BS EN 60770-3:2014

BSI Standards Publication

Transmitters for use in industrial-process control systems

Part 3: Methods for performance evaluation of intelligent transmitters

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National foreword

This British Standard is the UK implementation of EN 60770-3:2014. It is identical to IEC 60770-3:2014. It supersedes BS EN 60770-3:2006, which will be withdrawn on 27 June 2017.

The UK participation in its preparation was entrusted by Technical Committee GEL/65, Measurement and control, to Subcommittee GEL/65/2, Elements of systems.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Transmitters for use in industrial-process control systems - Part 3: Methods for performance evaluation of intelligent transmitters (IEC 60770-3:2014)

Transmetteurs utilisés dans les systèmes de commande des processus industriels - Partie 3: Méthodes d'évaluation des performances des transmetteurs intelligents (CEI 60770-3:2014)

Messumformer für industrielle Prozessleittechnik - Teil 3: Verfahren zur Bewertung der Leistungsfähigkeit von intelligenten Messumformern (IEC 60770-3:2014)

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Foreword

The text of document 65B/917/FDIS, future edition 2 of IEC 60770-3, prepared by SC 65B "Measurement and control devices" of IEC/TC 65 "Industrial-process measurement, control and automation" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60770-3:2014.

The following dates are fixed:

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This document supersedes EN 60770-3:2006.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 60770-3:2014 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60068-2-1	NOTE	Harmonized as EN 60068-2-1.
IEC 60068-2-2	NOTE	Harmonized as EN 60068-2-2.
IEC 60068-2-6	NOTE	Harmonized as EN 60068-2-6.
IEC 60068-2-31	NOTE	Harmonized as EN 60068-2-31.
IEC 60068-2-78	NOTE	Harmonized as EN 60068-2-78.
IEC 60654 Series	NOTE	Harmonized as EN 60654 Series (not modified).
IEC 61298 Series	NOTE	Harmonized as EN 61298 Series (not modified).
IEC 61508 Series	NOTE	Harmonized as EN 61508 Series (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60050	Series	International Electrotechnical Vocabulary (IEV)	-	-
IEC 60381	Series	Analogue signals for process control systems	HD 452.1 S1	
IEC 60529	-	Degrees of protection provided by enclosures (IP Code)	EN 60529	-
IEC 60721-3	Series	Classification of environmental conditions - Part 3: Classification of groups of environmental parameters and their severities	EN 60721-3	Series
IEC 61010-1	-	Safety requirements for electrical equipment for measurement, control and laboratory use - Part 1: General requirements	EN 61010-1	-
IEC 61032	-	Protection of persons and equipment by enclosures - Probes for verification	EN 61032	-
IEC 61158	Series	Industrial communication networks - Fieldbus specifications	EN 61158	Series
IEC 61298	Series	Process measurement and control devices - General methods and procedures for evaluating performance	EN 61298	Series
IEC 61298-1	2008	Process measurement and control devices - General methods and procedures for evaluating performance - Part 1: General considerations	EN 61298-1	2008
IEC 61298-2	2008	Process measurement and control devices - General methods and procedures for evaluating performance - Part 2: Tests under reference conditions	EN 61298-2	2008

IEC 61298-3	2008	Process measurement and control devices - General methods and procedures for evaluating performance - Part 3: Tests for the effects of influence quantities	EN 61298-3	2008
IEC 61298-4	-	Process measurement and control devices - General methods and procedures for evaluating performance - Part 4: Evaluation report content	EN 61298-4	-
IEC 61326	Series	Electrical equipment for measurement, control and laboratory use - EMC requirements	EN 61326	Series
IEC 61326-1	-	Electrical equipment for measurement, control and laboratory use - EMC requirements - Part 1: General requirements	EN 61326-1	-
IEC 61499	Series	Function blocks	EN 61499	Series
IEC 61804	Series	Function Blocks (FB) for process control	EN 61804	Series
CISPR 11	-	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement	EN 55011	-

CONTENTS

INTRODUCTION

New transmitters for use in industrial process control systems are now equipped with microprocessors which utilise digital data processing and communication methods, auxiliary sensors and artificial intelligence. This makes them more complex than conventional analogue transmitters and gives them considerable added value.

An intelligent transmitter is an instrument that uses digital data processing and communication methods for performing its functions and for safeguarding and communicating data and information on its operation. It may be equipped with additional sensors and functionality which support the main function of the intelligent transmitter. The variety of added functionality can for instance enhance accuracy and rangeability, self-test capabilities, and alarm and condition monitoring. Therefore accuracy-related performance testing, although still a major tool for evaluation, is no longer sufficient to show the flexibility, capability and other features with respect to engineering, installation, maintainability, reliability and operability.

Because of the complexity of intelligent transmitters, a close collaboration should be maintained between the evaluating body and the manufacturer during the evaluation. Note should be taken of the manufacturer's specifications for the instrument, when the test programme is being decided, and the manufacturer should be invited to comment on both the test programme and the results. His comments on the results should be included in any report produced by the testing organisation.

This part of IEC 60770 addresses, in its main body, structured and mandatory methods for a design review and performance testing of intelligent transmitters. Intelligent transmitters will, in many cases, also have the capacity to be integrated into digital communication (bus) systems, where they have to co-operate with a variety of devices. In this case, dependability, (inter)operability and real-time behaviour are important issues. The testing of these aspects depends largely on the internal structure and organisation of the intelligent transmitter and the architecture and size of the bus system. The Annexes A, B and C give a non-mandatory methodology and framework for designing specific evaluation procedures for dependability and throughput testing and function block testing in a specific case.

When a full evaluation, in accordance with this part of IEC 60770, is not required or possible, those tests which are required, should be performed and the results reported in accordance with the relevant parts of this standard. In such cases, the test report should state that it does not cover the full number of tests specified herein. Furthermore, the items omitted should be mentioned, in order to give the reader of the report a clear overview.

The structure of this part of IEC 60770 largely follows the framework of IEC 62098. For performance testing, the IEC 61298 series should also be consulted. A number of tests described there are still valid for intelligent transmitters. Further reading of the IEC 61069 series is recommended, as some notions in this part of IEC 60770 are based on concepts brought forward therein.

TRANSMITTERS FOR USE IN INDUSTRIAL-PROCESS CONTROL SYSTEMS –

Part 3: Methods for performance evaluation of intelligent transmitters

1 Scope

This part of IEC 60770 specifies the following methods.

- Methods for
  - assessment of the functionality of intelligent transmitters;
  - testing the operational behaviour, as well as the static and dynamic performance of an intelligent transmitter.
- Methodologies for
  - determining the reliability and diagnostic features used to detect malfunctions;
  - determining the communication capabilities of the intelligent transmitters in a communication network.

The methods and methodologies are applicable to intelligent transmitters, which convert one or more physical, chemical or electrical quantities into digital signals for use in a communication network (as specified in the IEC 61158 series or others) or into analogue electrical signals (as specified in the IEC 60381 series).

The methods and methodologies listed in this part of IEC 60770 are intended for use by:

– manufacturers to determine the performance of their products, and

– users or independent testing laboratories to verify equipment performance specifications.

Manufacturers of intelligent transmitters are urged to apply this part of IEC 60770 at an early stage of development.

This standard is intended to provide guidance for designing evaluations of intelligent transmitters by providing:

– a checklist for reviewing the hardware and software design in a structured way;

– test methods for measuring and qualifying the performance, dependability and operability under various environmental and operational conditions;

– methods for reporting the data obtained.

2 Normative references

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

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

IEC 60381 (all parts), *Analogue signals for process control systems*

IEC 60529, *Degree of protection provided by enclosures (IP Code)*

IEC 60721-3 (all parts), *Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severities*

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

IEC 61032, *Protection of persons and equipment by enclosures – Probes for verification*

IEC 61158 (all parts), *Industrial communication networks – Fieldbus specifications*

IEC 61298 (all parts), *Process measurement and control devices – General methods and procedures for evaluating performance*

IEC 61298-1:2008, *Process measurement and control devices – General methods and procedures for evaluating performance – Part 1: General considerations*

IEC 61298-2:2008, *Process measurement and control devices – General methods and procedures for evaluating performance – Part 2: Tests under reference conditions*

IEC 61298-3:2008, *Process measurement and control devices – General methods and procedures for evaluating performance – Part 3: Tests for the effects of influence quantities*

IEC 61298-4, *Process measurement and control devices – General methods and procedures for evaluating performance – Part 4: Evaluation report content*

IEC 61326 (all parts), *Electrical equipment for measurement, control and laboratory use – EMC requirements*

IEC 61326-1, *Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 1: General requirements*

IEC 61499 (all parts), *Function blocks*

IEC 61804 (all parts), *Function blocks (FB) for process control*

CISPR 11, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-300, in the IEC 61298 series and the following apply.

3.1
intelligent transmitter
transmitter provided with means for bi-directional communication with external systems and human operators for sending measurement and status information and receiving and processing external commands

3.2
single variable transmitter
transmitter that measures one single physical quantity

3.3
multivariable transmitter
transmitter that measures two or more identical or different physical quantities

3.4
adjustment
set of operations carried out on a measuring instrument in order that it provides given indications corresponding to given values of the measurand

Note 1 to entry: When the instrument is made to give a null indication corresponding to a null value of the measurand, the set of operations is called zero adjustment.

Note 2 to entry: Many manufacturers use the term calibration for adjustment of zero, span and linearity or conformity.

3.5
tuning
process of adjusting the various instrument parameters, required for obtaining a stable and optimal measurement

Note 1 to entry: This can range from "trial and error" to an automatic proprietary procedure provided by the manufacturer.

3.6
configuring
process of implementing the functionality required for a certain application

3.7
configurability
extent to which an intelligent transmitter can be provided with functions to control various applications

3.8
set-up
process of configuring, calibrating and tuning a transmitter for optimal measurement

3.9
operating mode
selected method of operation of a transmitter

4 Design assessment

4.1 General

The design review is meant to identify and make explicit, in a structured way, the functionality and capabilities of the intelligent transmitter under consideration. As stated in the introduction, intelligent transmitters appear in a great variety of designs. A design review is the necessary tool for showing the details of:

– the physical structure,
– the functional structure.

Subclause 4.2 guides the evaluator through the process of describing the physical structure of intelligent transmitters by identifying the hardware modules and the inputs and outputs to the operational and environmental domains. Thereafter, the functional structure can be described, using the checklist of 4.3. The checklist gives a framework of the relevant issues, which need to be addressed by the evaluator, mainly through adequate qualitative and quantitative experiments.

4.2 Transmitter analysis

4.2.1 General

Two different types of transmitters can be identified:

- **Single variable transmitter.** The measured value (output) represents one single physical quantity measured by one type of sensor.
- **Multivariable transmitter.** This type of transmitters appears in two versions:
  - An instrument providing a variety of measured values (outputs), each of which is related to a measurement of one distinct input quantity with a specific sensor.
  - An instrument providing derived measured values resulting from the measurement of more than one quantity through more than one type of sensor and processed through a distinct algorithm (e.g. flow computer, mechanical power meter). In many cases, the individual measured variables are also available to the user.

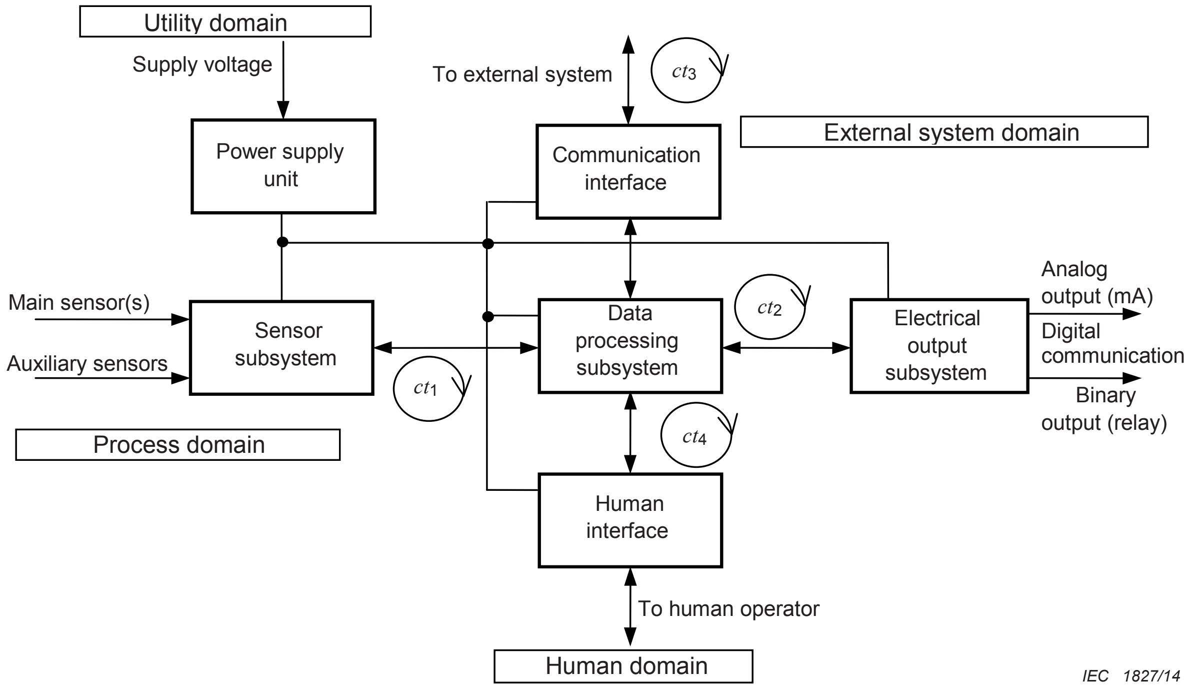
Each type of intelligent transmitter may be equipped with independent auxiliary sensors and auxiliary (mainly digital) outputs, which are not involved in the primary measurement process.

