SLOVENSKI STANDARD
SIST EN 60546-1:1998

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Controllers with analogue signals for use in industrial-process control systems - Part 1: Methods of evaluating the performance (IEC 60546-1:1987)

Controllers with analogue signals for use in industrial-process control systems -- Part 1: Methods of evaluating the performance

Regler mit analogen Signalen für die Anwendung in Systemen der industriellen Prozeßtechnik -- Teil 1: Methoden der Beurteilung des Betriebsverhaltens

Régulateurs à signaux analogiques utilisés pour les systèmes de conduite des processus industriels -- Partie 1: Méthodes d'évaluation des performances

Ta slovenski standard je istoveten z: **EN 60546-1:1993**

ICS:

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SIST EN 60546-1:1998 **en**

EUROPEAN STANDARD

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ENGLISH VERSION

Controllers with analogue signals for use in industrial-process control systems Part 1: Methods of evaluating the performance (IEC 546-1:1987)

Régulateurs à signaux analogiques utilisés pour les systèmes de conduite des processus industriels Première partie: Méthodes d'évaluation des performances (CEI 546-1:1987)

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This European Standard was approved by CENELEC on 1993-03-09. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B-1050 Brussels

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FOREWORD

At the request of CENELEC Reporting Secretariat SR 65B, HD 530.1 S1:1989 (IEC 546-1:1987) was submitted to the CENELEC voting procedure for conversion into a European Standard.

The text of the International Standard was approved by CENELEC as EN 60546-1 on 9 March 1993.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1994-03-01
- latest date of withdrawal of conflicting national standards (dow) -

Annexes designated "normative" are part of the body of the standard. In this standard, annex ZA is normative.

ENDORSEMENT NOTICE

The text of the International Standard IEC 546-1:1987 was approved by CENELEC as a European Standard without any modification.

Editorial modification to IEC 546-1:1987

In 3.1, the equation (3) shall read as follows:

$$y - y_0 = K'_{\mathrm{P}} A \left[(x - w) + \frac{1}{A T'_{\mathrm{I}}} \int_0^t (x - w)\, dt + \frac{T'_{\mathrm{D}}\, d(x - w)}{A\, dt} \right]$$

ANNEX ZA (normative)

OTHER INTERNATIONAL PUBLICATIONS QUOTED IN THIS STANDARD WITH THE REFERENCES OF THE RELEVANT EUROPEAN PUBLICATIONS

When the international publication has been modified by CENELEC common modifications, indicated by (mod), the relevant EN/HD applies.

IEC Publication	Date	Title	EN/HD	Date
27-2A	1975	Letter symbols to be used in electrical technology - Part 2: Telecommunications and electronics - First supplement	HD 245.2 S1*	1983
50(351)	1975	International Electrotechnical Vocabulary (IEV) - Part 351: Automatic control	-	-
68-2-1	1974	Environmental testing Part 2: Tests - Tests A: Cold	HD 323.2.1 S2*	1987
68-2-3	1969	Test Ca: Damp heat, steady state	HD 323.2.3 S2*	1987
68-2-6	1982	Test Fc and guidance: Vibration (sinusoidal)	HD 323.2.6 S2*	1988
68-2-31	1969	Test Ec: Drop and topple, primarily for equipment-type specimens	EN 60068-2-31*	1993
160	1963	Standard atmospheric conditions for test purposes	-	-
348	1978	Safety requirements for electronic measuring apparatus	HD 401 S1	1980
381*	-	Analogue signals for process control systems	-	-
382	1971	Analogue pneumatic signal for process control systems	-	-
801-3	1984	Electromagnetic compatibility for industrial-process measurement and control equipment - Part 3: Radiated electromagnetic field requirements	HD 481.3 S1	1987

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* HD 245.2 S1 is based on IEC 27-2:1972 + IEC 27-2A:1975 + IEC 27-2B:1980
HD 323.2.1 S2 is superseded by EN 60068-2-1:1993 + A1:1993 which are based on IEC 68-2-1:1990 + A1:1993
HD 323.2.3 S2 includes A1:1984 to IEC 68-2-3
HD 323.2.6 S2 includes A1:1983 + A2:1985 to IEC 68-2-6
EN 60068-2-31 includes A1:1982 to IEC 68-2-31
IEC 381-1:1982 is harmonized as HD 452.1 S1:1984

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Régulateurs à signaux analogiques utilisés pour les systèmes de conduite des processus industriels

Première partie: Méthodes d'évaluation des performances

Controllers with analogue signals for use in industrial-process control systems

Part 1: Methods of evaluating the performance

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.

2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.

3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by Sub-Committee 65B: Elements of Systems, of IEC Technical Committee No. 65: Industrial-process Measurement and Control.

This second edition replaces the first edition of IEC Publication 546 issued in 1976.

