



BSI Standards Publication

Audio/video, information and communication technology equipment

Part 2: Explanatory information related to IEC 62368-1:2018

National foreword

This Published Document is the UK implementation of IEC TR 62368-2:2019. It supersedes PD IEC/TR 62368-2:2015, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EPL/108, Safety of electronic equipment within the field of audio/video, information technology and communication technology.

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

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TECHNICAL REPORT

RAPPORT TECHNIQUE



**Audio/video, information and communication technology equipment –
Part 2: Explanatory information related to IEC 62368-1:2018**

**Équipements des technologies de l'audio/vidéo, de l'information
et de la communication –
Partie 2: Précisions relatives à l'IEC 62368-1:2018**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONALE

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CONTENTS

FOREWORD	6
INTRODUCTION	9
0 Principles of this product safety standard	10
1 Scope	12
2 Normative references	13
3 Terms, definitions and abbreviations	13
4 General requirements	16
5 Electrically-caused injury	23
6 Electrically-caused fire	70
7 Injury caused by hazardous substances	105
8 Mechanically-caused injury	109
9 Thermal burn injury	117
10 Radiation	126
Annex A Examples of equipment within the scope of this standard	133
Annex B Normal operating condition tests, abnormal operating condition tests and single fault condition tests	133
Annex C UV Radiation	136
Annex D Test generators	136
Annex E Test conditions for equipment containing audio amplifiers	137
Annex F Equipment markings, instructions, and instructional safeguards	137
Annex G Components	138
Annex H Criteria for telephone ringing signals	146
Annex J Insulated winding wires for use without interleaved insulation	148
Annex K Safety interlocks	148
Annex L Disconnect devices	148
Annex M Equipment containing batteries and their protection circuits	149
Annex O Measurement of creepage distances and clearances	158
Annex P Safeguards against conductive objects	158
Annex Q Circuits intended for interconnection with building wiring	159
Annex R Limited short-circuit test	160
Annex S Tests for resistance to heat and fire	160
Annex T Mechanical strength tests	162
Annex U Mechanical strength of CRTs and protection against the effects of implosion	163
Annex V Determination of accessible parts	163
Annex X Alternative method for determining clearances for insulation in circuits connected to an AC mains not exceeding 420 V peak (300 V RMS)	163
Annex Y Construction requirements for outdoor enclosures	164
Annex A (informative) Background information related to the use of SPDs	167
Annex B (informative) Background information related to measurement of discharges – Determining the R-C discharge time constant for X- and Y-capacitors	180
Annex C (informative) Background information related to resistance to candle flame ignition	192

Bibliography.....	193
Figure 1 – Risk reduction as given in ISO/IEC Guide 51.....	11
Figure 2 – HBSE Process Chart.....	12
Figure 3 – Protective bonding conductor as part of a safeguard.....	15
Figure 4 – Safeguards for protecting an ordinary person.....	19
Figure 5 – Safeguards for protecting an instructed person.....	19
Figure 6 – Safeguards for protecting a skilled person.....	20
Figure 7 – Flow chart showing the intent of the glass requirements.....	22
Figure 8 – Conventional time/current zones of effects of AC currents (15 Hz to 100 Hz) on persons for a current path corresponding to left hand to feet (see IEC/TS 60479-1:2005, Figure 20).....	25
Figure 9 – Conventional time/current zones of effects of DC currents on persons for a longitudinal upward current path (see IEC/TS 60479-1:2005, Figure 22).....	26
Figure 10 – Illustration that limits depend on both voltage and current.....	27
Figure 11 – Illustration of working voltage.....	39
Figure 12 – Illustration of transient voltages on paired conductor external circuits.....	41
Figure 13 – Illustration of transient voltages on coaxial-cable external circuits.....	42
Figure 14 – Basic and reinforced insulation in Table 14 of IEC 62368-1:2018; ratio reinforced to basic.....	43
Figure 15 – Reinforced clearances according to Rule 1, Rule 2, and Table 14.....	45
Figure 16 – Example illustrating accessible internal wiring.....	53
Figure 17 – Waveform on insulation without surge suppressors and no breakdown.....	56
Figure 18 – Waveforms on insulation during breakdown without surge suppressors.....	57
Figure 19 – Waveforms on insulation with surge suppressors in operation.....	57
Figure 20 – Waveform on short-circuited surge suppressor and insulation.....	57
Figure 21 – Example for an ES2 source.....	59
Figure 22 – Example for an ES3 source.....	59
Figure 23 – Overview of protective conductors.....	61
Figure 24 – Example of a typical touch current measuring network.....	64
Figure 25 – Touch current from a floating circuit.....	66
Figure 26 – Touch current from an earthed circuit.....	67
Figure 27 – Summation of touch currents in a PABX.....	67
Figure 28 – Possible safeguards against electrically-caused fire.....	75
Figure 29 – Fire clause flow chart.....	78
Figure 30 – Prevent ignition flow chart.....	83
Figure 31 – Control fire spread summary.....	85
Figure 32 – Control fire spread PS2.....	86
Figure 33 – Control fire spread PS3.....	87
Figure 34 – Fire cone application to a large component.....	96
Figure 35 – Flowchart demonstrating the hierarchy of hazard management.....	108
Figure 36 – Model for chemical injury.....	109
Figure 37 – Direction of forces to be applied.....	114
Figure 38 – Model for a burn injury.....	117