The generic transmitter model of Figure 1 gives a maximum configuration and is a tool for setting up a block scheme and concise description of the transmitter to be evaluated. It is also important for defining the functions to be considered in the performance tests (see Clause 5).

Functionally, a transmitter is an information transformer. Data enters and then exits the instrument through the various (external) domains given in Figure 1, following distinct data flow paths. The following paths can be defined, but are not always resident in a specific transmitter under consideration:

- Sensors (process domain) to external systems (remote data processing systems).
- Sensors (process domain) to operator displays (human domain).
- Sensors (process domain) to external systems (electrical outputs).
- Operator commands through local keyboard (human domain) to data processing subsystem, consequently affecting the above-mentioned data flows to external systems (remote data processing systems and electrical outputs).
- Remote commands (from external remote data processing systems) to the instrument’s data processing subsystem, consequently affecting the above-mentioned data flows to external systems (electrical outputs) and local operator displays (human domain).

A block scheme and description shall be included in the evaluation report and may be enhanced with photographs or drawings of important details.



Key

ct cycle time

Figure 1 – Intelligent transmitter model

For an intelligent transmitter, the main physical modules and provisions for connection to external systems and human operators are defined in 4.2.2 to 4.2.9.

4.2.2 Data processing subsystem

The data processing subsystem is the heart of an intelligent transmitter. Its main function is to provide and process the measured quantity(ies) for further real-time use by the human and communication interfaces and/or at the electrical output subsystem. Many transmitters measure one quantity by means of one (main) sensor, but derived measured values such as heat or mass flow and mechanical power require more sensors.

Besides the main measurement function, a transmitter may be equipped with a number of additional functions that can vary considerably from make to make. Amongst the additional functions that may be resident in a transmitter are:

– configuration;
– adjustment and tuning;
– self-testing, diagnostics, condition monitoring;
– external process control function;
– trending and data storage.

Part of the functionality may be located in external devices that are temporarily or continuously connected to the communication interface (e.g. configuring, trending).

4.2.3 Sensor subsystem

The sensor subsystem converts the physical or chemical quantity(ies) to be measured into electrical signals that are conditioned and digitised for use by the data processing unit. The subsystem may also be equipped with electrical circuits for sensing binary signals (e.g. change measurement range on an external command), or auxiliary sensors of a different type (e.g. auxiliary for compensation or internal diagnostics and condition monitoring purposes).

The sensor and sensor subsystem may be integrated with the other modules in one enclosure. The sensor can also be located remotely (e.g. densitometer, thermocouple transmitter). Certain transmitters (e.g. thermocouple and resistance thermometer detector (RTD)) utilise standardised (third party) sensors that provide an electric signal. In such a case, it may be agreed to perform the evaluation with an acceptable simulator instead of the application of the actual quantity.

Depending on the measurement principle used, the sensor may not require auxiliary (external) power (e.g. thermocouples) or it may require auxiliary power (e.g. strain gauges) or a specifically characterised power source (e.g. electromagnetic and Coriolis flowmeters).

Sensors are, in general, incorporated in the process installations and in many cases, they may also be in direct contact with the process medium. As such, medium properties, medium conditions and installation conditions may adversely influence them. As a remote unit, the sensor may also be subjected to more severe environmental conditions than the other subsystems. Moreover, it shall also be considered whether it is necessary to apply combined environmental and process conditions during an evaluation.

As part of the design review, a list of the types of sensors that are provided and their measuring ranges shall be compiled.

4.2.4 Human interface

The human interface is an important tool for direct interaction and communication with the human operator. It consists of integral means at the instrument for reading out data (local display) and provisions for entering and requesting data (local pushbuttons). Instruments may be provided that are not equipped with a human interface. Access to the database is then provided via the communication interface and the external system or a handheld terminal.

A list of the measurement data that can be shown on the display and the refresh rates, as well as the status data that can either automatically or on request be made available to the operator shall be tabulated. In addition, a summary of the functions and facilities for access and data presentation shall be made.

4.2.5 Communication interface

Transmitter intelligence is supported by the communication interface, which connects the instrument to external systems. Through the interface (wired or wireless), measurement and control data are transferred and access is also provided to the instrument's configuration data. In the case of hybrid (SMART) instruments, the digital signal is superimposed on an analogue current signal and it is made available at the electrical output subsystem. There may be instruments which do not have a communication interface. Then configuration and read-out of data may take place via the human interface

A list of the measurement data that can be transferred to a host and the refresh rates should be compiled. A summary of the status data that can either automatically or on request be transferred to the host shall also be listed. The functions and facilities for access and data presentation shall also be indicated.

4.2.6 Electrical output subsystem

Instruments suitable for connection to a fieldbus (or wireless) need not necessarily be provided with an electrical output subsystem.

The electrical output subsystem primarily converts digital information provided by the data processing subsystem into one or more analogue electrical signals. It may also be equipped with one or more binary (digital) electrical outputs. For these purposes, the instrument may require an additional power supply source.

A list of the measured variables assignable to each electrical output shall be tabulated. The analogue signal types and ranges (e.g. 4 mA to 20 mA or 1 V d.c.to 5 V d.c., etc.) shall also be included. A summary of the status data that can be made available at the binary (digital) output terminals shall be compiled.

4.2.7 Power supply unit

Many instruments still require a separate connection to an a.c. or d.c. mains supply. However more instruments are nowadays, "loop powered" which means that they receive power through the signal transmission line or electrical signal output line. While in wireless application it is necessary to specify the specific power source (e.g. battery).

4.2.8 External functionality

Through the data communication interface and the fieldbus, the instrument communicates with the host equipment (personal computer (PC) or link server, etc.). Through these facilities, parts of the transmitter functionality may be allocated in the host equipment. The following functions may be suitable for remote allocation:

– (Remote) configuration tool.

– Data storage (configuration, trend, transmitter condition).

– Parts of the adjustment and tuning procedure.

The external functionality (if present) shall be treated as an integral part of the transmitter.

4.2.9 Cycle times (ct)

The quality of a transmitter's real-time operation largely depends on:

– The time required to perform and transmit measurements and data to the external world.

– The cycle times for on-line diagnostic tests (ct_d).

The abbreviations ct_1 to ct_4 indicate the cycle times (refresh times) for internal data transfer between the various modules and to the external world. These cycle times do not have to be equal and they may be all or partly user-adjustable.

4.3 Aspects to be reviewed

4.3.1 General

The instrument shall be verified for correct operation prior to any check that may be required to determine the aspects of functionality and capabilities mentioned in the Tables 1 to 7. The instrument shall be error and fault free. This may be indicated on a local display or a remote device (handheld terminal or PC or host computer) connected via a bus system.

The Tables 1 to 7 form the checklist for determination of the implemented functions and properties of a transmitter under consideration. The evaluator shall take into account the aspects mentioned in the last column. Subclause 4.3.9 gives an example of the reporting format.

4.3.2 Functionality

Table 1 – Checklist for mapping functionality

Function/capability	Aspects to be considered during evaluation
Main function(s)	Give a concise description of the measurement principle(s). Describe instrument status information and measurement information (separate and derived quantities) available at the human and communication interfaces and electrical output subsystem. Describe the firmware structure (function blocks and how they can be organised) and rules for application software.
Auxiliary function(s)	Give a concise description of auxiliary analogue and digital input and output functions.
Downward compatibility	New releases of a transmitter should be compatible with old versions both in hardware and software. Check whether a new release of a transmitter hardware or firmware is downwards compatible with the old one and if the changes have been adequately documented (manufacturer's declaration, etc.)
Function blocks	List the available standardised function blocks (according to either IEC 61499 series or IEC 61804 series) or in case of proprietary function blocks, describe and categorise them in terms of: • time dependent function blocks (totalizers, controllers, timers, lead/lag); • time-independent function blocks, to be divided into: – calculation blocks (e.g. sensor linearization, square root, exponential); – logic blocks (and, or, etc.). For each function block give: • Name. • Adjustment range if user-adjustable. • Default values if applicable. • Check recognition and rejection of invalid values. For details on checking function block features, see Annex C.
Signal cut-off	• Check the availability of signal cut-off. Signal cut-off is usually possible at the lower end of the characteristic to avoid invalid or noisy signals, but also signal cut-off at the upper end can be present. Indicate which option is available and whether cut-off values are user-configurable. • Check whether a dead band is present between activation and release and whether it is user adjustable.
Filters	If filters are provided: • Are they analogue (hardware) or digital (software)? • What type (1st, 2nd order) and is the time constant adjustable?

4.3.3 Configurability

Table 2 – Checklist for mapping configurability

Function/capability	Aspects to be considered during evaluation
Fieldbus or wireless compatibility	Check whether the instrument under test is suited for either: • A connection to a fieldbus in accordance with the IEC 61158 series. • A connection to a wireless network (specify which standard). • Or a stand-alone application in combination with a temporary connection to a proprietary fieldbus. • Or a stand-alone application. Give a listing of fieldbus compatible instrument versions.
Configuration tools	Check if the instrument can be configured from: • Local controls (human interface) on instrument. • Remotely from a PC or a host computer. • Via a temporarily connected handheld communication unit. Notice obvious difficulties that appeared when configuring the instrument with these tools. Difficulties could be: – Incorrect entries due to too small distance between keys. • Some parameter entries may give an unnoticed change to other previously set parameters relevant to correct operation. – Inconsistencies in handling parameters such as no warning message when trying to change a protected parameter.
On-line (re)configuration	Check whether functions and parameters can be changed in control mode. If so, whether the output is unacceptably affected. Check whether there is a security mechanism that prohibits on-line access to all or some parameters and functions.
Off-line configuration	Check whether it is possible to set up and store configurations for a number of transmitters on a separate (off-line) PC. Measure the time required for off-line configuration.
Up/download to/from PC	Check if configuration upload is possible. Check if download of off-line prepared configurations is possible. Measure the time required to perform these actions: • When commissioning a fieldbus system. • In an operative (active) fieldbus system. (The time required for these actions may depend on the number of fieldbus participants in the system).
Configurable restart conditions	When a transmitter is provided with a process control function it may also be equipped with configurable restart conditions for after a power down. Conditions provided can be: • Return to last value. • Go to a user-defined value. • Return to manual mode. For transmitters with process control function, list any configurable restart functions after power down
Configurable fail-safe conditions	List the actions that can be configured in the transmitter in the event of detecting an internal failure or sensor failure.

4.3.4 Hardware configuration

Table 3 – Checklist for mapping hardware-configuration

Function/capability		Aspects to be considered during evaluation
Mechanical construction	Hinges/covers	Comment, for these items, on the complexity and soundness of construction and protection against damage. Refer, if applicable, to mechanical problems that have appeared during preparation of the evaluation and during the performance of any test. Comment, for internal modules, on the location/position and addressing of the hardware by DIP switches or software.
	Internal modules	
	Support	
	Protruding parts	
	Local controls	
	Sensor connections	
	Electrical connections	
	Mechanical connections	
Ease of mounting		The mounting procedure may influence the calibration. Check whether it draws adequate attention to alignment, fixation to installation, thermal insulation, etc. Notice any obvious difficulties that may have appeared when dismounting and mounting the instrument. Also, determine the time needed for correct mounting.

4.3.5 Adjustment and tuning

NOTE 1 Many manufacturers use the term calibration for the procedure of adjusting zero, span and in some cases linearity. This conflicts with the definitions for adjustment and calibration as given in IEC 60050-300

NOTE 2 Not all types of transmitters can be provided with user-accessible adjustment and tuning tools.

Table 4 – Checklist for mapping adjustment and tuning procedures

Function/capability	Aspects to be considered during evaluation
Adjustment procedure	Aspects to be considered are: • How many adjustment procedures exist and what are the differences (which one is advised etc., on-line and off-line adjustment and tuning or configuration)? • What external equipment is needed for calibration, adjustment and tuning? • How many times does the user have to interact and when? • Is any part of the procedure automatically performed? • Are adjustment, calibration and tuning data (name of operator, date, parameters, etc.) stored in non-volatile memory? • What are the range limits? • What is the resolution of zero/span adjustments both at upper and lower range limits? • Is linearization part of the procedure? • Measure the time required for adjustment, calibration and tuning. Record any obvious or potential difficulties that may have appeared when performing the procedure.
Tuning procedure	Certain instruments require adaptation and tuning to process conditions and properties, installation conditions and environmental conditions. Briefly describe the procedure. The following shall be considered: • In certain cases, tuning/adaptation may require the setting of fixed process related parameters particularly when configuring the instrument. Often, this method has limited validity, in particular where the actual process parameters may vary over a wide range. • It may also be an automatic procedure to be performed under live conditions. If so, how many times does the user need to interact? Are resulting parameters automatically activated or the can the user ignore/change them and fill in different values? Record the instrument's output during the procedure. The record may show the limitations of the procedure. • Can adjustment, and tuning be integrated inseparably into one procedure? • Measure the time required for tuning.

4.3.6 Operability

Table 5 – Checklist for mapping operability

Function/capability	Aspects to be considered during evaluation
Local controls (tools) for access	Give a concise description of: • The keys (pushbuttons) available. • Accessibility and protection against ingress of gas, water, dust. • Ergonomic layout and use of the keys. • Protection/suitability of keys for use in hazardous locations.
Local displays	Give a concise description of the data that can be shown on the local displays such as: • Number of lines and characters per line. • Control parameters given. • Error messages. • Readability of display without removing the electronics covers.
Human interface(s) at external system	Describe, for PC-based software, the organisation and hierarchy of the various user access groups and related displays and the possible availability of dedicated keyboards. Give, for a handheld communicator, a picture with layout of display and keyboard.
Provisions and tools for engineering and maintenance personnel	Give, for PC-based provisions, a concise description of the organisation and hierarchy of the engineering and maintenance related software and display templates. If available, list other hardware tools (such as switches, potentiometers, etc.) that can be used for configuration, installation, adjustments and calibration.
Process diagnostic aspects	Check whether the instrument – in addition to the main measuring function – has provisions for diagnosing defects and faults in the process and process installations such as: • Cavitation. • Product contamination. • Product inconsistencies (e.g. gas entrapped in liquid). • Blockage of product flow. • Excess vibration of installation. • Loop integrity and performance using information coming from the instruments and function blocks used in the loop. • Fracture, wear, fatigue or corrosion of piping or vessels, etc. Describe relevant tests and alarms implemented such as: • Analysis in time or frequency domain of main sensor signal. • Fingerprinting. • Availability of additional sensors. • Additional software tools for the accumulation of operational time, time at certain load, number of cycles. Check whether these tools are embedded in the transmitter or in the host. • Are tests on-line automatic or operator-initiated? • Are test parameters user-adaptable? • Actions of transmitter on appearance of diagnostic alarms.

