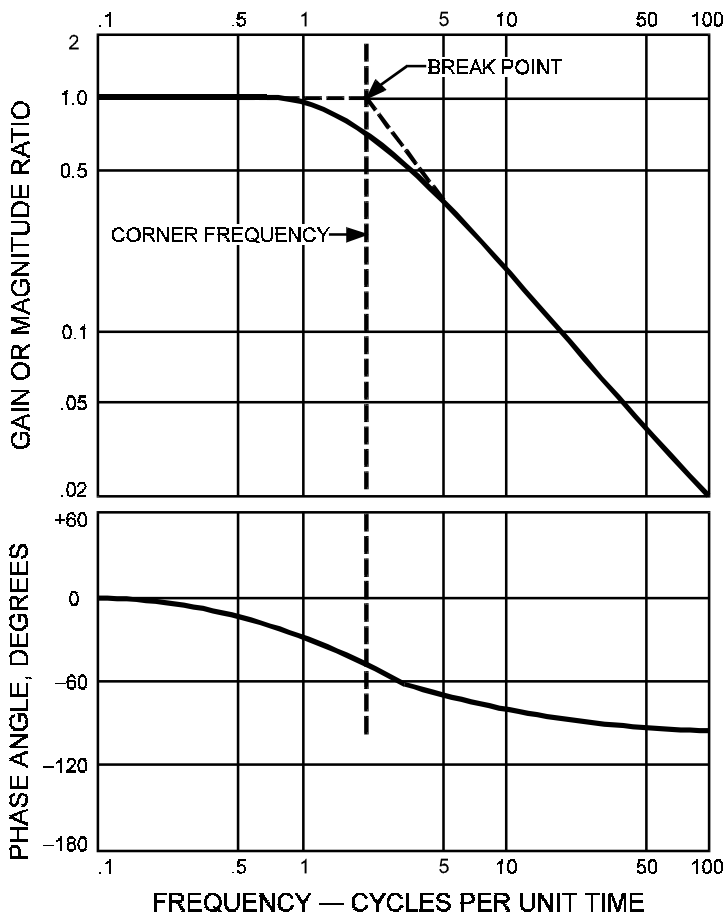

Figure 2 — Typical Bode diagram

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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)

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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)

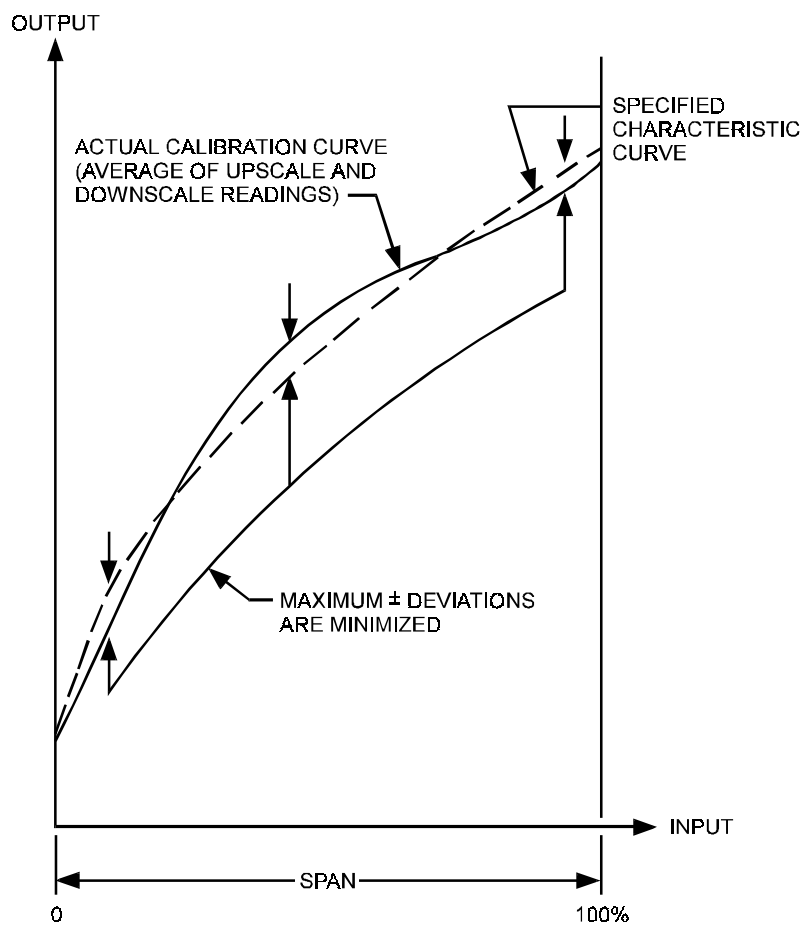

Figure 3 — Independent conformity

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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)