Figure 39 – Model for safeguards against thermal burn injury	119
Figure 40 – Model for absence of a thermal hazard.....	120
Figure 41 – Model for presence of a thermal hazard with a physical safeguard in place	120
Figure 42 – Model for presence of a thermal hazard with behavioural safeguard in place.....	120
Figure 43 – Flowchart for evaluation of Image projectors (beamers)	128
Figure 44 – Graphical representation of $L_{Aeq,T}$	130
Figure 45 – Overview of operating modes	135
Figure 46 – Voltage-current characteristics (Typical data).....	140
Figure 47 – Example of IC current limiter circuit.....	144
Figure 48 – Current limit curves	147
Figure 49 – Example of a dummy battery circuit.....	157
Figure 50 – Example of a circuit with two power sources.....	160
Figure A.1 – Installation has poor earthing and bonding; equipment damaged (from ITU-T K.66).....	168
Figure A.2 – Installation has poor earthing and bonding; using main earth bar for protection against lightning strike (from ITU-T K.66)	168
Figure A.3 – Installation with poor earthing and bonding, using a varistor and a GDT for protection against a lightning strike.....	169
Figure A.4 – Installation with poor earthing and bonding; equipment damaged (TV set)	169
Figure A.5 – Safeguards	170
Figure A.6 – Discharge stages	174
Figure A.7 – Holdover	175
Figure A.8 – Discharge	176
Figure A.9 – Characteristics.....	177
Figure A.10 – Follow on current pictures	178
Figure B.1 – Typical EMC filter schematic.....	180
Figure B.2 – 100 MΩ oscilloscope probes	182
Figure B.3 – Combinations of EUT resistance and capacitance for 1-s time constant.....	184
Figure B.4 – 240 V mains followed by capacitor discharge.....	186
Figure B.5 – Time constant measurement schematic	187
Figure B.6 – Worst-case measured time constant values for 100 MΩ and 10 MΩ probes	191
Table 1 – General summary of required safeguards	20
Table 2 – Time/current zones for AC 15 Hz to 100 Hz for hand to feet pathway (see IEC/TS 60479-1:2005, Table 11).....	26
Table 3 – Time/current zones for DC for hand to feet pathway (see IEC/TS 60479- 1:2005, Table 13).....	27
Table 4 – Limit values of accessible capacitance (threshold of pain).....	30
Table 5 – Total body resistances R_T for a current path hand to hand, DC, for large surface areas of contact in dry condition	32
Table 6 – Insulation requirements for external circuits	42
Table 7 – Voltage drop across clearance and solid insulation in series	47
Table 8 – Examples of application of various safeguards	77

Table 9 – Basic safeguards against fire under normal operating conditions and abnormal operating conditions	79
Table 10 – Supplementary safeguards against fire under single fault conditions	80
Table 11 – Method 1: Reduce the likelihood of ignition	82
Table 12 – Method 2: Control fire spread	91
Table 13 – Fire barrier and fire enclosure flammability requirements.....	98
Table 14 – Summary – Fire enclosure and fire barrier material requirements	102
Table 15 – Control of chemical hazards	107
Table 16 – Overview of requirements for dose-based systems	132
Table 17 – Safety of batteries and their cells – requirements (expanded information on documents and scope).....	151
Table B.1 – 100- MΩ oscilloscope probes	182
Table B.2 – Capacitor discharge	183
Table B.3 – Maximum $T_{measured}$ values for combinations of R_{EUT} and C_{EUT} for T_{EUT} of 1 s	190

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**AUDIO/VIDEO, INFORMATION AND
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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example, "state of the art".

IEC 62368-2, which is a Technical Report, has been prepared by IEC technical committee TC 108: Safety of electronic equipment within the field of audio/video, information technology and communication technology.

This third edition updates the second edition of IEC 62368-2 published in 2014 to take into account changes made to IEC 62368-1:2014 as identified in the Foreword of IEC 62368-1:2018.

This Technical Report is informative only. In case of a conflict between IEC 62368-1 and IEC TR 62368-2, the requirements in IEC 62368-1 prevail over this Technical Report.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
108/708/DTR	108/711/RVDTR

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

In this document, the following print types are used:

- notes/explanatory matter: in smaller roman type;
- tables and figures that are included in the rationale have linked fields (shaded in grey if “field shading” is active);
- terms that are defined in IEC 62368-1: in **bold type**.

In this document, where the term (HBSDT) is used, it stands for Hazard Based Standard Development Team, which is the Working Group of IEC TC 108 responsible for the development and maintenance of IEC 62368-1.

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

A list of all parts of the IEC 62368 series can be found, under the general title *Audio/video, information and communication technology equipment*, on the IEC website.

