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# INTERNATIONAL STANDARD

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**Process measurement and control devices – General methods and procedures for evaluating performance –**
**Part 2: Tests under reference conditions**

**Dispositifs de mesure et de commande de processus – Méthodes et procédures générales d'évaluation des performances –**
**Partie 2: Essais dans les conditions de référence**

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# PROCESS MEASUREMENT AND CONTROL DEVICES – GENERAL METHODS AND PROCEDURES FOR EVALUATING PERFORMANCE –

## Part 2: Tests under reference conditions

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International Standard IEC 61298-2 has been prepared by subcommittee 65B: Devices and process analysis, of IEC technical committee 65: Industrial-process measurement, control and automation.

This second edition cancels and replaces the first edition published in 1995 and constitutes a technical revision.

This edition is a general revision with respect to the previous edition and does not include any significant changes (see Introduction).

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

| FDIS | Report on voting |
|---|---|
| 65B/686/FDIS | 65B/694/RVD |

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

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61298 series, under the general title *Process measurement and control devices – General methods and procedures for evaluating performance*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

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# INTRODUCTION

This standard is not intended as a substitute for existing standards, but is rather intended as a reference document for any future standards developed within the IEC or other standards organizations, concerning the evaluation of process instrumentation. Any revision of existing standards should take this standard into account.

This common standardized basis should be utilised for the preparation of future relevant standards, as follows:

– any test method or procedure, already treated in this standard, should be specified and described in the new standard by referring to the corresponding clause of this standard. Consequently new editions of this standard are revised without any change in numbering and scope of each clause;
– any particular method or procedure, not covered by this standard, should be developed and specified in the new standard in accordance with the criteria, as far as they are applicable, stated in this standard;
– any conceptual or significant deviation from the content of this standard, should be clearly identified and justified if introduced in a new standard.

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# PROCESS MEASUREMENT AND CONTROL DEVICES – GENERAL METHODS AND PROCEDURES FOR EVALUATING PERFORMANCE –

## Part 2: Tests under reference conditions

## 1 Scope

This part of IEC 61298 specifies general methods and procedures for conducting tests and reporting on the functional and performance characteristics of process measurement and control devices. The tests are applicable to any such devices characterized by their own specific input and output variables, and by the specific relationship (transfer function) between the inputs and outputs, and include analogue and digital devices. For devices that require special tests, this standard should be used, together with any product specific standard specifying special tests.

This standard covers tests made under reference conditions.

## 2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-300, *International Electrotechnical Vocabulary (IEV) – Electrical and electronic measurements and measuring instruments (composed of Part 311, 312, 313 and 314)*

IEC 60050-351, *International Electrotechnical Vocabulary (IEV) – Part 351 : Control technology*

IEC 61298-1, *Process measurement and control devices – General methods and procedures for evaluating performance – Part 1: General considerations*

IEC 61010-1, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

## 3 Terms and definitions

For the purpose of this document, the following relevant terms and definitions, some of them based on IEC 60050(300) or IEC 60050(351), apply.

**3.1**
**variable**
quantity or condition whose value is subject to change and can usually be measured (e.g., temperature, flow rate, speed, signal, etc.)
[IEV 351-21-01, modified]

**3.2**
**signal**
physical quantity, one or more parameters of which carry information about one or more variables which the signal represents
[IEV 351-21-51, modified]

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**3.3**
**range**
range of values defined by the two extreme values within which a variable can be measured within the specified accuracy
[IEV 351-27-11, modified]

**3.4**
**span**
algebraic difference between the values of the upper and lower limits of the measuring range
[IEV 311-03-13]

**3.5**
**inaccuracy**
maximum positive and negative deviation from the specified characteristic curve observed in testing a device under specified conditions and by a specified procedure

NOTE 1 Accuracy is defined in IEC 60050-300, definition 311-06-08.

NOTE 2 The term inaccuracy is sometime referred to as measured accuracy. This term should not be used.

**3.6**
**error**
algebraic difference between the indicated value and a comparison value of the measured variable
[IEV 351-27-04, modified]

NOTE The error is positive when the indicated value is greater than the comparison value. The error is generally expressed as a percentage of the relevant ideal span.

**3.7**
**measured error**
largest positive or negative value of errors of the average upscale or downscale values at each point of measurement

**3.8**
**non-conformity**
the closeness with which a calibration curve approximates to a specified characteristic curve (which can be linear, logarithmic, parabolic, etc.)

NOTE Non-conformity does not include hysteresis.

**3.9**
**non-linearity**
deviation from linearity

NOTE 1 Linearity is defined in IEC 60050(300), definition 311-06-05.

NOTE 2 Non-linearity does not include hysteresis.

**3.10**
**non-repeatability**
deviation from repeatability

NOTE Repeatability is defined in IEC 60050(300), definition 311-06-06.

**3.11**
**hysteresis**
property of a device or instrument whereby it gives different output values in relation to its input values depending on the directional sequence in which the input values have been applied
[IEV 351-24-15, modified]

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**3.12**
**dead band**
finite range of values within which a variation of the input variable does not produce any measurable change in the output variable
[IEV 351-24-14, modified]

**3.13**
**dead-time**
time interval between the instant when a variation of an input variable is produced, and the instant when the subsequent variation of the output variable starts
[IEV 351-28-41]

(see IEC 60050-351, Figure 5)

**3.14**
**rise time**
for a step response, the duration of the time interval between the instant when the output variable (starting from zero) reaches a small specified percentage (for instance 10 %) of the final steady-state value, and the instant when it reaches for the first time a large specified percentage (for instance 90 %) of the same difference
[IEV 394-39-11, modified]

(see IEC 60050-351, Figure 3)

**3.15**
**settling time**
time interval between the instant of the step change of an input variable, and the instant when the output variable does not deviate by more than a specified tolerance from its final steady state value (see IEC 60050-351, Figure 3). For this standard, a tolerance of 1 % is adopted
[IEV 351-24-29]

**3.16**
**step response time**
time interval between the instant of a step change in the input variable and the instant when the output variable reaches for the first time a specified percentage of the difference between the final and the initial steady state value (see IEC 60050-351, Figure 3). For this standard , a specified percentage of 90 % is adopted
[IEV 351-24-28]

**3.17**
**time constant**
time required to complete 63,2 % of the total change of the output of a first-order linear system, produced by a step variation of the input variable
[IEV 351-24-24]

**3.18**
**test procedure**
statement of the tests to be carried out, and the conditions for each test, agreed between the manufacturer, the test laboratory, and the purchaser/user before the evaluation starts

**3.19**
**type tests**
a test of one or more devices made to a certain design to show that the design meets certain specifications

NOTE The type tests are in principle applied only on a sample. Normally are not repeated on all the individual units of equipment made in series.