The text of this standard is based on the following documents:

Six Months' Rule	Report on Voting
65B(CO)43	65B(CO)52

Full information on the voting for the approval of this standard can be found in the Voting Report indicated in the above table.

The following IEC publications are quoted in this standard:

Publications Nos. 27-2A (1975): Letter Symbols to Be Used in Electrical Technology, Part 2: Telecommunications and Electronics, First Supplement.
50(351) (1975): International Electrotechnical Vocabulary (IEV), Chapter 351: Automatic Control.
68-2-1 (1974): Basic Environmental Testing Procedures, Part 2: Tests — Tests A: Cold.
68-2-3 (1969): Test Ca: Damp Heat, Steady State.
68-2-6 (1982): Test Fc and Guidance: Vibration (Sinusoidal).
68-2-31 (1969): Test Ec: Drop and Topple, Primarily for Equipment-type Specimens.
160 (1963): Standard Atmospheric Conditions for Test Purposes.
348 (1978): Safety Requirements for Electronic Measuring Apparatus.
381: Analogue Signals for Process Control Systems.
382 (1971): Analogue Pneumatic Signal for Process Control Systems.
801-3 (1984): Electromagnetic Compatibility for Industrial-process Measurement and Control Equipment, Part 3: Radiated Electromagnetic Field Requirements.

CONTROLLERS WITH ANALOGUE SIGNALS FOR USE IN INDUSTRIAL-PROCESS CONTROL SYSTEMS

Part 1: Methods of evaluating the performance

INTRODUCTION

The methods of evaluation given in this standard are intended for use by manufacturers to determine the performance of their products and by users, or independent testing establishments, to verify manufacturers' performance specifications.

Part 2 of the standard, IEC Publication 546-2, describes a limited series of tests which may be used as acceptance tests.

The test conditions specified in this standard, for example the range of ambient temperatures, power supply, etc., shall be used when no other values are agreed upon by the manufacturer and the user.

The tests specified in this standard are not necessarily sufficient for instruments specifically designed for unusually arduous duties. Conversely, a restricted series of tests may be suitable for instruments designed to perform within a limited range of conditions.

It will be appreciated that the closest liaison should be maintained between an evaluating body and the manufacturer. Note shall be taken of the manufacturer's specifications for the instrument when the test program is being decided, and the manufacturer should be invited to comment on both the test program and the results. His comments on the results should be included in any report produced by the testing organization.

1. Scope

This standard applies to pneumatic and electric industrial-process controllers using analogue continuous input and output signals which are in accordance with current international standards.*

It should be noted that while the tests specified herein cover controllers having such signals, they can be applied in principle to controllers having different but continuous signals. These methods of evaluation may also be employed on devices which internally use digital concepts and elements provided the input and output signals are conventional analogue signals.

2. Object

This standard is intended to specify uniform methods of test for evaluating the performance of industrial-process controllers with analogue input and output signals.

When a full evaluation in accordance with this standard is not required, those tests which are required shall be performed and the results reported in accordance with those parts of the standard which are relevant. The testing program should be subject to an agreement between manufacturer and user, depending on the nature and the extent of the equipment under consideration.

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* IEC Publications 381 and 382.

3. Basic relations

3.1 *Input/output relations of idealized controllers*

In the most simple form, the relationship may be given by an equation generally presented in one of the following forms:

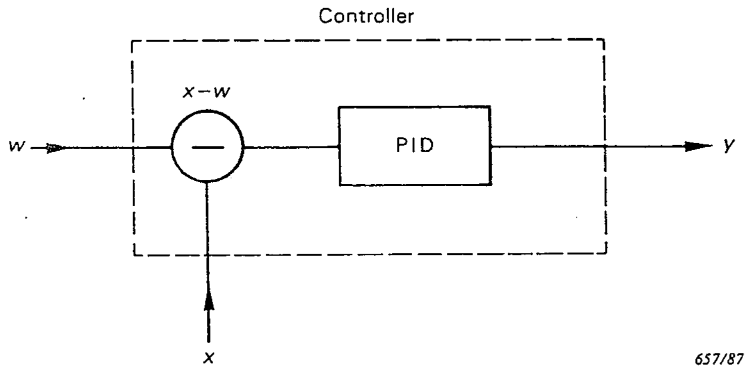

FIG. 1. — Basic signals to/from an idealized controller.

$$y - y_0 = K_p (x - w) + K_I \int_0^t (x - w)\, dt + K_D \frac{d(x - w)}{dt} \qquad (1)$$

$$y - y_0 = K_p \left[(x - w) + \frac{1}{T_I} \int_0^t (x - w)\, dt + T_D \frac{d(x - w)}{dt} \right] \qquad (2a)$$

or in the frequency domain:

$$F(j\omega) = K_p \left[1 + \frac{1}{j\omega T_I} + j\omega T_D \right] \qquad (2b)$$