In this document, only those subclauses from IEC 62368-1 considered to need further background reference information or explanation to benefit the reader in applying the relevant requirements are included. Therefore, not all numbered subclauses are cited. Unless otherwise noted, all references are to clauses, subclauses, annexes, figures or tables located in IEC 62368-1:2018.

The entries in the document may have one or two of the following subheadings in addition to the Rationale statement:

Source – where the source is known and is a document that is accessible to the general public, a reference is provided.

Purpose – where there is a need and when it may prove helpful to the understanding of the Rationale, we have added a Purpose statement.

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

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

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INTRODUCTION

IEC 62368-1 is based on the principles of hazard-based safety engineering, which is a different way of developing and specifying safety considerations than that of the current practice. While this document is different from traditional IEC safety documents in its approach and while it is believed that IEC 62368-1 provides a number of advantages, its introduction and evolution are not intended to result in significant changes to the existing safety philosophy that led to the development of the safety requirements contained in IEC 60065 and IEC 60950-1. The predominant reason behind the creation of IEC 62368-1 is to simplify the problems created by the merging of the technologies of ITE and CE. The techniques used are novel, so a learning process is required and experience is needed in its application. Consequently, the committee recommends that this edition of the document be considered as an alternative to IEC 60065 or IEC 60950-1 at least over the recommended transition period.

AUDIO/VIDEO, INFORMATION AND COMMUNICATION TECHNOLOGY EQUIPMENT –

Part 2: Explanatory information related to IEC 62368-1:2018

0 Principles of this product safety standard

Clause 0 is informational and provides a rationale for the normative clauses of the document.

0.5.1 General

ISO/IEC Guide 51:2014, 6.3.5 states:

“When reducing risks the order of priority shall be as follows:

- a) inherently safe design;*
- b) guards and protective devices;*
- c) information for end users.*

Inherently safe design measures are the first and most important step in the risk reduction process. This is because protective measures inherent to the characteristics of the product or system are likely to remain effective, whereas experience has shown that even well-designed guards and protective devices can fail or be violated and information for use might not be followed.

Guards and protective devices shall be used whenever an inherently safe design measure does not reasonably make it possible either to remove hazards or to sufficiently reduce risks. Complementary protective measures involving additional equipment (for example, emergency stop equipment) might have to be implemented.

The end user has a role to play in the risk reduction procedure by complying with the information provided by the designer/supplier. However, information for use shall not be a substitute for the correct application of inherently safe design measures, guards or complementary protective measures.”

In general, this principle is used in IEC 62368-1. The table below shows a comparison between the hierarchy required in ISO/IEC Guide 51 and the hierarchy used in IEC 62368-1:2018:

ISO/IEC Guide 51	IEC 62368-1
a) inherently safe design	1. inherently safe design by limiting all energy hazards to class 1
b) guards and protective devices	2. equipment safeguards
	3. installation safeguards
	4. personal safeguards
c) information for end users	5. behavioral safeguards
	6. instructional safeguards

Risk assessment has been considered as part of the development of IEC 62368-1 as indicated in the following from ISO/IEC Guide 51 (Figure 1) in this document. See also the Hazard Based Safety Engineering (HBSE) Process Flow (Figure 2) in this document that also provides additional details for the above comparison.