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**3.20**
**performance evaluation**
a complete test to establish the performance of a device under any likely operating conditions to permit comparison with the manufacturer's published or stated performance specification for the device, or the user's requirements

**3.21**
**routine test**
a simplified test to which each individual instrument is subjected during or after manufacture to ascertain whether it complies with certain criteria

**3.22**
**sample test**
a simplified test to check specific characteristics of a device

# 4 Accuracy related factors

## 4.1 Test procedures and precautions

### 4.1.1 Selection of ranges for test

Where there are switched ranges or dial settings (e.g., gain), the tests shall be repeated to cover all ranges or settings. When the Device Under Test (DUT) is supplied calibrated for use, the first set of tests shall be carried out without adjustment.

#### 4.1.1.1 Criteria

The measurements shall be performed with the devices operating at the minimum number of calibration settings necessary to establish the device performance in all required operational settings required by the test programme (see Clause 5 of IEC 61298-1).

Testing of a device which has provision for substantial adjustment of both span and lower range value may require an impractically large number of tests. In such a case, preliminary tests shall be conducted to determine the effect of changing span and lower range value adjustments on the characteristic being measured. This should enable some tests to be eliminated from the test programme in cases where the characteristic can be inferred reliably from fewer tests. For example, hysteresis may not be significantly affected by selection of the lower and upper range value if the span is held constant, and often may be inferred for different spans from measurements at a single span setting.

However, the report shall indicate clearly relevant values of the measured parameters for each setting of the adjustments, so that the values of inaccuracy, hysteresis, etc, can all be referenced to the same adjustment of the device.

#### 4.1.1.2 Setting of span and lower range value adjustments

Generally, unless otherwise specified in the test programme, the test for accuracy related factors shall be carried out with the adjustments set at the settings A, B, C, D, listed below, and in accordance with Table 1 whenever the span and/or the lower range value adjustments are adjustable further than the adjustments for the manufacturing tolerances.

NOTE For tests of dynamic behaviour, functional characteristics, and drift, refer to the appropriate clauses of this standard.

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**Table 1 – Settings of span and lower range value adjustments**

| Kind of test | | Adjustable span | Zero suppression and/or elevation |
|---|---|---|---|
| Complete Tests | Performance evaluation | A | B |
| | Type test | | |
| Simplified Tests | Routine tests | C | D |
| | Sample test | | |

Setting A – Span adjustment set at the maximum and minimum values specified by the manufacturer, and at one intermediate value.

Setting B – Normally, tests will be done at only one setting of lower range value, without suppression or elevation, but further tests at minimum and maximum settings may be required if the effects are significant.

Setting C – Unless otherwise specified in the test programme, the span shall be as set by the manufacturer.

Setting D – Unless otherwise specified in the test programme, the lower range value shall be as set by the manufacturer.

#### 4.1.2 Preconditioning cycles

Prior to recording observations, the DUT shall be preconditioned (see 7.12 of IEC 61298-1) and shall be exercised by three full range traverses in each direction.

#### 4.1.3 Number of measurement cycles and test points

The performance of the DUT shall be verified over the full range for increasing and decreasing values.

Taking into account the economic aspects outlined in 5.2 of IEC 61298-1, the number of measurement cycles and of test points shall be the lowest possible. The number and location of the test points shall be consistent with the kind of test, the degree of accuracy desired, and the characteristic being evaluated.

The number of increasing and decreasing test points shall be the same for each pre-determined test point, with the exception of 0 % and 100 %, that are reached only when going downscale or upscale.

The number of measurement cycles and the number of the test points depend on the kind of test under consideration. Unless otherwise specified for a particular type of device, the values and locations that should be adopted are given in Table 2.

#### 4.1.4 Additional tests where digital inputs and outputs are provided

Tests shall be made to ensure that the protocols comply with international standards (e.g., RS 232, IEEE 488) or the protocols fully specified by the DUT supplier. Tests shall be carried out to confirm that the DUT functions correctly to the specified protocol under reference conditions, and without error (or within any error rate specified by the supplier). The levels of logical "1" and "0" shall be determined. Appropriate tests shall also be made for display errors (missing digit sections, etc.), brightness, contrast, and angle of view before loss of brightness/contrast. The update rate shall be recorded, together with display (accuracy) errors.

#### 4.1.5 Measurement procedure

The first measurement shall be performed to the first significant value of the scale after 0 % of input span (e.g., 10 % of input span – see Table 2).

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Initially, an input signal equal to the lower range value is generated, and then the input signal is slowly increased to reach, without overshoot, the first test point; after an adequate stabilization period, the value of the corresponding input and output signal is noted.

Then the input signal is slowly increased to reach, without overshoot, the value of the next test point and, after a stabilization period, the corresponding value of the output signal is recorded.

The operation is repeated for all the predetermined values up to 100 % of the input span. After measurement at this point, the input signal is slowly brought down to the test value directly below 100 % of input span, and then to all the other values in turn down to 0 % of input span, thus closing the measurement cycle.

**Table 2 – Number of measurement cycles and number and location of test points**

| Kind of test | | Number of measurement cycles | Number of test points | Location of test points (% of input span) |
|---|---|---|---|---|
| Complete Tests | Performance evaluation | 3 or 5 | 6 | 0-20-40-60-80-100 |
| | Type tests | | 11 | 0-10-20-30-40-50-60-70-80-90-100 |
| Simplified Tests | Routine tests | 1 | 5 | 0-25-50-75-100 |
| | Sample tests | | | |

### 4.1.6 Processing of the measured values

The difference between the output signal values obtained at the various test points for each upscale and downscale traverse and the corresponding ideal values are recorded as the output errors.

The errors generally shall be expressed as percent of the ideal output span. On certain devices (e.g., recorders, or devices with adjustable gain), it may be more convenient to express the errors as percent of nominal input span (see 7.16 of IEC 61298-1).

For each measuring point, the readings obtained in successive cycles for upscale and downscale error, respectively, shall be averaged to give average upscale and downscale values, and these averaged to give the average value at that point.

All the error values thus obtained shall be shown in a table (see Table 3), and the average values shall be presented graphically (see Figure 1).

### 4.1.7 Determination of accuracy related factors

Because of the limited number of measurements (see 4.1.3), the accuracy related factors shall be determined by treating the errors in a mathematically simple way, and not on the basis of statistical methods. The different methods of treatment are described in the following clauses.

#### 4.1.7.1 Inaccuracy

Inaccuracy is determined from Table 3 by selecting the greatest positive and negative deviations of any measured value from the ideal value for increasing and decreasing inputs for any test cycle separately, and reporting this in percent of ideal output span.

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#### 4.1.7.2 Maximum measured error

Maximum measured error is determined from table 3 by selecting the greatest positive or negative value from the average upscale errors and the average downscale errors.

#### 4.1.7.3 Non-linearity

For devices that have a linear input/output relationship, the non-linearity is determined from the curve plotted using the overall average of corresponding upscale and downscale average errors (see Table 3 and Figure 1).

The maximum positive or negative deviation between the average curve and the selected straight line, expressed in percent of ideal output span, is the non-linearity, and is independent of dead band and hysteresis.

a) *Terminal based non-linearity*

Terminal based non-linearity is determined by drawing a straight line so that it coincides with the average calibration curve at the upper range value and at the lower range value.