4.3.7 Dependability

Table 6 – Checklist for mapping dependability

Function/capability	Aspects to be considered during evaluation
Transmitter diagnostics	Describe how the transmitter diagnoses internal failures and secures safe operation in case of failures. Mechanisms may be implemented for detecting: • Flash ROM failure; • no free time; • reference voltage failure; • drive current failure; • critical NVM failure; • auxiliary sensor failures (e.g. internal temperature, pressure). Fieldbus and wireless devices may provide specific messages such as: • I/O processor fault; • output not running; • static parameters lost; • calibration data read error. Check which diagnostics are performed: • On-line (in service) automatically, continuously or intermittently. • On-line (in service) user-initiated. • Offline (out of service). Does the manufacturer provide a coverage factor with respect to detection of internal failures?
Detection of incorrect use	Does the instrument or the fieldbus or wireless system detect errors and failures due to incorrect and/or unintended operation and/or maintenance actions such as: • incorrect address settings via jumpers or dip switches (if provided); • reverse connection of power wiring, connectors, printed circuit boards (if possible); • putting connectors at incorrect positions (if length of wiring permits this); • leaving an open circuit by not connecting a connector; • performing an incomplete or incorrect start-up procedure; • leaving the instrument at an incorrect security level; • multiple use of same tag names and numbers for different transmitters in a multi-drop digital communication system; • causing a short-circuit by touching adjacent parts when performing mechanical adjustments.
Alarms	Two groups of alarm types can be differentiated: • Process alarms (related to the above mentioned process diagnostic aspects). Alarm settings may be user-adjustable. • Self-test alarms (related to internal failures of the transmitter). These alarms are in general not user-changeable. List the alarms provided in both groups and indicate how they are communicated to: • Host via fieldbus or wireless. • Hard wired via relay outputs. • Local display. Check whether the alarms appear automatically on-line or only on user-request or in any other way.
Security against unauthorised access	Describe the implemented security methods: • Hardware (write protect switch). • Software (passwords, number of access levels and the degrees of access and configurability at these levels). • Access to local controls and adjustment/tuning facilities.

Function/capability	Aspects to be considered during evaluation
Maintainability	List the levels of repair that the manufacturer specifies (exchange of parts, exchange of complete instrument). Determine the time to repair (comprising of replacement in workshop including configuration, adjustment and tuning). What tools are required for maintenance? List procedures for preventive and/or predictive maintenance. Are provisions and algorithms implemented for the determination of degradation of operation?
Reliability	Give figure(s) for mean time between failures (MTBF) and their source, if provided: • Public database (e.g. MIL HDBK 217 or proprietary database). • Field experience (look for population and period of data collection over which figures are calculated). Is partial/complete redundancy provided or optionally available?
Environmental stress screening (ESS)	Does the manufacturer submit his production to ESS-testing? If so, what screening is provided: • Temperature cycling. • High temperature only (burn-in). • Vibration. • Electrical, other.

4.3.8 Manufacturer's support

Table 7 – Checklist for mapping manufacturer's support

Function/capability	Aspects to be considered during evaluation
Training	List training courses, mention also levels and length.
Manufacturer's maintenance support	• Does the manufacturer offer maintenance contracts (also online)? • What is their scope? • What is the guaranteed time for providing maintenance personnel on the spot?
Spares	• Mention the smallest replaceable unit. • Mention content/size of recommended stock of spare parts. • Spares availability after the end f the transmitter production.
Warranty	Indicate warranty period and the extent.

4.3.9 Reporting

The reporting format as given in Table 8 follows exactly the structure given above in the Tables 1 to 7.

Table 8 – Reporting format for design review

Function/capability	Observations and comments
Fieldbus compatibility	
Wireless compatibilty	
Configuration tools	
On-line reconfiguration	
Off-line configuration	
Up/download to/from PC	
Configurable transmitter output characteristics	
Etc…	

4.4 Documentary information

Table 9 summarises the relevant subjects, which shall be dealt with in the manufacturer's documentation:

Table 9 – Checklist on available documentation

Subject	Observations and comments
Instrument identification • Tag or shield on enclosure • Software identification • Designated use • Other safety related information	
Operating principle	
Application limits • Temperature • Vibration • Humidity • Power supply, etc.	
Electromagnetic compatibility EMC (IEC 61326 series) Environmental classification (IEC 60721-3 series) Operating conditions (IEC 60654 series) Enclosure classification (IEC 60529)	
Certification for application in hazardous areas	
Failure rate data (IEC 61508 series)	
Mechanical construction • Envelope dimensions, mounting • Housing, wetted materials and coating	
External wiring diagrams	
Software description (version numbers)	
Mounting and connecting instructions	

Subject	Observations and comments
Instructions for configuring	
Commissioning • Adjustments • Calibration • Tuning/initialisation	
Operating instructions	
Self-testing/fault finding	
Maintenance instructions	
Performance specifications	
Battery life specification (for wireless transmitters)	
Spare parts list	
Ordering information	
Manufacturer support facilities	
Type of documentation and how it is supplied, (printed, on CD, download from internet)	

5 Performance testing

5.1 General

The choice of transmitter to be submitted to the various tests is subject to negotiations between the parties involved in the evaluation. The guiding principle for setting up performance testing of an intelligent transmitter is a user's application. It is the basis for the definition of the requirements with respect to the measurement function(s), properties and operational environment of a transmitter. The study of the requirements and the actual instrument chosen for evaluation lead to the development of the test procedures and test facilities necessary for execution of the performance tests. At an early stage, the feasibility of testing has to be judged technically and in terms of costs. Depending on the quantity to be measured, the operating principle used in the instrument and the stated requirements, testing may become difficult and expensive.

5.2 Instrument considerations

5.2.1 General

The design review of Clause 4 gives a full insight into the capabilities of the transmitter under consideration in terms of measurement functions and supportive functions such as configuration, local control and self-tests and diagnostics. When a transmitter has an extensive functionality, it may be decided for cost and time reasons to not submit all functions listed to performance testing. It may be agreed that a function or certain functions shall be observed at some of the tests under influencing conditions. In certain cases, where standardized or well-described sensors (e.g. thermocouple and RTD) are used, the parties involved may agree on replacement of the actual physical quantity to be measured by a suitable simulator.

The definition of the measurement functions, to be involved in the evaluation, is based on the concept of data flow paths (see 4.2). The parties involved need to define the relevant data flow paths and measurement ranges of the transmitter to be evaluated. Tables 10 and 11 give examples of a format for listing and defining the functions to be evaluated. Table 10 is related to a single variable (differential pressure) transmitter and Table 11 is related to a transmitter with a derived variable (shaft power of a diesel engine) that is derived from 2 single variables (torque and speed).

5.2.2 Example of a single variable transmitter

The first measuring range column of Table 10 gives the ranges to be considered during the performance tests. The instrument in this example has an electrical output and observations are possible at a local display and at an external system. The local display has a low resolution and shall not be considered with respect to accuracy during the evaluation. The auxiliary temperature measurement shall be observed at the local display, but the actual temperature shall not be specifically controlled or externally measured with an accurate thermometer for that purpose.

The differential pressure transmitter has a capacitive pressure sensor and an internal temperature sensor of the resistance temperature detector type.

For testing, the actual physical quantity (differential pressure) shall be applied to the input.

Table 10 – Listing of functions of a single variable transmitter

	Measured values (outputs) to be observed							**Sensor characteristics**		**Related physical quantities to be provided at input(s)**		
			Type of output		Data flow path to:						Source	
Reference number	Measured Variable	Measuring range	Main	Auxiliary	Local display	External system.	Electrical output. 4 mA to 20 mA	Measurement principle	Measuring range	Quantity	Physical quantity	Simulator
1	Differential pressure	0 kPa to 5 kPa 0 kPa to 100 kPa [b]	S[a]			X	X	Capacitive	-500 kPa to +500 kPa	Pressure	X	
2	Internal temperature [c]	-40°C to +50 °C		S[a]	X			RTD	-40 °C to +100 °C	Temperature	X	

[a] S: Single variable.

[b] At the range of 0 kPa to 100 kPa a limited set of tests are to be performed; these tests shall be explicitly indicated in the matrices of 5.7 and 5.8.

[c] The internal temperature shall be monitored at the local display at all tests. Any large deviations to the ambient temperature may indicate defects.

5.2.3 Example of a derived variable transmitter

The first measuring range column of Table 11 gives the ranges to be considered during the performance tests. The instrument in this example does not have an electrical output and observations are possible at a local display and an external system. The auxiliary temperature measurement is observed at the local display, but the actual temperature is not specifically controlled or externally measured for that purpose. The torque and speed outputs are tested with the actual physical quantities applied to the sensor subsystem. For the mechanical power measurement, the torque and speed sensors can be bypassed and simulated by electrical signals equivalent to the output signals of the various sensors shown in the source columns.

Table 11 – Listing of functions of derived variable transmitter

Ref. no	Measured values (outputs) to be observed							Sensor characteristics		Related physical quantities to be provided at input(s)		
	Measured Variable	Measuring range	Type of sensor		Data flow path to:			Measurement principle	Measuring range	Quantity	Source	
			Main	Auxiliary	Local display	External system	Electrical output				Physical quantity	Simulator
1	Mechanical power	100 kW to 350 kW	C[a]		X	X		Strain gauge	10 kNm to 25 kNm	Torque		X
								Optical encoder	100 r.p.m. to 500 r.p.m.	Speed		X
2	Torque	10 kNm to 25 kNm	S[b]		X	X		Strain gauge	10 kNm to 25 kNm	Torque	X	
3	Speed	0 r.p.m.to 500 r.p.m.	S[b]		X	X		Optical encoder	0 r.p.m.to 500 r.p.m.	Speed	X	
4	Internal temperature	0 °C to 50 °C		S[b]	X			RTD	0 °C to 50 °C	Temperature		X

[a] C: Derived variable.

[b] S: Single variable.

5.3 Measurement considerations

5.3.1 General

An evaluation should measure the instrument's full characteristics at each test, which means that the measurements should be performed at a number of intervals sufficient to prove that the instrument conforms to its specifications. This evaluation can however become very expensive, particularly for derived measured values. In many cases, the added value to full characteristics measurements shall not be proportional to the costs.

Therefore, an evaluation comprises a full characteristic measurement at reference conditions and at various reduced sets of measurements, which depend on the influencing conditions to be applied, as listed in 5.8, and on the facilities available.

5.3.2 Single variables

5.3.2.1 General

For single variables, (as shown in Table 10) the procedures are described in 5.3.2.2 and 5.3.2.3.

5.3.2.2 Linear characteristic

For each single variable with a linear characteristic, slowly increase, without overshoot, the input signal from 0 % to 100 % and back to 0 % in steps of preferably 10 %. The steps shall not be larger then 20 %. After each step, the transmitter shall be allowed to attain steady state. Then note the corresponding values of input and output signals at each step. The measurement cycle shall at least be performed 3 times. The measurements in the upward and downward directions shall be averaged separately and shall be plotted on a graph. Moreover, the maximum hysteresis and maximum repeatability errors shall be calculated from the measurements. The basis for calculating the repeatability shall also be stated.

The reduced set of measurements, to be agreed upon between the parties involved, comprises measurement of either:

– zero and span shift (if the influencing quantity is expected to influence linearity, some intermediate points may be added), or
– point measurements at either 0 %, 10 %, 50 %, 90 % or 100 %.

NOTE When the 0 % or 100 % points are fixed values that cannot be surpassed, zero and span shifts can be derived from measurements at e.g. 2 % and 98 %.

5.3.2.3 Non-linear characteristic

For a non-linear function, the input intervals shall be chosen such that the specified characteristic curve is sufficiently covered. Unless agreed to otherwise, the conformity errors shall be determined as the differences between the specified characteristic and the separately averaged upward and downward measurements. They shall be plotted in a graph. Moreover, the maximum hysteresis and maximum repeatability errors shall be calculated from the measurements. The basis for calculating the repeatability shall also be stated.

The reduced set of measurements shall be agreed to by the parties involved.

5.3.3 Derived variable

For derived variables, (as shown in Table 11) the procedure is identical. One quantity is varied while the second is kept constant at the various relevant values. When the measurement circuit for the second quantity inherently causes a considerable hysteresis, the procedure is repeated by varying the second while the first is kept constant.

The reduced set of measurements shall be agreed to by the parties involved.

5.4 Test facilities

5.4.1 General

Figure 2 illustrates the basic test set-up. Depending on the type of transmitter and the quantity(-ies) to be applied and measured, the signal generator(s) and data acquisition equipment can become very complex.