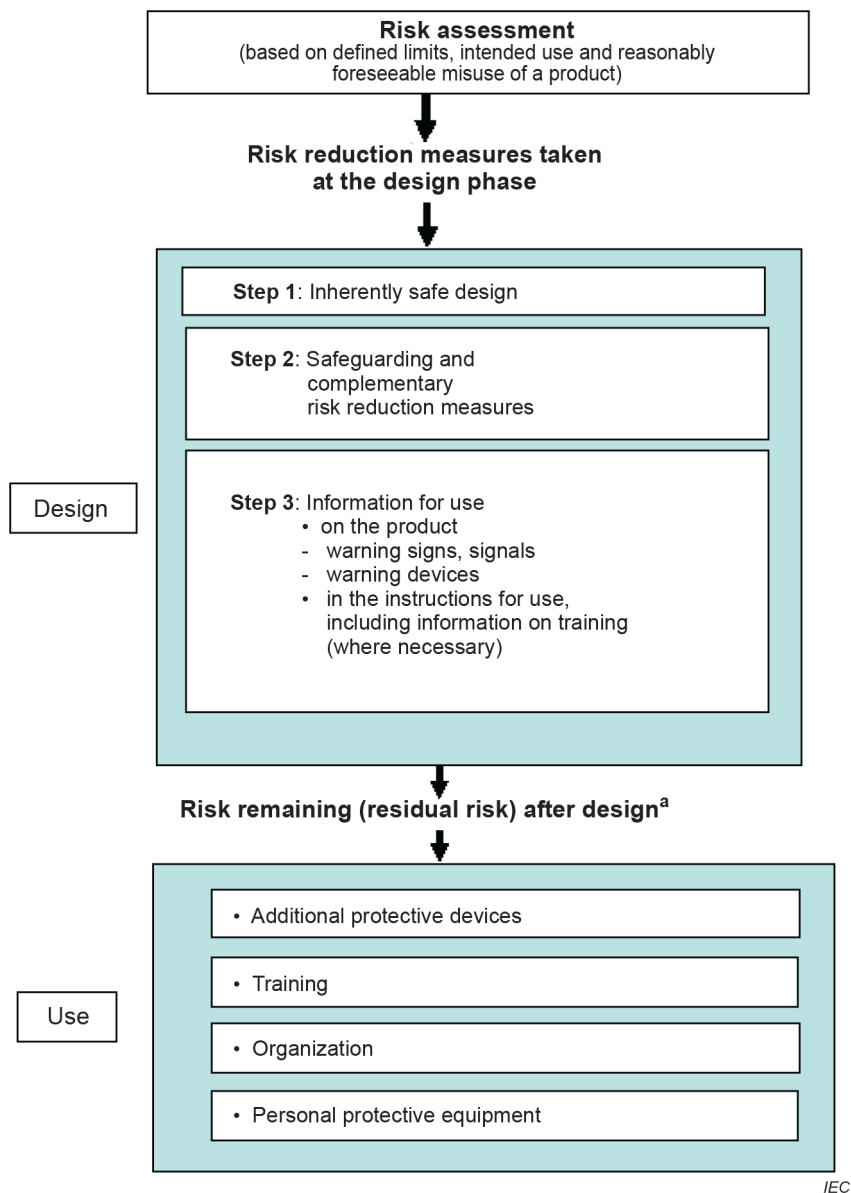


Figure 1 – Risk reduction as given in ISO/IEC Guide 51

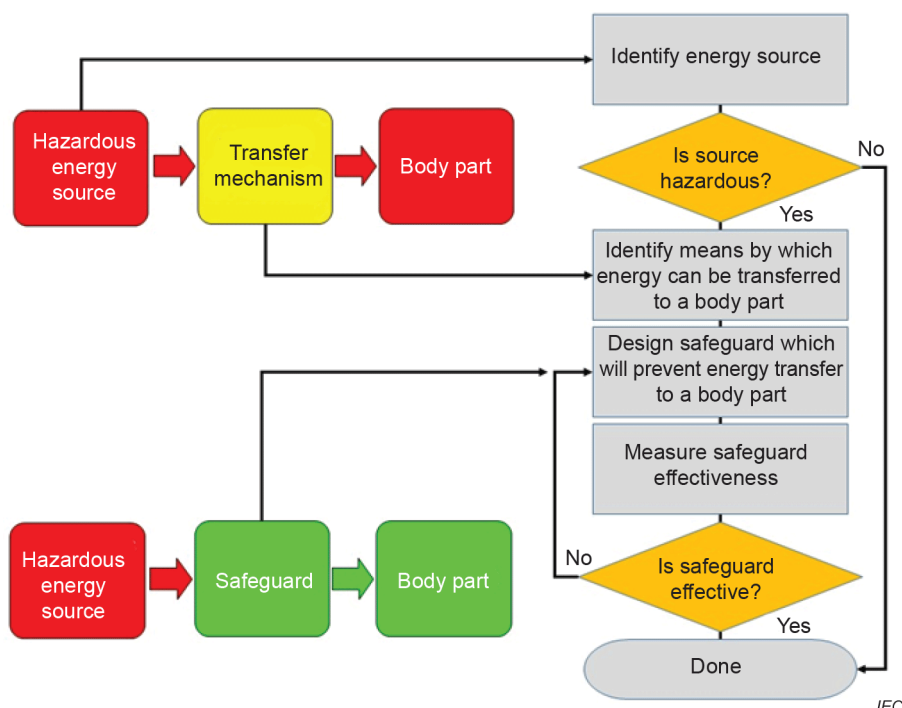


Figure 2 – HBSE Process Chart

0.5.7 Equipment safeguards during skilled person service conditions

Purpose: To explain the intent of requirements for providing **safeguards** against involuntary reaction.

Rationale: By definition, a **skilled person** has the education and experience to identify all class 3 energy sources to which he may be exposed. However, while servicing one class 3 energy source in one location, a **skilled person** may be exposed to another class 3 energy source in a different location.

In such a situation, either of two events is possible. First, something may cause an involuntary reaction of the **skilled person** with the consequences of contact with the class 3 energy source in the different location. Second, the space in which the **skilled person** is located may be small and cramped, and inadvertent contact with a class 3 energy source in the different location may be likely.

In such situations, this document may require an **equipment safeguard** solely for the protection of a **skilled person** while performing servicing activity.

1 Scope

Purpose: To identify the purpose and applicability of this document and the exclusions from the scope.

Rationale: The scope excludes requirements for functional safety. Functional safety is addressed in IEC 61508-1. Because the scope includes computers that may control safety systems, functional safety requirements would necessarily include requirements for computer processes and software.

The requirements provided in IEC 60950-23 could be modified and added to IEC 62368 as another –X document. However, because of the hazard-based nature of IEC 62368-1, the requirements from IEC 60950-23 have been incorporated into the body of IEC 62368-1 and made more generic.