NOTE Where calibrations in workshops and adjustments in the field are made, only terminal based non-linearity is of practical interest. Other expressions of non-linearity are sometimes used.

b) *Independent non-linearity*

Independent non-linearity is determined by drawing a straight line through the average 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 calibration curve.

c) *Zero based non-linearity*

Zero based non-linearity is determined by drawing a straight line so that it coincides with the average calibration curve at the lower range value (zero), and minimizes the maximum deviation.

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**Table 3 – Typical table of device errors**

| | 1st cycle | | 2nd cycle | | 3rd cycle | | Average of the cycles | | Total average |
|---|---|---|---|---|---|---|---|---|---|
| | Error (in % of ideal span) | | | | | | | | |
| Input in % span | Up actual | Down actual | Up actual | Down actual | Up actual | Down actual | Up actual | Down average | Average error |
| | % | % | % | % | % | % | % | % | % |
| 0 | | –0,04 | | –0,05 | | +0,06 | | –0,05 | –0,050 |
| 10 | +0,06 | +0,14 | +0,04 | +0,15 | +0,05 | +0,16 | +0,05 | +0,15 | +0,100 |
| 20 | +0,13 | +0,23 | +0,08 | +0,26 | +0,09 | +0,26 | +0,10 | +0,25 | +0,175 |
| 30 | +0,11 | +0,24 | +0,09 | +0,25 | +0,10 | +0,26 | +0,10 | +0,25 | +0,175 |
| 40 | –0,04 | +0,13 | –0,07 | +0,15 | –0,04 | +0,17 | –0,05 | +0,15 | +0,050 |
| 50 | –0,18 | –0,02 | –0,16 | +0,01 | –0,13 | +0,01 | –0,15 | 0,00 | –0,075 |
| 60 | –0,27 | –0,12 | –0,25 | –0,10 | –0,23 | –0,08 | –0,025 | –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 | –0,200 |
| 90 | –0,16 | –0,06 | –0,15 | –0,05 | –0,14 | –0,04 | –0,15 | –0,05 | –0,100 |
| 100 | +0,09 | | +0,11 | | +0,10 | | +0,10 | | +0,100 |

Non-repeatability = +0,05 %

Hysteresis = +0,22 %
= hysteresis error + dead band

Maximum measured error = –0,30 %

Inaccuracy = –0,32 % +0,26 %

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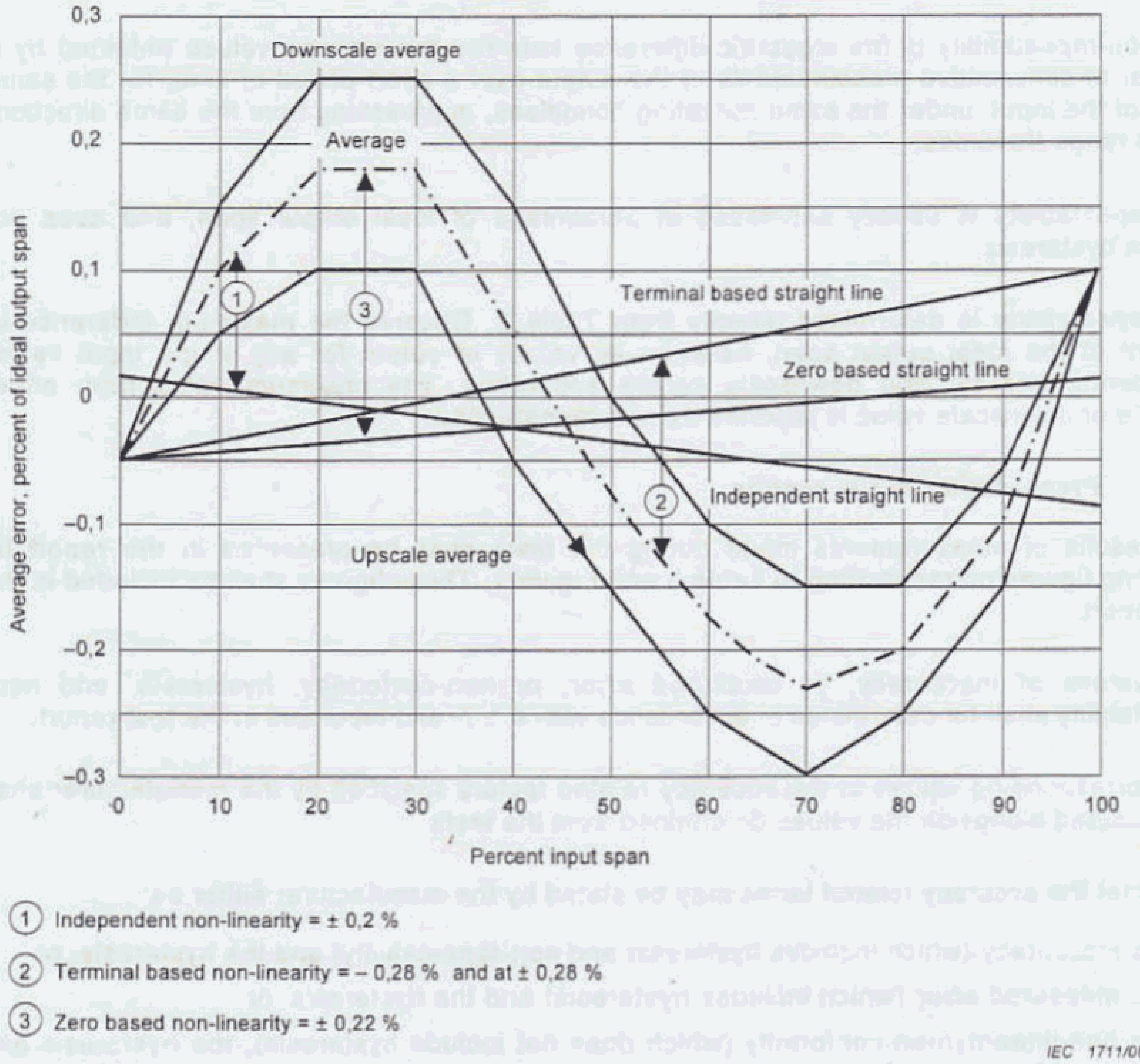


**Figure 1 – Error curves**

#### 4.1.7.4 Non-conformity

The term non-conformity (terminal based non-conformity, independent non-conformity, and zero based non-conformity) should be used for devices which have a non-linear input-output relationship (e.g., logarithmic, square root, etc.).

The non-conformity is determined and presented using the same procedures as for non-linearity.

#### 4.1.7.5 Hysteresis

Hysteresis is determined directly from the deviation values shown in Table 3, and it is the difference between consecutive upscale and downscale outputs for any single test cycle at the same test point.

The maximum value observed from all the test cycles is reported as "hysteresis", and shall be expressed as percent of the ideal output span. If required, hysteresis error may be determined by subtracting the value of dead band from the corresponding value of hysteresis for a given measured point; its maximum value may be reported, as "hysteresis error", in percent of the ideal output span.

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NOTE Dead band may be determined by a conventional dead band test as described in 4.2.2.

