ANSI/NEMA IA 2.2-1994 (R2002)

PROGRAMMABLE CONTROLLERS – EQUIPMENT REQUIREMENTS

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ANSI Approval Date
May 1, 2002

NEMA Standards Publication ANSI/NEMA IA 2.2-1994 (R2002)

Programmable Controllers - Equipment Requirements

Published by:

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209

www.nema.org

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FOREWORD

This Standards Publication is a NEMA Adoptive Standard based on Part 2 of IEC 1131, "Programmable Controllers."

This Standards Publication was prepared by a technical committee of the NEMA Automation Products and Systems Section. It was approved in accordance with the bylaws of NEMA and supersedes NEMA Standards Publication ICS 3-1988, Part 3-304.

This Standards Publication provides practical information concerning ratings, construction, test, performance and manufacture of industrial control equipment. These standards are used by the electrical industry to provide guidelines for the manufacture and proper application of reliable products and equipment and to promote the benefits of repetitive manufacturing and widespread product availability.

NEMA Standards represent the result of many years of research, investigation and experience by the members of NEMA, its predecessors, its Sections and Committees. They have been developed through continuing consultation among manufacturers, users and national engineering societies and have resulted in improved serviceability of electrical products with economies to manufacturers and users.

One of the primary purposes of this Standards Publication is to encourage the production of reliable control equipment which, in itself, functions in accordance with these accepted standards. Some portions of these standards, such as electrical spacings and interrupting ratings, have a direct bearing on safety; almost all of the items in this publication, when applied properly, contribute to safety in one way or another.

Properly constructed industrial control equipment is, however, only one factor in minimizing the hazards which may be associated with the use of electricity. The reduction of hazard involves the joint efforts of the various equipment manufacturers, the system designer, the installer and the user. Information is provided herein to assist users and others in the proper selection of control equipment.

The industrial control manufacturer has limited or no control over the following factors which are vital to a safe installation:

a. environmental conditions
b. system design
c. equipment selection and application
d. installation
e. operating practices
f. maintenance

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This publication is not intended to instruct the user of control equipment with regard to these factors except insofar as suitable equipment to meet needs can be recognized in this publication and some application guidance is given.

This Standards Publication is necessarily confined to defining the construction requirements for industrial control equipment and to providing recommendations for proper selection for use under normal or certain specific conditions. Since any piece of industrial control equipment can be installed, operated and maintained in such a manner that hazardous conditions may result, conformance with this publication does not by itself assure a safe installation. When, however, equipment conforming with these standards is properly selected and is installed in accordance with the National Electrical Code and properly maintained, the hazards to persons and property will be reduced.

To continue to serve the best interests of users, NEMA is actively cooperating with other standardization organizations in the development of simple and more universal metrology practices. In this Standards Publication, the U.S. customary units are gradually being supplemented by those of the modernized metric system known as the International Systems of Units (SI). This transition involves no changes in standard dimensions, tolerances, or performance specifications.

NEMA Standards Publications are subject to periodic review. They are revised frequently to reflect user input and to meet changing conditions and technical progress. Users should secure the latest editions. See the postal return card attached to the front cover of this Standards Publication for the proper procedure to obtain revision service for your copy of the publication.

Proposed revisions to this Standards Publication should be submitted to:

Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, DC 20037

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REFERENCED STANDARDS

The following standards contain provisions which, through reference in this text, constitute provisions of this NEMA Standards Publication. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

International Electrotechnical Commission
1, rue de Varembé
Geneva, Switzerland

IEC 1131-2 — *Programmable Controllers—Part 2: Equipment Requirements and Tests*

National Fire Protection Association
Publication Sales Department
Batterymarch Park
Quincy, MA 02269

ANSI/NFPA 70 — *National Electrical Code*

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AMENDMENTS

IEC 1131-2, "Programmable controllers • Part 2: Equipment requirements and tests," is adopted with the amendments noted below.

NEMA Adoptive Standard

Subclause 1.4.28: *Explanation*

Devices or circuits which are *isolated* as defined in subclause 1.4.28 may, but need not, be *isolated* as defined in ANSI/NFPA 70, *National Electrical Code*.

Authorized Engineering Information

Subclause 4.2: *Explanation*

The *equipment* classes defined in subclause 4.2 are not related to the circuit classes defined in Paragraph 725 of ANSI/NFPA 70, *National Electrical Code*.

Authorized Engineering Information

Where a conflict exists between the provisions of IA 2.2 and other NEMA Standards Publications, the provisions of IA 2.2 shall govern in the area of programmable controllers and their associated peripherals.

NEMA Standard

Where a conflict exists between provisions of IA 2.2 and ANSI/NFPA 70, *National Electrical Code*, the provisions of ANSI/NFPA 70 shall govern.

NEMA Standard

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INTERNATIONAL STANDARD

IEC 1131-2

First edition
1992-10

Programmable controllers –

Part 2:
Equipment requirements and tests

Automates programmables –

Partie 2:
Spécifications et essais des équipements



Reference number
IEC 1131-2: 1992(E)

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Spécifications et essais des équipements

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International Electrotechnical Commission
Международная Электротехническая Комиссия

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

PROGRAMMABLE CONTROLLERS –

Part 2: Equipment requirements and tests

FOREWORD

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

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

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

This part of International Standard IEC 1131 has been prepared by sub-committee 65A: Devices, of IEC technical committee No. 65: Industrial-process measurement and control.

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

Six Months' Rule	Report on Voting
65A(CO)22	65A(CO)27

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

Annexes A, B and D form an integral part of this part of IEC 1131.

Annex C and E are for information only.

IEC 1131 will consist of the following parts, of which this is the second, under the general title: Programmable controllers :

Part 1: 1992, General information.

Part 2: 1992, Equipment requirements and tests.

Part 3: Programming languages *(being printed).*

Part 4: User guidelines *(under consideration).*

Part 5: Messaging service specification *(under consideration).*

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INTRODUCTION

This part of IEC 1131 constitutes part 2 of a series of standards on programmable controllers and the associated peripherals and should be read in conjunction with the other parts of the series.

Where a conflict exists between this and other IEC standards (except basic safety standards), the provisions of this standard should be considered to govern in the area of programmable controllers and their associated peripherals.

Compliance with Parts 1 and 2 of this standard cannot be claimed unless *all tests and verifications required in part 2 are complied with.* See 5.4 for details.

Terms of general use are defined in part 1. The more specific terms are defined in a dedicated clause of each part.

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PROGRAMMABLE CONTROLLERS –

Part 2: Equipment requirements and tests

1 General

1.1 *Scope*

This International Standard applies to programmable controllers and their associated peripherals such as programming and debugging tools (PADTs), test equipment (TE) and man-machine interfaces (MMIs), etc.

Equipment covered in this standard is intended for use in overvoltage category II (see IEC 364-4-443), in low voltage installations, where the rated mains supply voltage does not exceed 1 000 V a.c. (50/60 Hz), or 1 500 V d.c., for the control and command of machines and industrial processes.

Programmable controllers and the associated peripherals are considered as components of a control system and may be provided as enclosed or open equipment. Therefore, *this standard does not deal with the automated system* in which the programmable controller system is but one basic component among many others including its application program.

Since programmable controllers are component devices, overall automated system safety including installation and application is beyond the scope of this standard. For further information, refer to IEC 1131-4 which is intended to help users in reducing the risks. However, electrical noise immunity and error detecting of the PC-system operation such as the use of parity checking, self-testing diagnostics, etc., are addressed.

1.2 *Object of the standard*

The purposes of this standard are:

– to establish the definitions and identify the principal characteristics relevant to the selection and application of programmable controllers and their associated peripherals;

– to specify the minimum requirements for the functional characteristics, service conditions, construction characteristics, general safety, and tests applicable to programmable controllers and the associated peripherals;

– to define, for each of the most commonly used programming languages: major field of application, syntactic and semantic rules, simple but complete basic sets of programming elements, applicable tests and means by which manufacturers may expand or adapt those basic sets to their own programmable controller implementations;

– to give general tutorial information and application guidelines to the user;

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– to define the communication between programmable controllers and other electronic systems using the Manufacturing Message Specification (MMS) defined in ISO/IEC 9506.

1.3 *Object of this part*

This part specifies

– the electrical, mechanical and functional* requirements for programmable controllers and the associated peripherals and the service, storage and transportation conditions that apply;

– the information that the manufacturer is required to supply;

– the test methods** and procedures that are to be used for the verification of compliance of programmable controllers and their associated peripherals with the requirements.

1.4 *Definitions*

NOTE - This clause contains the definitions of terms which are more specific to the object of this part in order to make it more self-contained. Terms of general use are defined in part 1.

1.4.1 **accessible part:**

1) A part which can be touched by the standard jointed test finger (see IEC 529) .

2) A conductive part which can readily be touched and which is not normally live, but which may become live under fault conditions. [IEV 441-11-10 modified]

1.4.2 **basic PC-system(s)**: Representative configuration(s) used for type tests. See figure 1, in 3.1 and 6.3.1.

1.4.3 **battery:** An electrochemical energy source which may be rechargeable or non-rechargeable.

1.4.4 **circuit, class I, class II, class III:** see equipment (1.4.16).

1.4.5 **clearance:** The shortest distance between two conductive parts, or between a conductive part and the bounding surface of the equipment, measured through air. The bounding surface is the outer surface of the enclosure considered as though metal foil is pressed into contact with accessible surfaces of insulating material.

1.4.6 **coating, protective:** A coating of suitable insulating material that covers the clearance and/or creepage distance of the printed board and conforms to the surface of the board in such a manner that the environment is excluded and the clearance and/or creepage distance can withstand the required impulse and continuous potential.

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* Functional requirements are contained in both the electrical and mechanical clauses.

** The tests are type tests or production routine tests, and not tests related to the ways programmable controller systems are applied.

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NOTE - Coating is normally applied to exclude the effects of atmosphere and to increase the dielectric properties of the clearance and/or creepage distances which would not normally be adequate without coating. Less effective coating may exclude the atmosphere but cannot be relied on to enhance the dielectric properties.

1.4.7 **comparative tracking index (CTI)**: The numerical value of the maximum voltage at which a material withstands 50 drops of NH_4Cl solution (ammonia chloride) without tracking (see IEC 112).

1.4.8 **coverage factor** (for modules, units, external wiring, internal wiring, removable cables, interconnections and functions): The percentage of modules, units, external wirings, internal wirings, removable cables, interconnections, functions, whose removal, absence or failure is detected by built-in test functions or by a suitable test program along with a proper functioning verification procedure. See 6.3.2.

1.4.9 **creepage distance**: The shortest path between two conductive parts, or between a conductive part and bounding conducting surface of the equipment, measured along the surface of the insulation.

1.4.10 **current sinking**: The act of receiving current.

1.4.11 **current sourcing**: The act of supplying current.

1.4.12 **diversity factor** (of an output module): Ratio of the permissible total current (total output current) to the sum of all maximum rated currents of multi-channel output module operating at the most adverse combination of normal service conditions.

1.4.13 **earth**: The conducting mass of the Earth, whose electric potential at any point is conventionally taken as zero. [IEV 151-01-07] (Synonymous with protective earth.)

1.4.14 **earth, functional, protective:**

1) **functional earth**: A low impedance path between electrical circuits and earth for non-safety purposes such as noise immunity improvement.

2) **protective earth**: A low impedance path under fault conditions including high voltage and/or current between the electrical circuit and earth to minimize the risk to the operator.

1.4.15 **enclosure**: A final mounting housing which provides protection against accidental contact with live and/or moving parts. (See equipment, open and equipment, enclosed.)

1.4.16 **equipment (or circuit) class I, class II, class III**: Class numbers designate the means by which electric shock protection is maintained in normal use and likely fault conditions of the installed equipment.

1) **class I circuit or equipment**: Circuit or equipment in which protection against electric shock does not rely on basic insulation only, but which includes an additional safety precaution in that accessible conductive parts are connected to the protective

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earthing conductor in the fixed wiring of the installation in such a way that they cannot become live in the event of a failure of the basic insulation. For equipment intended for use with a flexible cord, this provision includes the protective earthing conductor as part of the flexible cord.

NOTE - Class I equipment may have parts with double insulation or reinforced insulation, or parts operating at safety extra-low voltage.

2. **class II circuit or equipment:** Circuit or equipment in which protection against electric shock does not rely on basic insulation, but in which additional safety precautions, such as double insulation or reinforced insulation are provided, there being no provision for protective earthing or reliance upon installation conditions.

Such equipment may be of one of the following types:

i) insulation-encased class II equipment: equipment having a durable and substantially continuous enclosure of insulating material which envelops all conductive parts, with the exception of small parts, such as nameplates, screws and rivets, which are isolated from parts at hazardous voltage by insulation at least equivalent to reinforced insulation;

ii) metal-encased class II equipment: equipment having a substantially continuous metal enclosure, in which double insulation is used throughout, except for those parts where reinforced insulation is used;

iii) equipment which is a combination of types i) and ii).

NOTES

1 The insulated enclosure of a class II equipment may form a part of the whole of the supplementary insulation or of the reinforced insulation.

2 If equipment with double insulation and/or reinforced insulation throughout has a protective earthing terminal or contact, it is deemed to be of class I construction.

3 class II equipment may have parts operating at safety extra-low voltage.

3) **class III circuit or equipment:** Circuit or equipment in which protection against electric shock is provided by circuits supplied by safety extra-low voltage (SELV) and where voltages generated do not exceed the limits for SELV.

1.4.17 **equipment, enclosed:** Equipment which is enclosed on all sides with the possible exception of its mounting surface to prevent personnel from accidentally touching live or moving parts contained therein and to protect the equipment against ingress of medium size solid foreign bodies, and meeting requirements of mechanical strength, flammability, and stability (where applicable).

1.4.18 **equipment, fixed:** Equipment which is part of the permanent installation.

1.4.19 **equipment, hand-held portable:** Equipment which is intended to be held in one hand while being operated with the other hand.

1.4.20 **equipment, open:** Equipment which may have live electrical parts accessible, e.g. a main processing unit. An open equipment is to be incorporated into other assemblies manufactured to provide safety.

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1.4.21 **equipment, on-line pluggable:** Equipment which can be plugged or unplugged from the PC-system at any time including when the PC-system is operating, without disturbing or disrupting the normal operation of the PC-system and without any increased risk to the operator and the application.

1.4.22 **equipment, portable:** Enclosed equipment which is intended to be transported by hand-carrying, such as programming and debugging tools (PADTs) and test equipment (TE).

1.4.23 **hazardous voltage:** Voltage exceeding 42,4 V peak or d.c., existing in a circuit which does not meet the requirement for a limited energy circuit.

1.4.24 **immunity:** Ability of the PC-system to be unaffected or to maintain its operation within limits specified by the manufacturer when submitted to influencing quantities specified in this standard.

1.4.25 **input, digital, type 1/type 2 (type 1 digital input, type 2 digital input):**

1) **type 1 digital input:** Digital input for sensing signals from mechanical contact switching devices, such as relay contacts, pushbuttons, switches, etc.; type 1 digital inputs may not be suitable for use with solid state devices such as sensors, proximity switches, etc.

2) **type 2 digital input:** Digital input for sensing signals from solid state switching devices such as 2-wire proximity switches. This class could also be used for type 1 applications.

1.4.26 **insulation (basic, supplementary, double, reinforced):**

1) **basic insulation:** Insulation applied to live parts to provide basic protection against electric shock.

2) **supplementary insulation:** Independent insulation applied in addition to basic insulation in order to ensure protection against electric shock in the event of a failure of the basic insulation.

3) **double insulation:** Insulation comprising both basic insulation and supplementary insulation.

4) **reinforced insulation:** Single insulation system applied to live parts which provides a degree of protection against electric shock equivalent to double insulation under the conditions specified in this standard.

NOTE - The term "insulation system" does not imply that the insulation must be in one homogeneous piece. It may comprise several layers which cannot be individually tested as supplementary or basic insulation.

1.4.27 **interface:** Shared boundary between a considered system and another system, or between parts of a system, through which information is conveyed. See 3.1.

1.4.28 **isolated (devices, circuits):** Devices, circuits with no galvanic connection between them.

1.4.29 **live part:** Any conductor or conductive part which is at a voltage in normal use.

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1.4.30 **mains power supply:** Power from the conductors/mains of the permanent installation of the building at the supply voltage to the PC-system.

1.4.31 **main processing unit (MPU):** The portion of the PC-system which interprets or executes the (main part of the) application program. The MPU may include power supply, memory, and I/Os. See annex B of IEC 1131-1 and 3.1, 3.6 and annex A of this part.

1.4.32 **man-machine interface (MMI):** Manufacturer's catalogued peripheral equipped with pushbuttons, lamps, keyboards, displays or equivalent, intended as operator interface, such as motor control/monitor panel, general purpose operator interface, etc.

MMIs may be part of the permanent installation (e.g. mounted on front panels, doors, boards, etc.) or not.

1.4.33 **material group:** Classification of insulating materials in terms of comparative tracking index (CTI) range (see 4.3.3).

1.4.34 **micro-environment:** Ambient conditions which surround the clearance or creepage distance under consideration.

NOTE - The micro-environment of the clearance or creepage distance and not the environment of the equipment determines the effect of the insulation. The micro-environment may be better or worse than the environment of the equipment. It includes all factors influencing the insulation, such as climatic, electromagnetic, pollution, etc. (See IEC 664 for further information.)

1.4.35 **module:** Device such as an I/O board assembly which plugs into a back plane or base.

1.4.36 **multi-circuit module:** Module containing multiple isolated circuits. With respect to I/O modules, a module containing multiple isolated user signal interfaces.

1.4.37 **multi-channel module:** Module containing multiple input and/or output user signal interfaces. A multi-channel module may or may not be a multi-circuit module.

1.4.38 **output, not-protected, protected, short-circuit proof:**
See 3.3.2.2 and 3.3.3.2.

1.4.39 **overvoltage category** (of a circuit or within an electrical system): A conventional number based on limiting (or controlling) the values of prospective transient overvoltages occurring in a circuit (or within an electrical system having different nominal voltages) and depending upon the means employed to influence the overvoltages.

NOTE - In an electrical system, the transition from one overvoltage category to another of lower category is obtained through appropriate means complying with interface requirements, such as an overvoltage protective device or a series-shunt impedance arrangement capable of dissipating, absorbing, or diverting the energy in the associated surge current, to lower the transient overvoltage value to that of the desired lower overvoltage category.

1.4.40 **PC-system:** Synonymous with programmable controller system as defined in 2.5.1 of IEC 1131-1, see annex A of IEC 1131-1 and annex A of this part.

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1.4.41 **permanent installation:** See annex A of IEC 1131-1 or annex A of this part.

1.4.42 **pollution degree** (in the micro-environment): For the purpose of evaluating clearances and creepage distances, the following three degrees of pollution in the micro-environment are established:

1) **pollution degree 1**: No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.

2) **pollution degree 2:** Normally, only non-conductive pollution occurs. Occasionally, however, a temporary conductivity caused by condensation shall be expected.

3) **pollution degree 3**: Conductive pollution occurs, or dry, non-conductive pollution occurs which becomes conductive due to condensation which is expected.

NOTES

1 The conductivity of a polluted insulation is due to the deposition of foreign matter and moisture.

2 The minimum clearances given for pollution degrees 2 and 3 are based on experience rather than on fundamental data.

1.4.43 **protective earthing conductor, terminal, connection:** See earth, protective (1.4.14).

1.4.44 **rated supply voltage**: Mains voltage (for three-phase supply, the line-to-line voltage) for which the manufacturer has designed the apparatus.

1.4.45 **recurring peak voltage**: Peak value of a generated voltage whose characteristic is recurring at some specified period. Such recurring peak voltages are generally generated in switch-mode power supply circuits (a.c. or d.c. to d.c. converters). See 4.3.3.2.

1.4.46 **removable connector**: Connecting means intended to be used for operation or maintenance servicing of the PC-system by the user. Pluggable modules, peripherals, etc. are generally connected to the rest of the PC-system by such means.

1.4.47 **safety extra-low voltage (SELV):** A voltage which, under all operating conditions does not exceed 42,4 V peak or d.c. between conductors, or between any conductor and earth, in a circuit which is isolated from the mains power supply by means of a safety isolating transformer or an equivalent means. National regulations have to be considered for a correct isolation voltage rating.

1.4.48 **safety extra low-voltage circuit (SELV circuit)**: Circuit which is so designed and protected that under normal and single fault conditions the voltage between any two accessible parts, one of which may be earth or a conductive accessible part connected to earth, does not exceed the safety extra-low voltage and in which overvoltages higher than SELV are not generated.

1.4.49 **Subassembly:** Synonymous with unit (1.4.53).

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1.4.50 **temperature (ambient air):**

1) For enclosed non-ventilated equipment that is cooled by natural air convection, the equipment ambient air temperature is the room temperature 1 m away from the surface of the enclosure on a horizontal plane located at the vertical mid-point of the enclosure.

2) For enclosed ventilated equipment, the equipment ambient temperature is the temperature of the incoming air.

3) For open equipment, the ambient air temperature is the temperature of the incoming air immediately below the equipment.

1.4.51 **total output current** (of an output module): The current that a multi-channel module operating at the most adverse combination of normal service conditions can supply without any part of it (insulation, terminals, exposed conductive parts, etc.) exceeding the specified temperature limits.

NOTE - For a multi-channel module, the total output current is generally less than the sum of the output currents of the channels.

1.4.52 **test (routine, type, immunity type, withstand type):**

1) **routine test:** Test to which each individual catalogued device is subjected during or after its manufacturing process to ascertain whether it complies with certain criteria.

2) **type test:** Laboratory test to which one or several basic PC-systems or samples of catalogued devices is (are) subjected to ascertain that its (their) design(s) meet requirements expressed in this standard.

3) **immunity type test (immunity test):** Type test verifying that the basic PC-system operation is not altered by the application of specified influencing quantities which are intended to approximate normal service conditions.

During the test, the basic PC-system executes appropriate test programs to be provided by the manufacturer (see 6.3.2.2).

NOTE - Some tests may allow temporary alteration of the basic PC-system operation within limits that must be then specified by the manufacturer.

4) **withstand type test (withstand test):** Type test verifying that the application of more severe influencing quantities to the basic PC-system does not impair its ability to assume its intended mission. Unless otherwise specified, the basic PC-system is not energized during the withstand test. After a specified recovery period, a proper functioning verification procedure is performed as specified to check visually and/or by measurement that the test had no detrimental effect on the basic PC-system.

NOTE - The impact test (see 6.3.5.5.1) is classified as withstand test though it may affect the operability of the basic PC-system.

1.4.53 **unit:** For the purpose of this standard, a unit is an integral assembly (which may consist of modules plugged in or otherwise connected within the assembly) and which is connected to other units within the system by means of cables for permanently installed units and cables or other means for portable units.

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1.4.54 **wiring (internal, external):**

1) **internal wiring**: Wiring which is inside the open or enclosed PC-system equipment.

2) **external wiring**: Wiring of the PC-system equipment which is normally installed by the user.

1.5 *Normative references*

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 1131. At the time of publication, the editions indicated were valid. All documents are subject to revision, and parties to agreements based on this part of IEC 1131 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 38: 1983, *IEC standard voltages.*

IEC 50(151): 1978, *International Electrotechnical Vocabulary – Chapter 151: Electrical and magnetic devices.*

IEC 50(441): 1984, *International Electrotechnical Vocabulary – Chapter 441: Switchgear, controlgear and fuses.*

IEC 60-1: 1989, *High-voltage test techniques – Part 1: General definitions and test requirements.*

IEC 68-2-1: 1990, *Environmental testing – Part 2: Tests – Tests A: Cold.*

IEC 68-2-2: 1974, *Environmental testing – Part 2: Tests – Tests B: Dry heat.*

IEC 68-2-3: 1969, *Environmental testing – Part 2: Tests – Test Ca: Damp heat, steady state.*

IEC 68-2-6: 1982, *Environmental testing – Part 2: Tests – Test Fc and guidance: Vibration (sinusoidal).*

IEC 68-2-14: 1984, *Environmental testing – Part 2: Tests – Test N: Change of temperature.*

IEC 68-2-27: 1987, *Environmental testing – Part 2: Tests – Test Ea and guidance: Shock.*

IEC 68-2-30: 1980, *Environmental testing – Part 2: Tests – Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle).*

IEC 68-2-31: 1969, *Environmental testing – Part 2: Tests – Test Ec: Drop and topple, primarily for equipment-type specimens.*

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IEC 68-2-32: 1975, *Environmental testing – Part 2: Tests – Test Ed: Free fall.*

IEC 85: 1984, *Thermal evaluation and classification of electrical insulation.*

IEC 112: 1979, *Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions.*

IEC 255-4: 1976, *Electrical relays – Part 4: Single input energizing quantity measuring relays with dependent specified time.*

IEC 364-4-443: 1990, *Electrical installations of buildings – Part 4: Protection for safety – Chapter 44: Protection against overvoltages – Section 443: Protection against overvoltages of atmospheric origin or due to switching.*

IEC 417: 1973, *Graphical symbols for use on equipment – Index, survey and compilation of the single sheets.*

IEC 445: 1988, *Identification of equipment terminals and of terminations of certain designated conductors, including general rules of an alphanumeric system.*

IEC 529: 1989, *Degrees of protection provided by enclosures (IP Code).*

IEC 664: 1980, *Insulation co-ordination within low-voltage systems including clearances and creepage distances for equipment.*

IEC 695-2-1: 1980, *Fire hazard testing – Part 2: Test methods – Glow-wire test and guidance.*

IEC 707: 1981, *Methods of test for the determination of the flammability of solid electrical insulating materials when exposed to an igniting source.*

IEC 801-2: 1991, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 2: Electrostatic discharge requirements.*

IEC 801-3: 1984, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 3: Radiated electromagnetic field requirements.*

IEC 801-4: 1988, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 4: Electrical fast transient/burst requirements.*

IEC 801-5: 199X, *Electromagnetic compatibility for industrial-process measurement and control equipment – Part 5: Surge immunity requirements* (under consideration).