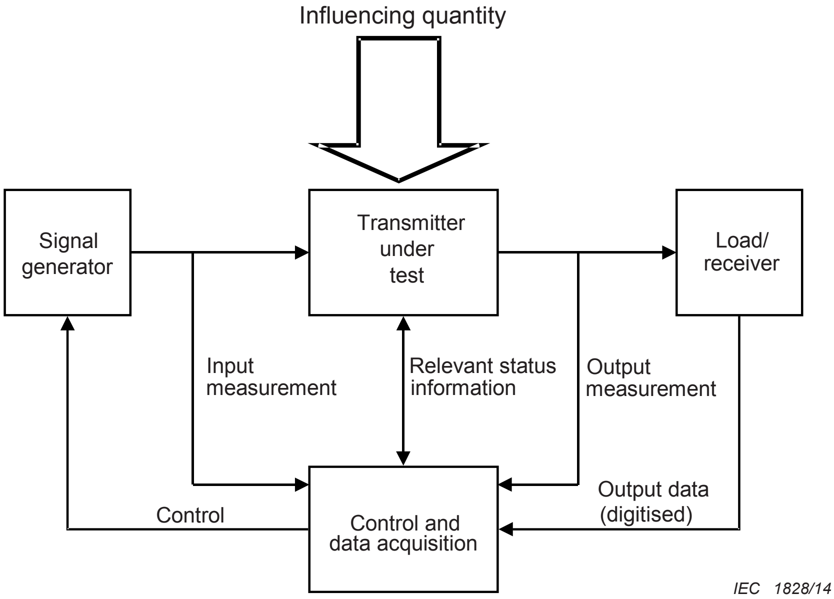


Figure 2 – Basic test set-up

5.4.2 Signal generator

The inputs to be applied to the transmitter shall be provided by signal generators traceable to reference standards or reference materials. The applied signals shall be steady, stable and free from drift over the period of measurement. If the signal generator contains periodic variations, measurements shall be averaged by integrating over a sufficiently long period of time by means of the so-called flying start and stop method. This means that the physical quantity applied to the instrument under test is under steady and controlled conditions at the required level during the measurement period (including the start and stop). This method also requires an accurate time measurement.

The applied signal(s) shall have an accuracy of at least 10 times, or at a minimum 4 times, the accuracy specified for the transmitter under consideration. For a transmitter providing a derived variable, each input requires a specific signal generator.

The dynamic properties of the signal generator(s) and the equipment for measuring the input and relevant output signals shall be superior to the dynamic behaviour of the transmitter under test.

It shall be noted that signal generators shall be adequately equipped with provisions to also perform the tests described in 5.8.

5.4.3 Output load/receiver

Current outputs shall be loaded with the maximum permitted or agreed upon resistive load.

Voltage outputs shall be loaded with the minimum permitted or agreed upon resistive load.

The transmitter shall be electrically connected to the fieldbus system and host computer with its fieldbus interface, as specified by the manufacturer.

With respect to data flows, a base load shall be defined at which the relevant data, necessary for proper measurement and operation, can be exchanged between the transmitter and fieldbus master and other fieldbus participants.

5.4.4 Control and data acquisition

The control and data acquisition unit can be fully automatic or it can be a manually and visually evaluator-operated system. The equipment used for measuring, recording and controlling the various signals shall not adversely affect the signals applied and measured. Note that the host computer may be partly used for data acquisition.

The overall uncertainty of the measuring equipment shall also be calculated using the uncertainties of the individual measuring instruments used.

5.5 Transmitter under test (testing precautions)

Prior to starting the tests, the transmitter shall be adjusted, calibrated and tuned (initialised) according to the manufacturer's instructions.

Before each test, the evaluator shall ensure that the transmitter is in an error- and fault-free state and in its normal operational mode. Prior to each, test reference measurements and checks are performed to determine shifts of the relevant characteristics during and after the test and to observe the possible appearance of alarm messages, indicating a faulty status of the instrument.

An adequate time, as specified by the manufacturer, shall be allowed (after switching on the power supply) in order to stabilize the transmitter and/or the associated test equipment. In the absence of a specification, a period of at least 15 minutes shall be allowed.

The measurement points used to determine the relevant performance characteristic should be distributed over the range. They should include points at or near the lower- and upper-range values. There should be at least six measurement points, and preferably more. The number and location of these measurement points should be consistent with the degree of precision required and the characteristic being evaluated. Each measurement point should be reached without any overshoot of the input signal.

At each point being observed, the recording shall be done after the device has stabilized at its apparent steady-state value.

All testing should be conducted with the instrument covers in place and with the device in an agreed mounting position, which shall be stated in the report.

Tests of a transmitter in a fieldbus system shall be considered carefully. The dynamic behaviour of the fieldbus system and host computer shall not obscure the transmitter characteristics. Preferably, transmitter tests are executed in a stand-alone configuration as shown in Figure B.1 and with a base load.

The host computer shall not be used for processing and storing test data in non-fieldbus-related applications in order to avoid interference of the fieldbus tasks.

5.6 Reference conditions for performance tests

The reference values for the environmental and operational test conditions are listed in Table 12. For more detailed information, see Clause 6 of IEC 61298-1:2008.

Table 12 – Reference environmental and operational test conditions

	Reference conditions
Ambient temperature [a]	20 °C ± 2 °C 15 °C to 25 °C recommended limits
Relative humidity See note	65 % ± 5 % 45 % to 75 % recommended limits
Atmospheric pressure	86 kPa to 106 kPa
Electromagnetic field	Value to be stated, if relevant
Electrical supply	- Specified voltage: ±1 % - Specified frequency: ±1 % - Harmonic distortion (a.c. supply): less than 5 % - Ripple (d.c. supply): less than 0,1 %
Mounting position	The instrument shall be mounted in one of its specified normal mounting positions in accordance with the manufacturer's instructions
Vibration	The instrument shall be installed such as to avoid any effect of vibrations induced from outside the instrument during the tests

[a] Tests shall preferably be done within the specified reference atmospheric conditions. They may – by exception – be done within the recommended limits; in no case shall they exceed these limits. When measurements within the recommended limits are unsatisfactory, they shall be repeated under the reference atmospheric conditions.

5.7 Test procedures for tests under reference conditions

Table 13 – Procedures for tests under reference conditions

Designation	**Test methods and information to be reported**	**Reference**	**Additional information**
• **Accuracy** **Single variable linear** • Linearity errors • Hysteresis • Repeatability	Measurements at least 3X in upward and downward direction at 10 % to 20 % intervals. Data (terminal-based processed) shall be plotted in a graph.	IEC 61298-2:2008, Clause 4	
• **Accuracy** **Single variable non-linear** • Conformity errors • Hysteresis • Repeatability	Measurements at least 3X in upward and downward direction at predefined intervals. Data (processed as agreed) shall be plotted in a graph.		
• **Accuracy** **Multivariable** • Conformity errors • Hysteresis • Repeatability	Measurements of one quantity at least 3X in upward and downward direction at predefined intervals where the other quantity is kept constant. Data (processed as agreed) shall be plotted in a graph.		
• **Conformity errors auxiliary sensors** • Hysteresis • Repeatability	Measurements at least 3X in upward and downward direction at 10 % to 20 % intervals Data shall be plotted in a graph.	IEC 61298-2:2008, Clause 4	Test may be skipped when sensors are not essential for correct operation
• Switching points binary input sensors	Determine threshold values for switching from logic "0" to "1" and reverse.		Optional test
• **Function blocks**	See Annex C.		

<table>
<tr><th>Designation</th><th>Test methods and information to be reported</th><th>Reference</th><th>Additional information</th></tr>
<tr><td>• Dead band</td><td>Measurement at 50 % (10 %, 90 % optional).</td><td>IEC 61298-2:2008, 4.2</td><td></td></tr>
<tr><td colspan="4">Procedure for dead band test.
• Slowly increase one input until detecting an output change. Note this signal as W_1.
• Slowly decrease that input until detecting an output change. Note this signal as W_2.
The difference ($W_1 – W_2$) is the dead band value. Measurement should be made 3 times; maximum value is quoted as the dead band. The test is for a transmitter with a derived measured variable repeated for the other input(s)
When the dead band is user-adjustable it shall be measured at the minimum and maximum values and the value required or advised for optimal operation (obtained by the tuning procedure, or described in the manual).</td></tr>
<tr><td colspan="4">Dynamic response
• The availability and settings (fixed or user-adjustable) of input filters shall be clearly reported.
• The dynamic response of a derived measured variable may be different for each of the involved single variables. Unless otherwise agreed, the dynamic effects of the separate functions and a combination shall be determined.
• The dynamic behaviour of transmitters in a fieldbus can be evaluated in 2 ways:
– The host computer records the response in real time and stores it for analysis.
– A second fieldbus instrument provided with an analogue output receives the measured value over the fieldbus. This output shall then be recorded with an external recorder.
• Dynamic tests in a fieldbus configuration are strongly influenced by the fieldbus cycle time and the fieldbus load. When the cycle time is user-adjustable, it shall be set to the minimum value. Furthermore, the base load shall be applied to the fieldbus system.</td></tr>
<tr><td>• Frequency response</td><td>Apply sinus signal with amplitude $<$ 5 %, starting at 0,01 Hz to a higher frequency at which the output is attenuated to less than 10 %. Report: – 3 dB point (relative gain 0,7); phase lag 45º and 90º maximum relative gain and corresponding frequency and phase lag.</td><td>IEC 61298-2:2008, 5.3</td><td>The test shall be performed until a frequency of not greater than 0,2 times the bus frequency.</td></tr>
<tr><td colspan="4">For fieldbus instruments, this test can be skipped or can be performed for obtaining reference data in the fieldbus system considered. The test results then include the dynamic behaviour of fieldbus system.</td></tr>
<tr><td>• Step response</td><td>Apply successively at least 3 steps up- and downward between 10 % and 90 %; 5 % and 15 %; 45 % and 55 %; 85 % and 95 %.
Determine step response time, dead time, overshoot and settling time (see Figure 3).
For each type of step determine the average unless the mutual differences are $>$30 % or $>$ 2 s, whichever is the greatest. In that case, the minimum and maximum values shall be reported. Also report possible limit cycling.</td><td>IEC 61298-2:2008, 5.4</td><td></td></tr>
<tr><td colspan="4">For fieldbus instruments, this test can be skipped or can be performed for obtaining reference data in the fieldbus system considered. The test results then include the dynamic behaviour of the fieldbus system.
For accurate response time measurements, excluding the dynamics of the fieldbus system, the transducer at the signal generator side (see Figure 2) should include a bus monitor to determine the exact time at which the step function arrives at the instrument's input.
When a signal generator influences the response time, some appropriate steps can be set depending on the type of transmitters, e.g. apply steps downward between 90 % and 0 %.</td></tr>
<tr><td>• Power requirements</td><td>Determine the maximum power consumption and the conditions for input(s) and output(s) at which it appears.</td><td>IEC 61298-3:2008, 12.1</td><td></td></tr>
<tr><td colspan="4">For loop-powered analogue 4 mA to 20 mA transmitters determine the voltage over the terminals at 100 % input. For fieldbus powered transmitters, determine minimum voltage or current at which the instrument can still operate.</td></tr>
</table>

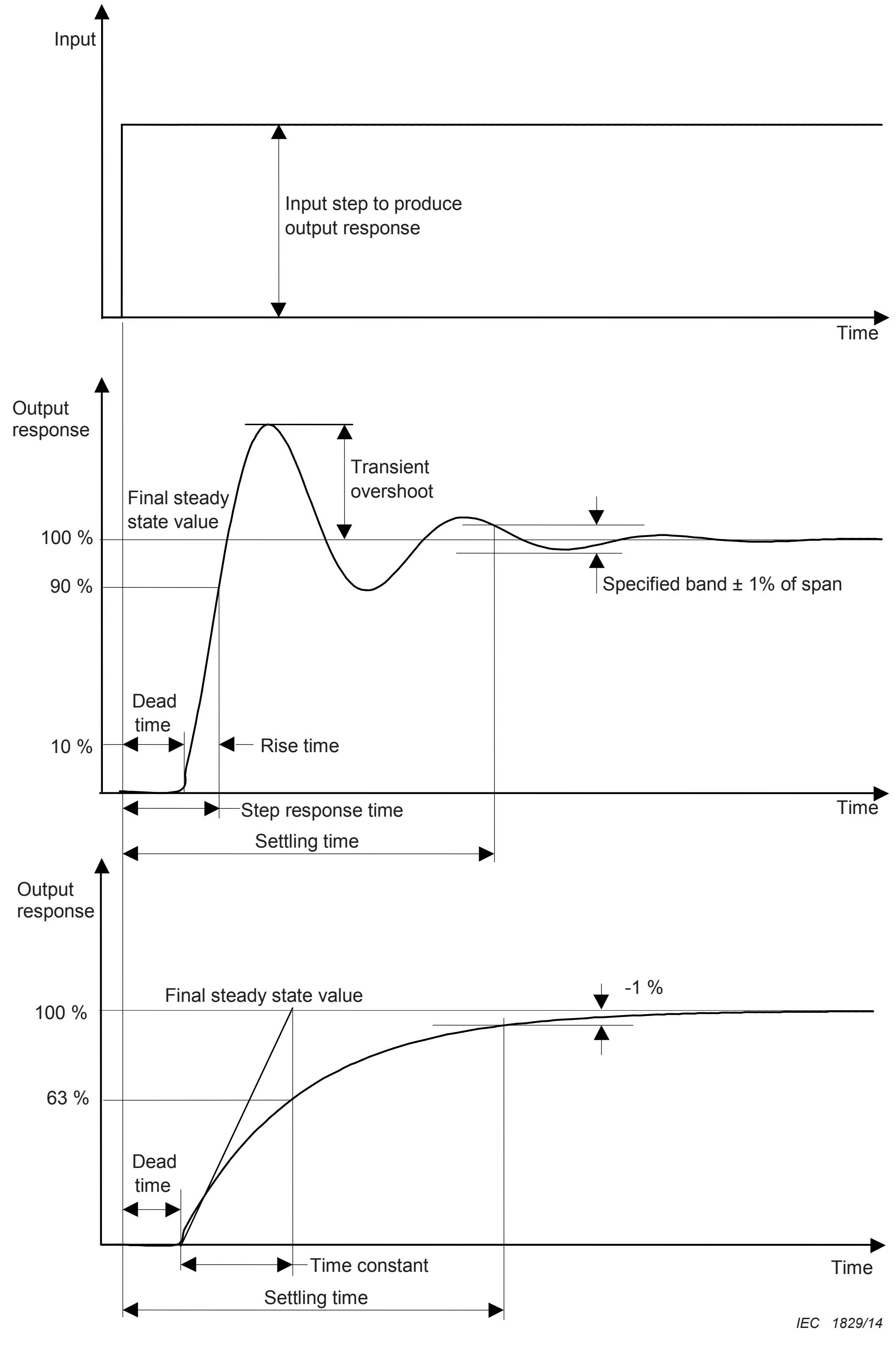


Figure 3 – Examples of step responses of electrical outputs of transmitters

5.8 Test procedures for determination of the effects of influence quantities

5.8.1 General

5.8.1.1 Overview

During and/or after the tests described in 5.8, the observations and measurements to be performed are presented in the Tables 14 to 18. The matrices are tools for designing a test programme for the evaluation of transmitters.