#### 4.1.7.6 Non-repeatability

The non-repeatability is the algebraic difference between the extreme values obtained by a number of consecutive measurements of the output over a short period of time, for the same value of the input, under the same operating conditions, approaching from the same direction, for full range traverses.

Non-repeatability is usually expressed in percentage of ideal output span, and does not include hysteresis.

Non-repeatability is determined directly from Table 3. Observe the maximum difference in percent of the ideal output span, between all values of output for any single input value, considering upscale and downscale curves separately. The maximum value from either upscale or downscale value is reported as non-repeatability.

### 4.1.8 Presentation of the results

The results of measurements made during the tests shall be presented in the report by including figures corresponding to Table 3 and Figure 1. These figures shall be included in the test report.

The values of inaccuracy, or measured error, or non-conformity, hysteresis, and non-repeatability shall be determined in accordance with 4.1.7, and tabulated in the test report.

The corresponding values of the accuracy related factors specified by the manufacturer shall be tabulated alongside the values determined from the tests.

Note that the accuracy related terms may be stated by the manufacturer either as:

- the inaccuracy (which includes hysteresis and non-repeatability) and the hysteresis; or
- the measured error (which includes hysteresis) and the hysteresis; or
- the non-linearity/non-conformity (which does not include hysteresis), the hysteresis and the dead band.

## 4.2 Specific testing procedures and precautions for the determination of dead band

### 4.2.1 Selection of ranges for test and preconditioning

Dead band is measured by using the same ranges and preconditioning as for the determination of accuracy related factors in 4.1.1 (Table 1) and 4.1.2.

### 4.2.2 Measurement procedure

Unless the dead band is known to be insignificant, it shall be measured as follows. Dead band shall be measured three times at each of three test points at 10 %, 50 % and 90 % of span, by proceeding as follows:

a) slowly increase the input variable to the DUT until a detectable output change is observed;

b) note the input value;

c) slowly decrease the input until a detectable output change is observed;

d) note the input value.

It shall be necessary to observe and record the output values at least three times, and preferably five times, over full range traverses in each direction. The increment through which the input signal is varied (difference between b) and d) above) is the dead band at this point.

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#### 4.2.3 Presentation of the results

The maximum value of dead band at each test point, shall be tabulated, in percent of ideal input span, in the test report.

The maximum overall value shall be reported as the dead band of the DUT.

If the dead band value is specified by the manufacturer, this value shall be reported beside the value determined in the test.

## 5 Dynamic behaviour

### 5.1 General considerations

The objective of this part of the standard is to give data that will characterize dynamic performance of the DUTs in a uniform, comparable manner.

For the purposes of this standard, sine wave and step input signals may be used for dynamic response tests, as required.

Sine wave test data are most generally useful for mathematical analysis, for graphical solution of control problems, and for characterization of dynamic performance of linear systems.

Step tests permit the measurement of the dead time, and give a qualitative evaluation of the non-linearity of the DUT.

In order to arrive at a practical number of tests, in accordance with 5.2 of IEC 61298-1, for the majority of equipment, only one value of output load and a minimum number of input signal configurations need be adopted.

It is realized that the data from the specified step and sine wave tests will not suffice to describe completely non-linearities of the DUT. However, this standard is intended to give comparable data useful to identify the dynamic behaviour of simple devices, and to give qualitative indications for the more complex ones. In special cases, more detailed testing may be specified in the test programme.

NOTE The specified output loads and the levels of input signals are sufficient to give valid data for the most usual test requirements, and qualitative indications on the effect of unusual large, changing signals.

### 5.2 General testing procedures and precautions

Testing shall be carried out with the span adjusted to the approximate mean of the maximum and minimum span, and with the lower range value set approximately at the mid-point of its permissible range of adjustment.

If there are adjustable functions (e.g., filters, dampers) provided to modify the dynamic behaviour of the DUT, tests shall be carried out with these adjustments set to have first their minimum and then, if required, their maximum effects.

For tests to assess the dynamic behaviour of devices with an electrical output, a realistic load on the electrical output may be simulated by the connection of a 0,1 µF capacitor across the resistive load, unless some other value is specified in the test programme.

### 5.3 Frequency response

A sinusoidal signal shall be applied by a function generator to the input of the DUT.

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The peak-to-peak amplitude of the sinusoidal signal should not exceed 20 % of span, but shall be sufficient to allow a valid measurement without causing distortion or saturation of the output.

The frequency of the input signal shall be increased in increments, from an initial value low enough to determine the static gain, to a higher frequency at which the output is attenuated to less than 10 % of its initial amplitude, or at which the phase lag will be 300°.

At least one complete cycle of the input and output shall be recorded simultaneously at each frequency step.

The results of these tests shall be presented graphically in the following form (see Figure 2):

– the gain and the phase lag shall be plotted against frequency on a logarithmic scale.

From the graphs, the following values shall be obtained:

a) the frequency at which the relative gain is 0,7;
b) the frequency at which the phase lag is 45°;
c) the frequency at which the phase lag is 90°;
d) the maximum relative gain, and the corresponding frequency and phase angle.

### 5.4 Step response

A series of step changes shall be applied to the input of the DUT. The rise time of the step input shall be small compared with response time of the DUT.

Input step and output response shall be recorded together.

The following input steps shall be applied:

– a step corresponding to 80 % of output span, giving an output change from 10 % to 90 %, then another from 90 % to 10 %;
– steps, corresponding to 10 % output span, giving output changes up and down as follows:

5 % to 15 %; 45 % to 55 %; and 85 % to 95 %.

The time for the output to reach and remain within 1 % of output span of its final steady value (settling time) shall be measured for each test condition. The amount of dead time and transient overshot, if any, shall be stated (see Figure 3).

NOTE Measurement of step response time, or time constant, may also be useful.

## 6 Functional characteristic

### 6.1 General

Only some of these tests require that the DUT is powered. These tests shall be carried out with the gain span adjusted to the approximate mean of the maximum and minimum span, and with the lower range value set approximately at the mid-point of its permissible range of adjustment. Further particular settings shall be defined for each test.

### 6.2 Input resistance of an electrical device

This test, applicable to voltage or current input devices, is to determine the effective resistance presented to d.c. input signals at the input terminals of the device.

The test is performed at 100 % input level, using the test setup shown in Figure 4.