IEC 947-1: 1988, *Low-voltage switchgear and controlgear – Part 1: General rules.*

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IEC 947-5-1: 1990, *Low-voltage switchgear and controlgear – Part 5: Control circuit devices and switching elements – Section One: Electromechanical control circuit devices.*

IEC 947-5-2: 1992, *Low voltage switchgear and controlgear – Part 5: Control circuit devices and switching elements – Section 2: Proximity switches.*

IEC 950: 1991, *Safety of information technology equipment, including electrical business equipment.*

ISO/IEC 9506-1, 1990: *Industrial automation systems – Manufacturing Message Specification – Part 1: Service definition.*

ISO/IEC 9506-2: 1990, *Industrial automation systems – Manufacturing Message Specification – Part 2: Protocol specification.*

2 Service conditions and physical environment related requirements

2.1 *Normal service conditions*

It is the user's responsibility to ensure that the following service conditions are not exceeded.

2.1.1 *Physical environmental conditions*

2.1.1.1 *Operating ambient air temperature*

Operating temperature ranges are given by the following table 1.

Table 1 – Operating ambient air temperature of PC-systems (°C) (note 1)

		Enclosed equipment (ventilated/non-ventilated)		Open equipment (note 2)	
	Type of limit	Permanent installation	Non-permanent installation	Permanent installation	Non-permanent installation
Temperature range	Max. Min.	40 5	40 5	55 5	$T_{max.}$ (note 3) $T_{min.}$ (note 3)
Average temperature over 24 h	Max.	35	35	50	T_{av} (note 3)

NOTES

1 See definitions in 1.4.50 and in annex A.

2 Open equipment is designed to be mounted within an enclosure where the equipment ambient air temperature which is measured immediately below each individual assembly may be up to 15 °C above the maximum room ambient air temperature.
No forced external cooling is assumed (see 4.5.1).
Open peripherals which are intended to be permanently installed as part of the PC-system shall meet the operating temperature range of the PC.

3 Equipment ambient air temperature limits ($T_{max.}$, T_{av}, $T_{min.}$) for open peripheral equipment not intended to be permanently installed shall be specified by the manufacturer.

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2.1.1.2 *Storage temperature*

The allowable temperature range is –25 °C to +70 °C.

2.1.1.3 *Relative humidity*

The manufacturer may select one of the two following levels.

Table 2 – Operating ambient air relative humidity (notes 1 and 2)

Relative humidity severity level	Relative humidity range
RH-1	50 % to 95 %
RH-2	5 % to 95 %
NOTES 1 Non-condensing. 2 See 2.1.2.2 for electrostatic discharge requirements.	

2.1.1.4 *Pollution degree*

The manufacturer shall specify the pollution degree for which the equipment is suitable.

2.1.1.5 *Corrosion immunity*

Corrosion conditions vary widely depending on the application and it is not possible to specify normal conditions of use. In case of severe service conditions, see 2.2.

The manufacturer shall specify the corrosion immunity of the equipment according to IEC 68.

2.1.1.6 *Altitude*

The equipment shall be suitable for operation up to 2 000 m.

2.1.2 *Electrical service conditions and requirements*

2.1.2.1 *A.C. and d.c. mains power supply*

Refer to 3.2.

2.1.2.2 *Electrical noise conditions*

Electrical noise conditions vary widely and depend on the installation wiring and other installed equipment and its proximity to the PC-system.

For the purpose of this standard, the minimum noise conditions to which the PC-system shall be immune are indirectly expressed by the requirements given in 3.9.1.

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For electrostatic discharge (ESD) the manufacturer may select one of the severity levels of the following table 3. Refer to IEC 801-2 for description of classes of installation.

Table 3 – Electrostatic discharge service conditions

ESD severity levels (coordinated with relative humidity severity levels) (note)		Class of installation (according to IEC 801-2)
Level RH-1	Level ESD-3	3
Level RH-2	Level ESD-4	4
NOTE – See table 2 for definition of relative humidity severity levels.		

2.1.2.3 *Overvoltage category. Control of transient overvoltages*

The nature of the installation shall be such that overvoltage category II conditions shall not be exceeded.

Transient overvoltages at the point of connection to the mains power supply shall be controlled not to exceed overvoltage category II, i.e. not higher than the impulse voltage corresponding to the rated voltage for basic insulation. The equipment or the transient suppression means shall be capable of absorbing the energy in the transient. (See 3.10.2.)

2.1.2.4 *Non-periodic overvoltages*

In the industrial environment, non-periodic overvoltage peaks may appear on mains power supply lines as a result of power interruptions to high energy equipment (e.g. blown fuse on one branch in a 3-phase system). This will cause high current pulses at relatively low voltage levels (approximately 2 x U_{peak}). The user shall take the necessary steps to prevent damage to the PC-system (e.g. by interposing a transformer). See IEC 1131-4 for additional information.

2.1.3 *Mechanical service conditions and requirements*

Vibration, shock and free fall conditions vary widely depending on the installation and environment and are very difficult to specify.

For the purpose of this standard, the service conditions are indirectly defined by the following test requirements which apply to fixed equipment as well as to unpackaged portable and hand-held portable equipment (see exceptions in 2.1.3.2). They do not apply to equipment containing assemblies other than PC-systems and/or associated peripherals.

Experience shows that equipment passing these tests are suitable for industrial use on stationary installations.

2.1.3.1 *Vibrations*

Immunity requirements are:

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Table 4 – Sinusoidal vibrations service conditions for PC-systems (notes 1, 2 and 3)

Frequency range Hz	Continuous	Occasional
$10 \leq f < 57$	0,0375 mm amplitude	0,075 mm amplitude
$57 \leq f \leq 150$	0,5 *g* constant acceleration	1,0 *g* constant acceleration
$150 < f$	Not defined	Not defined

NOTES

1 Applicable to each of three mutually perpendicular axes.

2 Test according to IEC 68-2-6, test Fc.

3 The manufacturer shall specify the method of mounting portable and hand-held portable peripherals on the test equipment.

2.1.3.2 *Shocks*

Immunity requirements are: Occasional excursions to 15 *g*, 11 ms, half-sine, in each of three mutually perpendicular axes (IEC 68-2-27).

NOTES

1 Devices containing CRTs are excluded from this requirement.

2 Electromechanical relays may temporarily respond to 15 *g* shocks. Temporary malfunctioning is allowed during the test, but equipment should be fully functional after the test.

2.1.3.3 *Free falls*

Immunity requirements for type tests are:

Table 5 – Free fall on concrete floor
(Applicable to portable and hand-held portable equipment)

	Portable and hand-held portable (Any weight) (Withstand)	Hand-held portable (Any weight) (Immunity)	Notes
Random drops	–	1 000 mm; 2 trials	1 and 2
Flat drops	100 mm; 2 trials	–	1
Supported drops	30° or 100 mm; 2 trials	–	1 and 3

NOTES

1 Caution: Temporary malfunctioning is allowed at the impact, but equipment shall be fully functional after the test and not cause a shock hazard. Therefore, if equipment is operating during the fall, erroneous operation could be introduced upon impact which may require operator correction.

2 From prescribed altitude (normal position of use) see IEC 68-2-32, Procedure 1.

3 From prescribed values given in 3.2.1 of IEC 68-2-31.

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2.2 *Special service conditions*

When the service conditions are more severe than those given in 2.1, or other adverse environmental conditions exist, (e.g. air pollution by dust, smoke, corrosive or radioactive particles, vapours or salts, attack by fungi, insects or small animals), the manufacturer should be consulted to determine suitability of the equipment or the steps to be taken.

2.3 *Requirements for transport and storage of modules and subassemblies*

The following requirements apply to PC-units placed within manufacturer's original packaging. Transport and storage of unpackaged portable equipment should not exceed the requirements of 2.1.

When components are included in the equipment which have particular limitations (e.g. CMOS components, batteries, etc.), the manufacturer shall specify the arrangements to be made for transport and storage.

2.3.1 *Temperature*

The allowable temperature range is –25 °C to +70 °C. See test procedure in 6.3.4.2.

2.3.2 *Relative humidity*

The relative humidity range is 5 % to 95 % (non-condensing).

2.3.3 *Atmospheric pressure*

The minimum atmospheric pressure for transportation shall be not less than 70 kPa (equivalent to 3 000 m altitude).

2.3.4 *Free falls*

Withstand requirements for PC-units within manufacturer's original packaging are given in table 6 below. After the test, they shall be fully functional and shall show no evidence of physical damage. See test procedure in 6.3.5.4.

Table 6 – Free fall on concrete floor
(Applicable to PC-units under manufacturer's original packaging)

Shipping weight without packaging kg	Random free fall drop height mm	Number of falls
< 10	1 000	5
10 to 40	500	5
> 40	250	5
NOTE – According to IEC 68-2-32, procedure 1.		

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2.3.5 *Other conditions*

The user should reach agreement with the manufacturer for any mechanical conditions that are not specified in this standard.

2.3.6 *Information to be provided by the manufacturer*

The manufacturer shall provide shipping and storing instructions.

2.4 *Transport and storage conditions of PC-systems incorporated in complete control assemblies*

These conditions are not part of this standard and therefore the manufacturer should be consulted.

3 Electrical requirements

NOTE - Functional requirements for PC-systems including those relating to basic and advanced functions of PADTs are given in 3.6, 3.7 and 3.8.

3.1 *General*

A typical PC-system and its interfaces are shown in figure 1 below.

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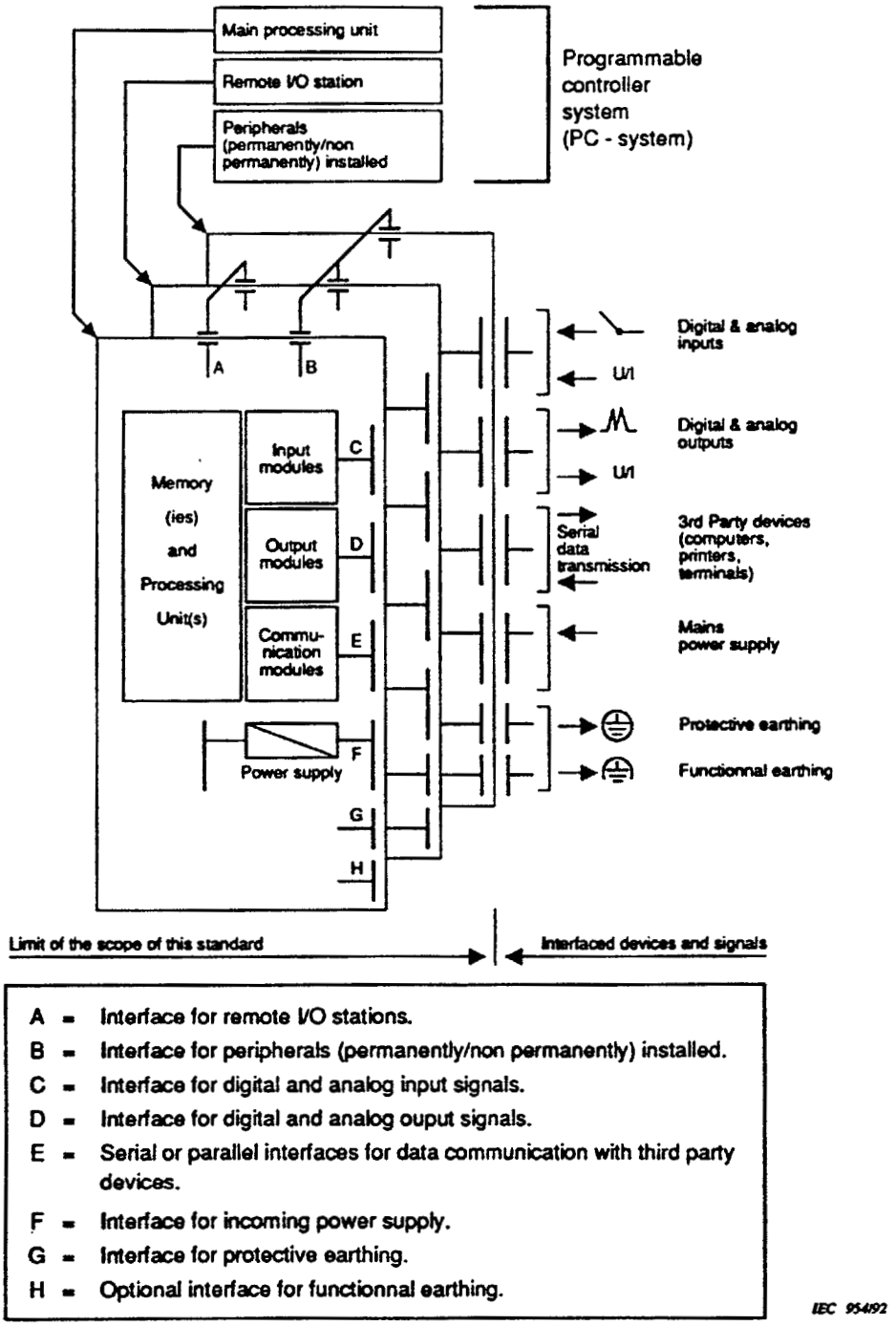


Figure 1 – Typical interface diagram of a programmable controller system

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3.2 *A.C. and d.c. power supply*

3.2.1 *Incoming power supply*

3.2.1.1 *Rated values and operating ranges*

Incoming power supplies to the PC-system and to the externally powered I/O modules shall be as shown in table 7 below:

Table 7 – Rated values and operating ranges of incoming power supply

Voltage		Frequency		Recommended use: R		Notes
Rated (U_e)	Tolerance Min. / Max.	Rated (F_n)	Tolerance Min. / Max.	Power supply	I/O signals	5
24 V d.c.	–15 % / +20 %	–	–	R	R	1
48 V d.c.	id	–	–	R	R	1, 2
24 V a.c.	–15 % / +10 %	50 Hz or 60 Hz	–5 % / +5 %	–	–	3
48 V a.c.	id	id	id	–	–	3
120 V a.c.	id	id	id	R	R	3, 4
230 V a.c.	id	id	id	R	R	3, 4
400 V a.c.	id	id	id	R	–	3, 4, 6

NOTES

1 In addition to the voltage tolerances, a total a.c. component having a peak value of 5 % of the rated voltage is allowed. The absolute limits are 30/19,2 V d.c. for 24 V d.c. and 60/38,4 V d.c. for 48 V d.c.

2 See item 5 of 3.3.1.2 if type 2 digital inputs are likely to be used.

3 A.C. voltage is in terms of the total r.m.s. voltage values measured at the point of entry to the equipment.
Total r.m.s. content of true harmonics (integral multiple of nominal frequency) less than 10 times nominal frequency may reach 10 % of the total voltage. Harmonic and other frequency content for higher frequencies may reach 2 % of the total voltage. However, to provide constant comparative results, the equipment shall be tested at the third harmonic only (10 % at 0 and at 180° phase angle).
The total content of harmonics of the power supply to the PC-system may be affected when the energy source output impedance is relatively high with regard to the input impedance of the PC-system power supply; sizing a dedicated power source such as an inverter for a PC-system may require an agreement between the user and the manufacturer. Use of line conditioner should be considered. See IEC 1131-4.

4 These rated voltages are derived from IEC 38.

5 For incoming voltages other than those given in the table such as 100 V a.c., 110 V a.c., 200 V a.c., 240 V a.c., 380 V a.c. or 110 V d.c., 125 V d.c., the tolerances given in the table and notes 1 and 3 apply. These voltage tolerances shall be used to calculate the input limits of 3.3.1.2, using the equations in annex B.

6 Three-phase supply.

7 For power supplies for analog I/Os, see item 5 of 3.4.1.2.3 and item 3 of 3.4.2.2.3.

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3.2.1.2 *Voltage drops and interruptions*

1) For short disturbances of the supply as defined in table 8 below, the PC-system (including RIOSs and non-permanently installed peripherals, see 3.7) shall maintain normal operation.

2) For longer interruptions of the supply(ies), the PC-system shall either maintain normal operation or go to a predefined state and have a clearly specified behavior until normal operation is resumed.

NOTE - Outputs and fast responding inputs energized by the same supply(ies) will respond to these power supply variations.

Table 8 – Normal service conditions: Voltage drops and interruptions

		Interruption time	Time interval between drops	Low voltage
D.C. supply	Severity level PS1	≤ 1 ms	≥ 1 s	Any voltage under lower operational limit U_{min} (note 2)
	Severity level PS2	≤ 10 ms	≥ 1 s	
A.C. supply		≤ 0,5 period (note 1)	≥ 1 s	

NOTES

1 Any arbitrary phase angle – (see test procedure in 6.3.7.2).

2 U_{min} is the U_e at minimum tolerance in table 7.

3 PS1 applies to PC-systems supplied by battery.
PS2 applies to PC-systems energized from rectified a.c. supplies and/or long d.c. lines.

3.2.1.3 *Non-periodic overvoltages*

See 2.1.2.4.

3.2.2 *Memory back-up*

Power back-up for volatile memories shall be capable of maintaining stored information for at least 300 h under normal service conditions, and 1 000 h at a temperature not greater than 25 °C when the energy source is at rated capacity. (For power back-up needing replacement, the rated capacity is the value used to designate the procedure and time interval for replacement.)

It shall be possible to change or refresh power back-up without loss of data in the backed-up portions of memory. (See also 2.3, 3.6.3 and 4.11.)

If a memory back-up battery is provided, a warning of low battery voltage shall be provided.

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3.2.3 *Information to be provided by the manufacturer*

In addition to the requirements stated in clause 5, the manufacturer shall provide the following information:

1) data to allow selection of a suitable power distribution network to provide specified voltage at each power utilization point. This information includes peak inrush, repetitive peak and steady-state r.m.s input currents under full load conditions;

2) external terminal identification for power supply interfaces;

3) typical example(s) for power supply system(s);

4) special supply installation requirements, if any, for PC-systems energized through multiple power supplies or supply voltages and frequencies not included in 3.2.1.1;

5) the effect of the following incorrect connections of power to the supply(ies):

- reverse polarity;
- improper voltage level and/or frequency;
- improper lead connection;

6) complete information on PC-system behaviour for typical power up/down sequences;

7) data to allow evaluation of the maximum values of interruption time which do not affect the normal operation of any PC-system configuration; PS class (PS-1 or PS-2) of d.c. supplied devices;

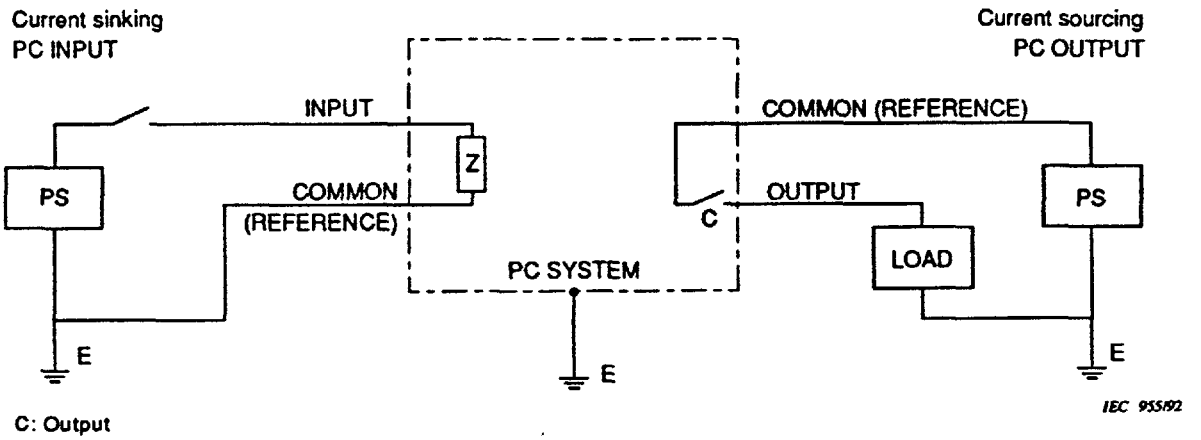
8) memory back-up time with respect to temperature and maintenance requirements;

9) recommended time interval between replacement of energy sources, if applicable, and recommended procedure and subsequent effects on the PC-system.

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3.3 *Digital I/Os*

The following figure 2 gives an illustration of definitions of some I/O parameters.



C: Output
– Mechanical or static contact (e.g. dry relay contact, triac, transistor or equivalent).

E: Earthings
– The earth shown are optional.
– Earthings is dependent on national regulations and/or application needs.

Z: Input
– Input impedance.

PS: External power supplies.

NOTE - Some applications may use only one PS common to inputs, outputs, and PC-system.

Figure 2 – I/O parameters

Digital I/Os shall comply with the following requirements:

1) the PC shall be provided with at least one type of input interface and one type of output interface among those defined respectively in 3.3.1, 3.3.2 and 3.3.3;

2) digital inputs shall comply with the requirements of the standard voltage ratings given in 3.3.1. Non-standard voltage digital inputs should be in accordance with the design equation given in annex B;

3) digital outputs shall comply with the requirements of the standard ratings given in 3.3.2.1 for a.c. or 3.3.3.1 for d.c.;

4) it shall be possible to interconnect inputs and outputs by means of a correct selection of the above digital I/Os, resulting in proper PC-system operation. (Additional external load shall be specified by the manufacturer if necessary);

5) it shall be possible to feed multi-circuit a.c. input modules from different phases and the modules shall then comply with the maximum voltage difference likely to occur between phases, or the user manual shall include a note indicating that all channels must be fed from the same phase;

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6) if a multi-channel a.c. circuit is intended for multi-phase use the circuit shall comply with the clearance and creepage distance requirements and the dielectric test corresponding to the voltage between phases.

NOTES

1 *Current sourcing inputs and current sinking outputs which may be required for certain applications are not covered in this standard. Special care should be exercised in their use. (Where positive logic, current sinking inputs and current sourcing outputs are used, any short-circuit to the reference potential and wire-breakage are interpreted by the inputs and loads as the "off state"; on the other hand, for current sourcing inputs and current sinking outputs, earth faults are interpreted as the "on state".) (See figure 2).*

2 *A PC-system may be offered with interfaces which are not covered in this standard, i.e., interfaces for TTL and CMOS circuits, etc. In such a case, the manufacturer's data shall give all relevant information to the user.*

3.3.1 *Digital inputs (current sinking)*

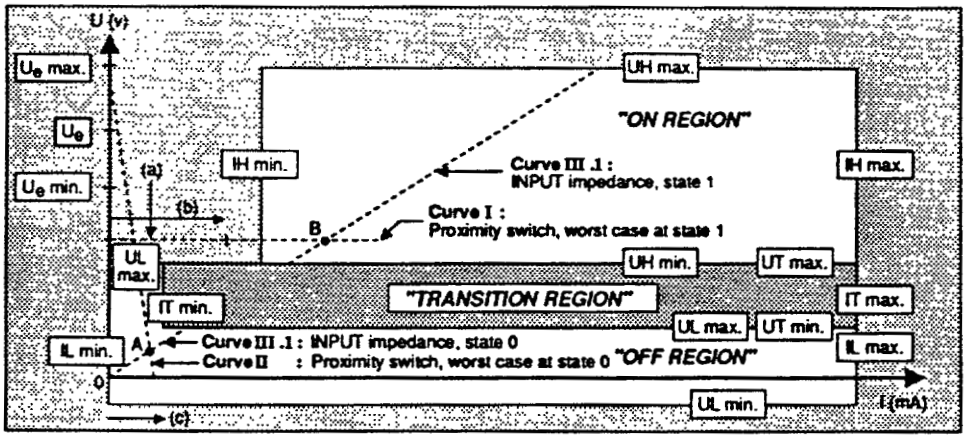
3.3.1.1 *Terminology (U/I operation regions)*

Figure 3 below represents graphically the limits and operating ranges which are used herein to characterize current sinking digital input circuits.

Operating region consists of "on region", "transition region" and "off region". It is necessary to exceed both *UT* min. and *IT* min. to leave the "off region", and to exceed *IH* min. before *UH* min. to enter the "on region": all input *U/I* curves shall remain within these boundary conditions. The region below zero volts is a valid part of the "off region" for d.c. inputs only.