The intent of the addition of the IEC 60950-23 requirements is to maintain the overall intent of the technical requirements from IEC 60950-23, incorporate them into IEC 62368-1 following the overall format of IEC 62368-1 and simplify and facilitate the application of these requirements.

Robots traditionally are covered under the scopes of ISO documents, typically maintained by ISO TC 299. ISO TC 299 has working groups for personal care robots and service robots, and produces for example, ISO 13482, *Robots and robotic devices – Safety requirements for personal care robots*.

2 Normative references

The list of normative references is a list of all documents that have a normative reference to it in the body of the document. As such, referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Recently, there were some issues with test houses that wanted to use the latest edition as soon as it was published. As this creates serious problems for manufacturers, since they have no chance to prepare, it was felt that a reasonable transition period should be taken into account. This is in line with earlier decisions taken by the SMB that allow transition periods to be mentioned in the foreword of the documents. Therefore IEC TC 108 decided to indicate this in the introduction of the normative references clause, to instruct test houses to take into account any transition period, effective date or date of withdrawal established for the document.

These documents are referenced, in whole, in part, or as alternative requirements to the requirements contained in this document. Their use is specified, where necessary, for the application of the requirements of this document. The fact that a standard is mentioned in the list does not mean that compliance with the document or parts of it are required.

3 Terms, definitions and abbreviations

Rationale is provided for definitions that deviate from IEC definitions or from Basic or Group Safety publication definitions.

3.3.2.1 electrical enclosure

Source: IEC 60050-195:1998, 195-06-13

Purpose: To support the concept of **safeguards** as used in this document.

Rationale: The IEC definition is modified to use the term “**safeguard**” in place of the word “protection”. The word “**safeguard**” identifies a physical “thing” whereas the word “protection” identifies the act of protecting. This document sets forth requirements for use of physical **safeguards** and requirements for those **safeguards**. The **safeguards** provide “protection” against injury from the equipment.

3.3.5.1 basic insulation

- Source: IEC 60050-195:1998, 195-06-06
- Purpose: To support the concept of **safeguards** as used in this document.
- Rationale: The IEV definition is modified to use the term “**safeguard**” in place of the word “protection”. The word “**safeguard**” identifies a physical “thing” whereas the word “protection” identifies the act of protecting. This document sets forth requirements for use of physical **safeguards** and requirements for those **safeguards**. The **safeguards** provide “protection” against injury from the equipment.

3.3.5.2 double insulation

- Source: IEC 60050-195:1998, 195-06-08
- Purpose: To support the concept of **safeguards** as used in this document.
- Rationale: See 3.3.5.1, **basic insulation**.

3.3.5.6 solid insulation

- Source: IEC 60050-212:2015, 212-11-02

3.3.5.7 supplementary insulation

- Source: IEC 60050-195:1998, 195-06-07
- Purpose: To support the concept of **safeguards** as used in this document.
- Rationale: See 3.3.5.1, **basic insulation**.

3.3.6.9 restricted access area

- Source: IEC 60050-195:1998, 195-04-04
- Purpose: To use the concept of “**instructed persons**” and “**skilled persons**” as used in this document.
- Rationale: The IEV definition is modified to use the terms “**instructed persons**” and “**skilled persons**” rather than “electrically **instructed persons**” and “electrically **skilled persons**.”

3.3.7.7 reasonably foreseeable misuse

- Source: ISO/IEC Guide 51:2014, 3.7
- Rationale: Misuse depends on personal objectives, personal perception of the equipment, and the possible use of the equipment (in a manner not intended by the manufacturer) to accomplish those personal objectives. Equipment within the scope of this document ranges from small handheld equipment to large, permanently installed equipment. There is no commonality among the equipment for readily predicting human behaviour leading to misuse of the equipment and resultant injury. Where a possible **reasonably foreseeable misuse** that may lead to an injury is not covered by the requirements of the document, manufacturers are encouraged to consider **reasonably foreseeable misuse** of equipment and provide **safeguards**, as applicable, to prevent injury in the event of such misuse. (Not all **reasonably foreseeable misuse** of equipment results in injury or potential for injury.)

3.3.8.1 instructed person

- Source: IEC 60050-826:2004, 826-18-02
- Rationale: The IEV definition is modified to use the terms “energy sources”, “**skilled person**”, and “**precautionary safeguard**”. The definition is made stronger by using the term “instructed” rather than “advised”.

3.3.8.3 skilled person

Source: IEC 60050-826:2004, 826-18-01

Rationale: The IEC definition is modified to use the phrase “to reduce the likelihood of”. IEC 62368-1, in general, tends not use the word “hazard”.

3.3.11.9 protective bonding conductor

Rationale: The **protective bonding conductor**, is not a complete **safeguard**, but a component part of the earthing system **safeguard**. The **protective bonding conductor** provides a fault current pathway from a part (insulated from ES3 by **basic insulation** only) to the equipment **protective earthing** terminal, see Figure 3 in this document.