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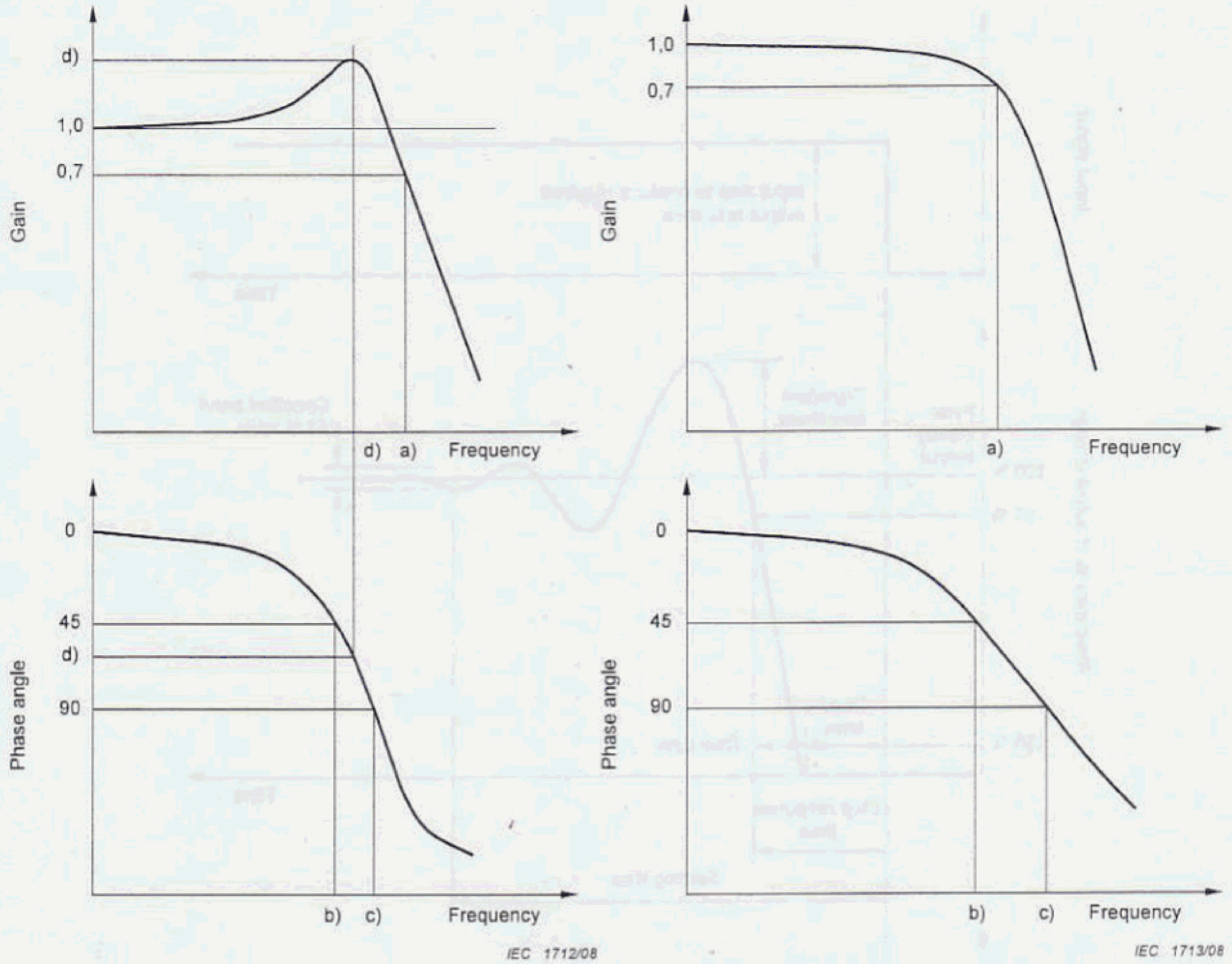


**Figure 2 – Two examples of frequency response**

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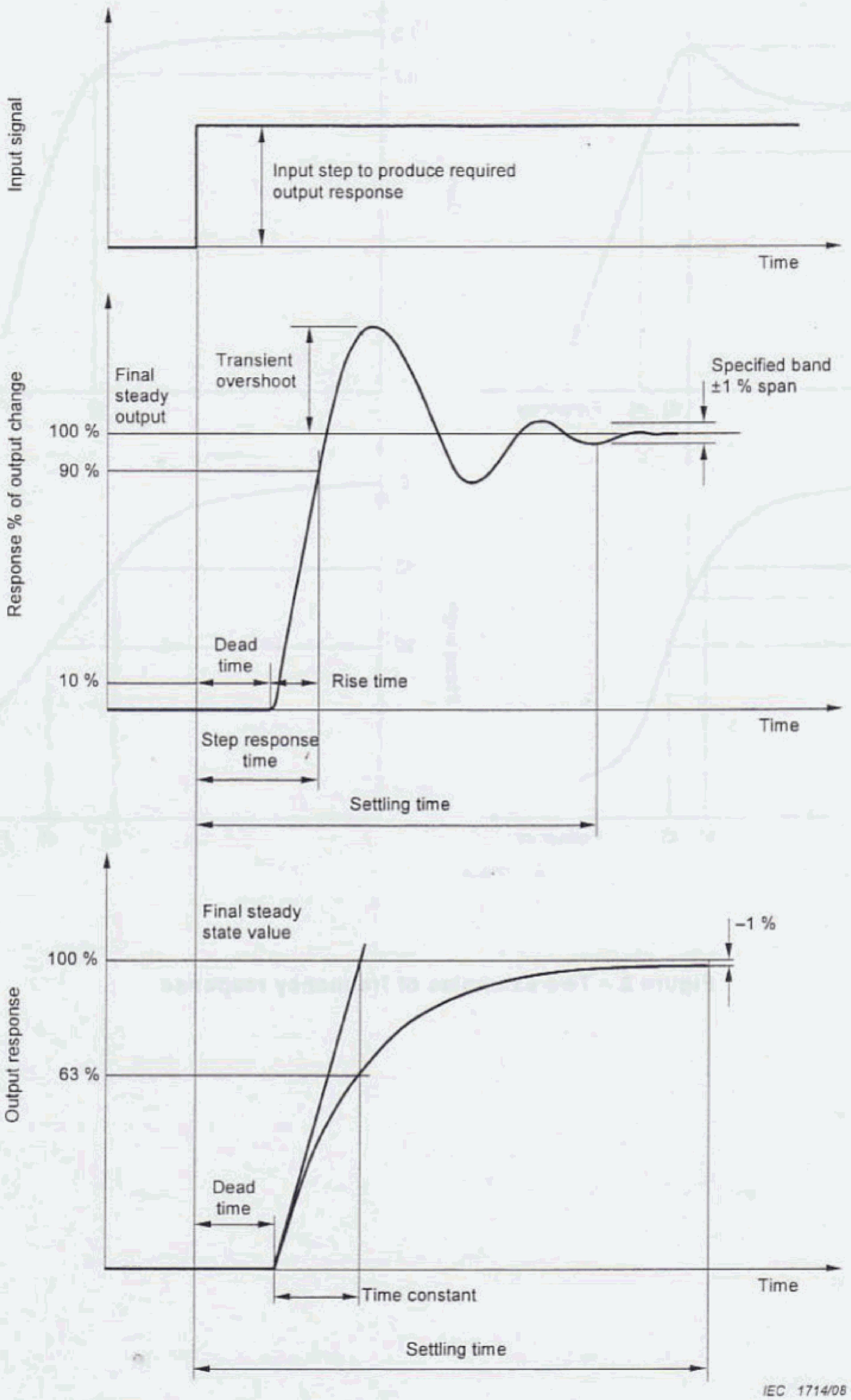