The figure also presents a graphical illustration of the method explained in 3.3.1.5 for determination of compatibility between a 2-wire proximity switch (curve I: worst case at state 1, curve II: worst case at state 0), and a given input impedance curve (curve III).

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- *UH* max. and *UH* min. are the voltage limits for the ON conditions (state 1)
- *IH* max. and *UH* min. are the current limits for the ON conditions (state 1)
- *UT* max. and *UT* min. are the voltage limits for the transition state (ON or OFF)
- *IT* max. and *IT* min. are the current limits for the transition state (ON or OFF)
- *UL* max. and *UL* min. are the voltage limits for the OFF conditions (state 0)
- *IL* max. and *IL* min. are the current limits for the OFF conditions (state 0)
- *UL* max. equals *UL* min. to *IT* min. and equals *UT* min. above *IT* min.
- U_e, U_e max. and U_e min. are the rated voltage and its limits for the external power supply voltage
- I, II, III, (a), (b), (c), A, B relate to the example described in 3.3.1.5.

Figure 3 – *U/I* operation regions of current sinking inputs

3.3.1.2 *Standard operating ranges for digital inputs (current sinking)*

Current sinking digital inputs shall operate within the limits presented in the following table 9.

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Table 9 – Standard operating ranges for digital inputs (current sinking)

ND: Not defined

Rated voltage U_e	Rated frequency F_n Hz	Type of limit	Type 1 limits (note 7)						Type 2 limits (note 7)						Notes
			State 0		Transition		State 1		State 0		Transition		State 1		
			UL V	*IL* mA	*UT* V	*IT* mA	*UH* V	*IH* mA	*UL* V	*IL* mA	*UT* V	*IT* mA	*UH* V	*IH* mA	
24 V d.c..	—	Max.	15/5	15	15	15	30	15	11/5	30	11	30	30	30	1, 2, 4, 5
		Min.	–3	ND	5	0,5	15	2	–3	ND	5	2	11	6	
48 V d.c.	—	Max.	34/10	15	34	15	60	15	30/10	30	30	30	60	30	1, 2, 4
		Min.	–6	ND	10	0,5	34	2	–6	ND	10	2	30	6	
24 V a.c.	50/60	Max.	14/5	15	14	15	27	15	10/5	30	10	30	27	30	1, 3
		Min.	0	0	5	1	14	2	0	0	5	4	10	6	
48 V a.c.	50/60	Max.	34/10	15	34	15	53	15	29/10	30	29	30	53	30	1, 3
		Min.	0	0	10	1	34	2	0	0	10	4	29	6	
100 V a.c. 110 V a.c. 120 V a.c.	50/60	Max.	79/20	15	79	15	1,1 U_n	15	74/20	30	74	30	1,1 U_n	30	1, 3, 4, 6
		Min.	0	0	20	1	79	2	0	0	20	4	74	6	
200 V a.c. 230 V a.c. 240 V a.c.	50/60	Max.	164/40	15	164	15	1,1 U_n	15	159/40	30	159	30	1,1 U_n	30	1, 3, 4, 6
		Min.	0	0	40	2	164	3	0	0	40	5	159	7	

NOTES

1 All logic signals are in positive logic. Open inputs shall be interpreted as state 0 signal. Compatibility with 2-wire proximity switches according to IEC 947-5-2 is possible with type 2 (see also note 3). See annex B for equations and assumptions used in developing values in this table and for additional comments.

2 The given voltage limits include all alternating voltage components.

3 Static switches may affect the total r.m.s. content of true harmonics of the input signals and therefore affect the compatibility of the input interface with proximity switches, especially for type 2, 24 V a.c. See 3.2.1.1 for requirements.

4 Recommended for common usage and future designs.

5 The minimum external power supply voltage for type 2, 24 V d.c. inputs connected to two-wire proximity switches should be higher than 20 V d.c. or *UH* min. lower than 11 V to allow sufficient safety margin.

6 As allowed by the current technology, and to encourage the design of single input modules compatible with all commonly used rated voltages, limits are absolute and independent of rated voltage (except *UH* max.) and based on equations given in annex B and respectively 100 V a.c. and 200 V a.c.

7 See definitions in 1.4.25.

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3.3.1.3 *Additional requirements*

Each input channel shall be provided with a lamp or equivalent means to indicate the state 1 condition when the indicator is energized.

3.3.1.4 *Information to be provided by the manufacturer*

In addition to the requirements of clause 5, the manufacturer shall provide the following information:

1) volt-ampere curve over the full-operating range, with tolerances or equivalent;

2) digital input delay time (TID) for 0 to 1 and 1 to 0 transitions;

3) existence of common points between channels;

4) effect of incorrect input terminal connection;

5) isolation potentials between channel and bus and between channels under normal service conditions;

6) type of input (type 1 or type 2);

7) monitoring point and binary state of visual indicator;

8) effects when withdrawing/inserting input module under power;

9) additional external load when interconnecting inputs and outputs, if needed;

10) explanation of signal evaluation (for example static/dynamic evaluation, interrupt release, etc.);

11) recommended cable and cord lengths depending on cable type and electro-magnetic compatibility;

12) terminal arrangements;

13) typical example(s) of external connections.

3.3.1.5 *Method for determination of compatibility with proximity switches*

For a given proximity switch, the following characteristics shall be identified:

i) when at state 1:

a) U_{drop}: maximum voltage drop at state 1

b) I_{hold}: minimum output current load at state 1

I: worst case output curve at state 1

ii) when at state 0:

c) I_{leak}: maximum output current at state 0

II: worst case output curve at state 0.

A given proximity switch shall be compatible with a given standard input (curve III: impedance curve of the input) if:

- its curves I and II do not enter the "transition region", and
- its I_{hold} is smaller than *IH* min.

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Worst case steady states 0 and 1 shall be respectively at points A and B (at crossings of III with II and I).

NOTE - This method may be used for any other type of static switch, such as outputs, etc.

3.3.2 *Current sourcing digital outputs for alternating currents*

3.3.2.1 *Rated values and operating ranges (a.c. r.m.s.)*

Digital a.c. outputs shall comply with the ratings given in the following table 10, at the output voltage(s) stated by the manufacturer according to 3.2.1.1 and IEC 947-5-1, utilization category AC-15. See item 9 of 3.3.2.3, for other utilization categories.

Table 10 – Rated values and operating ranges for current sourcing digital a.c. outputs

Rated current (state 1)	I_e (A)	0,25	0,5	1	2	Notes
Current range for state 1 (continuous at max. voltage)	Min. (mA) Max. (A)	10 [5] 0,28	20 0,55	100 1,1	100 2,2	1, 2
Voltage drop (state 1) – Non-protected output – Protected and short-circuit proof	 Max. (V) Max. (V)	 3 5	 3 5	 3 5	 3 5	1
Leakage current (state 0) – Solid state outputs – Electromechanical outputs	 Max. (mA) Max. (mA)	 5 [3] 2,5	 10 2,5	 10 2,5	 10 2,5	1 2, 3
Repetition rate for temporary overload – Solid state outputs – Relay based outputs	Operating cycles/min Min. Min.	 60 6	 30 6	 30 6	 30 6	4

NOTES

1 R.M.S. currents and voltages.

2 Figures between [ ] apply to module not equipped with RC network or equivalent surge suppressors. All other values apply to modules with suppression.

3 Leakage current for solid state outputs greater than 3 mA imply the use of additional external loads to drive type 2 inputs.

4 Typical waveform for temporary overloads ("normal conditions of use") are shown in figure 4. The test method given in IEC 947-5-1 applies to solid state outputs for "normal conditions of use" except that the repetition rate shall be as given in the table. For "abnormal conditions of use", the requirements given in IEC 947-5-1 apply.

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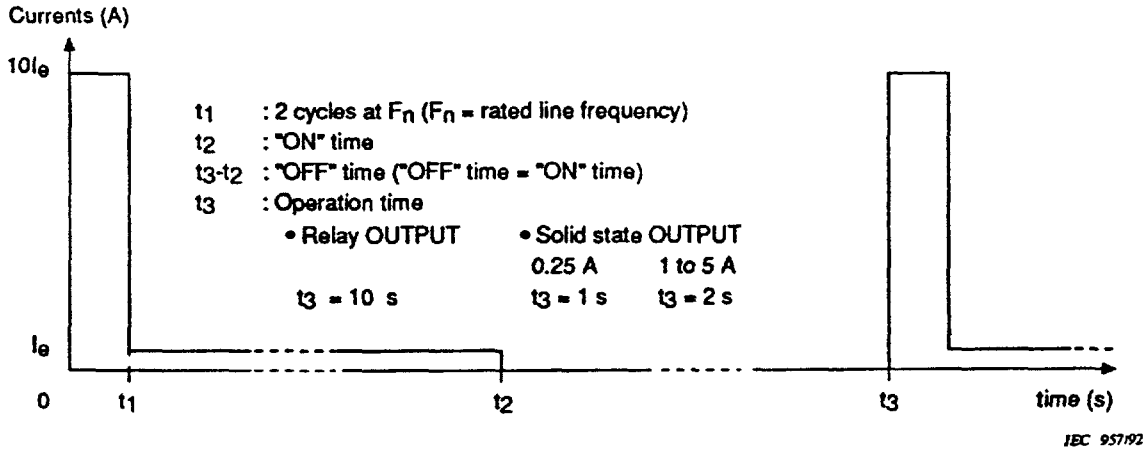


Figure 4 – Temporary overload waveform for digital a.c. outputs

NOTE - In IEC 947-5-1, the curve shown in figure 4 is named "AC-15, normal conditions of use".

3.3.2.2 *Additional requirements*

Output indicators

Each output channel shall be provided with a lamp or equivalent means to indicate the output state 1 condition when the indicator is energized.

Protected outputs

For outputs stated by the manufacturer to be protected:

1) the output shall either withstand and/or the associated protective device shall operate to protect the output for all steady state values of output current greater than 1,1 times the rated value;

2) after resetting or replacement of the protective device alone, as applicable, the PC-system shall return to normal operation;

3) during any overload, there shall be no evidence of risk of fire or electrical shock, and immediately after any overload, the maximum temperature rise of the I/O insulation shall not exceed the value specified in 4.4.2.

Optional restart capabilities may be selected among the three following types:

i) automated restart protected output: a protected output which automatically recovers after the overload is removed;

ii) controlled restart protected output: a protected output which is reset through signals (e.g. for remote control);

iii) manual restart protected output: a protected output which implies a human action to recover. (the protection may be fuses, electronic interlocks, etc.).
See test procedure in 6.3.8.3.2.

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NOTES

1 Operation under overload condition for an extended period of time may affect operating life of the module.

2 The protected outputs will not necessarily protect the external wiring. It is the user's responsibility to provide that protection when it is needed.

Short-circuit proof outputs

For outputs stated by the manufacturer to be short-circuit proof:

4) For all output currents greater than I_e max. and up to 2 times the rated value I_e, the output shall operate and withstand temporary overload(s). Such temporary overload(s) shall be specified by the manufacturer.

5) For all output currents prospectively above 20 times the rated value, the protective device shall operate. After resetting or replacement of the protective device alone, the PC-system shall return to normal operation.

6) For output currents in the range of 2 times to 20 times I_e, or for temporary overload(s) beyond the limits specified by the manufacturer (item 1 above), the module may require repair or replacement.

7) During an overload of 2 I_e applied for 5 min, there shall be no evidence of risk of fire or electrical shock and immediately after the overload, the maximum temperature rise of the I/O insulation shall not exceed the value specified in 4.4.2.

See test procedure in 6.3.8.3.2.

Not-protected outputs

For outputs stated by the manufacturer to be not-protected, their operation with the protective devices provided or specified by the manufacturer shall meet all the requirements stated for the short-circuit proof outputs.

Electromechanical relay outputs

Electromechanical relay outputs shall be capable of performing at least 0,3 million operations at the AC-15 utilization category (durability class 0.3) according to IEC 947-5-1.

NOTE - The type test is not required if the relay components have been shown to comply with the requirements of IEC 947-5-1.

3.3.2.3 *Information to be provided by the manufacturer*

In addition to the requirements of clause 5, the manufacturer shall provide the following information with respect to digital outputs for a.c. operation:

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1) type of protection (i.e. protected, short-circuit proof, not-protected output) and:

– for protected outputs: operating characteristics beyond 1.1 I_e including the current(s) level(s) at which the protecting device energizes, the current behaviour beyond, and the time(s) involved;

– for short-circuit proof outputs: information for replacement or resetting the protective device as required;

– for not-protected outputs: specification for protective device to be provided by the user, as required;

2) output delay time (TQD) and output transfer times (TQT) for state 0 to state 1 and state 1 to state 0 transitions;

3) commutation characteristics and turn-on voltage with respect to zero voltage crossing;

4) existence of common points between channels;

5) terminal arrangements;

6) typical example(s) of external connections;

7) number and type of outputs (e.g. NO/NC contacts, solid state, individually isolated channels, etc.) ;

8) for electromechanical relays, the rated current and voltage of the contacts for utilization category AC-15 and durability class according to IEC 947-5-1 and their mechanical life;

9) output ratings for the other utilization categories (AC-12, AC-13, AC-14) or other loads such as incandescent lamps;

10) total output current for multichannel modules (see definition in 1.4) ;

11) characteristics of suppressor networks incorporated into the output circuit against voltage peaks due to inductive kickback;

12) type of external protective networks, if required;

13) effects of incorrect output terminal connection;

14) insulation/potentials under normal service conditions between circuits and bus and between circuits;

15) monitoring points of visual indicators in the channel (e.g. MPU side/load side);

16) recommended procedures for changing output modules;

17) output behaviour during interruptions of MPU control, voltage drops and interruptions and power up/down sequences (see also 3.6) ;

18) way of operation (i.e. latching/non-latching type);

19) effects of multiple overloads on multi-circuit modules.

3.3.3 *Current sourcing digital outputs for direct current*

3.3.3.1 *Rated values and operating ranges*

Digital outputs shall comply with the ratings given in the following table 11, at the output voltage(s) stated by the manufacturer according to 3.2.1.1 and with IEC 947-5-1 for utilization category DC-13.

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Table 11 – Rated values and operating ranges for current sourcing digital d.c. outputs

Rated current (state 1)	I_e (A)	0,1	0,25	0,5	1	2	Notes
Current range for stage 1 at maximum voltage (continuous)	Max. (A)	0,12	0,3	0,6	1,2	2,4	
Voltage drop Not-protected output, protected and short-circuit proof	Max. (V)	3 3	3 3	3 3	3 3	3 3	1
Leakage current (state 0)	Max. (A)	0,4	1	2	2	4	2
Temporary overload	Max. (A)	According to manufacturer's specifications					

NOTES

1 For 1 A and 2 A rated currents, if reverse polarity protection is provided, a 5 V drop is allowed. This makes the output incompatible with a type 1 input of the same voltage rating.

2 The resulting compatibilities between d.c. outputs and d.c. inputs, without additional external load, are as follows:

Rated output current I_e (A):	0,1	0,25	0,5	1	2
Type 1:	yes	no	no	no	no
Type 2:	yes	yes	yes	yes	no

With adequate additional external load, all d.c. outputs may become compatible with all type 1 and type 2 d.c. inputs.

3.3.3.2 *Additional requirements*

Other requirements are the same as for current sourcing outputs for a.c. as defined in 3.3.2.2, except:

- for protected outputs: the limit is 1,2 I_e instead 1,1 I_e
- for electromechanical relay outputs: AC-15 is replaced by DC-13.

3.3.3.3 *Information to be provided by the manufacturer*

Information to be provided by the manufacturer for digital outputs for d.c. shall be the same as for digital outputs for a.c., as defined in 3.3.2.3, except that the specification of commutation for zero voltage crossing does not apply, and AC-12, AC-13, AC-14 are replaced by DC-12 and DC-13.

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3.4 *Analog I/Os*

3.4.1 *Analog inputs*

3.4.1.1 *Rated values and impedance limits*

Rated values of signal range and impedance for analog inputs to PC-systems shall be as specified in the following table 12.

Table 12 – Rated values and impedance limits for analog inputs

Signal range	Input impedance limits	Notes
–10 V, +10 V	≥ 10 kΩ	
0 V, +10 V	≥ 10 kΩ	
1 V, + 5 V	≥ 5 kΩ	
4 mA, 20 mA	≤ 300 Ω	
0 mA, 20 mA	≤ 300 Ω	1

NOTE

1 Not recommended for future designs.

Analog inputs may be designed to be compatible with standard thermocouples or standard resistive temperature devices (RTDs) such as 100 Ω Pt sensors. Thermocouple analog inputs shall provide a built-in cold-junction compensation.

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3.4.1.2 *Information to be provided by the manufacturer*

Table 13 – Analog inputs: information to be provided

3.4.1.2.1 Static characteristics	Units and examples
1) Input impedance in signal range	Ω
2) Analog input error	
– Maximum error at 25 °C	± % of full scale
– Temperature coefficient	± % of full scale/K
3) Maximum error over full temperature range	± % of full scale
4) Digital resolution	Number of bits
5) Data format returned to the application program	Binary, BCD, etc.
6) Value of LSB (least significant bit)	mV, mA
7) Maximum permanent allowed overload (no damage)	V, mA
8) Digital output reading under overload condition	e.g. flag
9) Type of input	e.g. differential
10) Common mode characteristic (d.c., 50 Hz, 60 Hz) if applicable	CMRR-dB, CMV-V
11) For other inputs (thermocouples, RTD, etc.)	
– type(s) of sensor(s)	J, K, T, etc.: Pt 100, etc.
– measurement range(s)	Min. °C to Max. °C
– linearization method	Internal or user-provided

3.4.1.2.2 Dynamic characteristics	Units and examples
1) Total input system transfer time (TAID + TAIT)	ms
2) Sample duration time (including settling time)	ms
3) Sample repetition time	ms
4) Input filter characteristics	
– order	First, second, etc.
– transition frequency	Hz
5) Maximum temporary deviation during each specified electrical noise test	± % of full scale

3.4.1.2.3 General characteristics	Units and examples
1) Conversion method	Dual slope, S.A., etc.
2) Operating modes	Trig, self-scan, etc.
3) Type of protection	RC, opto-isolator, MOVs, etc.
4) Isolation potentials under normal service conditions between channel and a) bus, b) other channels, c) power supply(ies) interface(s)	V
5) External power supply data, if required	Technical data
6) Common points between channels if any	
7) Type, length of cable, installation rules recommended to provide noise immunity	Twisted pair, 50 m max.
8) Calibration or verification to maintain rated accuracy	Month, years
9) Terminal arrangements	
10) Typical example(s) of external connections	
11) Effect of incorrect input terminal connection	

3.4.1.2.4 Miscellaneous characteristics	Units and examples
1) Monotonicity with no missing codes	Yes, no
2) Crosstalk between channels at d.c., 50 Hz and 60 Hz	dB
3) Non-linearity	% of full scale
4) Repeatability at fixed temperature after specified stabilization time	% of full scale
5) Life time of electromagnetic relay multiplexors, if applicable	Number of cycles, of hours

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3.4.2 *Analog outputs*

3.4.2.1 *Rated values and impedance limits*

Rated values of signals range and load impedance for analog outputs of PCs shall be as specified in the following table 14:

Table 14 – Rated values and impedance limits for analog outputs

Signal range	Load impedance limits	Notes
–10 V +10 V	≥ 1 000 Ω	1
0 V +10 V	≥ 1 000 Ω	1
+1 V + 5 V	≥ 500 Ω	1
4 mA, 20 mA	≤ 600 Ω	2
0 mA, 20 mA	≤ 600 Ω	2, 3

NOTES

1 Voltage analog outputs shall withstand any overload down to short circuit.

2 Current analog outputs shall withstand any overload up to open circuit.

3 Not recommended for future designs.

3.4.2.2 *Information to be provided by the manufacturer*

In addition to the requirements of clause 5, the manufacturer shall provide the following information:

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Table 15 – Analog outputs: information to be provided

3.4.2.2.1 Static characteristics	Units and examples
1) Output impedance in signal range	Ω
2) Analog output error	
– maximum error at 25 °C	± % of full scale
– temperature coefficient	± % of full scale/K
3) Maximum error over full temperature range	± % of full scale
4) Digital resolution	Number of bits
5) Data format in application program	Binary, BCD, etc.
6) Value of LSB (least significant bit)	mV, mA
3.4.2.2.2 Dynamic characteristics	**Units and examples**
1) Total output system transfer time (TAQD + TAQT)	ms
2) Settling time for full range change	ms
3) Overshoot	% of full scale
4) Maximum temporary deviation during electrical noise tests and test conditions	± % of full scale
3.4.2.2.3 General characteristics	**Units and examples**
1) Type of protection	Opto-isolators, etc.
2) Isolation potentials under normal service conditions between channel and a) bus, b) other channels, c) power supply(ies) interface(s)	V
3) External power supply data if required	Technical data
4) For current outputs with external supply, the maximum and minimum voltage drop across the output terminals in the full output range	V
5) Type, length of cable, installation rules recommended to provide noise immunity	Twisted pair, 50 m max.
6) Calibration or verification to maintain rated accuracy	Months, years
7) Terminal arrangements	
8) Common points between channels if any	
9) Allowed type(s) of loads	Floating, grounded
10) Maximum capacitive load (for voltage outputs)	pF
11) Maximum inductive load (for current outputs)	mH
12) Typical example(s) of external connections	
13) Output response at power up and power down	
14) Effect of incorrect output terminal connection	
3.4.2.2.4 Miscellaneous characteristics	**Units and examples**
1) Monotonicity	Yes, no
2) Crosstalk between channels at d.c., 50 Hz and 60 Hz	dB
3) Non-linearity	% of full scale
4) Repeatability at fixed temperature after specified stabilization time	% of full scale
5) Output ripple	% of full scale

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3.5 *Communication interfaces*

3.5.1 *General requirements*

The configuration which shall be tested according to clause 6 of this standard shall be equipped with communication interface modules where applicable and with communication links specified by the manufacturer.

Communication interface modules are subject to all general requirements relating to service conditions, mechanical construction, safety, markings, etc. (see in particular 2.1, 3.8, 3.9 and clause 4).

3.5.2 *Information to be provided by the manufacturer*

If the manufacturer provides communication interfaces to other than his own equipment, he shall provide the necessary information for correct operation. This information shall include, but not be limited to, type of link, baud rates, energization of the line, type of cable to be used, isolation characteristics, protocols, character encoding, frame encoding, etc.

3.6 *Main processing unit(s) and memory(ies) of the PC-system*

NOTE - This subclause should be read in conjunction with IEC 1131-1 and with 3.7 and 3.8 of this part (respectively: RIOSs and peripherals).

3.6.1 *General*

See figure 1 in 3.1, and annex A for the definition and illustration of PC-system, main processing unit (MPU), main memory and other terms used in this subclause.

3.6.2 *Requirements*

Main processing unit(s) and memory(ies) are part of the permanent PC-installation and therefore tested accordingly. They are subject to all general requirements relating to service conditions, mechanical construction, safety, markings, etc. (see in particular 2.1, 3.8, 3.9, 3.11 and clause 4)

3.6.3 *Information to be provided by the manufacturer*

1) organization, capacity of program memory;

2) organization, capacity of data memory and number of bits per word;

3) memory type(s) (i.e. CMOS-EPROM, etc.) available;

4) memory back-up functionality and service requirements if any;

5) data, constraints and procedures to determine a desired configuration (racks, cables, bus expanders, power supply unit, maximum number of I/Os per type, maximum number of I/O modules, etc.)

6) description of the programming languages supported by the PC-system (combination of the PADT and the main processing unit(s);

7) to what extent the languages defined in IEC 1131-3 are supported, including the differences if any (objects, instructions, semantic and syntactic rules, etc.);

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8) calculation methods to determine every memory utilization (user's application program and data, firmware program and data where applicable) and average, minimum and maximum value of every relevant time (scan time(s), system response time(s), transfer time(s), execution time(s));

9) mechanisms in which I/Os are processed (i.e. use of I/O image registers periodically refreshed by the system, immediate "get/put" type instructions, interrupt and event-driven programs, etc.) and their effect on the following subjects:

– system response time(s) ;

– restart capabilities (i.e. cold, warm, hot restart) ;

10) detailed times for inputs, outputs, processing, etc.

11) effect of non-permanently installed peripherals on every relevant time (see item 8 above) when they are plugged/unplugged, connected/disconnected to their PC-system interface;

12) PC-system status information concerning cold, warm and hot restart if applicable. Description and usage of programmable timers usable to determine the process-dependent difference between warm and hot restart;

13) test and diagnostic functions implemented (see 3.11) .

3.7 *Remote input/output stations (RIOSs)*

RIOSs are part of the permanent PC-installation and therefore to be tested accordingly. However, for ease of testing, isolated RIOSs may be tested separately where appropriate.

3.7.1 *Requirements*

1) Requirements for voltage drops and interruption of the power supply(ies) fully apply to RIOSs (see 3.2.1.2).

2) In case of loss of communication with the MPU application program, RIOSs shall be able to fix the states of their outputs to specified values, within specified delays and without passing through unspecified states and be capable of providing a fault indication signal.