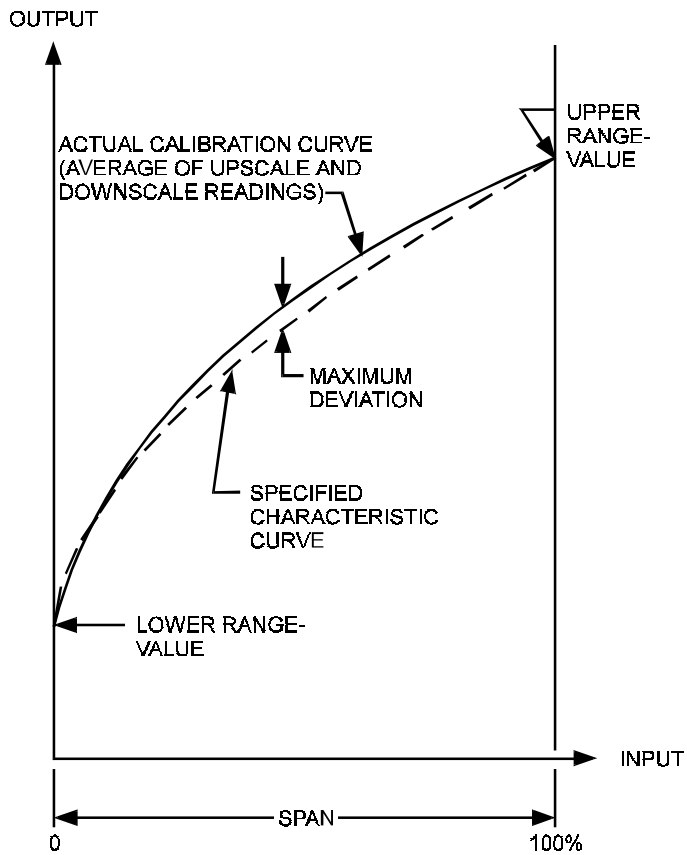

Figure 4 — Terminal-based conformity

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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)

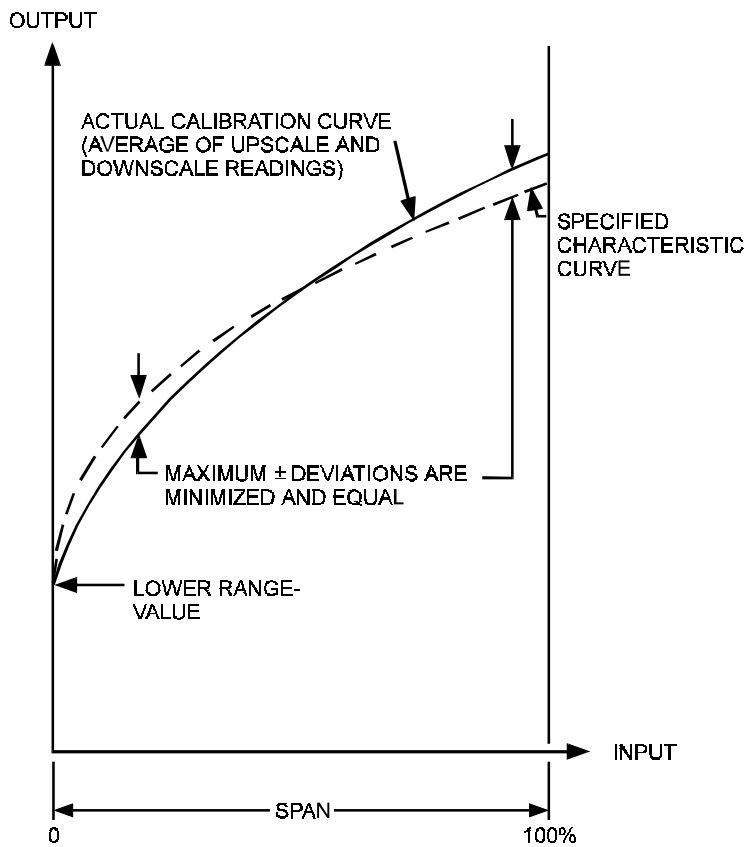

Figure 5 — Zero-based conformity

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

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

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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*.