**Figure 3 – Two examples of responses to a step input**

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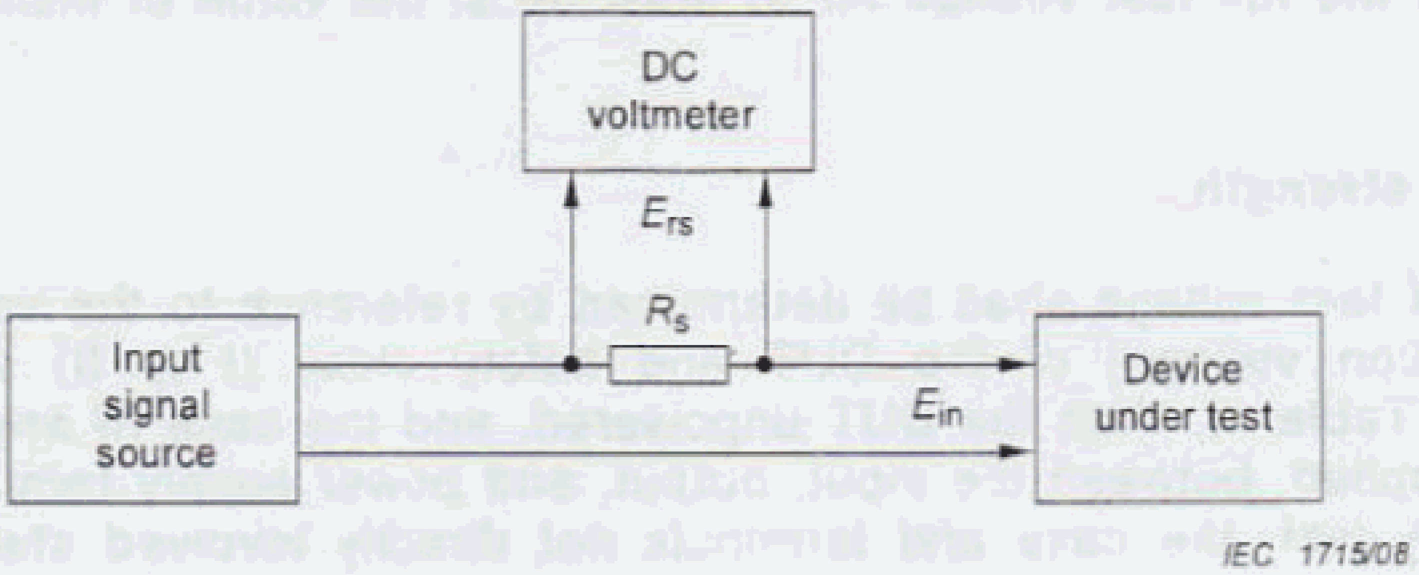


**Figure 4 – Test set-up for input resistance**

The test is carried out using a resistance which is placed in series with the input circuit of the device. Measurements of the voltage input signal and of the voltage drop across this series resistance shall be made, the actual value of its resistance shall then be measured, and the input resistance calculated from the formula:

$$R_{in} = E_{in} (R_s / E_{rs})$$

where

$R_{in}$ is the input resistance, in ohms;

$R_s$ is the series resistance, in ohms;

$E_{in}$ is the voltage input signal of the DUT, in volts;

$E_{rs}$ is the voltage drop across the series resistance, in volts.

## 6.3 Insulation of electrical devices

### 6.3.1 General considerations

These tests are simple electrical safety checks. Their inclusion is not intended as a formal assessment of the safety of the equipment, nor are the required test results intended as a design specification. For a full consideration of the safety aspects of the design of equipment, reference should be made to IEC 61010-1. The tests determine the degree of insulation of the circuits from the enclosure of the device, and its inherent safety when subjected to relatively high voltages between circuits and enclosure.

The insulation of the device shall be adequate to give a sufficient dielectric strength to prevent breakdown, and a sufficient dielectric resistance to prevent excessive leakage currents, or thermal breakdown.

Before type tests on insulation are performed, the device shall be stored for 4 h in a dry chamber with a temperature of 32 °C to 38 °C (for a tropicalized device, 42 °C to 48 °C) followed by a 24 h storage at the same temperature, but with a relative humidity of 90 % to 95 %; this humidity should be maintained during the subsequent tests. Tests shall be performed under these conditions of high relative humidity.

### 6.3.2 Insulation resistance

The DUT shall be set up for normal operation. The insulation resistance of each input and output circuit shall be measured if it is insulated from earth. The test shall be carried out on the unpowered DUT by applying the d.c. test voltage between the short-circuited input, output, or power supply terminals in turn and the enclosure connected to ground.

To avoid voltage surge, the applied test voltage shall be raised to its full value gradually, and, upon completion of the test period, shall then be reduced gradually. Unless otherwise agreed, the nominal d.c. test voltage shall be 500 V.

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After application of the full test voltage for at least 30 s, the value of insulation resistance shall be reported.

### 6.3.3 Dielectric strength

The r.m.s. value of test voltage shall be determined by reference to the value of the rated voltage (or insulation voltage) of the DUT and safety class (I to II) specified by the manufacturer (see Table 4). With the DUT unpowered, and the case (if any) fitted, the test voltage shall be applied, between the input, output, and power supply terminals in turn and earth. During every test, the case and terminals not directly involved shall be connected together and earthed.

The test voltage shall be a substantially sinusoidal alternating voltage with a frequency between 45 Hz and 65 Hz (mains frequency).

**Table 4 – Dielectric strength test voltages**

| Safety class | Rated voltage or isolation voltage d.c. or a.c. r.m.s.<br>V | Test voltage a.c. r.m.s.<br>kV |
|---|---|---|
| I | <60<br>60-250 | 0,50<br>1,50 |
| II | <60<br>60-250 | 0,75<br>3,00 |

The test voltage shall be raised gradually to its specified value, and by using such steps that no appreciable transients occur, and shall then be maintained at the specified level for 1 min.

During the test, no breakdown or flashover shall occur.

## 6.4 Power consumption

### 6.4.1 Electrical power consumption

This test shall be conducted at the input and load conditions which produce the maximum power consumption of the DUT.

If the power is a.c., the voltamperes consumed shall be measured, taking into account measurements of effective (r.m.s.) values. The measurement shall be made at the nominal voltage and frequency, and at the maximum voltage and minimum frequency specified by the manufacturer for the supply.

If the power is d.c., the watts consumed shall be measured at nominal supply voltage.

### 6.4.2 Air consumption

This test is made by measuring the air consumption of the DUT at steady-state input conditions, with the output connected to a sealed container to ensure no air flow from the output.

The air consumption shall be measured, and recorded at the input level which produces the maximum consumption, at nominal supply pressure.

The consumption shall be recorded in $m^3/h$ (at reference conditions; see 6.1 of IEC 61298-1).

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### 6.5 Output ripple of a device with an electrical d.c. output

The maximum peak-to-peak values, and the principal frequency component of any ripple content of the output shall be measured and recorded with 10 % and 90 % input signals at both minimum and maximum load.