These equations are valid for controllers with no interaction between the factors K_p, K_I and K_D. The equation for idealized controllers with interaction taken into account may be written as:

$$y - y_0 = K'_p A \left[(x - w) \frac{1}{A T'_I} \int_0^t (x - w)\, dt + \frac{T'_D\, d(x - w)}{A\, dt} \right] \qquad (3)$$

In this equation, A is the interaction factor that depends on the structure of the controller. It can often be written as:

$$A = 1 + \frac{T'_D}{T'_I} \quad (4a); \qquad K'_p = \frac{K_p}{A} \quad (4b);$$

$$T'_I = \frac{T_I}{A} \quad (4c); \qquad T'_D = A\, T_D \quad (4d).$$

where:

t = time
y = output signal (correcting variable (see note 1))
y_0 = output signal at time $t = 0$ (controller output balance)
x = measured value (controlled variable (see note 1))
w = set point value (reference input variable (see note 1))
K_p = proportional action factor (proportional-action coefficient (see note 2))
K_I = integral action factor (integral-action coefficient (see note 2))
K_D = derivative action factor (derivative-action coefficient (see note 2))
T_I = reset time
T_D = rate time
x and/or w and consequently also y can be functions of time t
$j = \sqrt{-1}$
ω = angular velocity
$\frac{d}{dt}$ = differential operator

Notes 1. — Definitions of terms in parentheses are given in IEC Publication 27-2A.

2. — Definitions of terms in parentheses are given in IEC Publication 50 (351).

3. — This standard is limited to P, PI, PD or PID controllers.

4. — The factors K_p, K_I and K_D may have the sign "plus" or "minus"; it is usual to associate "direct action" with the positive sign and "reverse action" with the negative sign.

5. — Symbols with prime (K'_p, T'_I, T'_D) represent nominal values, in contrast to effective values.

6. — Integral-action time constant and derivative-action time constant refer only to pure integral or derivative-action controllers (IEC Publication 50 (351)).

There are controllers with still other structures, for example where the differentiation is applied only to the measured value x, not to $(x - w)$.

Equation (3) becomes thereby:

$$y - y_0 = K'_p A \left[(x - w) + \frac{1}{A T'_I} \int_0^t (x - w)\, dt + \frac{T'_D}{A} \frac{d}{dt}(x) \right] \quad (5)$$

3.2 *Limitations*

The equations describing the performance of an actual controller are usually different from equations (1) to (5) because they include time constants and limitations.

Two commonly encountered deviations from the idealized controller equations can be expressed as follows:

a) Maximum integral gain V_I

Because of the finite integral gain of actual controllers, the integral part of equations (1) and (2) is an approximation of the actual response only for sufficiently high frequencies. For low frequencies, a controller may have an integral action [integral term of equation (2b)] expressed in the frequency domain as follows:

$$F(j\omega) = K_p \frac{V_I}{1 + j\omega T_I V_I} \quad (6)$$

b) Maximum derivative gain V_D

Because of the limited derivative gain of actual controllers, the derivative terms of equations (1) and (2) are an approximation of the actual response only for sufficiently low frequencies. In the most simple case, there may be additional time constant and proportional terms.

The derivative term of equation (2b) may then be expressed, in the frequency domain, as follows:

derivative action and time constant

$$F(j\omega) = \frac{j\omega T_D}{1 + j\omega T} \qquad (7)$$

or

proportional action, derivative action and time constant

$$F(j\omega) = K_p \frac{1 + j\omega T_D}{1 + j\omega T} \qquad (8)$$

where:

T = time constant of a first order time delay

The ratio $\frac{T_D}{T}$ may be constant for all adjustable values of T_D (depending upon the design of the controller). The ratio $\frac{T_D}{T}$ is then called maximum derivative gain or V_D.

3.3 *Dial graduation of controllers*

The action factors and action times as used in the equations shown above give an idealized description of the performance of a controller. Their values may differ from the values which are the graduations marked on the dials of the controller. The relationship between the dial graduations and the effective values, i.e. the "interaction formula", shall be provided by the manufacturer. The relationship may be expressed in algebraic form or by graphs, tables, diagrams, etc.

4. Definitions

4.1 *Proportional band*

The proportional band X_p of a linear controller, expressed in per cent, is given by the expression:

$$X_p = \frac{100}{K_p} \qquad (9)$$

4.2 *Direct acting*

Output y increases with increase in the measured value x.

4.3 *Reverse acting*

Output y decreases with increase in the measured value x.

4.4 *Offset*

The steady-state deviation between measured value x and set point w.

4.5 *Controller, proportional (P)*

A controller which produces proportional control action only.

4.6 *Controller, proportional plus derivative (rate) (PD)*

A controller which produces proportional plus derivative control action.

4.7 *Controller, proportional plus integral (reset) (PI)*

A controller which produces proportional plus integral control action.