Subclauses 5.8.1.2 to 5.8.1.6 give guidance on the use of the Tables 14 to 18.

5.8.1.2 Accuracy columns

Measured variable

Determine the relevant data flow paths for each quantity to be measured. For both single variable and multivariable transmitters, this column has to be split in a number of columns equal to the number of the determined relevant data flow paths. So in the example of Table 14, the column shall be split into six sub-columns for torque, r.p.m. and power at the local display and at the external system.

The symbols used in this column are:

Cr = reduced characteristic (zero and span shift for linear characteristic and an agreed number of measurement points for non-linear characteristics).

P = point measurement.

Pr = point measurement with recording during the test.

X = test or check as described below has to be executed.

It is advised to apply to the input, a slow triangular signal with a small amplitude of approximately 2 % during a Pr type point measurement. The applied test may force the instrument continuously or temporarily into a “hold” state. With a steady input applied, the evaluator may not observe a temporary “hold”. Moreover, when applying a triangular signal, possible delays in reaction time of the instrument’s outputs are also revealed.

Auxiliary functions

Auxiliary analogue functions shall be checked for their proper operation. Determine the number of relevant auxiliary functions and split this column accordingly. The following auxiliary functions may be provided:

– Analogue sensors (e.g. for internal temperature measurement).
– Digital inputs; check for correct operation by introducing in turn a logic "0" and a logic "1".
– Digital outputs; check for correct switching upon application of the relevant stimulus.

Intermediate/internal values

When the instrument has provisions for reading local or remote data or for reading intermediate data at electrical test points in the various data flow paths, these shall also be monitored and noted.

Determine the number of relevant intermediate values to be monitored and split this column accordingly. In case of failures or errors, these data may show in which part of the transmitter they occurred. Intermediate values that can be provided are:

– The “raw” electrical sensor signal.

– The converted (digitised) sensor signal before being processed (A/D output).

5.8.1.3 Dependability columns

Hardware damage

Observe the instrument for mechanical damage, malfunctions or degraded operation during and/or after the test.

Communication

Check the communication via local controls. This comprises the unobstructed access to the instrument via local pushbuttons and undisturbed read-out of data via local displays.

Check the communication via a fieldbus. This comprises the unobstructed access to the instrument via the host and fieldbus and undisturbed read-out of data via the host's displays.

Also check the communication in both the human and external system domain for delays or temporary stops as a result of the applied test.

Software configuration

Check the software configuration for any corruption or change due to the applied test condition with respect to integrity of user-accessible data, functions and cycle times.

Diagnostic messages

Check diagnostic displays (local and at the PC or handheld terminal) and report diagnostic messages and process alarms that may appear as a result of the applied test condition.

Instruments may be equipped with a variety of diagnostic tests that can be run either automatically or initiated by the operator in a healthy or a faulty instrument. If the instrument is not fully operating as expected, the evaluator shall check the operation of the instrument with the operator-controlled diagnostic facilities.

5.8.1.4 Stability columns

Step response

Introduce steps from 45 % to 55 % and back to the input and report any change in time for the output to reach a stable position (within 1 % of the span of the final steady state). If limit cycling appears, report the amplitude and cycle time.

Stability

Check the (steady state) stability of the instrument at 10 %, 50 % and 90 % input. Report obvious instability and/or limit cycling. In the last case, also report the amplitude and cycle time. In case of instability or limit cycling, perform the auto-tuning procedure and report the resulting changes of the relevant control parameters and possible improvement of stability.

Auto-adjustment/auto-tuning

Perform the auto-adjustment and auto-tuning procedures.

For the auto-adjustment procedure, report possible changes of the zero and span, linearity and time required for performing it.

For the auto-tuning procedure, report possible changes of the relevant control parameters and time required for performing it.

Possible stability changes resulting from performing these procedures shall also be reported.

5.8.1.5 Time of measurements

As the measurements and observations during and after each test are not always the same, the table distinguishes two situations in the column "Time of measurement".

D = shift measurements with respect to initial measurements before the test and observations during test.

A = shift measurements with respect to initial measurements before the test and observations after test.

5.8.1.6 Test method rows

The test levels mentioned in the test method rows, are preferred levels derived from the standards mentioned in the reference column. When they exceed the specifications the test levels shall be reduced unless the manufacturer explicitly agrees on the levels in this standard.

5.8.2 Process domain

5.8.2.1 General

In the process domain, the performance of a transmitter can be affected by disturbances in the sensor subsystem that originate at the process and from installation and by electrical disturbances on the wiring to remote sensors and electrical loads. Therefore, this domain is divided into two sub-domains:

– sensor disturbances;
– wiring disturbances.

5.8.2.2 Sensor disturbances

The listings of parameters under the effects of medium properties, medium conditions and installation conditions are not exhaustive and can be extended when necessary.

Moreover, the severity levels for these tests need to be defined in detail, by taking into account the evaluation objectives when drafting the evaluation.

Table 14 – Methods for testing immunity to sensor disturbances – Matrix of instrument properties and tests

Designation		Accuracy			Dependability				Stability			References
	Time of measurement	Measured variable(s)	Further auxiliary I/O	Intermediate values	Damage/loss of operation	Software configuration	Communication	Diagnostic messages	Step response	Stability	Auto-adjustment/auto-tuning	
Input over-range	D	P [a]		X	X		X	X				
	A	Cr		X	X	X	X	X				
Test method	Overload each separate sensor with the maximum permitted signal for 1 min. Observe the behaviour of the transmitter during the overload period. After a 5 min recovery time at 50 % input, measurements and observations shall be performed. This test can damage the transmitter under test. It should be performed as the last test. Safety measures may also be required.											
Effect of medium properties	D	Cr	X	X				X	X	X	X	
	A	Cr	X	X				X	X	X	X	
Test parameters	Depending on the physical quantity to be measured and the measuring principle used, the influence of the following properties can be considered: • density • conductivity • magnetic permeability • viscosity • corrosiveness • transparency • dielectric constant • compressibility • thermal expansion • chemical/physical composition • velocity of sound											
Effect of medium conditions	D	Cr	X	X	X		X	X	X	X	X	
	A	Cr	X	X	X		X	X	X	X	X	
Test parameters	Depending on the physical quantity to be measured and the measuring principle used, the influence of the following conditions can be considered: • pressure • temperature • medium (solids, liquids, gas) • two-phase fluids (liquid/gas or liquid/solids) • medium pollution causing signal interference • flow rate (high, low, fluid in rest)											
Effect of installation	D	Cr	X	X	X			X	X	X	X	

Designation		Accuracy			Dependability				Stability			References
	Time of measurement	Measured variable(s)	Further auxiliary I/O	Intermediate values	Damage/loss of operation	Software configuration	Communication	Diagnostic messages	Step response	Stability	Auto-adjustment/auto-tuning	
	A	Cr	**X**	**X**	**X**			**X**	**X**	**X**	**X**	
Test parameters	• Mounting position of the sensor assembly This test is only applicable to instruments that are inherently sensitive, by design, to the mounting position of the sensor assembly. The parties involved can agree on other positions other than those mentioned below, including upside down. The sensor assembly shall be tilted ±10° and ±90° in 2 mutually perpendicular planes from the agreed reference position. In every position, relevant measurements and observations shall be made. • Flow profile disturbances This test is specific to the evaluation of flowmeters and transmitters which have a flowing medium passing through the sensor. The test can include disturbances caused by: upstream valves, piping geometry (space bend, T-bend, elbow, abrupt diameter changes all with agreed geometry), packing partly obstructing piping, misalignment of piping, etc. • Electrical current through process medium • Layer built-up in or on the sensor assembly • Degree of heat insulation • Mechanical stress on piping connections or fittings											

[a] See 5.8.1.2 under "measured variable" for symbols.

5.8.2.3 Wiring disturbances

Table 15 – Methods for testing immunity to wiring disturbances

Designation		Accuracy			Dependability				Stability			References
	Time of measurement	Measured variable(s)	Further auxiliary I/O	Intermediate values	Damage/loss of operation	Software configuration	Communication	Diagnostic messages	Step response	Stability	Auto-adjustment/auto-tuning	
Earthing	D	Cr	X		X		X	X		X		
	A	Cr	X		X		X	X		X		
Test method	Successively connect each electrical terminal (sensors, outputs, fieldbus) to ground. Take care to eliminate any effect(s) due to earthing of the input signal source(s).											
Line impedance	D	Cr	X		X		X	X		X		
	A	Cr	X		X		X	X		X		
Test method	Introduce an impedance corresponding to the specified type of wiring between the sensor and transmitter body. It may be agreed to limit it to a resistive impedance instead of a full resistive/capacitive/inductive simulation.											
Line break	D	Pr	X		X		X	X		X		
	A	P	X		X		X	X		X		
Test method	Each relevant electrical connection (sensors, electrical outputs, communication) shall be interrupted for 5 min and the change in operation and measurement during the test shall be observed and reported. At the moment of line break, the inputs shall be at 50 %. Check the instrument for line break detection and the availability of configurable actions, in case of line break.											
Short-circuit	D	Pr	X		X		X	X		X		
	A	P	X		X		X	X		X		
Test method	Short-circuit each relevant electrical connection (sensors, electrical outputs, communication) for 5 min and observe the change in operation and measurement during the test. Before short-circuiting, the inputs shall be at 50 %. If the instrument can be configured for certain actions, as a result of short-circuit detection, these shall also be investigated.											
Common mode interference	D	Cr	X		X		X	X		X		IEC 61298-3:2008, 13.1
	A	Cr	X		X		X	X		X		
Test method	This test is only applicable to I/O-circuits that are isolated from earth. Care should be taken so that the input signal generator(s) is/are not affected by the common mode test signal. Superimpose a signal of 250 V/50 Hz with variable (360°) phase between earth and the relevant terminals unless the manufacturer specifies a lower value. A 10 kΩ resistor shall be connected in series with the test source. Then, repeat the test using a ± 50 V d.c. voltage or a voltage 1 000 times the input span, whichever is less, unless the manufacturer specifies a lower value.											
Series mode interference	D	Cr	X		X		X	X		X		IEC 61298-3:2008, 13.2
	A	Cr	X		X		X	X		X		

Designation		Accuracy			Dependability				Stability			References
	Time of measurement	Measured variable(s)	Further auxiliary I/O	Intermediate values	Damage/loss of operation	Software configuration	Communication	Diagnostic messages	Step response	Stability	Auto-adjustment/auto-tuning	
Test method	The test only applies to transmitters with a remote sensor assembly. For devices with isolation between input and output circuits, the electrical output circuit should be earthed during the test. For each input circuit, apply a 50 Hz series mode voltage with variable (360°) phase and determine at 10 % and 90 % input the test level at which the various measurement characteristics show shifts of 0,5 %. Then, increase the voltage to 1 V and perform further measurements. For current inputs, apply a series mode current signal with an amplitude of 10 % peak-to-peak.											
Conducted RF disturbances	D	Pr			**X**		**X**	**X**		**X**		IEC 61326-1
	A	Cr	**X**		**X**	**X**	**X**	**X**		**X**		
Test method	The test shall be performed according to IEC 61326. The RF signal level shall be 3 V in the frequency range of 0,15 MHz to 80 MHz. During the test, the inputs shall be at 50 % and the relevant outputs shall be recorded. Temporary and permanent effects on operation and measurement characteristics shall be determined as functions of the interference signal frequency.											
Electrical fast transients (Burst)	D	Pr			**X**		**X**	**X**		**X**		IEC 61326-1
	A	Cr	**X**		**X**	**X**	**X**	**X**		**X**		
Test method	The test shall be performed according to IEC 61326. Electrical fast transients of 1 kV shall be applied to the relevant cables (I/O, communication) between the various subsystems of the transmitter. During the test, the inputs shall be at 50 % and the relevant outputs shall be recorded. Temporary and permanent effects on operation and measurement characteristics shall be determined as functions of the interference signal frequency.											
Surge	D	Pr			**X**		**X**	**X**		**X**		IEC 61326-1
	A	Cr	**X**		**X**	**X**	**X**	**X**		**X**		
Test method	The test shall be performed in accordance with IEC 61326 at ± 1 kV line to ground. During the test, the inputs shall be at 50 % and the relevant outputs shall be recorded. Temporary and permanent effects on operation and measurement characteristics shall be determined as functions of the interference signal frequency.											