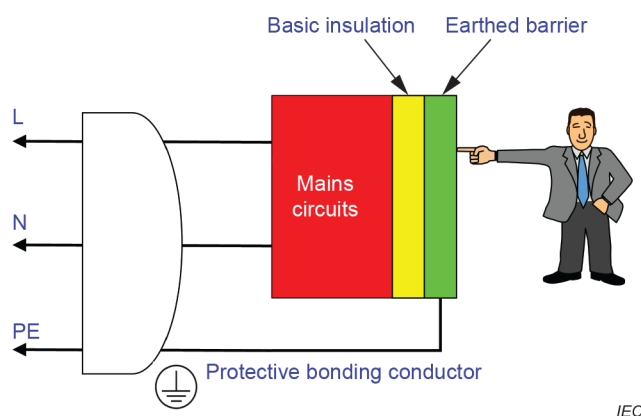


Figure 3 – Protective bonding conductor as part of a safeguard

The parts required to be earthed via a **protective bonding conductor** are those that have only **basic insulation** between the parts and ES3, and are connected to **accessible** parts.

Only the fault current pathway is required to be a **protective bonding conductor**. Other earthing connections of **accessible** conductive parts can be by means of a functional earth conductor to the equipment PE terminal or to a **protective bonding conductor**.

3.3.14.3 prospective touch voltage

Source: IEC 60050-195:1998, 195-05-09

Purpose: To properly identify electric shock energy source voltages.

Rationale: The IEC definition is modified to delete “animal”. The word “person” is also deleted as all of the requirements in the document are with respect to persons.

3.3.14.8 working voltage

Source: IEC 60664-1:2007, 3.5

Purpose: To distinguish between **RMS. working voltage** and the peak of the **working voltage**.

Rationale: The IEC 60664-1 definition is modified to delete “RMS”. IEC 62368-1 uses both **RMS. working voltage** and peak of the **working voltage**; each term is defined.

3.3.15.2 class II construction

Source: IEC 60335-1:2010, 3.3.11

Purpose: Although the term is not used in the document, for completeness, it was decided to retain this definition.

Rationale: The word “appliance” is changed to “equipment”.

4 General requirements

Purpose: To explain how to investigate and determine whether or not safety is involved.

Rationale: In order to establish whether or not safety is involved, the circuits and construction are investigated to determine whether the consequences of possible fault conditions would lead to an injury. Safety is involved if, as a result of a **single fault condition**, the consequences of the fault lead to a risk of injury.

If a fault condition should lead to a risk of injury, the part, material, or device whose fault was simulated may comprise a **safeguard**.

Rationale is provided for questions regarding the omission of some traditional requirements appearing in other safety documents. Rationale is also provided for further explanation of new concepts and requirements in this document.

Reasonable foreseeable misuse

Rationale: Apart from Annex M, this document does not specifically mention foreseeable misuse or **abnormal operating conditions**. Nevertheless, the requirements of the document cover many kinds of foreseeable misuse, such as covering of ventilation openings, paper jams, stalled motors, etc.

functional insulation

Rationale: This document does not include requirements for **functional insulation**. By its nature, **functional insulation** does not provide a **safeguard** function against electric shock or electrically-caused fire and therefore may be faulted. Obviously, not all **functional insulations** are faulted as this would be prohibitively time-consuming. Sites for **functional insulation** faults should be based upon physical examination of the equipment, and upon the electrical schematic.

Note that **basic insulation** and **reinforced insulation** may also serve as **functional insulation**, in which case the insulation is not faulted.

functional components

Rationale: This document does not include requirements for functional components. By their nature, individual functional components do not provide a **safeguard** function against electric shock, electrically-caused fire, thermal injury, etc., and therefore may be candidates for fault testing. Obviously, not all functional components are faulted as this would be prohibitively time-consuming. Candidate components for fault testing should be based upon physical examination of the equipment, upon the electrical schematic diagrams, and whether a fault of that component might result in conditions for electric shock, conditions for ignition and propagation of fire, conditions for thermal injury, etc.

As with all **single fault condition** testing (Clause B.4), upon faulting of a functional component, there shall not be any safety consequence (for example, a benign consequence), or a **basic safeguard**, **supplementary safeguard**, or **reinforced safeguard** shall remain effective.

In some cases, a pair of components may comprise a **safeguard**. If the fault of one of the components in the pair is mitigated by the second component, then the pair is designated as a **double safeguard**. For example, if two diodes are employed in series to protect a **battery** from reverse charge, then the pair comprises a **double safeguard** and the components should be limited to the manufacturer and part number actually tested. A second example is that of an X-capacitor and discharge resistor. If the discharge resistor should fail open, then the X-capacitor will not be discharged. Therefore, the X-capacitor value is not to exceed the ES2 limits specified for a charged capacitor. Again, the two components comprise a **double safeguard** and the values of each component are limited to values for ES1 under **normal operating conditions** and the values for ES2 under **single fault conditions**.

4.1.1 Application of requirements and acceptance of materials, components and subassemblies

Purpose: To accept components as **safeguards**.

Rationale: This document includes requirements for **safeguard** components. A **safeguard** component is a component specifically designed and manufactured for both functional and **safeguard** parameters. Examples of **safeguard** components are capacitors complying with IEC 60384-14 and other components that comply with their related IEC component document.