3) The MPU system shall provide the user's application program with relevant information on current status of RIOSs.

3.7.2 *Information to be provided by the manufacturer*

In addition to the requirements of clause 5, the manufacturer shall provide the following information:

1) specifications for the selection of adequate cables and other devices needed for the communication link;

2) specifications for proper installation of the whole system (including proper selection of energy source(s));

3) type of I/O communication network (point to point, star, multidrop, ring, etc.) ;

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4) principles, procedures and transmission speeds used on the communication link and their capability to transfer data from and to the RIOSs with respect to error coding/detection and to the delays of transmission in the best, most likely and worst cases;

5) effect on transfer time(s) introduced to provide remote input information and RIOSs status to the user's application program and to transmit its logical decisions to remote outputs;

6) specified values and delays according to 3.7.1;

7) configuration related data: maximum number of RIOSs in one single PC-system configuration, min./max. size of each;

8) which I/O modules of the total I/O system may not be used in RIOSs and/or which of their functions are altered if any;

9) type, architecture and characteristics of redundancy if provided;

10) modems/repeaters if applicable. Maximum distance with or without repeaters;

11) terminating devices if required;

12) physical characteristics of the communication interface including isolation characteristics, maximum acceptable common mode voltage, built-in short-circuit protections, etc.;

13) type of standard link interface (i.e. RS 232, RS 422, RS 485, RS 511, etc.);

14) functional and safety earthing specifications;

15) procedures for making/breaking logical and physical connection of a RIOS to a PC-system (e.g. "on line") .

3.8 *Peripherals (PADTs, TEs, MMIs)*

3.8.1 *Requirements*

1) Peripherals which are not a permanent part of the PC-system shall cause no malfunction of the system when making or breaking communication with an operating system.

2) Connectors for the peripherals shall be polarized to prevent improper connection, or the PC-system shall be so designed that no malfunction occurs.

3) The system consisting of the peripheral and the PC-system shall be designed to ensure that the edited program executing in the PC-system is functionally identical to the edited program displayed on the peripheral.

4) If on-line modification of the application program and/or the modes of operation of the PC-system by a peripheral is possible (i.e. when the PC-system is in active control of a machine or industrial process), then:

– the peripheral shall automatically give clear warnings equivalent to "during on-line modification, program display may differ from application program, control of the machine/process may be interrupted during ... ms, etc.", as applicable,

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– the peripheral shall ask similar meaning words to "do you really want to carry out this action?" and execute the command only after a positive reply has been given by the operator,

– it shall be possible to upload the new application program to the manufacturer's supplied data media and verify, on line, that the record is functionally equivalent to it,

– means shall be provided to minimize unauthorized use of these functionalities (hardware or software).

3.8.2 *Information to be provided by the manufacturer*

1) Clear warnings and precautions to be observed when using functions enabling alteration of control conditions such as PC-system status modification, changing of data or programs in the memory, forcing input or output signal, etc.

2) Usability of peripherals at RIOSs.

3) Service conditions for peripherals which are intended for use in an environment less severe than stated in clause 2 (such peripherals may need to be remotely connected to the rest of the PC-system through communication lines).

3.9 *Noise immunity and emitted noise*

3.9.1 *Electrical noise immunity requirements*

As receiving equipment, PC-systems are affected by interferences from conducted noise, radiated electromagnetic fields, and electrostatic discharges. General rules of installation which shall be followed to limit coupling factors and consequently interfering voltages at withstandable levels are noted in IEC 1131-4.

The PC-system shall comply with the requirements in table 16.

NOTES

1 Conditions of use may require immunity to higher levels of electrical noise than the minimum given above. The manufacturer may select such higher values given in annex C. These higher levels shall be stated by the manufacturer and the tests conducted according to these levels.

2 The reference document for detailed tutorial and consideration is IEC 801.

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Table 16 – Electrical noise immunity requirements for PC-system and stand-alone peripherals (notes 1 and 2)

Electrical noise tests		Electrical noise severity levels			
	Maximum surge energy Minimum source impedance	All power supplies	Digital I/Os $U_e \geq 24$ V	Digital I/Os $U_e < 24$ V Analog, communication I/Os	Notes
Electrostatic discharge	150 pF/150 Ω				3, 4
– For level RH-1: ESD-3	–	8 kV	8 kV	8 kV	
– For level RH-2: ESD-4	–	15 kV	15 kV	15 kV	
Radioelectromagnetic field		10 V/m	10 V/m	10 V/m	3
Conducted noise					
– Fast transient Common mode	4 mJ/spike at 2 kV on 50 Ω	2 kV	1 kV	0,25 kV	3
– Damped oscillatory wave Series mode	200 Ω	1 kV	1 kV	–	3, 5

NOTES

1 Tests are performed on basic PC-system(s) (representative configuration(s) constituted by the PC configuration, and all peripherals that can be connected and which are intended for use under the normal service conditions). If peripherals are claimed to be on-line pluggable then the test procedure shall simulate on-line making/breaking of the physical peripheral connection to the PC-system. When permanently installed, peripherals shall be placed in their "monitor" mode or equivalent. (There is no requirement for simulation of operator's keying.)

2 Tests are performed on operated peripherals providing stand-alone functions such as off-line documentation, programming, compiling, editing, duplicating memory storages, etc.

3 Analog I/Os and fast responding digital inputs may be affected temporarily during the disturbance but shall resume normal operation after the disturbance, and shall stay within the manufacturer's specified limits (see item 5 of 3.4.1.2.2 and item 4 of 3.4.2.2.2).

4 Electrostatic discharges are applicable to all accessible conductive parts and insulating surfaces of the PC-system normally accessible to the operator such as switches, keyboards, module external packaging, shielding part of connectors etc. and to the protective and/or functional earth terminals, but not to the signal lines.

5 Revision of these requirements is under consideration pending availability of IEC 801-5.

3.9.2 *Information to be provided by the manufacturer*

The manufacturer shall state if his peripherals are intended to be used under normal service conditions or solely in a less severe environment (e.g. office environment).

3.9.3 *Emitted noise*

Due to differing national regulations, emission levels cannot be specified. Equipment shall meet the levels specified in every country of concern.

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3.10 *Dielectric properties*

3.10.1 *General*

Isolation may be provided for either safety (i.e. protection against electric shock) or functional purposes (e.g. RFI immunity). Isolation requirements (clearance/creepage) for safety purposes are given in 4.3.

3.10.2 *Dielectric withstand requirements*

1) Unless otherwise specified by the manufacturer, clearance and creepage requirements of 4.3 shall be verified by mechanical measurement where possible.

2) If mechanical measurement is not performed, the electrical test of 6.3.6.1.1 shall be carried out.

Exceptions:

This test need not be done:

– between isolated SELV circuits and accessible conductive parts (frames, enclosures, earth terminal, etc.);

– on units (parts of the basic PC-system) which have been tested separately according to the relevant standards provided:

a) the values given in table 17 below have been met, and

b) their dielectric strength is not impaired by assembly;

– between isolated circuits on printed wiring boards providing the specified clearances and creepage distances have been met. See 4.3.

3) When subject to the dielectric test, insulation between isolated circuits other than SELV circuits and

a) other non-SELV circuits,

b) accessible conductive parts

shall withstand the application of test voltage corresponding to their class and their rated voltage, as specified in table 17 below:

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Table 17 – Dielectric withstand voltages for impulse a.c. power frequency and d.c. tests

Rated voltage of circuit U_e V a.c. r.m.s. or V d.c. (note 2)		Test voltages at 2 000 m (note 1) V		
For basic and supplementary insulation	For reinforced insulation (note 3)	Impulse, peak 1,2/50 µs (note 4)	A.C. r.m.s.	D.C. (note 4)
$0 < U_e \leq 50$		500	350	500
$50 < U_e \leq 100$	$0 < U_e \leq 50$	800	560	800
$100 < U_e \leq 150$	$50 < U_e \leq 100$	1 500	1 060	1 500
$150 < U_e \leq 300$	$100 < U_e \leq 150$	2 500	1 780	2 500
$300 < U_e \leq 600$	$150 < U_e \leq 300$	4 000	2 830	4 000
	$300 < U_e \leq 600$	6 000	4 230	6 000

NOTES

1 See annex D: correction factor for testing at other altitudes.

2 Rated voltage at the field wiring terminals of the device or circuit.

3 Class II and applicable class III circuits.

4 See 6.3.6.1.1.

NOTE - To recognize current practices, the manufacturer may elect alternatively to verify the dielectric strength by the application of 2 U_e + 1000 V a.c., for a minimum duration of 1 min.

4) When subject to the dielectric test, isolation between isolated SELV circuits and other non-SELV circuits shall withstand the application during three cycles of 1500 V a.c. r.m.s voltage or its equivalent peak value (i.e. 2 121 V) for the impulse or d.c. voltage, regardless of altitude.

NOTE - Applicable national regulations shall be also considered for SELV circuits.

5) When the assembly includes an equipotential conductor isolated from the accessible conductive parts, it shall be regarded as an isolated circuit and shall be tested to the same voltage as the assembly to which it belongs.

3.10.3 *Information to be provided by the manufacturer*

In addition to the requirements of clause 5, the manufacturer shall provide the following information through convenient documentation and marking:

1) rated isolation voltage and class of each PC-system subassembly;

2) maximum permanent current withstandable by the incorporated protective conductors and connections (see item 6 of 4.7.2).

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3.11 *Self-tests and diagnostics*

3.11.1 *General*

The manufacturer shall provide means of self-tests and diagnostics of the PC-system operation. Such means shall be built-in services of the PC-system, and/or recommended ways to implement the intended application.

3.11.2 *Requirements*

1) The following means shall be provided:

a) a means for monitoring the user's application program (i.e. watchdog timer, etc.);

b) a hardware or software means to check the memory integrity;

c) a means to check the validity of the data exchanged between memory(ies), processing unit(s) and I/O modules;

d) a means to check that internal voltages and currents delivered by the power supply unit(s) do not exceed the limits allowed by the hardware design;

e) a means to monitor the status of MPU.

2) The permanently installed PC-system shall be capable of operating an alarm signal on an alarm output. When the system is monitored as "functioning correctly" this alarm output shall be in a predetermined state; in the other case it shall go to the opposite state. The manufacturer shall specify the conditions of the "correct functioning state" and the self-tests which are executed to drive this alarm output;

3) RIOSs shall be capable of operating an alarm signal on an alarm output (for example, through a digital output module) in the event of loss of power or loss of normal communication with the MPU and go to a predetermined state (see 3.7).

3.11.3 *Information to be provided by the manufacturer*

In addition to the requirements of clause 5, the manufacturer shall provide the following information through convenient documentation and marking:

1) description of tests and diagnostics which are implemented and when they are executed (i.e. permanently, periodically, upon user's application program request, during start-up procedure, etc.) ;

2) correct functioning state and driving conditions of the alarm output(s) (see 3.11.2).

4 Mechanical requirements

4.1 *General*

This section specifies mechanical construction requirements for PC-systems equipment (i.e. MPU, RIOSs, permanently/non-permanently installed peripherals). Components connected to the mains power supply of the installation such as power supplies, I/O modules, communication interfaces, memory subsystems are considered subject to the provisions of this clause.

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The programmable controller equipment and the associated peripherals shall be constructed to withstand the conditions stated in clauses 2 and 3.

4.2 *Protection against electrical shock hazard*

1) Each entity of the PC-system shall be designed to meet class I, class II or class III specifications as defined in 4.2.1, 4.2.2 or 4.2.3.

2) Open equipment is not required to meet IP2X requirement. However, warning labels, hazard symbol 417-IEC-5036, and/or mechanical disconnect means shall be required on the final system enclosure to be provided by the user, to minimize the risk of accidental shock hazard during maintenance. Opening of the enclosure shall only be possible by means of a key or tool.

3) Any class I or class II enclosed equipment shall be IP2X according to IEC 529.

4) Apertures in class II equipment shall be tested with the test pin as specified in figure 20 and 2.1.2 of IEC 950.

5) Leakage current of cord connected devices shall comply with the limits specified in IEC 950.

NOTE - The insulating properties of lacquer, enamel, ordinary paper, cotton, oxide film on metal parts and beads shall not be relied upon to give the required protection against accidental contact with hazardous live parts.

4.2.1 *Class I equipment*

1) For equipment for use with a flexible cord (such as PADTs) this provision includes a protective conductor as part of the cordset (i.e. earth ground conductor).

2) Some accessible conductive parts of a PC-system, which do not constitute a danger, need not be connected to the protective circuit of the PC-system. This applies to screws, rivets and nameplates.

3) When a part of the PC-system is removed from the enclosure, for normal maintenance for example, the protective circuits serving the other parts of the PC-system shall not be interrupted.

4) Protective earthing requirements are specified in 4.7.

4.2.2 *Class II equipment*

1) In certain cases such as signal level terminals (less than 30 V r.m.s.), limiting impedance may be used in lieu of double insulation provided the limiting impedance limits the exposed terminals to a current of 5 mA and open circuit voltage of 30 V r.m.s., or 42.4 V d.c.

2) Class II equipment may be provided with means for maintaining the continuity of circuits (i.e. grounded internal components or conductive surfaces) provided that these circuits are double insulated from the accessible circuits of the equipment.

3) Class II equipment may be provided with means for connection to earthing field terminals for functional purposes (such as radio frequency interferences suppression) provided the double insulation system is still provided for protective purposes.

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4.2.3 *Class III equipment and safety extra low voltage (SELV) circuits*

1) Isolation requirements between SELV circuits and the mains power supply are expressed in 3.10.2.

2) Class III equipment may be provided with means for functional earth field wiring.

3) Wiring for SELV circuits shall be either segregated from the wiring for circuits other than SELV, or the insulation of all conductors shall be rated for the higher voltage. Alternatively, earthed screening or additional insulation shall be arranged around the wiring for SELV circuits or around the wiring of other circuits.

4.3 *Clearance and creepage distances requirements*

1) The extent to which the manufacturing process can control the mechanical tolerance decides the limits to which practical clearance and creepage distances can approach the theoretical minimum values given in the tables 18 to 24 of 4.3:

– It is possible to approach minimum values when the equipment is manufactured in a factory under controlled conditions and finished to a point where additional assembly other than the connections to the field wiring terminals prior to placing the equipment in service is not necessary.

– Replacement of components normally effected in service shops or in normal use (e.g. fuses) are considered to be part of controlled conditions. Routine maintenance schedules for testing or examining insulation are expected.

– Increased clearances are required when the equipment is field-mounted and field-connected because the method of mounting and the method of wiring at the field wiring terminals have to be considered.

– In all cases the values given shall be met or exceeded.

2) The actual clearance and creepage distances requirements will be based on the highest voltage and micro-environment specified by the manufacturer for each circuit.

3) In place of the requirements for clearances and creepage distances expressed in 4.3.1.1, 4.3.2 and 4.3.3, the values in the chart below that correspond to the current practice may be used for basic and supplementary insulation, up to pollution degree 2 and regardless of CTI. In that case, no type test is required: compliance shall be verified by measurement.

Rated voltage of circuit U_e V a.c. r.m.s. or V d.c.	Clearance mm	Creepage distances mm
$0 < U_e \leq 50$	1,6	1,6
$50 < U_e \leq 300$	2,0	3,2
$300 < U_e \leq 600$	4,8	6,4

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4.3.1 *Clearances relating to normal overvoltage category*

4.3.1.1 *Clearances for other than field wiring terminals*

Clearances associated with basic and supplementary insulation and clearances associated with reinforced insulation (class II equipment) are given in table 18. They correspond to the impulse withstand voltage of table 17 in 3.10.2.

Table 18 – Minimum clearances in air corresponding to overvoltage category II conditions (except for field wiring terminals)

(Derived from IEC 664)

Rated voltage of circuit U_e (note 1) V a.c. r.m.s. or V d.c.		Rated impulse withstand voltage (notes 2 and 3) V	Minimum clearance mm		
For basic and supplementary insulation	For reinforced insulation	At 2 000 m altitude	Pollution degree 1	2	3
$0 < U_e \leq 50$		500	0,06	0,2	0,8
$50 < U_e \leq 100$	$0 < U_e \leq 50$	800	0,12	0,2	0,8
$100 < U_e \leq 150$	$50 < U_e \leq 100$	1 500	0,8	0,8	0,8
$150 < U_e \leq 300$	$100 < U_e \leq 150$	2 500	2,0	2,0	2,0
$300 < U_e \leq 600$	$150 < U_e \leq 300$	4 000	3,5	3,5	3,5
	$300 < U_e \leq 600$	6 000	6,5	6,5	6,5

NOTES

1 Rated voltage at the field wiring terminals of the device or circuit.

2 See annex D: correction factor for testing at other altitudes.

3 1,2 µs rise time; 50 µs wide at 1/2 amplitude; 0,6 J maximum energy.

1) Clearances can be verified by mechanical measurement or by dielectric tests according to table 17 in 3.10.2.

2) Clearances to walls of metal enclosures which may be deflected shall not be less than 12 mm.

3) The above clearances do not apply to printed wiring boards with suitable protective coating.

4) The above clearances do not apply to areas where impulse voltages do not occur.

4.3.1.2 *Field wiring terminal clearances*

Minimum clearances at field wiring terminals from terminal to terminal and from terminal to enclosure shall comply with the requirements of table 19.

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Table 19 – Minimum clearances in air at field wiring terminals

Rated voltage of circuit U_e V a.c. r.m.s. or V d.c.	Termination clearances mm	
	General case	To walls of metallic enclosures which may be deflected
$0 < U_e \leq 50$	1,6	12
$50 < U_e \leq 300$	3,2	12
$300 < U_e \leq 600$	6,4	12

4.3.2 *Clearances for micro-environment where the voltages are known and controlled*

In the case where the equipment is not connected directly to the mains and the peak voltages are known and controlled, the minimum clearances corresponding to these peak voltages are given in table 20.

Table 20 – Minimum clearances in air for micro-environment where the voltages are known and controlled

(Definitions and entries in this table are derived from IEC 664)

Peak voltage including all transients and impulses V	Minimum clearances mm		
Up to 2 000 m altitude (note)	Pollution degree 1	2	3
$0 < U_e \leq 500$	0,06	0,20	0,80
$500 < U_e \leq 630$	0,12	0,20	0,80
$630 < U_e \leq 800$	0,25	0,25	0,80
$800 < U_e \leq 1\,000$	0,40	0,40	0,80
$1\,000 < U_e \leq 1\,200$	0,80	0,80	0,80
$1\,200 < U_e \leq 1\,500$	1,2	1,2	1,2
NOTE - See annex D: correction factor for testing at other altitudes.			

1) Clearances shall be verified by mechanical measurement.

2) Clearances to walls of metal enclosures which may be deflected shall not be less than 12 mm.

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4.3.3 *Creepage distances for basic and supplementary insulation*

Since creepage distances are at least equal to or greater than clearances, the actual values shall be selected to meet the requirements of both this subclause and subclauses 4.3.1 or 4.3.2 as applicable.

Table 21 – Classification of material group according to comparative tracking index (CTI)*

(Definitions and entries in this table are derived from IEC 664)

CTI	Material group
100 ≤ *CTI* < 175	IIIb
175 ≤ *CTI* < 400	IIIa
400 ≤ *CTI* < 600	II
600 ≤ *CTI*	I
* See IEC 112, for the method of determining CTI.	

4.3.3.1 *Minimum creepage distances (basic and supplementary insulation)*

Minimum creepage distances given in this subclause are for a.c. r.m.s. or d.c. voltages which contain no impulse. For micro-environment where impulse voltage will be present (e.g. overvoltage category II or recurring peak voltages), other additional requirements apply. (See respectively 4.3.1 and 4.3.3.2.)

4.3.3.1.1 *Minimum creepage distances for other than printed wiring boards*

Creepage distances shall be not less than values given in table 22 nor be less than the appropriate clearances.

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Table 22 – Minimum creepage distances in millimetres for other than printed wiring boards (note 1)

(Definitions and entries in this table are from IEC 664)

Working voltage V a.c. r.m.s. or V d.c. (note 2)		Pollution degree 1 (note 3)	Creepage distances (note 4) mm					
			Pollution degree 2			Pollution degree 3		
			Material group			Material group		
			I	II	IIIa, IIIb	I	II	IIIa, IIIb
Basic and supplementary insulation	$0 < U_e \leq 50$	0,18	0,6	0,85	1,2	1,5	1,7	1,9
	$50 < U_e \leq 100$	0,25	0,71	1,0	1,4	1,8	2,0	2,2
	$100 < U_e \leq 160$	0,32	0,8	1,1	1,6	2,0	2,2	2,5
	$160 < U_e \leq 320$	0,75	1,6	2,2	3,2	4,0	4,5	5,0
	$320 < U_e \leq 630$	1,8	3,2	4,5	6,3	8,0	9,0	10,0
	$630 < U_e \leq 1\,000$	3,2	5,0	7,1	10,0	12,5	14,0	16,0 (note 5)
Reinforced insulation	$0 < U_e \leq 50$	0,25	0,71	1,0	1,4	1,8	2,0	2,2
	$50 < U_e \leq 100$	0,42	1,0	1,4	2,0	2,5	2,8	3,2
	$100 < U_e \leq 160$	0,75	1,6	2,2	3,2	4,0	4,5	5,0
	$160 < U_e \leq 320$	1,8	3,2	4,5	6,3	8,0	9,0	10,0
	$320 < U_e \leq 630$	4,2	6,3	9,0	12,5	16,0	18,0	20,0
	$630 < U_e \leq 1\,000$	7,5	10,0	14,0	20,0	25,0	28,0	32,0 (note 5)

NOTES

1 Creepage distances given in this table are for a.c. r.m.s. or d.c. voltages which contain no impulses. For micro-environment where impulse voltages will be present, other additional requirements apply:

– for overvoltage category II, the creepage distances shall be not less than the appropriate clearance distances values (see 4.3.1);
– creepage (and clearance) distances of high frequency voltages generated in switch-mode power supplies shall be evaluated using table 24 in 4.3.3.2.

2 V a.c. r.m.s. of sinusoidal or non-sinusoidal wave.

3 For all material groups.

4 Creepage (and clearance) distances between circuits shall be that corresponding to the highest working voltage and the corresponding dielectric withstand voltage.

5 Only for material group IIIa. Material group IIIb is in general not recommended for application in pollution degree 3 above 630 V.

6 Maximum recurring peak voltages in normal operation shall be limited to the values in 4.3.3.2 to prevent degradation of insulation by partial discharges.

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4.3.3.1.2 *Minimum creepage distances for printed wiring boards*

Creepage distances associated with basic and supplementary insulation for protective coated and uncoated areas of printed wiring boards shall be not less than given in the table 23 below nor be less than the values of the appropriate clearances.

Table 23 – Minimum creepage distances for printed wiring boards (notes 1, 6 and 9) (Basic and supplementary insulation)

(Definitions and entries in this table are from IEC 664)

Circuit voltage V a.c. r.m.s. or V d.c. (note 2)	Areas of PWBs with protective coating mm (notes 3, 4, 5 and 6)	Uncoated areas of PWBs mm	
		Pollution degree 1 (note 7)	Pollution degree 2 (note 8)
$0 < U_e \leq 50$	0,025	0,025	0,04
$50 < U_e \leq 100$	0,1	0,1	0,16
$100 < U_e \leq 160$	0,25	0,25	0,4
$160 < U_e \leq 320$	0,75	0,75	1,6
$320 < U_e \leq 630$	1,8	1,8	3,2
$630 < U_e \leq 1\,000$	3,2	3,2	5

NOTES

1 Creepage distances given in this table are for a.c. r.m.s. or d.c. voltages which contain no impulses. For micro-environment where impulse voltages will be present, other additional requirements apply:
- for installation category II, the creepage distances shall be not less than the appropriate clearance distances values (see 4.3.1);
- creepage (and clearance) distances of high frequency voltages generated in switch-mode power supplies shall be evaluated using table 24 in 4.3.3.2.2.

2 V a.c. r.m.s. of sinusoidal or non-sinusoidal wave.

3 Protective coating shall adhere to the board insulation to result in an effectively solid insulation so as to exclude moisture and pollution and to withstand the specified overvoltages given in 3.10.2.

4 Suitable for all material groups and pollution degrees 1, 2 and 3.

5 No test is required if the manufacturer provides evidence that the protective coating has been tested according to either the test given in 6.3.5.5.7 or an equivalent acceptable independent laboratory test.

6 A test board, coated but without components, shall withstand the appropriate dielectric test voltage given in 3.10.2.

7 For all material groups.

8 For material groups I, II, IIIa.

9 Creepage (and clearance) distances between circuits shall be those corresponding to the highest working voltage and the corresponding dielectric withstand voltage.

10 Maximum recurring peak voltages in normal operation shall be limited to the values in 4.3.3.2 to prevent degradation of insulation by partial discharges.