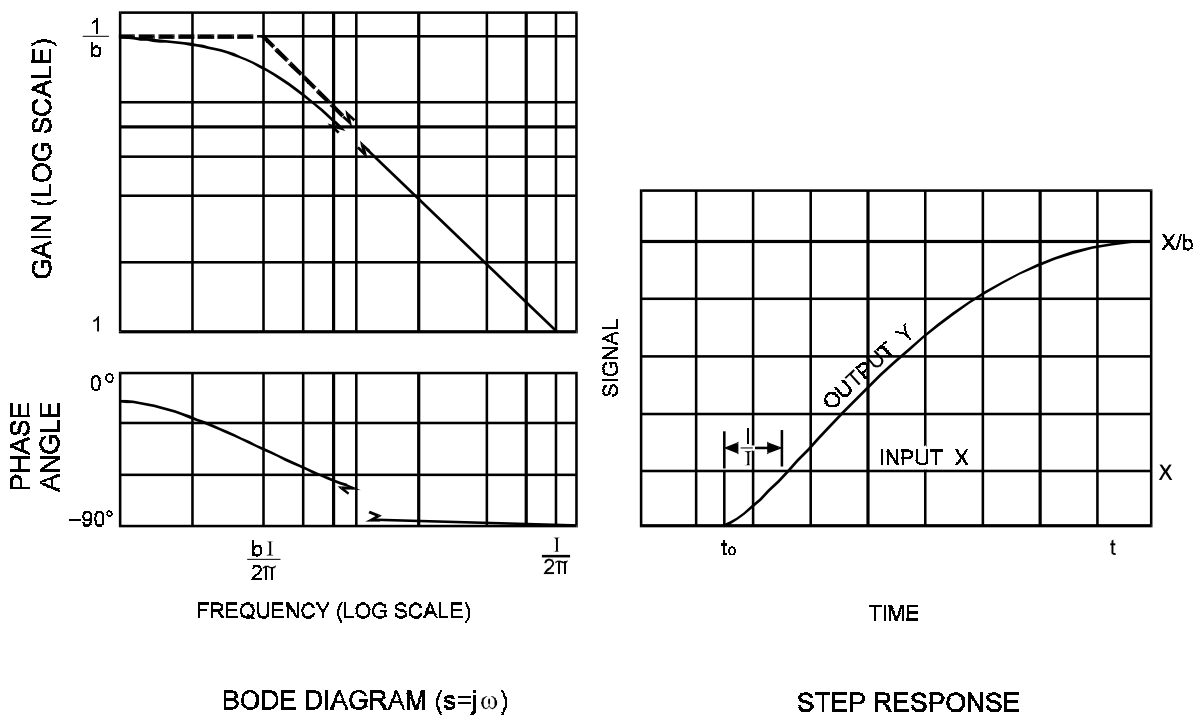

Figure 6 — Integral control action

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*.

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

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

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*.