### 6.6 Air flow characteristics of a pneumatic device

#### 6.6.1 Initial setting up

The airflow characteristic is the relationship between the delivered/exhausted output airflow and the deviation of input (see Figure 6).

NOTE Generally, it is sufficient to measure the airflow characteristic at only one value of span (since a change of gain affects only the input scale and not the shape of the characteristic or the maximum airflow values), and at only one recommended value of supply pressure. If required, the maximum delivered/exhausted airflow values should also be measured at maximum and minimum specified supply pressures.

Means to feed and measure air into or out of the output line should be installed, as shown in Figure 5.

Ensure the piping arrangement does not affect the results. In particular, avoid long lengths and narrow bore of pipes, and ensure the flow capacity of the supply pressure regulator used in the test is larger than the maximum delivered flow of the DUT specified by the manufacturer.

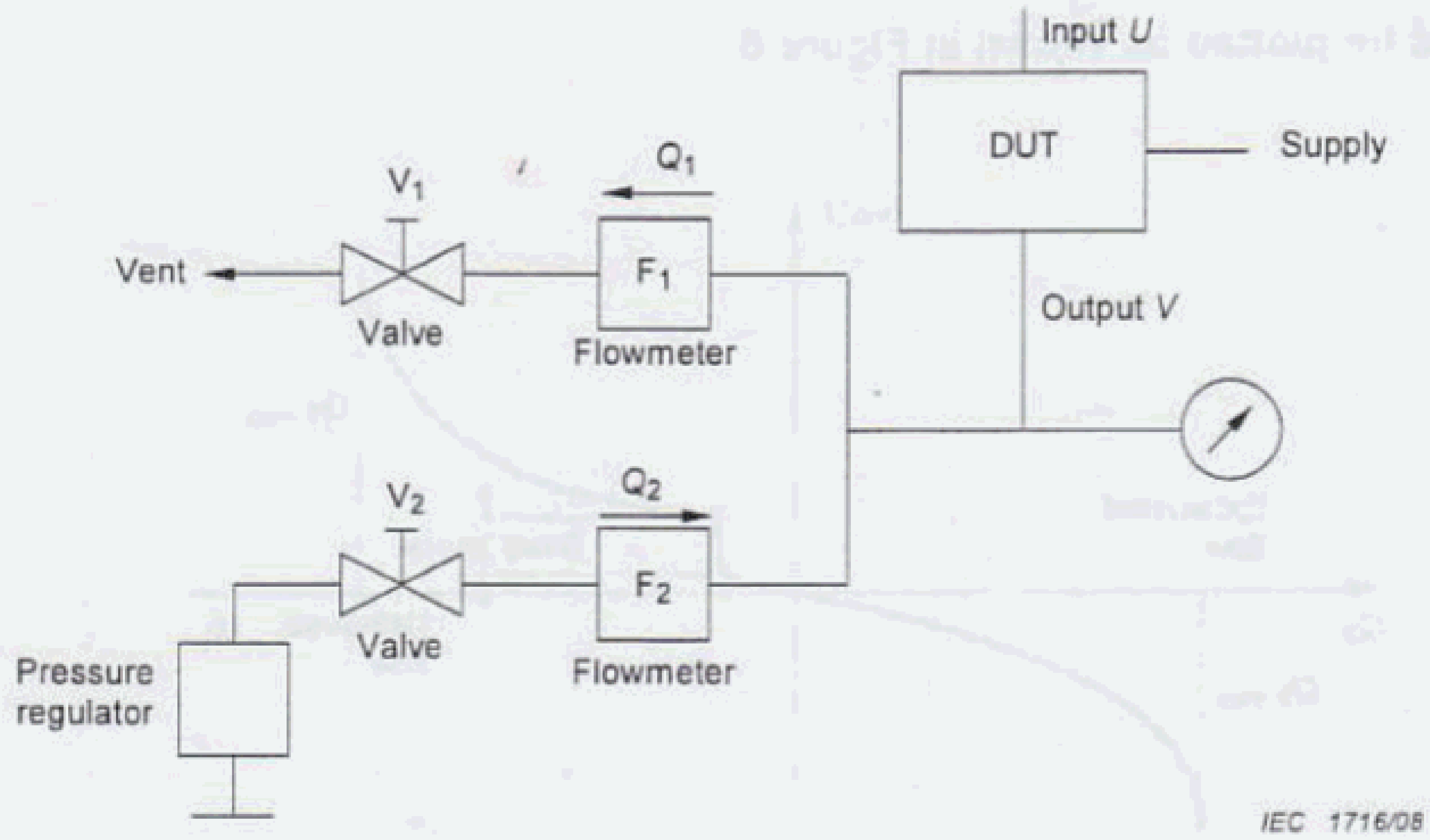


**Figure 5 – Test arrangement for measurement of airflow characteristics**

Close both valves $V_1$ and $V_2$ (see Figure 5). Make any necessary preliminary adjustments to the DUT, and secure them in position. Adjust the input signal until the output signal is balanced to 50 % of its span. Read the adjusted value of input signal as $U_0$. If required, the test can be repeated at other output settings of 10 % and 90 %.

#### 6.6.2 Delivered flow $Q_1$

Ensure that valve $V_2$ is closed.

Gradually open the valve $V_1$ in order to obtain a small delivered flow rate, x. Rebalance the output signal $V$ to 50 % of its span by re-adjusting the input signal $U$, and record it as $U_1$. Determine the deviation of the input signal as:

$$\Delta U_1 = U_1 - U_0$$

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Proceed in the same way with increasing flow rates up to the maximum flow $Q_1$ max. in order to reveal any discontinuity in the deviation of the input signal $\Delta U$. Reclose the valve $V_1$.

The maximum delivered flow $Q_1$ max. is the maximum flow rate at which the output signal $V$ can be rebalanced to its previous value of 50 %.

NOTE Increasing flow rates over this value will cause a lower output value, which cannot be rebalanced by further re-adjustment of input signal $U$.

### 6.6.3 Exhausted flow $Q_2$

Ensure that valve $V_1$ is closed.

Gradually open valve $V_2$ in order to feed a small exhausted flow rate of y into the DUT.

Follow the procedure in 6.6.2 to determine the deviation of the input signal $U$ up to the maximum flow $Q_2$ max.

The maximum exhausted flow $Q_2$ max. is the maximum flow rate at which the output signal $V$ can be rebalanced to its previous value of 50 %.

NOTE Increasing flow rates over this value will cause a higher output value, which cannot be rebalanced by further re-adjustment of input signal $U$.

### 6.6.4 Data presentation

The data should be plotted as shown in Figure 6.