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4.3.3.2 *Creepage distance requirements for recurring peak voltages*

4.3.3.2.1 *Rationale*

The phenomenon of partial discharges will occur on a surface which is subjected to long periods of high humidity and recurring peak voltages (impulses). These recurring peaks will dry out small areas between the conductors which will then flash over, giving rise to small sections of tracking. Eventually total tracking will occur between conductors and breakdown occurs. The values given in the table 24 in 4.3.3.2.2 will prevent any partial discharge from occurring, and are valid for pollution degrees 1 to 3.

4.3.3.2.2 *Creepage distance requirements for recurring peak voltages*

In addition to the clearance and creepage distance requirements of the preceding clauses, when recurring peak voltages are present the creepage distance requirements given in table 24 below shall also be met.

Table 24 – Minimum creepage distances related to recurring peak voltages on uncoated printed wiring boards (pollution degrees 1 to 3) (note 1)

Maximum recurring peak voltage (note 2)	Creepage distance mm	Maximum recurring peak voltage (note 2)	Creepage distance mm
		1 140	1,5
		1 150	1,6
330	0,1	1 250	1,8
400	0,2	1 650	3,0
450	0,25	1 700	3,2
600	0,4	2 200	5,0
640	0,5	2 300	5,5
800	0,75	2 800	8,0

NOTES

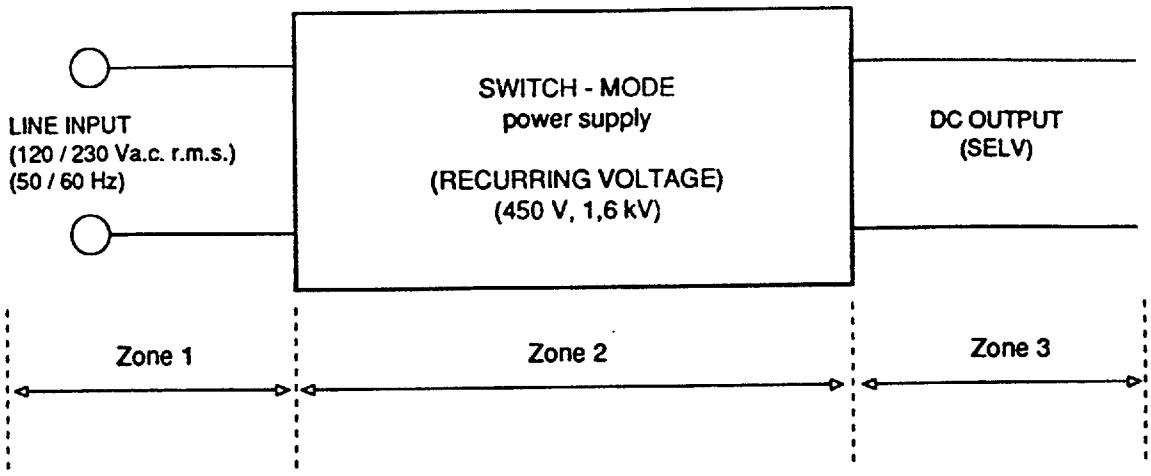
1 This table does not apply to peak values of 50 Hz/60 Hz wave of the mains power supply (see 3.2.1.3). However, it does apply to short duration peaks superimposed on the 50 Hz/60 Hz wave.

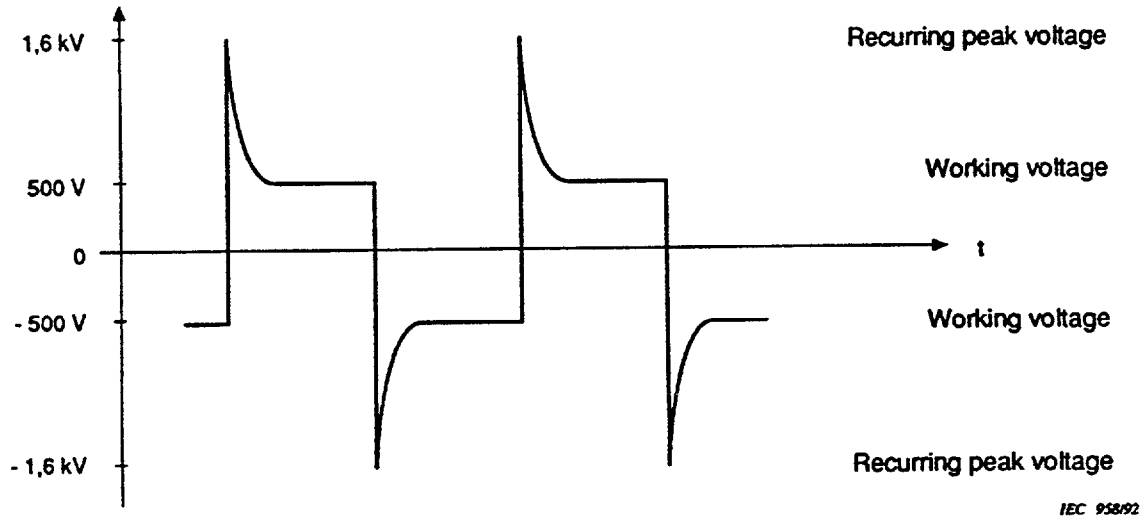
2 Recurring peak voltage values are based on statistical evaluation of partial discharge data.

4.3.3.2.3 *Example*

The following figure 5 shows which requirements apply to each part of a typical design of a power supply:

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Zone 1: Creepage distance ≥ 2,0 mm, controlled by minimum clearance for overvoltage category II, as given in table 18 in 4.3.1.1.

Zone 2: Creepage distance ≥ 3,0 mm (pollution degree 1 assumed), controlled by recurring peak voltage, as given in table 24 in 4.3.3.2.2.

Creepage distance ≥ 3,2 mm (pollution degree 2 assumed), controlled by creepage distances for PWBs, as given in table 23, in 4.3.3.1.2.

Zone 3: No requirements for SELV.

Figure 5 – Creepage distances of circuits where recurring peak voltages are generated

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4.3.4 *Creepage distances for reinforced insulation*

Creepage distances shall be double the value for basic insulation.

4.4 *Flammability requirements for insulating materials*

4.4.1 *Non-metallic materials*

All non-metallic materials employed in the PC-system (i.e. printed wiring boards, plastic enclosures, wire insulation, etc.) with exceptions as noted below shall have suitable flame retardant properties to prevent or minimize the spread of flame and comply with a vertical flame spread rating of FV1 or FV0 as given in clause 9 of IEC 707.

No tests are required if the manufacturer provides evidence that the material complies with IEC 707 or alternatively the IEC 695-2-1 glow-wire test, under the conditions given in table 25 below.

Table 25 – Flammability of non-metallic materials

(Glow-wire test, see IEC 695-2-1)

	Test temperature °C	Length of application s	Extinguishing time s
Live parts supports	750	30	≤ 30
Enclosures	650	30	≤ 30

Exceptions:

1) Printed wiring boards: printed wiring board materials may have a flame rating of FV2 provided there is no combustible material less than 300 mm below the plane of the board. If the board is not manufactured with accompanying housing or enclosure, the board shall be rated FV1 or FV0 as above.

2) Decorative material (cosmetic plastics): non-metallic materials used solely for decorative purposes (i.e. not for support of live parts or enclosure protection) require no special flame retardant additive.

4.4.2 *Temperature limits of materials*

The temperature rise limits as specified in the following table 26 shall not be exceeded by the equipment or parts defined in its complete system when tested at full load and under normal service conditions:

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Table 26 – Temperature rise limits (notes 1, 3, 4 and 5)

Device			Maximum temperature rise °C	
			Open equipment (note 2)	Enclosed equipment (note 2)
Hand-held accessible devices		Metallic Non-metallic	5 10	15 25
Parts intended to be touched in normal operation		Metallic Non-metallic	15 25	30 40
Parts not intended to be touched in normal operation		Metallic Non-metalllic	25 (note 7) 35	40 (note 7) 50
Terminals (note 6)	Bare copper		45	60
	Bare brass/tin Plated copper and brass		50	65
	Silver or nickel plated Copper or brass		55	70

NOTES

1 Temperature rise limits are based on an ambient temperature given in 2.1.1.1.

2 Open equipment and enclosed equipment are defined in 1.4.

3 All other materials employed within the PC-system not covered in the table shall be in compliance with the relevant requirements for that particular component as based on a 55 °C ambient for open equipment and 40 °C for enclosed equipment.

4 The maximum temperature for several classes of insulation is given in IEC 85.

5 Enclosed units shall be tested with the maximum components mounted and energized.

6 The terminals shall be wired with conductors of the minimum size stated by the manufacturer. If the manufacturer does not state wire sizes the minimum size in table 27 in 4.6.2.2 shall be used.

7 Temperature rise limits may be exceeded if proper warning signs are provided.

4.5 *Enclosures*

4.5.1 *Evaluation of enclosures for open equipment (power dissipation)*

The manufacturer's documents shall provide information to allow the evaluation of the power dissipation of every PC-configuration, sub-assembly and module and provide information regarding minimum spacing required to assure adequate cooling under normal service conditions.

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4.5.2 *Moving parts in non-portable devices*

Moving parts (e.g. fans, disk drives, printers, etc.) located within non-portable devices which could cause possible injury to service personnel during routine maintenance shall be arranged or enclosed to provide protection against such injury. Protective guards, enclosures, control rooms or similar means should be considered. If such protective devices are not provided with the programmable control system, suitable installation instructions, warning labels, or the equivalent shall be provided to clearly indicate the user's installation requirements.

4.5.3 *Enclosures for portable equipment*

Mechanical enclosures for portable equipment shall meet the general enclosure requirement of IEC 950.

4.5.3.1 *Protection against access to hazardous live or moving parts*

Portable equipment shall provide on all outer surfaces degree of protection IP2X against contact with hazardous live or moving parts, according to IEC 529. This protection shall also be applicable with the service doors opened or covers of service openings removed.

Class II portable equipment shall in addition prevent contact with bare parts at hazardous voltages and be tested by the application of the test pin defined in figure 20 of IEC 950 to all openings in the enclosure.

Class III portable equipment only needs to be verified for protection against contact with moving parts, since SELV is not hazardous.

4.5.3.2 *Shafts and knobs*

Shafts and knobs external to the enclosure shall not be in contact with hazardous live parts. If the parts are normally held or actuated in normal operation, the insulation provided shall be such that the shafts and knobs do not become live in the event of an insulation fault.

4.5.3.3 *Plug connections*

Portable equipment connected to the mains power supply by use of a cordset (removable or fixed) shall be so designed that there is no risk of electric shock from charged capacitors when touching the pins of the plug and/or receptacle.

4.5.3.4 *Accessibility of live parts through their supporting surfaces*

Portable equipment shall be constructed so that all live parts shall be at a distance of at least 6 mm from any openings (measured vertically) in their supporting surfaces.

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4.5.3.5 *Stability*

Equipment shall be constructed so that it operates in all positions to be expected in normal operation, and, does not become unstable when tipped in any direction 15° from the intended operating position.

4.5.3.6 *Mechanical strength*

The mechanical strength of the enclosure shall be such as to withstand rough handling in normal use. The protection provided by the enclosures shall be verified after the application of the standard IEC impact test (see 4.2.4 of IEC 950).

4.5.3.7 *Flammability*

Non-metallic materials employed in the enclosure shall comply with the flammability requirements of 4.4.1.

4.6 *Terminal connection mechanical requirements*

NOTE - The applicability of the requirements of IEC 947-1 to this subclause is under consideration.

4.6.1 *Constructional requirements*

1) Terminals shall be so designed that loose strands of wire shall not reduce the required clearance/creepage requirements.

2) All parts of terminals which maintain contact and carry current shall be of metal of adequate mechanical strength.

3) Terminal connections shall be such that the conductors may be connected by means of screws, springs, or other equivalent means such as wire wrap, termi-point, fast-on connection, clamp-type connection so as to ensure that the necessary contact pressure is maintained over the full range of service conditions.

4) Terminals shall not allow the conductors to be displaced or be displaced themselves in a manner detrimental to the operation of the equipment and the insulation shall not be reduced below the rated values.

5) The mechanical design of the interfaces shall allow that no elementary conductor is subjected to bending of a radius of curvature less than six times its diameter after removal of the common elements (armouring, sheaths, fillers).

6) Clearances between wiring terminals and terminal to earthed parts are given in 4.3.1.2.

4.6.2 *Connecting capacity*

4.6.2.1 *General*

The wire sizing of the terminal shall be in accordance with local, and/or national electrical standards as applicable. Terminals shall be suitable for the wire size(s), number of wires, and type of wire (copper, aluminium, etc.) required for the intended application. See IEC 1131-4 for more information.

4.6.2.2 *Minimum requirements for field wiring terminals*

The following table 27 specifies the minimum range of wire sizes which shall be properly accepted by the terminal with respect to the type of interfaces.

NOTE - Stranded wires may be used if they are suitably terminated.

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Table 27 – Minimum range of wires sizes for field wiring terminals

Type of interface	Minimum range of wire sizes mm²	
	Low limit	High limit
Digital inputs	0,5 (AWG20)	1,5 (AWG16)
Digital outputs	0,5 (AWG20)	2,0 (AWG14)
Analog I/Os	0,18 (AWG24)	1,5 (AWG16)
Communication	0,18 (AWG24)	1,5 (AWG16)
Mains power supply (note)	1,5 (AWG16)	2,5 (AWG12)
Protective earth (note)	1,5 (AWG16)	2,5 (AWG12)

NOTE - The minimum size of the conductor for the connection to the mains power supply and protective earth is generally specified in the national wiring rules.

4.6.3 *Information to be provided by the manufacturer*

In addition to the requirements of clause 5, the manufacturer shall provide the following information through convenient documentation and/or marking:

1) type, cross-sectional area and material of the conductors that may be connected to the PC system;

2) recommendations for use of shielded cables, and how they are to be connected and earthed.

4.7 *Provisions for protective earthing*

NOTE - The requirements specified below do not apply to SELV circuits where protective earthing is not required.

4.7.1 *Constructional requirements*

4.7.1.1 *Class I equipment*

1) The accessible parts (e.g. chassis, framework and fixed metal parts of metal enclosures) other than those which do not constitute a danger shall be electrically interconnected and connected to a protective earth terminal for connection to an external protective conductor. This requirement can be met by the normal structural parts providing adequate electrical continuity and applies whether the equipment is used on its own or incorporated in an assembly.

2) Cords or cables that supply transportable peripherals shall be provided with a protective earthing conductor.

3) Protective earthing conductor insulation shall be green with a yellow stripe.

4) Accessible isolated conductive parts are considered not to constitute a danger if they are so located as to exclude any contact with live parts and withstand the

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dielectric test voltage of table 17 in 3.10.2 for reinforced insulation corresponding to the highest rated operational voltage of the unit.

4.7.1.2 *Class II equipment*

Class II equipment may have an internal functional bonding conductor but shall not be provided with an earthing terminal or an earthing conductor in the supply cord.

4.7.2 *Protective earthing terminal*

If the PC-system is provided with a protective earthing terminal (class I equipment), the following requirements also apply in addition to the previous general connection specifications:

1) the protective earthing terminal shall be readily accessible and so placed that the connection of the equipment to the protective earthing conductor is maintained when the cover or any removable part is removed;

2) products which are intended for cord connected use (such as peripherals) shall be provided with a protective earthing terminal integral to the plug cap, or socket (if removable cordset);

3) the protective earthing terminal shall be of the screw type and shall be made of brass or other suitable non-corrosive material;

4) the clamping means of protective earthing terminals shall be adequately locked against accidental loosening and it shall not be possible to loosen them without the aid of a tool;

5) protective earthing terminals and earthing contacts shall not be electrically connected to the neutral terminal at the PC-system.

NOTE - A terminal intended to be connected to the PEN (protective earth neutral) conductor may fulfil the function of the protective earthing terminal.

6) the protective earthing terminal and subsequent protective equipment internal to the PC-system shall provide 0,1 Ω protective earthing continuity under 30 A continuous fault conditions;

7) the protective earthing terminal shall have no other function.

4.8 *Functional earthing*

There are no constructional requirements such as noise immunity control, RFI protection, etc., for functional earthing terminals (except for marking requirements as given in 4.12.2.6).

4.9 *Interconnecting cables and cords*

4.9.1 *General*

The following requirements shall apply to interconnecting cords or cables provided by the manufacturer for the internal and/or external wiring of PC-system.

4.9.2 *Wiring internal to the PC-system (internal wiring)*

1) The insulation, when provided, on all internal wiring of the equipment shall be rated for the voltage and the temperature conditions of use.

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2) All splices and connections shall be mechanically secure and provide electrical continuity.

3) Internal wiring shall be so routed and secured that neither it nor related electrical connections are likely to be subjected to stress or mechanical damage.

4) Internal wiring that is subject to flexing in its intended use or maintenance and whose conductors are solid or the insulation of which is less than 0,8 mm thick shall be tested for flexing integrity as specified in 6.3.5.5.4. This requirement does not apply to SELV circuits.

4.9.3 *Connectors and wiring external to the PC-system (external wiring)*

NOTE - This clause applies to the PC-system and the manufacturer supplied cables with connectors only and does not apply to the whole industrial control system in which the PC-system is employed.

1) Cables and cords provided for the interconnection of open equipment shall comply with the requirements of 4.9.2.

2) Cable assemblies and flexible cords provided for interconnection between sections of equipment or between units of a PC-system shall be a type that is acceptable for the voltage and temperature involved and shall be provided with suitable strain relief.

3) Misalignment of plug and socket connectors, insertion of a multi-pin connector in a connector other than the one intended to receive it and plugging and unplugging of connectors that are accessible to the operator shall not result in mechanical damage or risk of fire to the PC-system or electric shock or injury to persons from the PC-system.

4) To prevent incorrect operation when making and breaking interconnections between portions of the PC-system either the connector socket shall be polarized to prevent improper insertion or the PC-system shall be designed so that no malfunction occurs or the manufacturer shall provide clear instructions to the user on the actions to be taken when connecting or disconnecting.

5) Protective earthing conductor insulation shall be green with a yellow stripe.

4.9.4 *Internal and external wiring*

Connectors shall be positioned so that wires and cables need not be routed over operator devices and their identification.

4.10 *Plugging/unplugging of removable units*

1) Modular construction of PC-equipment should be designed to minimize damage to PC-system, when inserting or removing modules. Modules of the same type or family and accordingly marked shall be interchangeable when de-energized. Adjustments or setting of parameters such as address, threshold, gain, and data transmission speed may be required prior to using the new module in the intended operation.

2) All units requiring plugging or unplugging during operation or maintenance shall withstand the number of insertions and withdrawals given in table 28 without adverse effect on their contact making effectiveness.

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Table 28 – Insertion/withdrawal of removable units (minimum number of cycles)

	Permanently installed units	Non-permanently installed units
Plug-in type	50	500
Type with removable terminal blocks	20	500

4.11 *Battery requirements*

4.11.1 *General*

Battery cases or compartments shall be designed to protect against accumulation of flammable gases or damage from spilling of corrosive liquid as applicable.

4.11.2 *Non-rechargeable batteries*

1) Non-rechargeable batteries (e.g. lithium) if used shall be provided with suitable protection (internal to the battery cell or external components) so as to minimize the risk of battery explosion. Parameters to be considered in the design should include temperature, reverse current flow (charging), limited discharge, etc. to minimize the risk of battery charging.

2) Means shall be provided to prevent inadvertent charging and to limit the discharge current of non-rechargeable batteries.

4.11.3 *Memory back-up*

Memory back-up requirements are expressed in 3.2.2.

4.12 *Markings and identification*

4.12.1 *General marking requirements*

Each PC-unit shall be marked in a clear and legible manner as follows:

1) manufacturer's name or trademark symbol;

2) model number or name;

3) software serial number and/or revision level (see item 6 of 6.2), where applicable;

4) hardware serial number and/or revision level (see item 6 of 6.2), and date code or equivalent;

5) fuse replacement information, if applicable;

6) power rating information in volts, amperes, and/or voltamperes, and frequency and polarity where connection to the mains power supply occurs;

7) equipment class designation, if applicable.

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I/O modules shall be marked with their:

1) rated voltage and current (as applicable);

2) function identifier.

Live parts, protective earth terminals and functional earth terminals markings shall be as required in 4.12.2.

4.12.2 *General identification requirements*

4.12.2.1 *Functional identifications*

1) The function of each I/O module shall be unambiguously identifiable when it is placed in its service position and operating, by means of a convenient manufacturer's mark.

2) All operator's switches, indicator lamps, and connectors shall be identified or have provisions for identification.

4.12.2.2 *Module location and module identifications*

Space shall be provided for identification of each module and I/O channel on or near to the modules.

4.12.2.3 *External wiring terminals identification*

External wiring terminals shall be marked to indicate the proper connections for the power supply, load, control circuit, and the like, or a wiring diagram coded to the terminal marking shall be provided.

4.12.2.4 *Live parts*

A live part exceeding SELV limits and likely to be mistaken as dead-metal (non-energized metal) and exposed to personnel under normal installation or maintenance shall be marked with the following "Dangerous voltage" symbol (417-IEC-5036-a):



4.12.2.5 *Protective earth terminals markings*

1) The protective earth terminals markings shall be durable and clearly identifiable.

2) The identification shall be achieved by the notation PE according to 5.3 of IEC 445, or by a graphical symbol for use on equipment.

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3) The graphical symbol to be used is the symbol 417-IEC-5019-a shown below in compliance with IEC 417, which shall progressively supersede the previously recommended symbol (417-IEC-5017-a).



4.12.2.6 *Functional earth terminals markings*

Functional earth terminals (i.e. used for non-safety purposes such as noise immunity improvement) shall be marked with the following symbol 417-IEC-5018-a:



5 Information to be provided by the manufacturer

5.1 *General*

The manufacturer shall provide users with information required for the application, design, installation, commission, operation and maintenance of the PC-system. In addition, the manufacturer may provide user training.

In this subclause only the general concept of the written information to be provided is stated. The required informations to be given in each level of documentation as defined below, is listed in various subclauses of all parts of this standard.

5.2 *Index of information to be provided*

The following table 29 lists all cross references to other areas where manufacturer's information is required.

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Table 29 – Index: Information to be provided

Part	Subclause	Object
1	4.2.3	Total response time(s) formula
2	Note 3 of 2.2.2.2	Equipment ambient temperature limits
	2.1.1.3	Relative humidity
	2.1.1.4	Pollution degree
	2.1.1.5	Corrosion protection
	2.1.2.2	Electrostatic discharge severity level
	2.1.3.1	Vibrations
	2.3	Special transport and storage conditions
	2.3.6	Transport and storage
	Note 3 of 3.2.1.1	Sizing of a dedicated power source
	Note 5 of 3.2.1.1	Non-standard power supplies
	3.2.3	Power supply
	Item 4 of 3.3	Additional external load
	Item 5 of 3.3	A.C. inputs fed from several phases
	Note 2 of 3.3	Non-standard digital I/Os
	3.3.1.4	Digital inputs
	3.3.2.2	Protected/non-protected outputs
	3.3.2.2	Short-circuit proof outputs
	3.3.2.3	A.C. digital outputs
	3.3.3.3	D.C. digital outputs
	3.4.1.2	Analog inputs
	3.4.2.2	Analog outputs
	3.5.2	Communication interfaces
	3.6.3	MPU, PC configuration
	3.7.2	Remote input/output stations
	3.8.2	Peripherals
	Note 1 of 3.9.1	Noise immunity
	3.9.2	Noise immunity
	3.10.3	Insulation properties
	3.11.3	Self-tests and diagnostics
	Item 2 of 4.2	Warning labels/open equipment
	Note 6 of table 26 (4.4.2)	Terminal connections
	4.5.1	Enclosures (power dissipation)
	4.5.2	Enclosures (moving parts)
	4.6.3	Terminal connections
	4.12	Markings
	5.4	Compliance with this standard
	5.5	Reliability
	5.6	Safety
	Item 7 of 6.3.2.2	Coverage factors
3		Under consideration
4		Under consideration
5		Under consideration

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5.3 *Type and contents of written documentation*

Three levels of documentation are defined:

- catalogues and datasheets;
- user's manuals;
- technical documentation.

5.3.1 *Catalogues and datasheets*

These documents shall contain the description and the specifications of the PC-system and its associated peripherals and other relevant information to aid in understanding the application and use of these products including functional characteristics, equipment configuration rules, normal service conditions, physical dimensions and weights, and list compliances with standards and certifications. Moreover, these documents shall clearly specify the limits of the contract and of the guarantee of the manufacturer.

5.3.2 *User's manuals*

These documents shall include the necessary information for the proper installation, wiring, troubleshooting, user programming and commissioning of the PC-system. They shall include as a minimum:

1) All information which is required throughout all parts of this standard (see table 29 in 5.2).
2) All information contained in catalogues and data sheets as required in 5.2.
3) Installation and commissioning instructions.
4) Programming and troubleshooting instructions.
5) Maintenance and service requirements.
6) Accessory and spare parts lists (e.g. fuses).

5.3.3 *Technical documentation*

The manufacturer optionally may provide a set of documents which contain more information than those given in the users manual such as: schematic diagrams, internal or external data protocols, bus assignments, physical dimension requirements, energy available, firmware, internal test programs or repair procedures, etc.