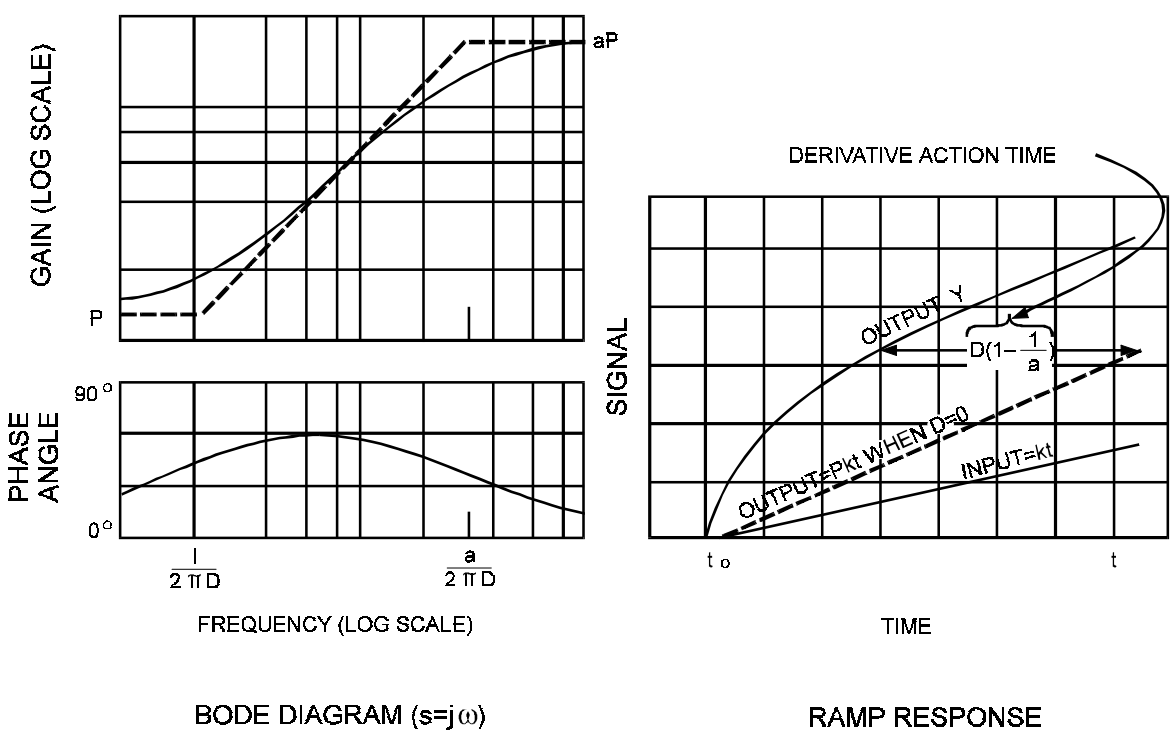

Figure 7 — Proportional plus derivative control action

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,

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

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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*.

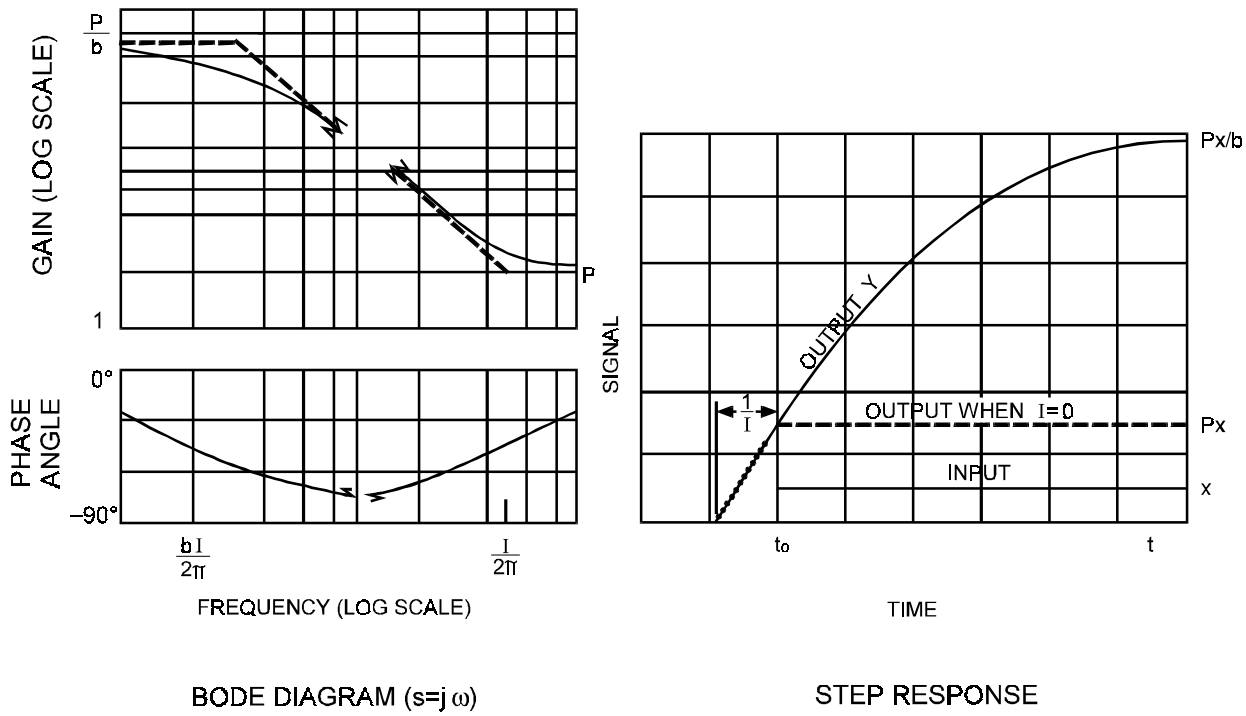

Figure 8 — Proportional plus integral control action

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*

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