5.8.3 Utility domain

Table 16 – Methods for testing the immunity to disturbances of the power utilities

Designation		Accuracy			Dependability				Stability			References
	Time of measurement	Measured variable(s)	Further auxiliary I/O	Intermediate values	Damage/loss of operation	Software configuration	Communication	Diagnostic messages	Step response	Stability	Auto-adjustment/auto-tuning	
Supply voltage/frequency variation	D	Cr	X	X	X		X	X		X	X	IEC 61298-3:2008, 12.1
	A	Cr	X	X	X		X	X		X	X	
Test method	For transmitters with separate power supplies, apply the following variations: a) a.c. supplies: nominal value + 10 %/-15 %, in combination with frequency variations of +2 %/-10 % from nominal, or manufacturer's limit if less, resulting in 9 sets of measurements. b) d.c. supplies: nominal value +20 %/-15 % or manufacturer's limit if less. For 2-wire transmitters determine: a) minimum voltage with 250 Ω load for the instrument to maintain a 100 % electric output. b) minimum current for the instrument to provide correct digital output (local or remote via fieldbus).											
	D	Pr			X		X	X		X		IEC 61298-3:2008, 12.2
	A	Cr	X		X		X	X		X		
Test method	From the nominal voltage, step changes (rise time < 1 ms), of + 10 % (a.c. supplies) or 20 % (d.c. supplies) and -15 % shall be applied for 10 ms, 100 ms, 1 000 ms and 10 000 ms and the output shall be recorded. Sufficient steps shall be applied to characterize temporary or permanent effects and recovery time for the relevant outputs.											
Supply voltage depression	D	Pr			X		X	X		X		IEC 61298-3:2008, 12.3
	A	P	X		X		X	X		X		
Test method	The sensor signal(s) shall be such that the output(s) of the transmitter is (are) at 100 %. Then reduce the supply voltage to 75 % of nominal value for a period of 5 s. The rise time should be no faster than 100 ms in order to avoid transients. Report transients in percent of span and distortion and recovery times after restoring the nominal supply.											
Power interruptions	D	Pr			X		X	X		X		IEC 61326-1
	A	P	X		X	X	X	X		X		
Test method	NOTE The test method described here is an extension of that described in IEC 61326. The sensor signal(s) shall be such that the electrical output(s) of the transmitter is (are) at 100 %. The power supply shall be interrupted for periods up to 500 ms. The interruption period shall be gradually increased from 5 ms to 500 ms and the output(s) (both electrical and software) shall be recorded. The transmitter behaviour (total distortion time and recovery time) on return of power shall also be observed. Additionally, the transients (amplitude and duration) on the output shall be determined at 5 ms, 20 ms, 50 ms, 100 ms, 200 ms and 500 ms.											
Harmonic distortion	D	Cr			X		X	X		X		IEC 61298-3:2008, Clause 14
	A	Cr	X		X		X	X		X		
Test method	Apply harmonic distortion (second to fifth harmonics, or as agreed) to the fundamental supply frequency. Distortion levels of 2 % and 10 % shall be used and the phase shift shall be varied through 360°. The instrument's output(s) shall successively be adjusted to 10 % and 90 % before the test.											

Designation		Accuracy			Dependability				Stability			References
	Time of measurement	Measured variable(s)	Further auxiliary I/O	Intermediate values	Damage/loss of operation	Software configuration	Communication	Diagnostic messages	Step response	Stability	Auto-adjustment/auto-tuning	
Conducted RF disturbances	D	Pr			**X**		**X**	**X**		**X**		IEC 61326-1
	A	Cr	**X**		**X**	**X**	**X**	**X**		**X**		
Test method	The test shall be performed according to IEC 61326. The RF signal level shall be 3 V (unmodulated) in the frequency range of (0,15 to 80) MHz. During the test, the inputs shall be at 50 % and the relevant outputs shall be recorded. Temporary and/or permanent effects on operation and measurement characteristics shall be determined as functions of the interference signal frequency.											
Electrical fast transients (Burst)	D	Pr			**X**		**X**	**X**		**X**		IEC 61326-1
	A	Cr	**X**		**X**	**X**	**X**	**X**		**X**		
Test method	The test shall be performed according to IEC 61326. Electrical fast transients of 2 kV shall be directly injected in the power supply circuit. During the test the inputs shall be 50 % and the relevant outputs shall be recorded. Temporary and/or permanent effects on operation and measurement characteristics shall be determined as functions of the interference signal frequency.											
Surge	D	Pr			**X**		**X**	**X**		**X**		IEC 61326-1
	A	Cr	**X**		**X**	**X**	**X**	**X**		**X**		
Test method	The test shall be performed in accordance with IEC 61326 at test levels of respectively ± 1 kV peak line to line and ± 2 kV peak line to ground. During the test the inputs shall be at 0 % and the relevant outputs shall be recorded. Temporary and/or permanent effects on operation and measurement characteristics shall be determined as functions of the interference signal frequency.											

5.8.4 Environmental domain

Table 17 – Methods for testing the immunity to environmental disturbances

Designation		Accuracy			Dependability				Stability			References
	Time of measurement	Measured variable(s)	Further auxiliary I/O	Intermediate values	Damage/loss of operation	Software configuration	Communication	Diagnostic messages	Step response	Stability	Auto-adjustment/auto-tuning	
Ambient temp: performance	D	Cr	X	X	X		X	X	X	X		IEC 60068-2-1
	A	Cr	X	X	X		X	X	X	X		IEC 60068-2-2
Test method	The transmitter is submitted 2 times to ambient temperatures in the following range, but not exceeding the manufacturer's specified operating temperatures limits: + 20 °C, + 40 °C, + 60 °C, + 85 °C, + 20 °C, 0 °C, – 20 °C, – 40 °C, + 20 °C. Allow sufficient time (not less than 4 h) for stabilization at each temperature. Perform, at the end of each stabilization period, the relevant measurements and checks. Perform the second cycle without any adjustment to the transmitter. If agreed by the parties involved, tests at only the following temperatures, + 20 °C, minimum specified operating temperature, maximum specified operating temperature, and + 20 °C after the test can be sufficient and acceptable.											
Ambient temp: operability	D	Cr			X		X	X		X	X	
	A	Cr	X		X		X	X		X	X	
Test method	With the power switched off, submit the transmitter (for at least 6 h) to the minimum and then to the maximum specified ambient temperatures. Then, switch the power on and check the instrument for correct start-up and operation. After correct start up, relevant measurements shall be performed. The initialization procedure, as described by the manufacturer, shall then be performed. Any differences with respect to initialization at room temperature shall be reported. The differences may be different parameters, increased time for performing the procedure or shifts of characteristic.											
Relative humidity	D	Cr	X	X	X		X	X		X		IEC 60068-2-78
	A	Cr	X	X	X		X	X		X		
Test method	The ambient atmospheric conditions of the transmitter shall be changed from reference conditions to 40 °C ± 2 °C and to 93^{+2}_{-3} % RH in 2 h. Maintain the transmitter in these conditions for at least 48 h. For the initial 4 h and the final 4 h, the instrument shall be powered. In between, the power shall be switched off. After the 48 h period, the relative humidity and temperature shall be lowered (in 2 h) and kept for at least 4 h at reference atmospheric conditions. Measurements and observations shall be performed: • at the end of the initial 4 h, while still under power, • directly after powering up the transmitter in the final 4 h period, • at the end of the final 4 h, • at the end of the 4 h period, after the test at reference atmospheric conditions.											
Mounting position	D	Cr	X		X		X	X		X		IEC 61298-3:2008, Clause 9
	A	Cr	X		X		X	X		X		
Test method	This test is only applicable to transmitters that are inherently sensitive to the mounting position. Positions other than those mentioned below may be agreed upon. Tilt the transmitter ±10° and ±90° in 2 mutually perpendicular planes from the reference position. In every position, relevant measurements shall be made.											
Drop and topple	D	Pr			X		X	X				IEC 60068-2-31
	A	Cr	X		X		X	X		X		

Designation		Accuracy			Dependability				Stability			References
	Time of measurement	Measured variable(s)	Further auxiliary I/O	Intermediate values	Damage/loss of operation	Software configuration	Communication	Diagnostic messages	Step response	Stability	Auto-adjustment/auto-tuning	
Test method	The transmitter sits in its normal position on a smooth, rigid surface of concrete or steel. It is tilted over one bottom edge until the distance between the opposite edge and the test surface is either 25 mm, 50 mm, or 100 mm (value chosen by agreement), or the angle made by the bottom and the test surface is 30°. In the less severe condition, it is then allowed to fall freely on to the test surface. The transmitter shall be subjected to one drop about each of four bottom edges. This test may be skipped if there is no need or requirement for transmitters.											
Mechanical vibration	D	Pr			X		X	X		X		IEC 60068-2-6
	A	Cr	X		X		X	X		X		
Test method	**Test preparations** Mount the transmitter rigidly on the vibration machine's test table with the standard bracket. Then subject the transmitter to vibration in three mutually perpendicular axes in the frequency range of 10 Hz to 500 Hz at the following level: from 10 Hz to 60 Hz at 0,14 mm amplitude and from 60 Hz to 500 Hz at 19,6 m/s^2 acceleration. Make sure that all bolt/screw connections are made correctly with the manufacturer's recommended torque. Mount the reference accelerometer at the point of support and a second accelerometer on that part of the transmitter that is expected to show the largest amplification. Record the amplitude ratio Q between the two and the output(s) as a function of the vibration frequency. **Execution of test** The test consists of three distinct stages: **First stage: initial resonance search** The sweep rate shall be approximately 0,5 octave per minute. The instrument shall be operated with input(s) that provide 50 % output signal(s). **Second stage: endurance at critical frequency** Determine the highest resonance peak and corresponding frequency from the Q-record. Then vibrate the transmitter at this frequency for 30 min. **Third stage: final resonance search** Identical to the initial resonance search. Changes to the resonance peaks and corresponding frequencies with respect to initial resonance search shall be noted.											
Power freq. magnetic field	D	Pr	X		X		X	X		X		IEC 61326-1
	A	P	X		X	X	X	X		X		
Test method	The test shall be performed according to IEC 61326. The transmitter shall be exposed to a magnetic field of 30 A/m (r.m.s.), 50/60 Hz directed along its major axis.											
Radiated electromagnetic interference	D	Pr			X		X	X		X		IEC 61326-1
	A	Cr	X		X	X	X	X		X		
Test method	The test shall be performed according to IEC 61326 at a test level of 10 V/m. During the test the input shall be at 50 % and the instrument's output shall be recorded as a function of frequency for determination of temporary and permanent shifts.											
Electrostatic discharges	D	Pr			X		X	X		X		IEC 61326-1
	A	Cr	X		X	X	X	X		X		
Test method	Electrostatic discharges in accordance with IEC 61326, (contact: 4 kV, air: 8 kV) shall be applied to metal parts of the transmitter most likely to be touched by personnel during normal operation and maintenance.											

5.8.5 Time domain

Table 18 – Methods for testing the immunity to degradation in time

Designation		Accuracy			Dependability				Stability			References
	Time of measurement	Measured variable(s)	Further auxiliary I/O	Intermediate values	Damage/loss of operation	Software configuration	Communication	Diagnostic messages	Step response	Stability	Auto-adjustment/auto-tuning	
Start-up drift	D	Pr					X	X		X		IEC 61298-2:2008, 7.1
	A	P					X	X		X		
Test method	Prior to test, subject the unpowered transmitter to the reference conditions for at least 12 h. Then switch on power with input signal(s) that provide 90 % output signal(s) and record the transmitter until the outputs stabilize, but not longer than 4 h. The time to reach stable outputs and shifts shall be measured. Repeat test with 10 % output.											
Long-term drift	D	Pr	X	X	X		X	X		X		IEC 61298-2:2008, 7.2
	A	Cr	X	X	X		X	X		X		
Test method	Operate the transmitter for 30 days with a steady input signal to provide 90 % output(s). Record the output(s) at least once per day. Preferably record the inputs and output(s) automatically every hour or even more frequently. Care shall be taken to ensure that changes due to environmental conditions, other than time, do not mask the effects of long-term drift. The long-term drift is the maximum change in the recorded output observed during the test period. It is expressed as a percentage of span. From sufficient automatic measurements, a trend drift/month can be derived.											
Accelerated life test	D	Cr		X	X		X	X	X		X	IEC 61298-3:2008, Clause 23
	A	Cr		X			X	X	X		X	
Test method	This test is only applicable to instruments that are inherently sensitive to ageing caused by cyclic variations of the measured quantity(ies). Cycle the relevant input quantity sinusoidally over 100 000 cycles (unless agreed otherwise) with an input signal that varies approximately from 5 % to 95 %. Adjust the frequency to a value at which the amplitude ratio of input and output is > 0,95. Stop the cycling at regular intervals of 10 000 cycles (or others to be agreed) in order to perform relevant measurements and observations. Any malfunction during the test period shall be reported, together with the number of cycles completed.											

6 Other considerations

6.1 Safety

The transmitter shall be examined to determine the degree to which the design protects against accidental electric shock, in accordance with IEC 61010-1.

For application in hazardous locations, a transmitter shall be certified by an authorized body, in accordance with the relevant standards.

6.2 Degree of protection provided by enclosures

If requested, tests shall be made in accordance with IEC 60529 and IEC 61032.

6.3 Electromagnetic emission

If required, emission measurements shall be performed in accordance with CISPR 11.

6.4 Variants

Important variants or options listed by the manufacturer shall be described in the report.

7 Evaluation report

After the completion of the tests, the evaluation report shall be prepared in accordance with IEC 61298-4.

The results of the design review and the details of the test results shall be reported as indicated in 4.2.8 and Clause 5 of this standard.

The following supporting information shall also be included in the evaluation report:

– Date, location of test facilities; names of the persons who conducted and reported the tests as well as their qualifications.
– Description of the transmitter tested, including model number, serial number, whether it is tested as a stand-alone instrument or as a fieldbus participant. In the latter case, the fieldbus type and configuration (host and number and type of instruments) shall also be reported.
– Motivation of tests included and omitted. Any other conditions affecting the test results (e.g. deviations from recommended environmental conditions) should also be reported.
– Description of test set-up and list of test equipment used.
– Input data: ranges, (% of span) and the location of input measurement equipment.
– Output data: ranges (% of span) and the location of output transducer connection.
– Manufacturer’s comments both on test programme and test results.

The test laboratory shall store all the original documentation related to the measurements made during the tests for at least two years after the report is issued.

Annex A
(informative)

Dependability testing

A.1 General

The dependability testing methodology given in Annex A is only relevant for instruments that have provisions for self-testing and/or are equipped with redundant parts and/or can communicate their state to an external system. These tests may be particularly important for transmitters that are to be used in safety-related applications. Manufacturers are urged to integrate the test methods described in their design process.