5.4 *Information on compliance with this standard*

Compliance with parts 1 and 2 of this standard cannot be claimed unless all tests and verifications required in this part are complied with. See 6.2 for details.

5.5 *Information on reliability*

If the manufacturer provides values of the mean time between failures (MTBF) of any subassembly or module, and of the type-test configuration(s) (basic PC-system(s)) under normal service conditions the manufacturer shall also explain the method used to determine it.

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5.6 *Information on safety*

The manufacturer's data shall include the following information as a minimum:

1) Protective earthing requirements and recommendations concerning personnel safety circuits.

2) Suggested requirements to the user for the maintenance of protective devices, such as protective earthing circuits, overcurrent protective devices, and batteries utilized for memory back-up, etc.

3) If the PC-system is provided as "open equipment", the type of enclosure required to provide the required level of safety and environmental protection and guidelines for mounting, spacing, and/or internal barriers or shields if needed for safety.

4) Precautionary instructions, if removal of any module while the equipment is in operation can affect safety related to electrical shock, fire hazard and electrical damage.

6 Tests and verifications

6.1 *General*

The object of this clause is to define how to verify compliance of the programmable controller and the associated peripherals with the requirements set forth in parts 1 and 2 of this standard. This compliance verification includes:

- verification by type tests given in 6.3;
- verification by suitable examination, visual inspection or/and measurement.

These tests are qualification tests, and not tests related to the ways PCs are applied: according to the scope of this standard, the above compliance verification may not cover the verification of the ability of the PC-system to satisfy the intended automated system requirements; where needed, special tests not covered by this standard shall be agreed by the manufacturer and the user.

In addition, routine tests are specified in 6.4.

6.2 *Compliance with this standard*

1) Compliance with parts 1 and 2 of this standard cannot be claimed unless *all tests and verifications required in this part are complied with.* Moreover, the manufacturer's obligations expressed in this part are not waived if no type test is required, or if the test conditions are restricted for practical reasons*.

2) Compliance with constructional requirements and information to be provided by the manufacturer shall be verified by suitable examination, visual inspection, and/or measurement.

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* On the other hand, user's obligations are considered in several subclauses of this part: 1.1, 2, 3.2, item 2 of 4.2, 5.6, etc. and in IEC 1131-4.

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3) All characteristics not tested according to this clause 6 shall be verifiable under a procedure to be agreed to by the manufacturer and the user.

4) The manufacturer shall be able to give enough information on all requirements on this part when claiming compliance for his implementation.

5) It is the manufacturer's responsibility to ensure that delivered programmable controllers equipment and associated peripherals are similar to the sample(s) which have been type-tested according to this standard and therefore that they comply with all requirements of this standard.

6) Significant modifications shall be indicated through the use of suitable revision level indexes, markings (see 4.12.1) and shall comply with this standard.

NOTE - A new type test may be required to confirm compliance.

7) Where the manufacturer is allowed to select among several options he shall clearly specify in his catalogues and/or datasheets those to which any portion of the PC-system equipment complies. This applies to severity classes of voltage drops (i.e. PS1 or PS2), relative humidity (i.e. RH-1 or RH-2), electrostatic discharges (i.e. ESD-3 or ESD-4), types of digital inputs (type I or type II).

6.3 *Type tests*

6.3.1 *Equipment to be tested*

Basic PC-system(s) shall consist of:

- the main processing unit (MPU);
- remote input/output station(s) (RIOSs), if applicable;
- and appropriate peripherals that can be connected and which are intended for use under the normal service conditions.

If the PC-system is of modular structure:

- the MPU and each RIOS of the basic PC-system(s) shall include at least one interface module of each type listed below if such a module is supplied or recommended:

  - digital d.c. input module, digital d.c. output module,
  - digital a.c. input module, digital a.c. output module,
  - analog input module, analog output module,
  - communication interface module,

- appropriate catalogued options such as power supply units, application memory(ies), processing unit(s) etc. shall be used to build the basic PC-system(s).

Peripherals shall be connected to their interface with the rest of the basic PC-system using the catalogued means or according to manufacturer's specifications.

Unless otherwise specified in this standard, the manufacturer may elect either that each type test be performed on a new basic PC-system or that several type tests be performed on the same basic PC-system. In any case each type test need not be performed more than once for a particular type of equipment.

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For a family of very similar modules (i.e. modules using the same schematic and basic manufacturing and differing mainly by impedance adaptation), and for type tests which shall be obviously not dependent on the differences between the modules, the manufacturer may elect to include in the basic PC-system only one arbitrarily chosen member of this family.

Test configurations more simple than the basic PC-system may be used to verify unit/module and overall PC-system compliance when new units or modules are introduced to the marketplace after a modular programmable controller has been successfully tested according to this standard, provided that these test configurations and the appropriate test programs provided by the manufacturer allow proper verification as if they had been tested within the originally tested basic PC-system.

See figure 1, page 47.

6.3.2 *Verification procedure*

6.3.2.1 *General*

1) Type tests shall be conducted on the basic PC-system(s) defined in 6.3.1, unless otherwise specified.

2) For each test, the manufacturer shall:

- specify how this configuration shall be installed and externally connected;
- provide the suitable test programs which shall be run during the test;
- provide the proper operation verification procedure including the way to measure accuracy and temporary deviations of analog I/Os.

3) The appropriate test programs and proper functioning verification procedures provided by the manufacturer shall satisfy the requirements given in 6.3.2.2.

4) The adequacy of the test programs and proper functioning verification procedures shall be verified by the measurement of the coverage factors for modules, units, external I/O wiring and removable connectors as required in item 7 of 6.3.2.2.

6.3.2.2 *Requirements for test programs and proper functioning verification procedures (PFVPs) to be provided by the manufacturer*

1) During the type tests, there shall be no:

- destruction of hardware;
- modification of the operating system and test programs and/or alteration of their execution;
- unintended modification of system and application data stored or exchanged;
- erratic or unintended behaviour of the basic PC-system;
- deviation of the analog I/Os out of the limits specified in item 5 of 3.4.1.2.2 and item 4 of 3.4.2.2.2.

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2) All relevant functions and parts of the basic PC-system (i.e. units and modules) shall be functioning in such a way that the information paths to/from these functions and parts are exercised.

3) All the I/O and communication channels of the basic PC-system shall be exercised.

4) All external and internal product status information reporting means such as displays, lamps, alarm signals, self-test results registers shall be exercised. The test procedures shall include conditions to verify the related activities.

5) All various PC-system operation modes significant for the user's implementation such as start-up and shut-down, cold/warm/hot restart, "normal run", "normal stop", "program/monitor with PADTs", etc. as applicable shall be verified for performance and behaviour.

6) Initialization and reset conditions of all system components shall be checked for controlled start-up and shut-down. The various modes such as "run", "program", "monitor", shall be verified for performance and behaviour.

7) Coverage factors for modules, units, external I/O wiring and removable connectors of each test program shall be 100 %. This applies to fuses, batteries, etc. Optionally, the manufacturer should provide in his documentation satisfactorily information on the coverage factors of both the built-in self-tests and test programs for functions internal to modules/units. (Such factors cannot be equal to 100 %.)

8) Any special feature/performance not covered in this standard but necessary to the proper operation of the basic PC-system shall be exercised and tested.

NOTE - Depending on the interpretation of basic PC-system as defined in 6.3.1, the requirement of item 3 above may involve large amounts of equipment and highly complex procedures. Therefore, clarification of this requirement is under consideration.

6.3.3 *General conditions for tests*

1) The tests shall be carried out in accordance with the appropriate test procedure.

2) The tests shall be carried out under the general test conditions given in table 30 below, unless otherwise specified.

3) Unless otherwise specified, no sequence is imposed for type tests.

4) Unless otherwise specified, the conditions given in table 30 shall apply.

Table 30 – General conditions for tests

	Test conditions
Mains power supply	Rated voltage and frequency
Temperature	15 °C to 35 °C
Relative humidity	45 % to 75 %
Barometric pressure	860 kPa to 1 060 kPa (650 mm Hg to 800 mm Hg)
Output loads	Outputs loaded to rated load
Pollution	Pollution degree 1

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6.3.4 *Climatic tests*

6.3.4.1 *General conditions*

1) Tests are performed on unpackaged equipment.

2) Temperature sensitive components that are normally serviced and removed by the user may be removed, if so requested by the manufacturer.

6.3.4.2 *Dry heat and cold withstand tests*

Table 31 – Dry heat and cold withstand tests

	Dry heat	Cold
Reference test	IEC 68-2-2, test Bb	IEC 68-2-1, test Ab
Preconditioning	According to manufacturer's specifications	
Initial measurement	According to PFVP (6.3.2.2)	
Conditioning	Power supply unconnected	
Temperature	+70 °C ± 2 °C	–25 °C ± 3 °C
Duration of exposure	96 h ± 1 h	96 h ± 1 h
Measuring and/or loading during conditioning:	None	
Recovery		
• procedure	IEC 68-2-2, test Bb	IEC 68-2-1, test Ab
• time	1 h minimum	
• climatic conditions	See 6.3.3	
• special caution	no condensation (note 1)	
• power supply	Power supply unconnected	
Final measurements	According to PFVP (6.3.2.2)	

NOTE - All external and internal condensation shall be removed by air flow prior to connecting again the basic PC-system to a power supply.

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6.3.4.3 *Variation of temperature*

Table 32 – Change of temperature, withstand and immunity tests

	Withstand test (note 1)	Immunity test (note 2)
Reference test	IEC 68-2-14, test Na	IEC 68-2-14, test Nb
Preconditioning	According to manufacturer's specifications	
Initial measurements	According to PFVP (6.3.2.2)	
Conditioning	Power supply unconnected	
Low temperature	–25 °C ± 3 °C	+5 °C ± 2 °C (note 3)
High temperature		
• open equipment	+70 °C ± 2 °C	+55 °C ± 2 °C (note 3)
• enclosed equipment	+70 °C ± 2 °C	+40 °C ± 2 °C (note 3)
Exposure time at each temperature	3 h ± 30 min	3 h ± 30 min
Transport time	Less than 3 min	Not applicable
Temperature variation speed	Not applicable	3 °C/min ± 0,6 °C/min
Number of cycles	2	5
Measurement and/or loading during conditioning	None	Note 4
Recovery		
• procedure	IEC 68-2-14, test Na	Not applicable
• time	Less than 2 h	Not applicable
• climatic conditions	See 6.3.3 (note 5)	Not applicable
• power supply	Power supply unconnected	
Final measurements	According to PFVP (6.3.2.2)	

NOTES

1 PFVP according to 6.3 performed after recovery.

2 PFVP according to 6.3 performed during test.

3 The time for stabilization of temperature depends on the load and the test program: this time is included in the exposure time.

4 Multichannel output modules shall be derated as specified by the manufacturer.

5 All external and internal condensation shall be removed by air flow prior to connecting again the basic PC-system to a power supply.

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6.3.4.4 *Cyclic damp heat withstand test*

Table 33 – Cyclic (12 + 12) damp heat withstand test

Reference test	IEC 68-2-30, test Db
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Conditioning	None
Details of mounting/support	None
Variant	2
Special precautions	Power supply disconnected
Temperature	+55 °C
Number of cycles	2
Measurement and/or loading during conditioning	None
Recovery	
• procedure	
• time	
• climatic conditions	Under controlled conditions prescribed in IEC 68-2-30
• power supply	Power supply disconnected (note)
Final measurements	Dielectric test and insulation test in addition to PFVP (6.3.2.2)

NOTE – All external and internal condensation shall be removed by air flow prior to connecting again the basic PC-system to a power supply.

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6.3.5 *Mechanical tests*

6.3.5.1 *Vibrations (type test associated with normal service conditions)*

Table 34 – Immunity vibration test

Reference test	IEC 68-2-6, test Fc
Requirement reference	Subclause 2.1.3.1
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Details of mounting/support	According to manufacturer's specifications for portable and hand-held portable equipment
Motion	Sinusoidal
Vibration amplitude/acceleration	
10 Hz ≤ *f* ≤ 57 Hz	0,075 mm amplitude
57 Hz ≤ *f* ≤ 150 Hz	1,0 *g*
Vibration type	Sweeping, at a rate of 1 octave/min (± 10 %)
Vibration duration	10 sweep cycles per axis on each of three mutually perpendicular axes
Measurement and verification during loading	According to PFVP (6.3.2.2)
Verification after tests	According to PFVP (6.3.2.2)

6.3.5.2 *Shocks (type test associated with normal service conditions)*

Table 35 – Immunity shock test

Reference test	IEC 68-2-27, test Ea
Reference test	Subclause 2.1.3.2
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Details of mounting/support	According to manufacturer's specifications for portable and hand-held portable equipment
Type of shock	Half sine
Shock severity	15 *g* peak, 11 ms duration
Application	Two shocks per axis, on three mutually perpendicular axes
Measurement and verification during loading	According to PFVP (6.3.2.2)
Verification after tests	According to PFVP (6.3.2.2)

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6.3.5.3 *Free falls (type test associated with normal service conditions)*

Table 36 – Free falls immunity/withstand tests (portable and hand-held portable equipment)

Reference tests • Random and flat drops • Supported drops	 IEC 68-2-32, procedure 1 IEC 68-2-31, subclause 3.2.1
Requirement reference	Subclause 2.1.3.3
Preconditioning Initial measurements Details of mounting/support	According to manufacturer's specifications According to PFVP (6.3.2.2) Equipment equipped with catalogued cable(s)
Measurement and verification during loading Verification after the tests	According to PFVP (6.3.2.2) According to PFVP (6.3.2.2)

6.3.5.4 *Free falls (type test associated with transport and storage conditions)*

Table 37 – Free falls withstand test (units within manufacturer's original packaging)

Reference test	IEC 68-2-32, procedure 1
Requirement reference	Subclause 2.3.4
Selection of samples Initial measurements Details of mounting/support	Each type of manufacturer's original packaging with the heaviest unit using it According to PFVP (6.3.2.2) Equipment equipped with catalogued cable(s)
Measurement and verification during loading Verification after the test	None According to PFVP (6.3.2.2)

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6.3.5.5 *Safety related tests*

6.3.5.5.1 *Impact withstand test (type test associated with transport and storage conditions)*

Table 38 – Impact withstand test*

Reference test	IEC 950
Requirement reference	Subclause 4.5.3.6
Selection of sample(s) Exceptions Initial measurements Details of mounting/support	Enclosed equipment with voltage greater than SELV and equipment containing moving parts Test performed neither on hand-held portable equipment nor on displays nor lamps According to PFVP (6.3.2.2)
Description of the test Number of trials Verification after the test	See figure 6 below *One per surface* Perform the accessibility test (6.3.5.5.2) *Perform the dielectric test* (6.3.6.1.1)
* The unit may be non-functioning after the test.	

Impact test procedure:

The impact is imparted to the sample by a solid, smooth steel sphere approximately 50 mm in diameter and with a mass of 500 g ± 25 g (see figure 6 below)

– Top surfaces: The sphere is to fall freely from rest through a vertical distance of 1 300 mm to the rest of the top surfaces.

– Vertical surfaces: The sphere is suspended by a cord and swings as a pendulum dropping through a vertical distance H of 1 300 mm to the sphere impact position.

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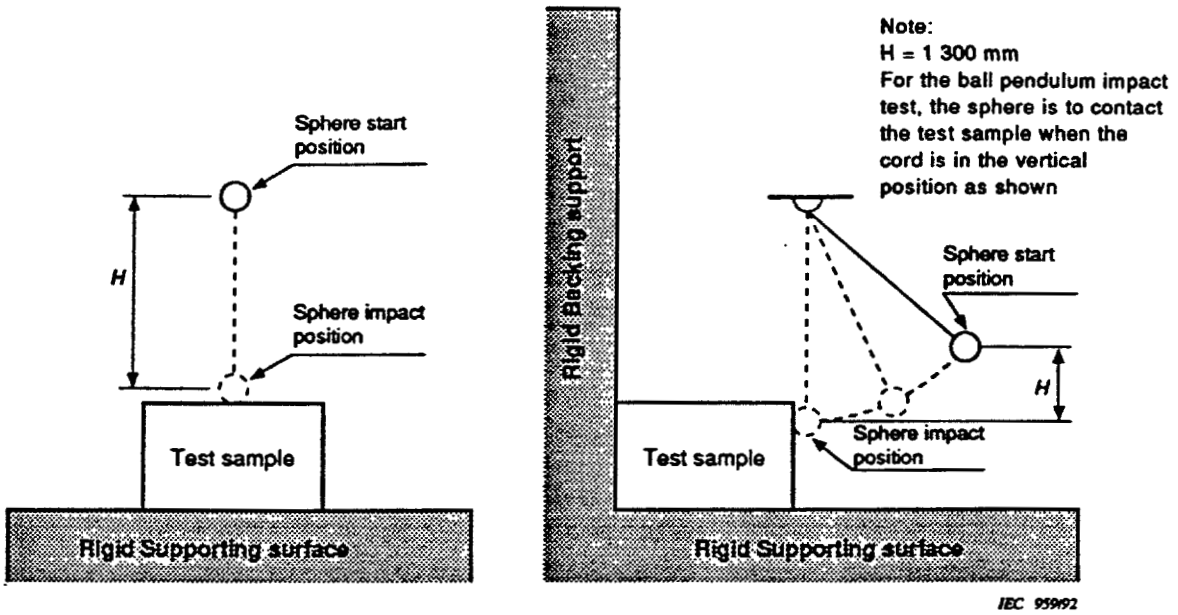


Figure 6 – Impact withstand test procedure

6.3.5.5.2 *Accessibility tests*

Table 39 – Accessibility tests*

Reference tests • Class I equipment • Class II equipment	 IEC 529 IEC 950, subclause 2.1, test pin of figure 20
Requirement references	Subclauses 4.2, 4.5.2 and 4.5.3
Selection of sample(s)	Class I and Class II enclosed equipment and enclosed equipment containing moving parts
Number of samples	One equipment of each type
Preconditioning	Clean and new
Details of mounting/support	According to manufacturer's specifications
Drain/ventilation holes	Configuration used in operating conditions
Moving parts test	Equipment energized and operating
Electrical shock test	Equipment de-energized
Test description	The finger (IP2X) and, where applicable, the test pin shall not make contact with any live part (except for SELV circuits) or any moving part (except smooth rotating shafts)

* For open equipment, no test is required, and the user is responsible for the safety of the equipment.

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6.3.5.5.3 *Verification of clearance distances at field wiring terminals*

Table 40 – Verification of clearance distances at field wiring terminals

Reference test	Physical measurement
Requirements references	Subclauses 4.3 and 4.5

6.3.5.5.4 *Verification of internal/external wiring characteristics*

Integrity of internal/external wiring

This integrity shall be initially tested and then verified during the vibration tests specified in 6.3.5.1, and after the vibration, shock and free fall tests specified in 6.3.5.1, 6.3.5.2 and 6.3.5.3.

Wire and cable flexing withstand test

– Requirement reference: subclause 4.9.2

The flexing test applies to wiring subject to flexing under normal service conditions and maintenance, and where conductors are solid or insulation is less than 0,8 mm thick.

– Test procedure:

The flexing test consists of flexing the wire/cable assembly between the two extreme points of travel for the cable.

Number of flexing cycles:

- 500 if flexing under normal service conditions;
- 25 if flexing only during maintenance operations;

– Pass/fail criteria:

The wiring shall be considered acceptable if after this test:

- the PFVP (6.3.2.2) is performed successfully;
- the insulation passes the application of the dielectric test (6.3.6.1.1 and the following insulation breakdown test method);

– Insulation breakdown test method:

The wiring being tested is removed from the equipment and the portion of the cable having been flexed is wrapped with a conducted foil. The applicable test voltage as given in table 17 in 3.10.2 is then applied between each conductor in turn and the common connection of all other conductors and this conducting foil.

Mechanical properties of terminals

NOTE - The applicability of the requirements of IEC 947-1 to this subclause is under consideration.

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Verification of the protection against the effect of improper connections

– Requirement references:

Item 2 of 3.8.1, 4.9, item 2 of 4.12.2.1, 4.12.2.3 to 4.12.2.6.

– Verifications:

Connectors shall have either mechanical key or proper warning to prevent improper connections. User's manuals shall indicate correct connections to be made and include appropriate warnings as applicable.

Routing of wirings

– Requirement reference: subclause 4.9.4.

6.3.5.5.5 *Flammability of insulating materials*

– Requirement reference: subclause 4.4.

Applicable tests shall be performed for each material for which the manufacturer does not provide an acceptable compliance certificate.

6.3.5.5.6 *Temperature rise test*

Table 41 – Temperature-rise test

Reference test	Not applicable
Requirement reference	Subclause 4.4.2
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Details of mounting/support	According to manufacturer's specifications
Loading	The basic PC-system shall be operated with all I/O modules at their rated "ON" operating conditions (100 % duty cycle)
Measurement and verification during loading	According to PFVP (6.3.2.2)
Verification after the tests	According to PFVP (6.3.2.2)

6.3.5.5.7 *Protective coating test*

Requirement reference: subclause 4.3.3.1.2.

NOTE - Alternative tests are under consideration.

1) Testing shall be done on test-PWBs with parallel printed conductors with a length of at least 100 mm, whereby the creepage distances have to be in accordance with the actual application. For the test-PWB, the same coating material, the same PWB material, and the same manufacturing (processing) procedure shall be used as during the normal equipment manufacturing procedure.

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2) The test shall be done on three test PWBs. The sequence of tests shall be:

   a) ageing of samples,

   b) dielectric test,

   c) adherence test.

3) Ageing of samples

Reference test:	IEC 68-2-3, test Ca
– test time (warm damp, constant):	56 days
– storage time and conditions:	28 days at 110 °C
– pass/fail criteria:	the dielectric test and the adherence test have to be passed thereafter

4) Dielectric test

Procedure:

Select the d.c. test technique and test voltage levels in accordance with the applicable dielectric withstand requirements of 3.10. Perform the test on three test PWBs; the test voltage shall be applied between:

   a) their parallel printed conductors;

   b) these printed conductors and a test electrode that is put on the PWB.

Pass/fail criteria:

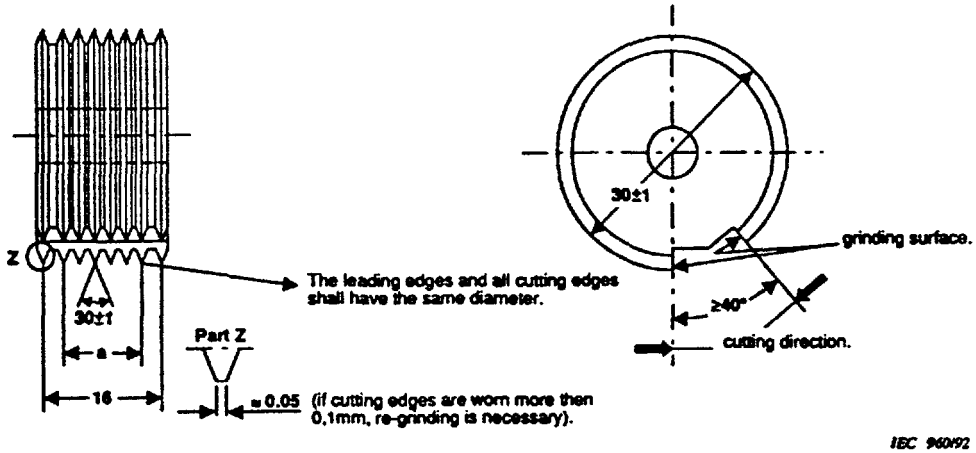
There shall be no flashover or breakdown of the insulation.

5) Adherence test (cross-cut adherence test)

Multi-blade tool:

The cutting tool shall be as defined in figure 7. The distance between two blades shall depend on the thickness of the protective coating:

thickness in µm:	distance between blades (a/5)
thickness < 60:	1 mm
60 ≤ thickness < 120:	2 mm



Dimensions in millimetres

Figure 7 – Multiblade tool with six blades

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Handbrush:

The handbrush shall have 110 to 150 bundles of polyamide bristles; each bristle shall be 12 mm to 15 mm long and 0,4 mm to 0,5 mm thick.

Procedure:

The appropriate cutting tool shall be used to draw two perpendicular cuts down to the basic material so that a grid of 25 squares results. The cut shall be drawn smoothly (not jerkily) with a speed of 0,02 m/s to 0,05 m/s.

A magnifying glass shall be used to verify that the cuts have suitably reached the basic material. The handbrush shall be used to brush the grid five times forth and back in a diagonal direction under soft pressure.

Pass/fail criteria:

Total chipped area shall be smaller than 5 % of the grid area. No separation, fracturing, or delamination of the coating from the surface of the base material or conductor is allowed.

6.3.5.6 *Verification of terminal connection characteristics*

Verify that requirements of 4.6 are met.