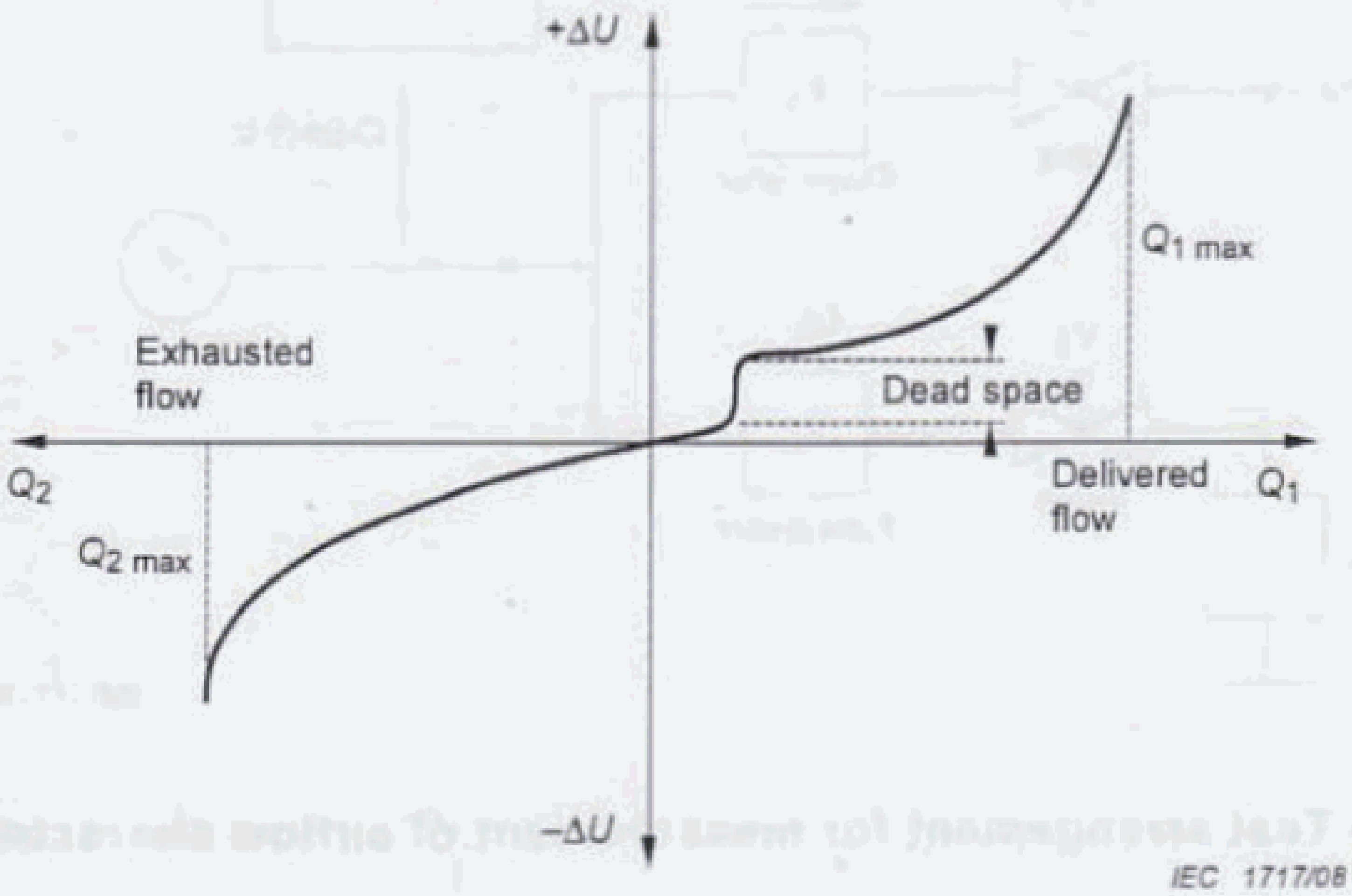


**Figure 6 – Typical air flow characteristics**

From the graph of results, the following are determined:

a) maximum delivered flow ($Q_1$ max.);

b) deviation $\Delta U_1$ when delivering lower flow rates;

c) maximum exhausted flow ($Q_2$ max.);

d) deviation $\Delta U_2$ when exhausting lower flow rates;

e) the height of the output relay dead space as a percent of input U span, and the corresponding air flow rate (delivered or exhausted). The output relay dead space is the discontinuity in the flow characteristics in Figure 6.

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The flow rate values should be reported for standard conditions (temperature and pressure) in $m^3/h$. Report also the adjusted gain and supply pressure value.

### 6.7 Limits of adjustments of lower range value and span

Adjustments for lower range value and span are of two types: those designed to compensate for manufacturing tolerances, or other small deviations; and those designed to elevate, or suppress, the input signal range for its specified output range.

In some instances, the adjustments to compensate for manufacturing tolerances are made by the manufacturer, and, upon completion of the operation, the adjusting means are sealed by encapsulation. However, if the adjusting means are accessible, testing shall be conducted to determine the limits of adjustment. The test for lower range value and span adjustment limits should cover the four combinations of extreme settings of the lower range value and span adjustment.

If the DUT has a separate elevation or suppression adjustment, a test of this capability shall be performed in conjunction with the test of the lower range value adjustment of the DUT, i.e., the elevation/suppression adjustment is set at each of its extreme values in the direction which will be additive to the effect of each lower range value adjustment. This method gives the absolute lower range value adjustment capability of the DUT.

### 6.8 Switching differential

This test is to determine the difference between the value of input to just activate a switching action, and the value of input to just de-activate it (differential gap in IEC 60050-351, Figure 11).

The test is performed at least three set switching points: 10 %, 50 %, and 90 % of input span. The input signal is changed gradually until the switch turns on. The signal is reversed, and changed gradually until the switch is de-activated.

The algebraic difference between the two input levels is the switching differential gap and should be expressed in percent of ideal input span.

If the switch is equipped with adjustable dead band, the test is performed at minimum and maximum differential adjustment.

## 7 Drift

### 7.1 Start-up drift

This test should be carried out by measurement of the changes which occur in the output after energizing the DUT.

Prior to the test, the device is subjected to ambient environmental conditions, or as advised by the manufacturer, for a period of at least 12 h, but not energized. The span should be adjusted to the approximate mean of the maximum and minimum span, and with the lower range value set approximately at the mid-point of its permissible range of adjustment.

With a 90 % input signal applied to the device, it should be switched on, and the output monitored until the output stabilizes (for a maximum period of 4 h). The measurements obtained shall be recorded, and the start-up drift reported as the time for the output to reach and remain within the manufacturer's specified limits.

### 7.2 Long-term drift

The device shall be operated for 30 days and, where practical, a steady input signal

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corresponding to 90 % of span shall be maintained. The span should be adjusted to the approximate mean of the maximum and minimum span, and with the lower range value set approximately at the mid-point of its permissible range of adjustment. For devices which have an intermittent or sample input, or for which it is not practical to maintain a constant test input signal (e.g., some types of analysers), an input corresponding to 90 % span shall be applied at least once each day. The input and output shall be measured, preferably each working day, and the output drift determined and corrected by calculation for any small variation of input. Care should be taken that changes due to ambient environmental conditions, other than time, do not mask the effects of long-term drift. The lower range value and span shall be measured and recorded immediately before and after the 30 day test period. The measured data should be processed to determine a best fit straight line and verify if there is a drift in one direction or a random drift.

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