Acceptance of components and component requirements from IEC 60065 and 60950-1

Purpose: To accept both components and sub-assemblies investigated to the legacy documents, IEC 60065 and IEC 60950-1, and components complying with individual component requirements within these documents during the transition period.

Rationale: To facilitate a smooth transition from the legacy documents IEC 60065 and IEC 60950-1 to IEC 62368-1, including by the component supply chain, this document allows for acceptance of both components and sub-assemblies investigated to the legacy documents. Individual component requirements within these documents may be used for compliance with IEC 62368-1 without further investigation, other than to give consideration to the appropriate use of the component or sub-assembly in the end-product.

This means, for example, if a switch mode power supply is certified to IEC 60065 or IEC 60950-1, this component can be used in equipment evaluated to IEC 62368-1 without further investigation, other than to give consideration to the appropriate use of the component, such as use within its electrical ratings.

This also means, for example, since IEC 60950-1 allows for wiring and cables insulated with PVC, TFE, PTFE, FEP, polychloroprene or polyimide to comply with material requirements for parts within a **fire enclosure** without need for the application of a flammability test, the same wire can be used to comply with the requirements in 6.5.2 for insulation on wiring used in PS2 or PS3 circuits and without the need for application of a flammability test per IEC 60332 series or IEC TS 60695-11-21 as normally is required by 6.5.1.

4.1.5 Constructions and components not specifically covered

For constructions not covered, consideration should be given for the hierarchy of safeguards in accordance with ISO/IEC Guide 51.

4.1.6 Orientation during transport and use

See also 4.1.4

In general, equipment is assumed to be installed and used in accordance with the manufacturer's instructions. However, in some cases where equipment may be installed by an **ordinary person**, it is recognized that it is common practice to mount equipment as desired if screw holes are provided, especially if they allow mounting to readily available brackets. Hence, the exception that is added to 4.1.6.

Examples of the above: a piece of equipment, such as a television set or a video projector, that has embedded screw mounting holes that allow it to be attached to a wall or other surface through the use of commercially available vertically or tilt-mountable brackets, shall also take into account that the mounting surface itself may not be vertical.

It is also recognized that **transportable equipment**, by its nature, may be transported in any and all orientations.

4.1.8 Liquids and liquid filled components (LFC)

The one-litre (1 l) restriction was placed in 4.1.8 since the origin of some of the requirements in Clause G.15 came from requirements in documents often applied to smaller systems. Nevertheless, such a limitation does not always negate the allowed application of 4.1.8 and Clause G.15 to systems with larger volumes of liquid, but it could impact direct (automatic) applicability to the larger systems.

4.2 Energy source classifications

Classification of energy sources may be done whether the source is **accessible** or not. The requirements for parts may differ on whether the part is **accessible** or not.

4.2.1 Class 1 energy source

A class 1 energy source is a source that is expected not to create any pain or injury. Therefore, a class 1 energy source may be **accessible** by any person.

Under some specific conditions of abnormal operation or **single fault conditions**, a class 1 energy source may reach class 2 limits. However, this source still remains a class 1 energy source. In this case, an **instructional safeguard** may be required.

Under **normal operating conditions** and **abnormal operating conditions**, the energy in a class 1 source, in contact with a body part, may be detectable, but is not painful nor is it likely to cause an injury. For fire, the energy in a class 1 source is not likely to cause ignition.

Under **single fault conditions**, a class 1 energy source, under contact with a body part, may be painful, but is not likely to cause injury.

4.2.2 Class 2 energy source

A class 2 energy source is a source that may create pain, but which is unlikely to create any serious injury. Therefore, a class 2 energy source may not be **accessible** by an **ordinary person**. However, a class 2 energy source may be **accessible** by:

- an **instructed person**; and
- a **skilled person**.

The energy in a class 2 source, under contact with a body part, may be painful, but is not likely to cause an injury. For fire, the energy in a class 2 source can cause ignition under some conditions.

4.2.3 Class 3 energy source

A class 3 energy source is a source that is likely to create an injury. Therefore a class 3 energy source may not be **accessible** to an **ordinary person** or an **instructed person**. A class 3 energy source may, in general, be **accessible** to a **skilled person**.

Any source may be declared a class 3 energy source without measurement, in which case all the **safeguards** applicable to class 3 are required.

The energy in a class 3 source, under contact with a body part, is capable of causing injury. For fire, the energy in a class 3 source may cause ignition and the spread of flame where fuel is available.

4.3.2 Safeguards for protection of an ordinary person

The required **safeguards** for the protection of an **ordinary person** are given in Figure 4.