The dependability testing method described in Annex A considers the behaviour of an instrument in a failed state. Two types of faults are distinguished:

– internal hardware faults,
– human faults of process operators and maintenance personnel.

The actual programme for the dependability test shall be established in co-operation with an expert from the manufacturer. It begins with a design analysis, in which the expert explains in detail the design of the transmitter. Based on his explanation, the evaluator identifies the most critical areas in the design, and determines where faults will be introduced. For this purpose, the manufacturer shall provide detailed functional block diagrams, circuit and wiring diagrams. The information shall be used to set up a scheme defining:

– the locations where hardware failures will be introduced by the evaluator,
– the type of failure and how a suitable failure simulation is achieved,
– the locations where maintenance errors can be introduced.

Furthermore, successful performance of these tests requires that:

– The manufacturer be present during these tests and provide special tools (e.g. special clamps fitting for integrated circuits (ICs)) and special printed circuit board (PCB) with accessible test points.
– These tests shall be carefully considered, since they may cause damage. If the manufacturer states prior to any of these tests that it will cause damage, then the test shall not be performed. This statement shall then be included in the test report. On the other hand, depending on the design, PCB tracks may need to be cut open for a realistic introduction of the fault signal.

The transmitter under test shall only be challenged by single failures.

A.2 Design analysis

The design analysis leads to a schematic as shown in Figure A.1. This schematic, including the points where failures have been injected, shall be published in the evaluation report.

A.3 Reference conditions

For details on domains and cycle times, refer to 4.1 of IEC 62098:2000. Some qualitative aspects of dependability are considered in 4.2.6 of this part of IEC 60770.

Dependability testing, in the context of this part of IEC 60770, provides a method for injecting a hardware fault (hardware domain) and maintenance errors (human domain) and how the transmitter behaves after faults and errors are introduced. The tests not only apply to stand-alone transmitters, but to transmitters connected to a multi-instrument fieldbus. In the latter case, the communication link and the other instruments shall not be influenced by a transmitter failure.

The reference conditions for the fault injection test are that the transmitter is error and fault free. Before introducing a fault, the transmitter shall be set to the normal operational mode and self-test alarms shall be cleared. If self-test alarms cannot be cleared, the manufacturer shall inspect, reset or repair the instrument.

During the test, the transmitter shall be operated with a low frequency triangular input signal between 45 % and 55 % of the input range and the output shall be recorded. The position and time of introduction of the fault are then recorded so that possible delays between the fault appearance and the effects on the output (loss of signal, hold, instability, etc.) can be distinguished. After the introduction of the failure, the input signal shall also be varied to the range limits. The behaviour of the transmitter output in a failed state may also differ at various levels of the input signal.

NOTE When performed with a constant 50 % input signal, relevant information such as the appearance of a temporary "hold"-state, as a result of the fault, may be lost or difficult to determine.

The reference conditions for the maintenance error test are initially identical to the reference conditions for the fault injection test described above. Thereafter, the transmitter is switched off and the maintenance error is introduced. Then the power is switched on and the instrument is again initialized, in accordance with the necessary procedures.

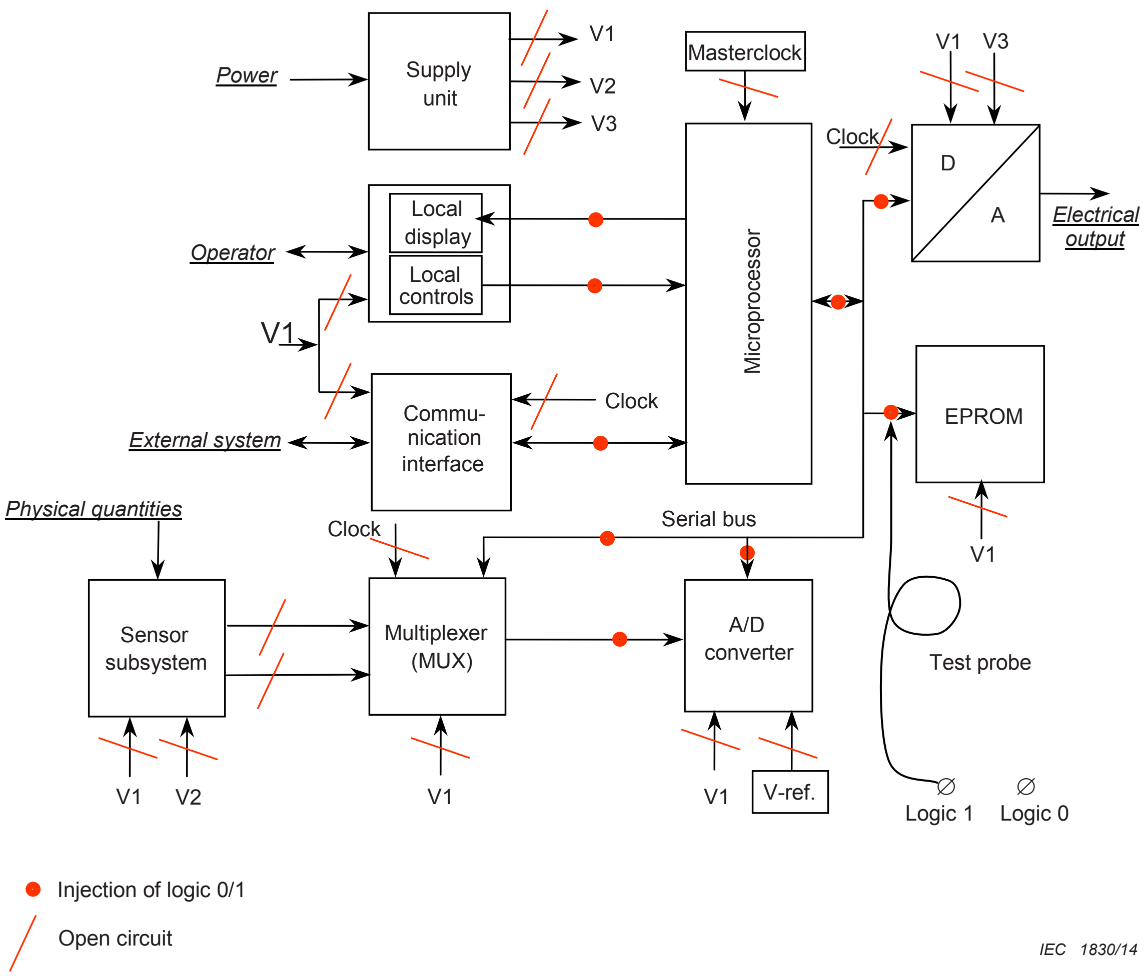


Figure A.1 – Example schematic of a transmitter

A.4 Fault injection test for internal instrument failures

NOTE Further guidance on these tests can also be found in IEC 61069-5 and IEC 62098.

The test is comprised of two phases.

Phase 1: Here an expert of the manufacturer provides a detailed explanation of the transmitter design. Based on the expert's explanation, the evaluator identifies the most critical areas in the design.

Phase 2: Here the evaluator defines the actual positions of where the faults are to be inserted. Moreover, the expert and evaluator shall discuss the method to introduce the faults. At the end of this phase, there should be a worked out plan and a matrix table (see Figure A.3) for performing and reporting the tests. Four types of faults can be distinguished:

- Loss of supply voltages and master clock and secondary clocks as shown in Figure A.1 by the slashed lines.
- Integrated circuit faults result in loss of output signals on control, address or data lines (see dots in Figure A.1). It results in a continuous logic "0" or "1" on these lines. These failures may be injected by forcing the indicated test points to "0" and "1" with a test probe that is alternately connected to the logic "0" or the logic "1" of the instrument. In case one of the circuits involved has a low impedance, this straightforward test may not be possible as it causes a power down of the whole instrument. In that case, the line is cut open and the test can, in most cases, still be performed with a switch as shown Figure A.2. Moreover, with this test tool the loss of an input signal at an IC can also be simulated. This is important for signals that come from one shared source and go to different circuits, as is shown in Figure A.1 at the internal serial bus.
- Loss of signal simulated via a line break indicated in Figure A.1 by the slashed lines. This type of failures can also be made with the test tool shown in the Figure A.2.
- Not shown in the drawings are single component failures (resistor, diode, capacitor, transistor, etc). The failure modes can be an open circuit or a short-circuit.

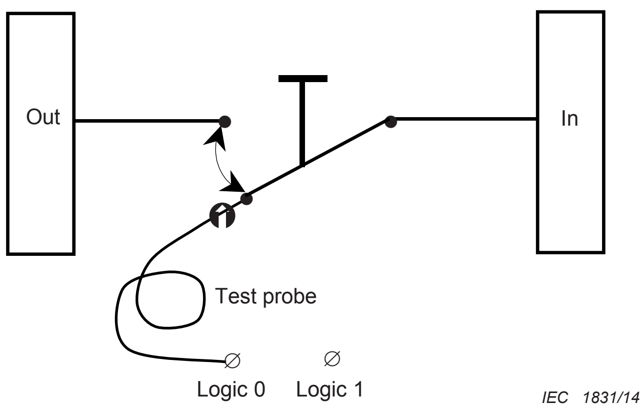


Figure A.2 – Test tool for low impedance circuits and shared circuits

A.5 Observations

A.5.1 General

The following four generic questions are essential for checking and observing the behaviour of a transmitter when it is stressed by internal failures, either in a stand-alone application or when it forms part of a multi-instrument fieldbus system. For each evaluation, these questions need to be adapted to the specifics of the transmitter design and the communication link.

a) **Are the transmitter and digital communication system functions affected?**
   - In the stand-alone situation, the regular update rate of the output, with a triangular input, shall not be affected.
   - In the communication link configuration, communication with the link host shall not be affected and also the operation of the other instruments on the link shall not be affected.

b) **Do the transmitter and communication system report the failures?**
   - automatically by on-line diagnostics in an acceptable time? if not:
   - automatically by a periodic test? if not:
   - by manual request through off-line diagnostics?
   - does reporting appear on:
     - operator displays?
     - maintenance displays?

c) **Do the transmitter or communication system take protective measures upon failures to**
   - continue operation by means of redundant parts?
   - continue (degraded) operation by means of back-up facilities?
   - provide failure isolation?
   - provide a shutdown when unable to continue safe operation?

d) **Is on-line repair possible without affecting the communication system operation?**
   - Does the failure report give correct information for the exchange of failed part?
   - Can defective parts be exchanged without affecting the digital communication system?
   - Which tools are required for repair?
   - Is the repaired module automatically restarted and put on-line after exchange?
   - Is the operation of the digital communication system affected by having the repaired module restart and come on-line?

A.5.2 Reporting and ranking of fault behaviour

The matrix of Figure A.3 gives an example on how the data can be collected and reported. In this example, the transmitter has an electrical analogue (mA) output and local controls. It shall be noted that for each evaluation, the matrix needs to be adapted to the design of the transmitter under evaluation (e.g. when the instrument does not have a local display, the related rows in the matrix can be deleted). In the example, the various rows are organized as follows:

- Rows 5 to 25 show the functional availability of the electrical output signal, the digital output signal on the fieldbus and the output on the local display.
- Row 8, 15 and 22 could represent the fail-safe condition (security). Any discrepancy between these rows in a failed state may also contain diagnostic information for finding the failed module or component.
- Rows 26 to 30 show the integrity of the instrument in a failed state.
- Rows 31 and 32 show the degree of backup in case of a failure.

	A	B	C	D	E	F	G	H	I
2	Description of injected faults	Supply system	MUX., A/D converter	Communication module	Microprocessor	Memories (EPROM's)	DAC module	Local controls/display	Discrete components
3	*Check to be performed*								
4	*Reference number*								
5	Electrical output follows input?								
6	Electrical output frozen at last value?								
7	Electrical output at undefined value?								
8	Electrical output to 0 %?								
9	Electrical output to 100 %?								
10	Electrical output unstable?								
11	Electrical output at predefined value								
12	Fieldbus output follows input?								
13	Fieldbus output frozen at last value?								
14	Fieldbus output at undefined value?								
15	Fieldbus output to 0 %?								
16	Fieldbus output to 100 %?								
17	Fieldbus output unstable?								
18	Fieldbus output at predefined position?								
19	Local display follows input?								
20	Local display frozen at last value?								
21	Local display at undefined position?								
22	Local display to 0 %?								
23	Local display to 100 %?								
24	Local display unstable?								
25	Local display at predefined position?								
26	Communication OK?								
27	Alarm appears on local display?								
28	Collect alarm on host operator display?								
29	Alarm on host diagnostic display?								
30	Type of alarm								
31	Local manual control possible?								
32	Manual control from host?								

IEC 1832/14

Figure A.3 – Matrix for reporting fault behaviour

When a transmitter has intelligence and a self-test capability, it is expected that the instrument shall give a self-test alarm message immediately (or in a reasonable time) after a fault appears. Preferably, it should then be able to distinguish between:

– **Non-fatal errors:** in this case the normal operating mode is maintained.

– **Fatal errors:** the transmitter is automatically forced to a fail-safe position. In this case, any deviation from fail-safe is unacceptable.

Safety may be further enhanced when the instrument is equipped with a means to force the instrument into a safe condition by manual control.

The matrix of Figure A.4 gives a severity ranking of combinations of events that can appear during these tests, for fatal and non-fatal errors.

The manufacturer shall demonstrate the capability of the transmitter's self-testing software for detecting and displaying errors. This can be expressed as a coverage percentage.