6.3.5.7 *Plugging/unplugging of removable units*

Table 42 – Insertions/withdrawals of removable units

Requirements references	Subclause 3.8.1, item 1 of 3.9.1, 4.9 and 4.10
Description of the test for permanently installed units	50 (20) insertions/withdrawals are performed without power; then the equipment shall pass the PFVP (6.3.2.2)
Description of the test for non-permanently installed units	500 insertions/withdrawals are performed while the basic PC-system is performing functional test programs as required for PFVP (6.3.2.2) Insertions and withdrawals shall not affect the proper operation of the basic PC-system. Communication on the physical link during the test is not required.

6.3.6 *Electrical tests*

CAUTION: It may be necessary to install an external impedance (a filter) to protect the test equipment that is connected to the basic PC-system being tested.

6.3.6.1 *Safety related tests*

6.3.6.1.1 *Dielectric test*

Exceptions:

These tests need not be done:

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– between isolated SELV circuits and accessible conductive parts (frames, enclosures, earth terminal, etc.)

– on units (parts of the basic PC-system) which have been tested separately according to the relevant standards, provided:

a) the values given in table 17 in 3.10.2 have been met, and

b) their dielectric strength is not impaired by assembly.

– between isolated circuits on printed wiring boards providing the specified clearances and creepage distances have been met. See 4.3.

Test conditions:
The tests are done on each unit and module connected in the test circuit as shown in figure 8. If required, tests can be done on individual modules with the remaining modules removed. All mechanical switches shall be in the "ON" closed position.

Test technique:
One may select any one of the following techniques:

– Impulse test, according to IEC 60-1 and the following conditions:

Pulse characteristics:	1,2/50 µs ± 20 %
Source impedance:	500 Ω ± 10 %
Source energy:	0,5 J ± 20 %
Length of connection:	≤ 2 m
Number of impulses:	3 positive and 3 negative
Time between two impulses:	≥ 5 s

– a.c. r.m.s. voltage test

Number of periods:	≥ 3
Voltage signal:	starting from 0 V (zero crossing)
Short-circuit current:	≤ 5 mA

– d.c. voltage test

Pulse duration at d.c. value:	10 ms ± 20 %
Pulse rise/fall times:	> 1,2 µs
Number of pulses:	1 positive and 1 negative
Time between pulses:	≤ 5 s
Short-circuit current:	≤ 5 mA

NOTES

1 In general, preference should be given to the impulse test; however, where filter capacitors are used (line to earth), the d.c. test is recommended.

2 See annex D: correction factors for test voltages corresponding to barometric pressure or altitude.

3 To recognize current practice, the manufacturer may elect alternatively to verify the dielectric strength by the application of 2 U_e + 1 000 V a.c., for a minimum duration of 1 min.

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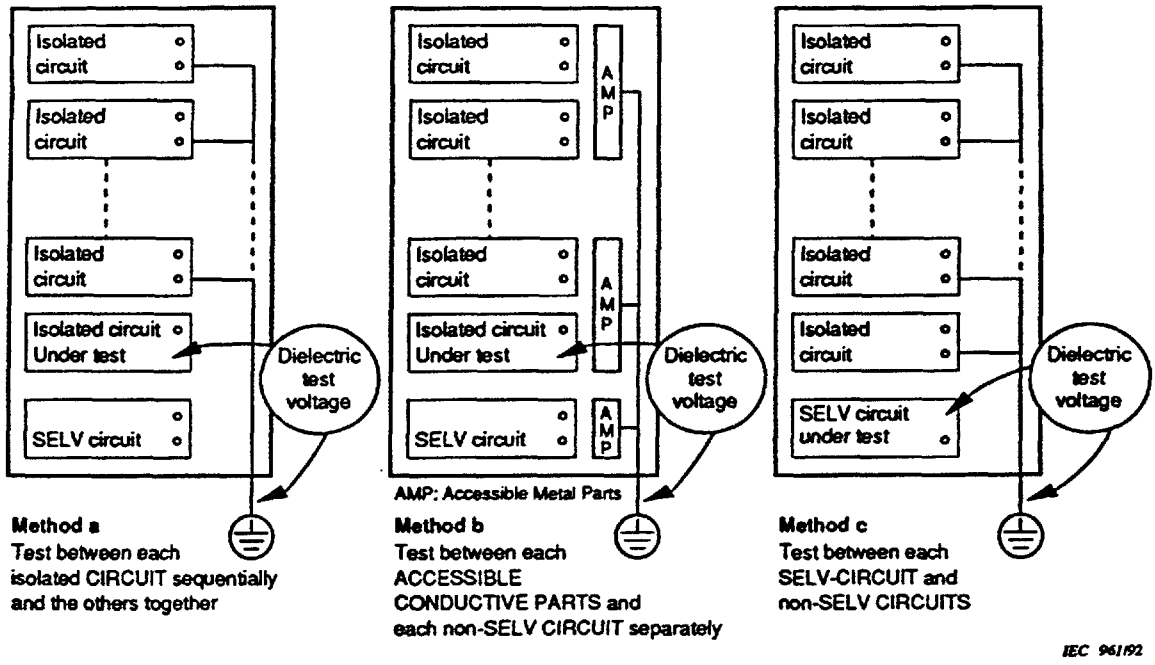


Figure 8 – Dielectric test procedures

Test method:
The test voltage shall be applied as follows:

a) Between isolated circuits other than SELV circuits

The test voltage shall be applied between each isolated circuit and the remaining circuits connected together to the earth. The test voltage shall be that given in table 17 in 3.10.2 corresponding to the highest rated voltage and class of the circuits.

b) Between isolated circuits other than SELV circuits and accessible conductive parts (frame, enclosure, protective earth terminal, functional earth terminal, etc.)

The voltage shall be applied between each isolated circuit sequentially and accessible conductive parts. The test voltage shall be that given in table 17 in 3.10.2 corresponding to the rated voltage and class of the circuit.

c) Between isolated SELV circuits and other non-SELV circuits

The test voltage shall be applied between each isolated SELV circuit and the remaining non-SELV circuits connected together to the earth. The test voltage shall be 1500 V a.c. r.m.s. or its equivalent peak value for the impulse and d.c.

Pass/fail criteria:
There shall be no unintentional flashover or breakdown of the insulation during the test. Eventual operation of protecting devices provided on the units shall not be considered as a failure (an intentional flashover is one which might be the result of the normal action of a surge suppression device incorporated in the equipment).

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6.3.6.1.2 *Protective earthing continuity test*

Requirement reference: item 6 of 4.7.2

Test description:
A constant current of 30 A for at least 2 min shall be injected between the earthing terminal or contact and each of the accessible metal parts intended to be earthed. The current shall be maintained or adjusted accordingly during the test to 30 A. Any convenient low voltage not exceeding 12 V can be used. The voltage drop shall be measured between the points of current flow, care being taken that the contact resistance between the tip of the measuring probe and the metal part underneath does not influence the test results.

Pass/fail criteria:
The resistance shall not exceed 0,1 Ω.

6.3.6.1.3 *Stored energy injury risk test*

Requirement reference: subclause 4.5.3.3.

Selection of samples:
Portable peripherals connected to the mains power supply by use of a cordset (removable or fixed) shall comply with this test.

Test description:

- the test shall be applied to each individual pin of the plug and to the receptacle;
- the cordset shall be disconnected from the mains power supply, the peripheral being in operation;
- in a delay not exceeding 1 s from the instant of deconnection, and for each of the pins/receptacle, both the voltage and the short-circuit current between the pin or receptacle tested and the local protective earth shall be measured.

Pass/fail criteria:
For all tests (i.e. one test per pin or receptacle), the voltage shall not exceed 42,4 V peak or d.c., or 30 V r.m.s. and the discharge current shall not exceed 5 mA.

6.3.6.2 *Noise immunity tests*

6.3.6.2.1 *Electrostatic discharge test*

The following test is considered to be a first step in the direction of commonly used tests for the qualitative evaluation of the performance of electronic equipment.

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Table 43 – Electrostatic discharge immunity test

Reference test	IEC 801-2
Requirement reference	Subclause 3.9.1
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Details of mounting/support	According to manufacturer's specifications
Selection of application points	All exposed conductive parts and insulating surfaces of the basic PC-system normally accessible to the operator (see 3.9.1)
• Exception	Signal lines; circuits or live parts becoming accessible only during maintenance operations
Discharge characteristics • test peak voltage	
RH-1 / ESD-3	8 kV
RH-2 / ESD-4	15 kV
Time between two discharges	> 1 s
Number of discharges on each selected point	10 discharges after the equipment is discharged to earth
Measurement and verification during loading	According to PFVP (6.3.2.2)
Pass/fail criteria	There shall be no deviation other than allowances for analog and fast responding I/Os. If the system deviates only once during the test, a second trial of 10 discharges shall be performed; if only one more unallowed deviation is observed, failure to the ESD test shall be declared

6.3.6.2.2 *Radiated electromagnetic field test*

Table 44 – Radiated electromagnetic field immunity test

Reference test	IEC 801-3
Requirement reference	Subclause 3.9.1
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Details of mounting/support	The basic PC-system is placed on a wooden table in a shielded room, in the far field generated by the radiated antenna.
Frequency range to be swept	27 MHz to 500 MHz
Sweep speed	$1{,}5 \times 10^{-3}$ decade/s
Test field strength	10 V/m
Measurement and verification during loading	According to PFVP (6.3.2.2)
Pass/fail criteria	There shall be no deviation other than manufacturer-specified allowances for analog I/Os.

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6.3.6.2.3 *Fast transient burst test*

Table 45 – Fast transient burst immunity test*

Reference test	IEC 801-4
Requirement reference	Subclause 3.9.1
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Details of mounting/support	The test equipment configuration shall be such as to eliminate the radiated EMI received on I/O wiring by the specified capacitive coupling
Severity level at rated voltage	According to requirement in 3.9.1
• A: (all power supplies)	2 kV, repetition frequency of spikes: 2,5 kHz ± 20 %
• B: (digital I/Os, $U_e \geq 24$ V)	1 kV, repetition frequency of spikes: 5 kHz ± 20 %
• C: (digital I/Os, $U_e < 24$ V, analog I/Os, communication I/Os)	250 V, repetition frequency of spikes: 5 kHz ± 20 %
Duration	10 s minimum
Application points/methods	Positive and negative common mode
• A	Direct coupling by wired capacitance method
• B and C	Capacitive clamp method
Measurement and verification during loading	According to PFVP (6.3.2.2)
Pass/fail criteria	

* The repeatability of this test is closely related to the number and relative position of wires within the capacitive coupling.

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6.3.6.2.4 *Damped oscillatory wave test*

Table 46 – Damped oscillatory wave immunity test

Reference test	IEC 255-4
Requirement reference	Subclause 3.9.1
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Details of mounting/support	According to manufacturer's specifications
Test description	See figure 9 below
• waveform	Damped oscillating wave the envelope of which reaches 50 % of the initial peak value after 3 to 6 cycles (verify the sinusoidal shape of the wave)
• frequency	1 MHz
• source impedance	200 Ω ± 10 %
• repetition rate	400 per s
• test duration	2 s minimum
• length of connection	2 m maximum
• severity level at rated voltage	According to requirement in 3.9.1
A: (all power supplies)	1 kV
B: (digital I/Os, $U_e \geq 24$ V)	1 kV
C: (digital I/Os, $U_e < 24$ V, analog I/Os, communication I/Os)	No test
• Application points/method	Series mode
A	Wiring terminals
B	Wiring terminals
Measurement and verification during loading	According to PFVP (6.3.2.2)
Pass/fail criteria	There shall be no deviation

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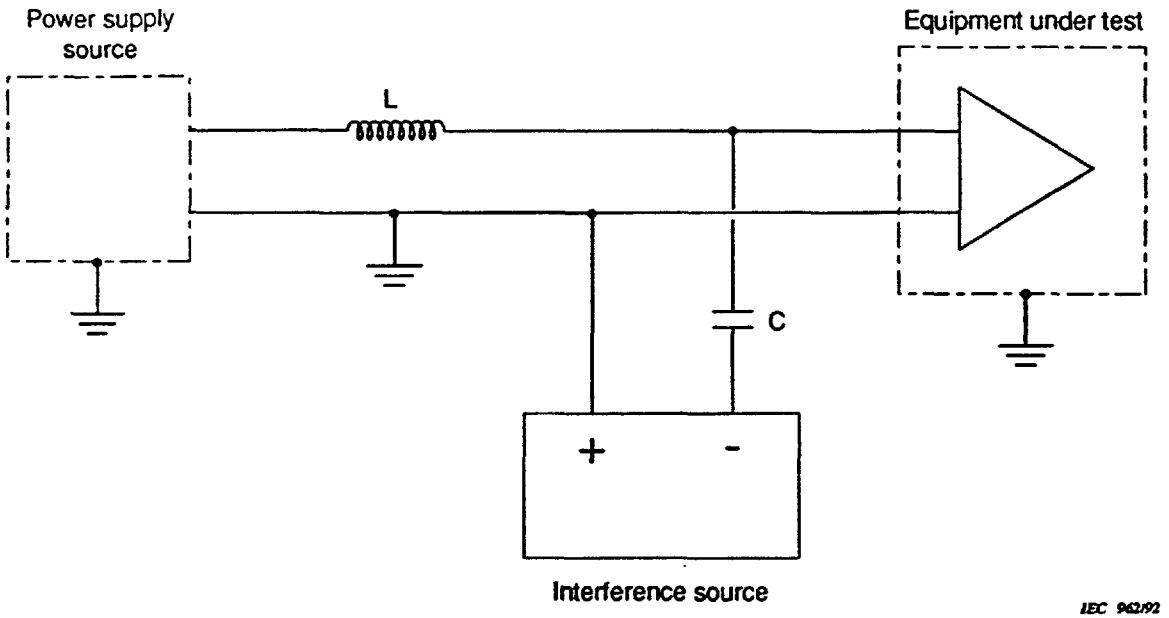


Figure 9 – Connection diagram for damped oscillatory wave test series mode (normal mode)

6.3.7 *Verification of a.c. and d.c. power supply characteristics*

Perform the proper functional verification procedure of 6.3.2.2 during tests under 6.3.7.1., 6.3.7.2 and 6.3.7.3.

6.3.7.1 *Incoming power supply voltage and frequency variation tests*

6.3.7.1.1 *Voltage and frequency range test*

Table 47 – Voltage and frequency range immunity test (note 1)

Reference test	None	
Requirement reference	Subclause 3.2.1.1	
Preconditioning	According to manufacturer's specifications	
Initial measurements	According to PFVP (6.3.2.2)	
Description of tests	Test A	Test B
• a.c. voltage (k x U_e) (note 2)	0,85	1,10
• a.c. frequency (k x F_n) (note 2)	0,95	1,05
• d.c. voltage (k x U_e) (note 2)	0,85	1,20
• ripple continuous (k x U_e) (note 2)	0,05	0,05
• test duration	30 min	30 min
Measurement and verification during loading	According to PFVP (6.3.2.2)	
Verification after tests	According to PFVP (6.3.2.2)	

NOTES

1 If there are separate mains supplies to the PC-system the tests may be done on each supply separately.

2 See precise definitions in 3.2.1.1.

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6.3.7.1.2 *Third harmonic immunity test*

Table 48 – Third harmonic immunity test*

Reference test	None
Requirement reference	Subclause 3.2.1.1
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Description of tests	A third harmonic voltage (150 Hz or 180 Hz) adjusted to 10 % of the mains rated voltage is added to the a.c. mains power supply with 0° and 180° (see figure 10)
Test duration for each phase	5 min
Measurement and verification during loading	According to PFVP (6.3.2.2)
Verification after tests	According to PFVP (6.3.2.2)
* If there are separate mains supplies to the PC-system the tests may be done on each supply separately.	

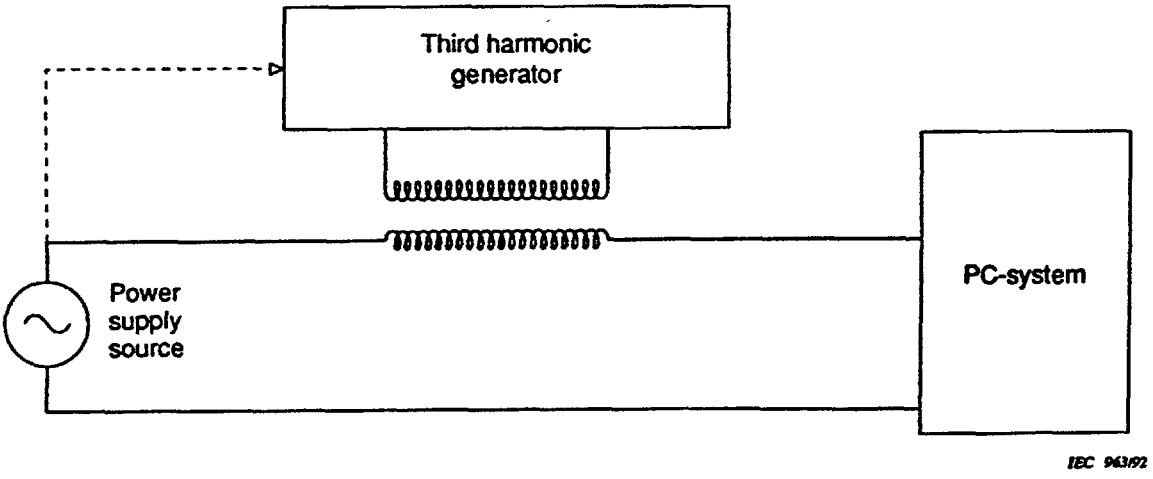


Figure 10 – Third harmonic immunity test

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6.3.7.2 *External energy supply interruption tests*

6.3.7.2.1 *Momentary interruption immunity test*

Table 49 – Momentary external energy supply interruption immunity test

Reference test	None
Requirement reference	Subclause 3.2.1.2
Preconditioning	According to manufacturer's specifications
Initial measurements	According to PFVP (6.3.2.2)
Supply voltage and frequency	Rated values
Test description	
A.C. supply interruption	
• duration, base	0,5 period, starting at zero-crossing (notes 1 and 2)
• number of trials	20
• time interval between trials	1 s ≤ time interval ≤ 10 s
D.C. supply interruption	
• duration	PS1: 1 ms; PS2: 10 ms; (note 2)
• number of trials	20
• time interval between trials	1 s ≤ time interval ≤ 10 s
Measurement and verification during loading	According to PFVP (6.3.2.2) Normal operation shall be maintained (note 3)
Verification after the tests	According to PFVP (6.3.2.2)

NOTES

1 Optionally, the manufacturer may elect to interrupt the supply at a random phase angle.

2 The manufacturer may state longer interruptions.

3 Fast responding inputs energized by the same power supply may be affected temporarily during the disturbance but shall resume normal operation after the disturbance.

6.3.7.2.2 *Shut-down test (sudden supply interruption)*

Requirement reference: Item 2 of 3.2.1.2

Test description:
During shut-down due to the supply interruption the system behaviour shall be observed. The test is repeated twice.

Pass/fail criteria:
The requirement given above shall be met. In addition, from the start of interruption to shut-down, there shall be no change not caused by the normal test program and no erratic or unintended condition of any kind.

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6.3.7.2.3 *Start-up test (voltage applied normally)*

When the external supply is applied for a time specified by the manufacturer, the PC-system shall start again according to the specifications of the manufacturer (automatic or manual restart, initialization sequence, etc.). During the start-up there shall be no erratic or unintended condition.

6.3.7.3 *External energy supply variation tests (immunity tests)*

6.3.7.3.1 *General*

Reference requirements: subclause 3.2.1.2.
At voltages below the minimum normal service conditions limits and/or frequencies beyond the normal conditions limits, the PC-system shall "either maintain normal operation or go to a predefined state and have a clearly specified behaviour until normal operation is resumed".

Pass/fail criteria:
During the tests, the PFVP (6.3.2.2.) shall insure that the behaviour of the basic PC-system is as specified by the manufacturer and that there is no change not caused by the PFVP test program and no erratic or unintended conditions of any kind.

6.3.7.3.2 *Gradual shut-down/start-up test*

Table 50 – Gradual shut-down/start-up test

Reference test	None
Requirements references	Subclause 3.2.1.2, items 6 and 7 of 3.2.3, item 17 of 3.3.2.3
Preconditioning	The behaviour of the basic PC-system shall be according to PFVP (6.3.2.2) at minimum operational voltage and frequency (test A of 6.3.7.1.1) and at maximum operational voltage and frequency (test B of 6.3.7.1.1)
Test description	See figure 11, test A
• initial/final conditions	Power supply at rated values (U_e, F_n)
• lowest voltage (V)	0 (zero)
• speed of voltage decrease/increase (V/s)	U_e / 60 ± 10 %
• waiting time at lowest voltage (s)	10 s ± 20 %
• number of trials	3
• time interval between trials	1 s < time interval ≤ 10 s
Measurement and verification during loading	According to PFVP (6.3.2.2)
• voltage shut-down limit (SDL)	The voltage at which the basic PC-system starts the manufacturer's specified shut-down sequence or initiates a behaviour not in accordance with the PFVP during the decreasing voltage sequence.
• average SDL ($SDL_{av.}$)	The average of three measured SDL
Pass/fail criteria	According to 6.3.7.3.1

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6.3.7.3.3 *Gradual supply voltage variation tests*

Table 51 – Gradual supply voltage variation tests

Reference test	None	
Requirements references	Subclause 3.2.1.2, items 6 and 7 of 3.2.3, item 17 of 3.3.2.3	
Preconditioning	The behaviour of the basic PC-system shall be according to PFVP (6.3.2.2) at minimum operational voltage and frequency (test A of 6.3.7.1.1) and at maximum operational voltage and frequency (test B of 6.3.7.1.1)	
Description of tests	Test B (fast variations) (see figure 11)	Test C (slow variations) (see figure 11)
• initial/final conditions	Power supply at rated values (U_e, F_n)	
• lowest voltage (V)	0 (zero)	0,9 $SDL_{av.}$ ± 10 % (note)
• speed of voltage decrease/increase (V/s)	U_e / 5 ± 10 %	U_e / 60 ± 10 %
• waiting time at lowest voltage (s)	0 (zero)	0 (zero)
• number of trials	3	3
• time interval between trials	1 s < time interval ≤ 5 s	
Measurement and verification during loading	According to PFVP (6.3.2.2)	
Pass/fail criteria	According to 6.3.7.3.1	

NOTE - $SDL_{av.}$ is a result of gradual shut-down test (see 6.3.7.3.2).

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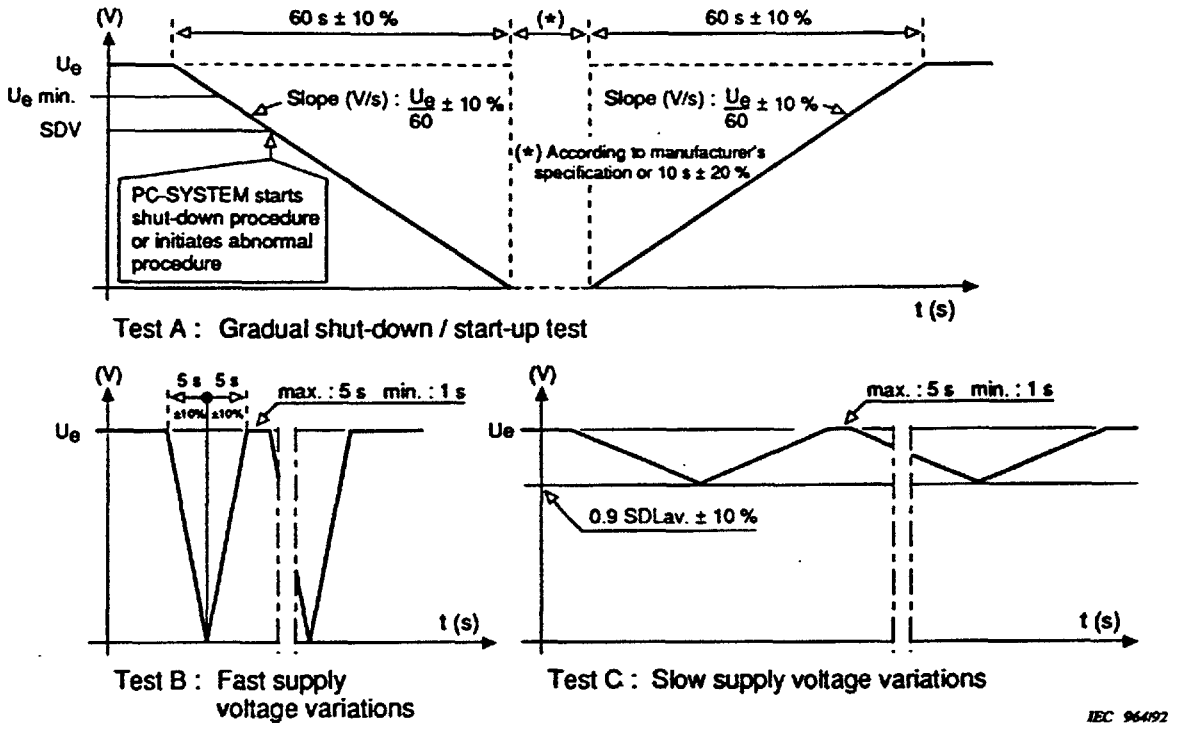


Figure 11 – External energy supply variation tests

6.3.7.4 *Improper power supply connection tests*

Requirement reference: item 5 of 3.2.3.