Fatal errors			
Alarm	Fail safe	Manual control	Severity
no	no	no	12
no	no	yes	11
yes	no	no	10
yes	no	yes	9
no	yes	no	8
no	yes	yes	7
yes	yes	no	6
yes	yes	yes	5
Non fatal errors			
Alarm		Manual control	Severity
no		no	4
no		yes	3
yes		no	2
yes		yes	1

IEC 1833/14

Figure A.4 – Ranking of various types of failure modes

A.6 Human faults

A.6.1 Mis-operation test

Mis-operation considers errors and faults made by operators and engineers when the transmitter is in the normal operational state. These errors and faults can be:

– The use of incorrect or incomplete codes/commands for the control and for the call-up of displays and accessible parameters.

– Random operations at the keyboard, touch screen or other input devices connected to the host.

– Creation of overflow conditions via local and remote controls by introducing, in a short period, a large amount of commands.

– Unauthorized access attempts such as the use of inhibited or constrained commands for manipulation of the transmitter and tampering with mechanical provisions (keylocks, etc.).

Prior to these tests, the transmitter shall be adjusted to its normal operational mode without any failure or failure indication. During the test, the instrument shall be operating. At the introduction of the fault and thereafter, the instrument shall be checked for:

– temporary or continuous loss of operation, loss of communication with the external system or damage,

– appearance and storage of warning and alarm messages,

– distortion of messages or the appearance of incorrect messages and data on displays.

A.6.2 Maintenance error test

This test is comprised of two phases.

Before the actual performance of this test, an expert from the manufacturer explains the maintainability of the instrument. The evaluator then decides which errors are to be introduced. The evaluator shall also decide which modules are exchangeable, how they fit together and how they are interconnected by wiring and connectors and whether there are jumpers to be inserted etc. Maintenance personnel can make incorrect connections upon exchange of a module and they can forget to insert a jumper. Based on this review, the evaluator sets up a list with the types of errors that shall be introduced for testing. This list shall be incorporated in the matrix of Figure A.4. The evaluator can use the following listing as a guideline for the definition of the maintenance errors to be introduced, such as:

- incorrect address settings via jumpers or DIP switches;
- reverse connection of power wiring, connectors, printed circuit boards (if possible);
- putting connectors at incorrect positions (if length of wiring permits this);
- leaving an open circuit by not connecting a connector;
- performing incomplete or incorrect start-up procedure;
- leaving the instrument at an incorrect security level;
- multiple use of same address in a multi-drop digital communication system;
- causing a short-circuit by touching adjacent parts when performing mechanical adjustments.

Prior to the introduction of an error, the transmitter shall be put into a state in which exchange of modules or maintenance is permitted (usually with power switched off). After introduction of an error, all actions that are required to re-activate the repaired instrument are performed (switch on power, calibrate, tune, etc.).

A.6.3 Expectations and reporting

The list of errors to be introduced is incorporated in the matrix of Figure A.3. Ranking can follow the matrix of Figure A.4. The expectations and presumptions for these tests are:

- Human faults and errors shall not lead to dangerous conditions in the process to be measured and/or controlled by a transmitter. The instrument should not be affected by misoperation and it should auto-correct human errors as much as possible or should warn the operator.
- Procedures of accessing, commissioning and operating the instrument shall be short, transparent, self-explaining and self-correcting (fault tolerant).
- The design shall be such that incorrect maintenance actions are prevented by:
  - Mechanical measures such as asymmetry, mechanical blocking, different wire lengths, etc. (first line of defence; inherently safe).
  - Provisions to prevent start up when applying power (second line of defence). In this case, the error is removed and the instrument is inspected for any permanent effect or damage after the correction of the error and re-application of power.
  - Provisions to report a faulty state when power up is successful (third line of defence). In this case, all questions as stated in the matrix of Figure A.3 need to be answered.
  - The first two options to prevent incorrect maintenance actions are inherently safe. The third can be dangerous.

Annex B
(informative)

Throughput testing

B.1 General

NOTE 1 These tests can be ignored for transmitters with fixed functionality and where no parallel user-accessible functions are provided.

NOTE 2 See also IEC 62098.

The procedures described below are for transmitters that are functionally organized as time-critical multi-tasking systems, in which tasks can be modified, switched on or off or sped up by the user. The transmitter may be operated in a stand-alone application (see Figure B.1) or as part of a fieldbus system (see Figure B.2). Throughput testing in a fieldbus system may require a link with more than one and possibly with the maximum amount of instruments connected. The host computer shall be equipped with a fieldbus interface and fieldbus-related software for reading output data and with a means for operator access to the instruments. It shall be noted that the characteristics of the host computer need to be stated as they can influence the dynamic performance of the fieldbus system.

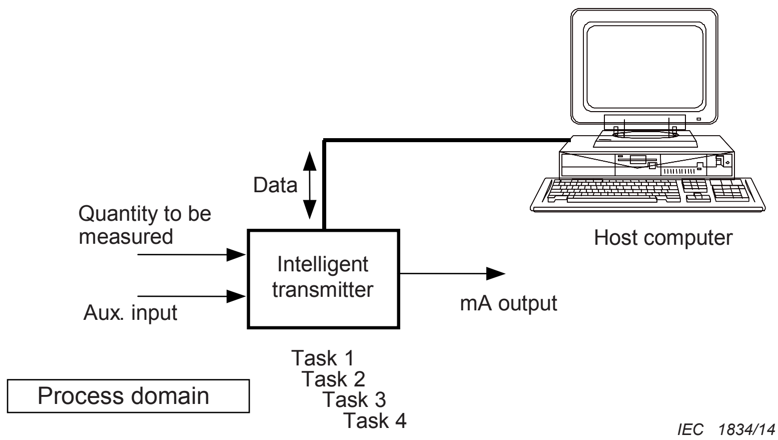


Figure B.1 – Transmitter in stand-alone configuration

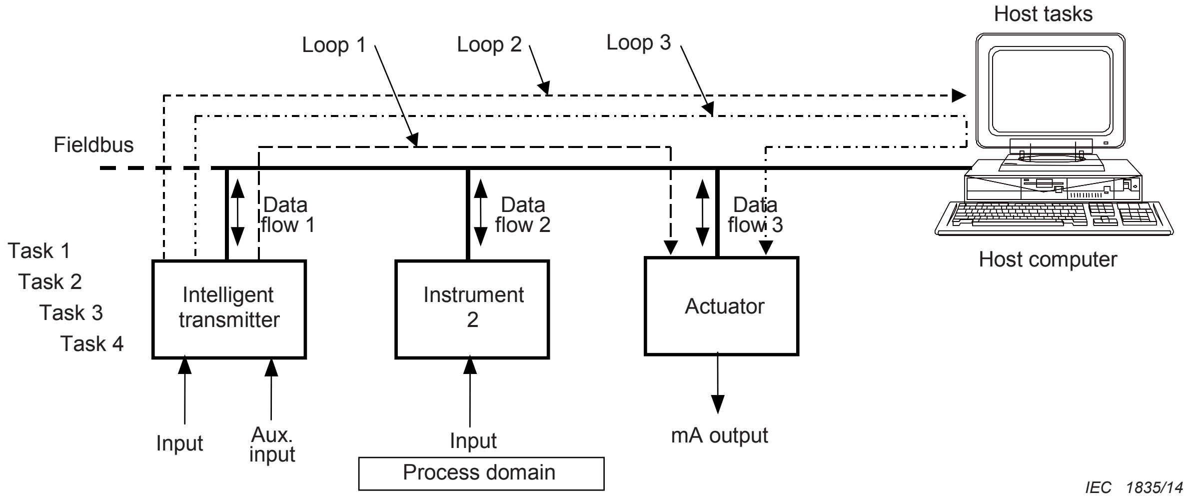


Figure B.2 – Transmitter as a participant in a fieldbus installation

B.2 Transmitter throughput (stand-alone)

B.2.1 Reference conditions

– Analyse the functional design (see Figure B.1) and define the relevant tasks that can be executed in parallel.

– Define the base load for the transmitter and a minimum size application program, necessary for basic operation, with as many tasks as possible being switched off. The cycle times that are adjustable shall be set to the agreed values.

– Define and measure the average cycle time for the transmitter and its communication interface for connection to the host computer. For measurement of the cycle times, the input to the transmitter shall be a triangular signal.

– Measure the call-up times of the relevant types of displays (process-to-operator) and the access times (operator-to-process) at the base load.

These are the reference figures for comparing the behaviour at increased software load.

The following shall also be given by the manufacturer:

– Throughput limits, in relation to cycle times, and the effects to be expected when reaching these limits and a list of measures to be taken in order to prevent passing throughput limits.

– Information on the structure of the multitasking software and the assignment of priorities to the various tasks.

B.2.2 Test conditions

In the stand-alone tests, the transmitter shall be connected to auxiliary equipment (computer or hand-held terminal) for read out and access as shown in Figure B.1. The input shall be connected to a triangular wave generator. The output shall be recorded. The software load shall then be increased as follows:

– Switch on successively the various tasks available.

– Decrease the cycle times – as far as adjustable – both of the main measurement task and of the other tasks.

B.2.3 Observations and measurements

During each test, the following observations and measurements shall be made:

– The average cycle time. At the applied test conditions, the average cycle time of the transmitter may be:
  - unaffected,
  - slowed down
  - temporarily stopped,
  - continuously stopped.

– Loss of information.

– Relevant diagnostic messages.

B.3 Throughput in a fieldbus configuration

B.3.1 Reference conditions

– Analyse the functional design of the transmitter and the fieldbus system. Then define the relevant data flows of the transmitter under test and the various instruments and host of the fieldbus system (see Figure B.2).

– Define the base loads for the transmitter (as described above) and of the fieldbus system. The base load of the fieldbus system should comprise a minimum size hardware configuration and a minimum size application programme.

– Define and measure the average cycle times for the transmitter. For the measurement of the cycle times, the input to the transmitter shall be a triangular signal. The input signal shall either be generated by the host computer or by one of the instruments. It shall be sent to the transmitter with the highest priority that can be user adjustable.

– Measure call-up times of relevant types of displays (process-to-operator) and the access times (operator-to-process) at the base load.

These data are the reference figures for comparing the behaviour when increasing the software load.

The following shall be known about the instrument and the fieldbus system:

– Procedures and methods for calculating and/or predicting the load factors with respect to the various cycle times, the execution times of the tasks used and the number of instruments connected to the fieldbus.

– Throughput limits, in relation to cycle times, and the effects to be expected when reaching these limits and a list of measures to be taken in order to prevent passing throughput limits.

– Call-up and access times in relation to the fieldbus configuration.

– Information on the sizes of buffers and the message transfer mechanisms.

– Information on the structure of the multitasking software and the assignment of priorities.

B.3.2 Test conditions

Besides the host computer, no additional computers or hand-held terminals shall be connected to any of the instruments.

Measurements and further observations at the main data flow routes shall be performed, while successively increasing the hardware load and the software load by:

– Increasing the number of active instruments, up to the maximum.

In order to limit the costs of testing, this test condition can be limited to an increase to an arbitrarily agreed upon number of instruments on the fieldbus.

– Activating the trend task at the host computer.
– Activating the alarm handling task and triggering it with:
  - process alarm bursts from the instruments with a predefined length.
  - steady continuous process alarm rates.
– Report request.
– Up-loading or downloading a configuration from or to one of the instruments.

B.3.3 Observations and measurements

During each test condition, the behaviour of the instrument and the fieldbus system, including its operator interface, shall be observed. The following observations and measurements shall be made:

– Whether the average cycle times of the transmitter are:
  - unaffected,
  - slowed down (measurement),
  - temporarily stopped (measurement),
  - continuously stopped.
– Slow down of operator call-up commands and operator access to I/O devices at the operator interface (measurement).
– System alarm message indicating overload.
– Specifically for alarm burst and steady alarm rate tests determine the points of reaching overflow and/or loss of messages (measurement).
– Correct time labelling (sequence of events) at operator interface.
– Loss of information.
– Relevant diagnostic messages.

B.3.4 Precautions

It is important to take into account, when designing the test procedures for a specific fieldbus system, the way the transmitter, fieldbus and other instruments are inherently interacting or can be made to interact by a user. Setting, for instance, wrong priority levels or assuming a data transfer method not used in the system under consideration may lead to incorrect test methods and conclusions. Care shall be taken so that the host computer and its fieldbus interface are set up according to the rules given by the transmitter. The host computer shall not be used for processing and storing test data in non-fieldbus-related applications, in order to avoid interference of the fieldbus tasks.

Annex C
(informative)

Function block testing

C.1 General

Annex C gives some general rules for testing function blocks. For a specific function block, the rules shall be further detailed to demonstrate its full capacity. For the purpose of evaluation, function blocks are differentiated into two main groups:

– Time-dependent function blocks.

– Time-independent function blocks.

C.2 General qualitative checks

– Restart conditions after short-duration power interruptions.

– The effects of introducing negative parameters.

– Protection against division by zero.

– Bumpless transfer from manual-to-automatic and setpoint tracking facilities.

– Manual output control facilities.

– What symbol or number represents indefinite.

– Possible saturation effects due to the introduction of large values of input data and/or parameters by which the corresponding outputs are reaching their limits.

C.3 Time-dependent function blocks

Time-dependent function blocks, in particular control algorithms (e.g. PID) having an integral action shall be submitted to the following additional tests:

– Reset wind-up protection. This is a software provision available for setting output limits. This provision shall be verified for automatic adaptation to the physical limitations of the hardware of the output circuits. When adaptation is not provided, real reset wind-up protection may be partial or ineffective.

– The resolution with which the integral action is calculated shall be checked. In the case of too small a resolution, the integral action shall become inactive, although a deviation may still exist between the setpoint and the measured value.

C.4 Time-independent function blocks

The following time-independent function blocks shall be verified on the following aspects:

– To what extent are calculations performed in engineering units and how is scaling provided.

– The protection provided against unrealistic parameter settings (such as a warning when operator tries to set a low limit at a value exceeding the high limit).

– The effects of exceeding the resolution of the calculation capacity (single or double precision). An inefficient method of calculation may cause considerable errors.

– The effects of extreme values. Some actual calculations at extreme inputs and parameter settings can be performed and compared with the theoretical formula.

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