6.3.7.4.1 *Reversal of d.c. power supply polarity test (withstand test)*

The rated voltage of reverse polarity shall be applied for 10 s. The results shall comply with the conditions stated by the manufacturer (such as fuse blowing).

After the test the basic PC-system shall pass the proper verification procedure (see 6.3.2.2). Protective devices such as fuses may be reset prior to verification.

6.3.7.4.2 *Improper voltage level and/or frequency test*

For voltage level above the maximum normal service conditions limit U_e max. or/and frequencies beyond the normal service conditions limits F_n max. and F_n min., the test shall be agreed between the user and the manufacturer.

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6.3.7.5 *Verification of memory back-up characteristics*

6.3.7.5.1 *Back-up duration withstand test*

Table 52 – Back-up duration withstand test

Reference test	None	
Requirements references	Subclause 3.2.1.2, items 6 and 7 of 3.2.3, item 17 of 3.3.2.3	
Preconditioning	According to PFVP (6.3.2.2)	
Duration of preparation	According to manufacturer's specifications (energy source may require time to be fully charged)	
Test to be performed	Either test A or test B defined below	
Description of tests	Test A	Test B
• initial conditions	Energy source fully charged; external energy supply disconnected	
• temperature (°C)	Open equipment 55 °C Enclosed equipment 40 °C	General conditions (6.3.3)
• duration (h)	300	1 000
Verification after the tests	According to PFVP (6.3.2.2) The PC-system shall be fully operational. No loss of retentive data is allowed.	

6.3.7.5.2 *Verification of manufacturer's method of changing the energy source*

Table 53 – Change of energy source test

Reference test	None
Requirements references	Subclause 3.2.2, item 9 of 3.2.3
Preconditioning	According to PFVP (6.3.2.2)
Replacement of energy source	According to manufacturer's specifications (energy source may require time to be fully charged)
Verification after the tests	According to PFVP (6.3.2.2) The PC-system shall be fully operational. No loss of retentive information is allowed.

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6.3.7.5.3 *Verification of other requirements*

1) Check the required warning of low energy source voltage (see 3.2.2). (Remove the energy source and apply the proper controlled voltage in place of the energy source.)

2) If non-rechargeable energy sources are used, verify that design requirements of 4.11 are met.

6.3.8 *Verification of input/output characteristics*

6.3.8.1 *General*

1) Test procedures are not defined in detail hereinafter. Detailed procedures shall be agreed upon by the user and the manufacturer and shall be such that the conditions defined in 6.2 shall not be impaired.

2) Though test procedures are not defined in detail, all tests which are referenced shall be performed.

3) Unless otherwise specified in this subclause, all tests shall be carried out twice on the same I/O channel(s):

First test: at minimum service temperature (*T* min.), i.e. 5 °C or *T* min. given in 2.1.1.1.

Second test: at maximum service temperature (*T* max.), i.e. 40 °C/55 °C or *T* max. given in 2.1.1.1.

4) It is not required to test more than one analog input channel and one digital input channel of each type, but all different types which are represented in the basic PC-system shall be tested.

5) All channels of multi-channel output modules shall be tested (see item 10 of 3.3.2.3).

6.3.8.2 *Verification of digital inputs*

6.3.8.2.1 *Operating range test*

Requirement reference: subclause 3.3.1.2
(Verify that all requirements are met)

Test procedures: Under consideration.

6.3.8.2.2 *Reversal of signal polarity test (withstand test)*

Requirement reference: Item 4 of 3.3.1.4

Test procedure:
A signal of reverse polarity for digital inputs shall be applied for 10 s.

Verification:
The results shall be as stated by the manufacturer. The device shall pass the PFVP (see 6.3.2.2). Protective devices such as fuses may be reset prior to verification.

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6.3.8.2.3 *Verification of other requirements*

Verify that the general requirements for digital I/Os under 3.3 and the requirement of 3.3.1.3 are met.

6.3.8.3 *Verification of digital outputs*

6.3.8.3.1 *Operating range test*

Requirement reference: subclauses 3.3.2.1, 3.3.2.2 and 3.3.3.1
(Verify that all requirements are met)

Test procedures:

- Current range: Under consideration.
- Voltage drop: Under consideration.
- Leakage current: Devices/circuits intended for output protection shall not be removed.
- Temporary overload: According to IEC 947-5-1, (AC-15 or DC-13, as applicable). For short-circuit proof outputs, the current values shall be respectively 20 I_e / 2 I_e ("two times the rated value", as given in 3.3.2.2).

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6.3.8.3.2 *Test of protected, not-protected, and short-circuit proof outputs*

Table 54 – Overload and short-circuit tests for digital outputs

Reference test	None				
Requirements references	Subclauses 3.3.2.2 (a.c. outputs) and 3.3.3.2 (d.c.outputs)				
Preconditioning	According to manufacturer's specifications				
Details of *mounting/support*	According to manufacturer's specifications				
Loading	It is sufficient to check one I/O channel of each type under test				
Initial measurements	According to PFVP (6.3.2.2)				
Description of the tests	A	B	C	D	E
• prospective currents (k x I_e)	1,2/1,3 (note 1)	1,5	2	5	21
• duration of test (min)	5	5	5	5	5
• order of trials					
first series (at T min.)	1	2	3	4	5
second series (at T max.)	6	7	8	9	10
• time intervals between tests	10 min ≤ time intervals ≤ 60 min				
Application of the tests					
• protected outputs	Yes	Yes	Yes	Yes	Yes
• short-circuit proof outputs	No	No	Yes (note 2)	No	Yes (note 4)
• not-protected outputs (note 3)	No	No	Yes (note 2)	No	Yes (note 4)
Measurement and verification	See requirements in 3.3.2.2 and 3.3.3.2				
• during the overload	No evidence of risk of fire or electrical shock				
• immediately after overload	Maximum temperature rise of the I/O insulation shall not exceed the value of 4.4.2				
• after overload and proper resetting	According to PFVP (6.3.2.2)				

NOTES

1 1,2 for a.c. outputs, 1,3 for d.c. outputs.

2 For currents in the range of two times to 20 times I_e, the module may require repair or replacement.

3 Protective device(s) to be provided or specified by the manufacturer shall be installed.

4 Protective device(s) shall operate. They shall be reset or replaced as applicable for the following test.

5 An alternative method for testing of protected outputs is under consideration. See annex E.

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6.3.8.3.3 *Reversal of signal polarity test (withstand test)*

Requirement reference: item 13 of 3.3.2.3
If the equipment is designed to prevent reversal of signal polarity, the withstand test may be not carried out and replaced by proper visual inspection.

Test procedure:
A signal of reverse polarity for digital d.c. outputs shall be applied for 10 s.

Verification:
The results shall be as stated by the manufacturer.

The device shall pass the PFVP (see 6.3.2.2.). Protection devices such as fuses may be reset prior to verification.

6.3.8.3.4 *Verification of other requirements*

Verify that general requirements for digital I/Os under 3.3 and the remaining requirements of 3.3.2.2 are met (output indicators and electromechanical relay outputs).

6.3.8.4 *Verification of analog I/Os*

6.3.8.4.1 *Operating range tests*

Requirement reference: subclause 3.4.1.1
(Verify that all requirements are met)

Test procedures: Under consideration.

6.3.8.4.2 *Overload withstand test for analog inputs*

Requirement reference: item 7 of 3.4.1.2.1

Test procedure: Under consideration.

Measurement and verification

- During loading:

  During the application of specified maximal overload, no physical damage or abnormal phenomenon (smoking, smelling, overheating) shall be detected.

- After the test:

  The accuracy shall be verified for the minimal and the maximal value of the input range according to PFVP (see 6.3.2.2).

6.3.8.4.3 *Short-circuit test (voltage output) and open circuit test (current output)*

When the short circuit (for a voltage output) or the open circuit (for a current output) is realized, no physical damage or abnormal phenomenon (smoking, smelling, overheating) shall be detected. After the test, perform the proper functional verification procedure of 6.3.2.2.

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6.3.8.4.4 *Voltage supply variation test*

This test shall be performed when the analog I/O modules are externally energized by an independent power supply (i.e. independent from the other I/O modules power supply(ies) of the basic PC-system).

The power supply is replaced by a variable power source. The voltage is adjusted to the extreme values of the specified range of voltage supply. The module shall then pass the PFVP and the output variations shall be inside the specified range (see 6.3.2.2).

6.3.8.4.5 *Reversal of signal polarity test (withstand test)*

Requirement reference: item 11 of 3.4.1.2.3
If the equipment is designed to prevent confusion of signal polarity, the withstand test may not be carried out and replaced by proper visual inspection.

Test procedure:
A signal of reverse polarity for unipolar analog inputs shall be applied for 10 s.

Verification:
The results shall be as stated by the manufacturer. The device shall pass the PFVP (see 6.3.2.2.). Protection devices such as fuses may be reset prior to verification.

6.3.8.4.6 *Verification of other requirements*

Type tests are not required; all characteristics non-tested shall be verifiable under a procedure to be agreed upon by the manufacturer and the user.

6.3.9 *Verification of MPU characteristics*

Requirement reference: subclause 3.6
Type tests are not required; all characteristics non-tested shall be verifiable under a procedure to be agreed upon by the manufacturer and the user.

6.3.10 *Verification of remote I/O stations*

6.3.10.1 *Response time test*

Requirement references: item 4 of 3.7.2 and item 5 of 3.7.2
This test verifies the effect on transfer time(s) introduced to provide remote input information and RIOSs status to the application program and to transmit its logical decisions to remote outputs.

Procedure:
An application test program consisting of copying input status to outputs is run in four similar configurations:

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- local inputs to local outputs
- remote inputs to local outputs
- local inputs to remote outputs
- remote inputs to remote outputs

Pass/fail criteria:
The total system response times and the subsequent variations of transfer time(s) shall conform to the manufacturer's published specifications.

6.3.10.2 *Loss of communication test*

Requirement references: item 2 of 3.7.1, item 3 of 3.7.1 and item 6 of 3.7.2
When communication is removed, outputs shall assume a manufacturer's specified state within a manufacturer's specified interval without erratic or unintended behaviour, and the communication error shall be signaled to the user.

Procedure:
The test is performed by disconnecting a) the link, b) the RIOS external power supply, and observing the behaviour of the basic PC-system (i.e. of the MPU as well as of the RIOS and of their outputs).

Pass/fail criteria:
According to requirements.

6.3.10.3 *Verification of other requirements*

Type tests are not required; all characteristics non-tested shall be verifiable under a procedure to be agreed upon by the manufacturer and the user.

6.3.11 *Verification of peripheral characteristics*

Requirement reference: subclause 3.8.1
Type tests are not required; all characteristics non-tested shall be verifiable under a procedure to be agreed upon by the manufacturer and the user.

6.3.12 *Verification of basic PC-system self-tests and diagnostics*

Requirement reference: subclause 3.11.2
Type tests are not required; all characteristics non-tested shall be verifiable under a procedure to be agreed upon by the manufacturer and the user.

6.3.13 *Verification of markings and manufacturer's documentation*

Requirement references: subclause 4.12 and clause 5
Verify that requirements of 4.12 and clause 5 are met.

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6.4 *Routine tests*

6.4.1 *Dielectric strength tests*

The manufacturer shall either perform the standard test (see 6.4.1.1), or the optional test (see 6.4.1.2)

6.4.1.1 *Standard dielectric strength test (withstand test)*

Table 55 – Standard routine a.c. and d.c. dielectric strength withstand test

Requirement reference		Subclause 3.10		
Selection of sample(s) • SELV circuits • $0 < U_e \leq 50$ • $50 < U_e$ Test methods and application points		 No test Sample testing according to manufacturer's instructions All units shall be tested As specified in 6.3.6.1.1 (note 1)		
Rated voltage of circuit Ue (V a.c. r.m.s. or V d.c.) (note 3)		Test voltages at 0 m altitude (note 2) (V)		
For basic and supplementary insulations	For reinforced insulation (note 4)	Impulse, peak 1,2/50 µs (note 5)	A.C. r.m.s.	D.C. (note 6)
$0 < U_e \leq 50$		500	350	500
$50 < U_e \leq 100$	$0 < U_e \leq 50$	800	560	800
$100 < U_e \leq 150$	$50 < U_e \leq 100$	1 500	1 060	1 500
$150 < U_e \leq 300$	$100 < U_e \leq 150$	2 500	1 780	2 500
$300 < U_e \leq 600$	$150 < U_e \leq 300$	4 000	2 830	4 000
	$300 < U_e \leq 600$	6 000	4 230	6 000
Pass/fail criteria	There shall be no unintentional flashover or breakdown of the insulation during the test. Eventual operation of the protecting devices provided on the units shall not be considered as a failure.			

NOTES

1 When the assembly includes an equipotential conductor isolated from the accessible exposed conductive parts, it shall be regarded as an isolated circuit and shall be tested to the same voltage as the assembly to which it belongs.

2 See annex D: correction factor for testing at other altitudes. These test values are 1,27 times smaller than applicable type test values.

3 Rated voltage at the field wiring terminals of the device or circuit.

4 Class II and applicable class III circuits.

5 1,2 µs rise time; 50 µs wide at 1/2 amplitude; 0,6 J maximum energy.

6 Pulsed d.c.; pulsed width: 10 ms, rise and fall times not less than 1,2 µs.

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6.4.1.2 *Alternative dielectric strength test (withstand test)* (for class I equipment only)

The manufacturer may elect to use the following test which is more stringent than the standard test required in 6.4.1.1 for all rated voltages U_e smaller than 150 V. However, it must be noticed that the minimum values of clearance and creepage distances which are required in 4.3 may not be large enough to pass this test: therefore, in that case, it is recommended to refer to IEC 664 for designing the PC-system, and to adapt subsequently the values of the dielectric type test (see 6.3.6.1.1), where applicable.

Table 56 – Alternative routine a.c. and d.c. dielectric strength withstand test

Selection of sample(s) • SELV circuits	No test			
• $0 < U_e \leq 50$ • $50 < U_e$	Sample testing according to manufacturer's instructions All units shall be tested			
Test methods and application points	As specified in 6.3.6.1.1 (note 1)			
Dielectric test duration	It is the option of the manufacturer to perform the 1 s or 1 min test			
	Test voltages and durations (note 2)			
Rated voltage U_e (V)	A.C. voltage r.m.s. (V)		D.C. voltage (V)	
(note 3)	1 min	1 s	1 min	1 s
$U_e \leq 50$	500	600	700	850
$50 < U_e \leq 600$	1 000 + 2 U_e	1,2 x (1 000 + 2 U_e)	1,414 x (1 000 + 2 U_e)	1,414 x 1,2 x (1 000 + 2 U_e)
Pass/fail criteria	There shall be no unintentional flashover or breakdown of the insulation during the test. Eventual operation of the protecting devices provided on the units shall not be considered as a failure.			

NOTES

1 When the assembly includes an equipotential conductor isolated from the accessible exposed conductive parts, it shall be regarded as an isolated circuit and shall be tested to the same voltage as the assembly to which it belongs.

2 Regardless of altitude.

3 Rated voltage at the field wiring terminals of the device or circuit.

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6.4.2 *Protective earthing continuity test (withstand test)*

This test is intended to verify acceptable earthing continuity for all accessible metal parts intended to be earthed. The test shall be performed on all non-SELV rated voltage units.

The application points are between the earthing terminal or contact and the accessible metal parts intended to be earthed.

The resistance shall not exceed 0,1 Ω.

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Annex A
(normative)

Illustration of PC-system hardware definitions

The following figure A.1 illustrates the hardware in the PC-system as defined for the purposes of parts 1 and 2 of IEC 1131.

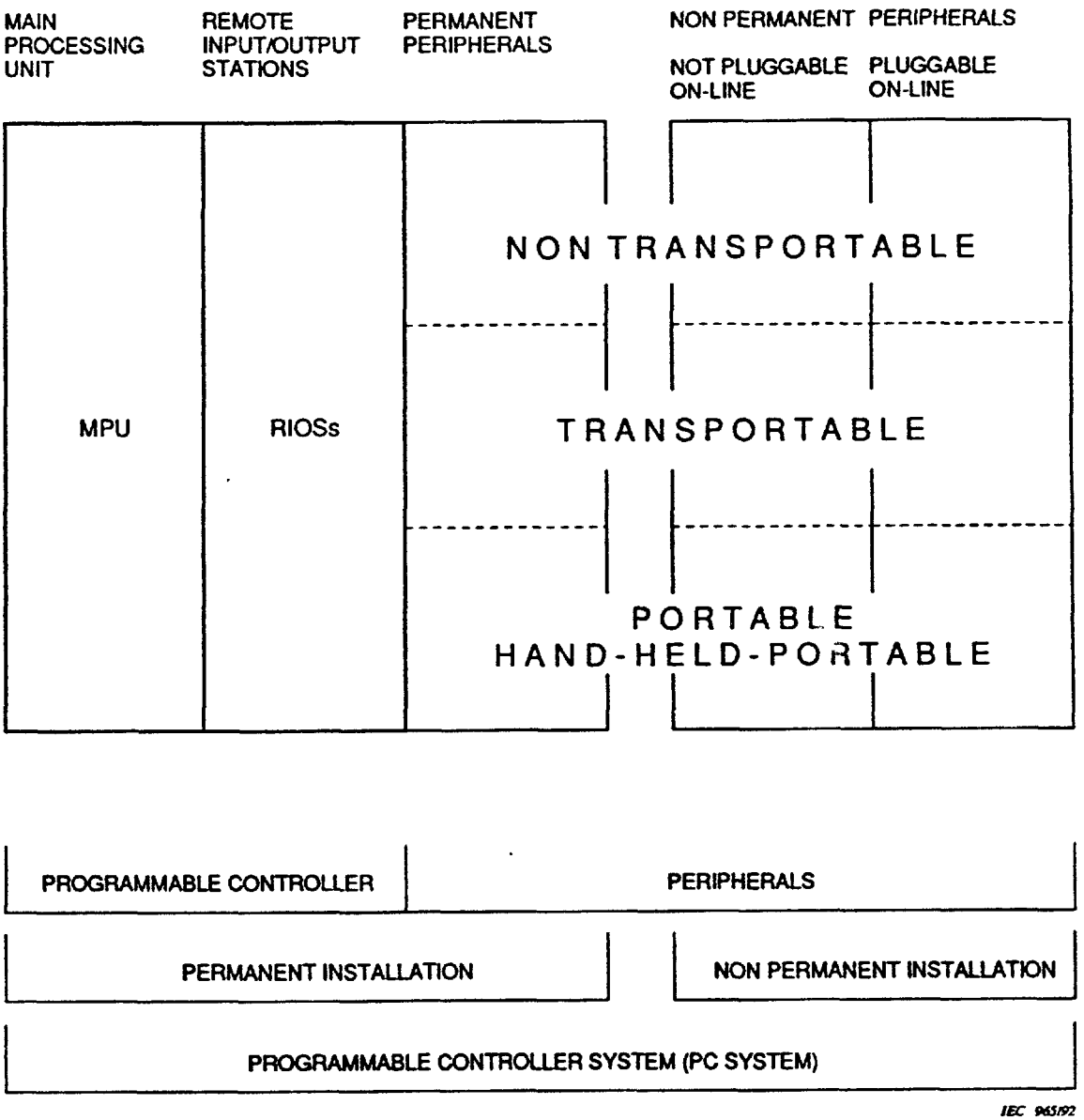


Figure A.1 – Programmable control system (PC-system)

Transportable, portable and hand-held portable peripherals have specific requirements and have to be distinguished from permanently installed peripherals (see 2.1.3.3, 3.9.2 and 4.5.3).

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Annex B
(normative)

Input table equations

The following equations were used to generate table 9 in 3.3.1.2 (with some exceptions explained in the notes).

D.C. equations	A.C. equations	
UH max. = 1,25 U_n	UH max. = 1,1 U_n	
UH min. = 0,8 U_n – U_{drop} – 1 V	UH min. = 0,85 U_n – U_{drop} – 1 V	(notes 1 et 2)
UT max. = UH min.	UT max. = UH min.	
UT min. = 0,2 U_n	UT min. = 0,2 U_n	(note 1)
UL max. = UH min. (I < IT min.)	UL max. = UH min. (I < IT min.)	
UL min. = –3 V (24 V d.c.)	UL min. = 0	
UL min. = –6 V (48 V d.c.)		
IT min. = $\frac{UH \text{ max.} - UT \text{ min.}}{Z}$	IT min. = I_{leak} + 1 mA (nominal voltages ≤ 120 V)	
	IT min. = I_{leak} + 2 mA (nominal voltages > 120 V)	
Z = Empirical worst case relay contact		
Open contact impedance = 100 kΩ		
UL min., = ND (Not defined)	IL min. = 0	
Type 1 inputs:	Type 1 inputs:	
IH max. = IT max. = IL max. = 15 mA	IH max. = IT max. = IL max. = 15 mA	
IH min. = IT min. + 1 mA	IH min. = IT min. + 1 mA	
U_{drop} = 3 V (3.3.3.1)	U_{drop} = 5 V (3.3.2.1)	Note 3
Type 2 inputs:	Type 2 inputs:	
IH max. = IT max. = IL max. = 30 mA	IH max. = IT max. = IL max. = 30 mA	
IH min. = I_{hold} + 1 mA	IH min. = I_{hold} + 1 mA	
I_{leak} = IT max. = 1,5 mA	I_{leak} = I_n max. = 3 mA	(note 4)
U_{drop} = UD max. = 8 V	U_{drop} = UD max. = 10 V a.c.	(note 4)
I_{hold} = I_a min. = 5 mA	I_{hold} = I_a min. = 5 mA	(note 4)

NOTES

1 For all 100/110/120 V a.c. and all 200/220/230/240 V a.c. inputs, U_n has been respectively selected as 100 V a.c. and 200 V a.c., in order to allow compatibility of a single module with various supply voltages.

2 1 V drop (a.c. r.m.s. or d.c.) is assumed for the connecting leads.

3 Maximum values of voltage drops of digital outputs for d.c. and a.c.

4 These values of I_{leak}, U_{drop} and I_{hold} are also those adopted in IEC 947-5-2.

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Annex C
(*informative*)

Recommended higher immunity levels for electrical noise tests

If higher immunity levels than the minimum stated in 3.9.1 are required, the following electrical noise severity levels given in table C.1 below are recommended as standard.

When severe noise conditions exist, levels higher than those given in this table are subject to agreement between the manufacturer and the user.

For further information regarding description of typical noise producing environments and the approximate severity levels, see IEC 1131-4 and IEC 801.

Table C.1 – Electrical noise tests for PC-system and stand-alone peripherals (notes 1 and 2)

Recommended levels higher than minimum required

Electrical noise tests		Electrical noise severity levels			Notes
	Maximum surge energy Minimum source impedance	All power supplies	Digital I/Os $U_e \geq 24$ V	Digital I/Os $U_e < 24$ V Analog I/Os, communication I/Os	
Electrostatic discharge – Level RH-2: ESD-4	150 pF/150 Ω	15 kV	15 kV	15 kV	3 and 4
Radiated electromagnetic field	–	10 V/m	10 V/m	10 V/m	3
Conducted noise – Fast transient Common mode	4 mJ/spike at 2 kV on 50 Ω	4 kV	2 kV	0,5 kV	3
– Damped oscillatory wave Series mode	200 Ω	2 kV	2 kV	–	3 and 5
For notes 1, 2, 3, 4 and 5, see table 16 in 3.9.1.					

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Annex D
(normative)

Correction factors for test voltages

Table D.1 – Correction factors for test voltages corresponding to barometric pressure or altitude

Altitude of test m	Barometric pressure kPa	Correction (multiplication) factor for test voltage (note)
0	101,3	1,27
500	95,0	1,19
1 000	90,0	1,13
2 000	80,0	1,00
3 000	70,0	0,88
4 000	62,0	0,78
5 000	54,0	0,68
6 000	47,0	0,59
7 000	41,0	0,51
8 000	35,5	0,44

NOTE - At a given altitude, corrections for normal variations in barometric pressure are disregarded.

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Annex E
(informative)

Testing of protected outputs

The following alternative method is under consideration for testing of protected outputs in addition to the method given in 6.3.8.3.2.

In the case of protected outputs, tests A, B, C, D and E may be replaced by the following method:

Test procedure:

- First series (at *T* min.)
  - Search and measurement of the threshold I_p of the protective function while causing the output load to vary slowly by using a variable resistor;
  - then, submitting the protective function to two tests of 5 min each, during which the protected output is loaded respectively at 1,1 I_p (prospective current) and at 0,9 I_p.
- Second series (at *T* max.)
  - Same as first series, but at *T* max.

Measurement and verification:

- As specified in 6.3.8.3.2.

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NEMA STANDARDIZATION BACKGROUND

The purpose of NEMA standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

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National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 1)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 6)

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(Standardization Policies and Procedures, pp. 5)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 5)

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Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword or throughout the text.

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