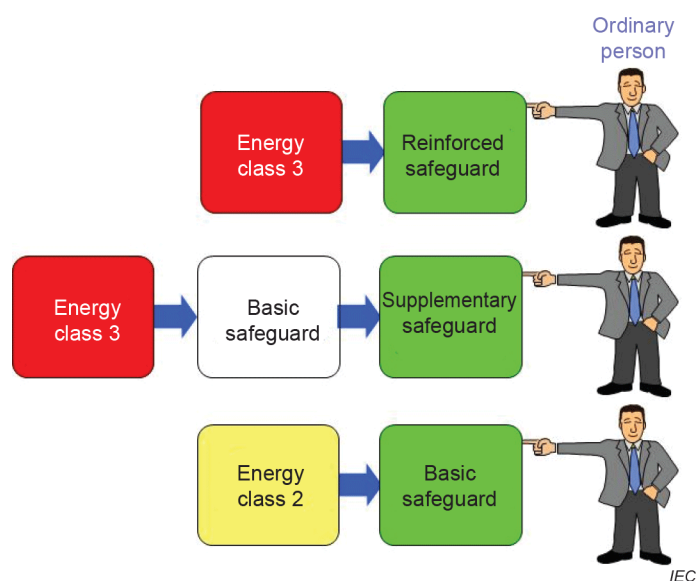


Figure 4 – Safeguards for protecting an ordinary person

4.3.3 Safeguards for protection of an instructed person

The required **safeguards** for the protection of an **instructed person** are given in Figure 5.

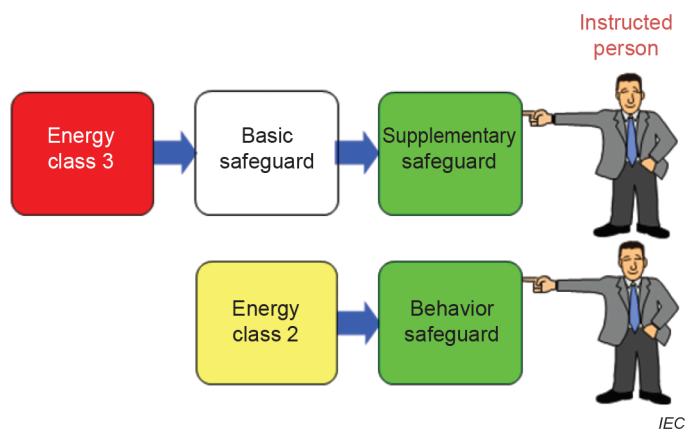


Figure 5 – Safeguards for protecting an instructed person

4.3.4 Safeguards for protection of a skilled person

The required **safeguards** for the protection of a **skilled person** are given in Figure 6.

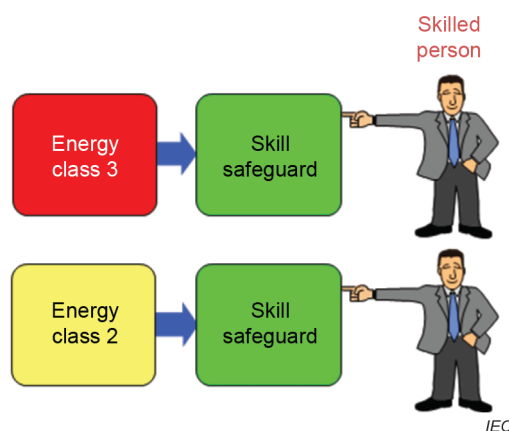


Figure 6 – Safeguards for protecting a skilled person

Table 1 in this document gives a general overview of the required number of **safeguards** depending on the energy source and the person to whom the energy source is **accessible**. The different clauses have requirements that sometimes deviate from the general principle as given above. These cases are clearly defined in the requirements sections of the document.

Table 1 – General summary of required safeguards

Person	Number of safeguards required to be interposed between an energy source and a person		
	Class 1	Class 2	Class3
Ordinary person	0	1	2
Instructed person	0	0	2
Skilled person	0	0	0 or 1

For a **skilled person**, there is normally no **safeguard** required for a class 3 energy source. However, if there are multiple class 3 energy sources **accessible** or if the energy source is not obvious, a **safeguard** may be required.

4.4.2 Composition of a safeguard

Purpose: To specify design and construction criteria for a single **safeguard** (basic, supplementary, or reinforced) comprised of more than one element, for example, a component or a device.

Rationale: **Safeguards** need not be a single, homogeneous component. Indeed, some parts of this document require a single **safeguard** be comprised of two or more elements. For example, for thin insulation, two or more layers are required to qualify as **supplementary insulation**. Another example is protective bonding and **protective earthing**, both of which are comprised of wires, terminals, screws, etc.

If a **safeguard** is comprised of two or more elements, then the function of the **safeguard** should not be compromised by a failure of any one element. For example, if a screw attaching a **protective earthing** wire should loosen, then the current-carrying capacity of the **protective earthing** circuit may be compromised, making its reliability uncertain.

4.4.3 Safeguard robustness

Rationale: **Safeguards** should be sufficiently robust to withstand the rigors of expected use throughout the equipment lifetime. Robustness requirements are specified in the various clauses.

4.4.3.4 Impact test

Rationale: **Stationary equipment** can, in some cases, be developed for a specific installation in which it is not possible for certain surfaces to be subjected to an impact when installed as intended. In those cases, the impact test is not necessary when the installation makes clear that the side cannot be impacted.

4.4.3.6 Glass impact tests

Source: IEC 60065

Purpose: Verify that any glass that breaks does not cause skin-lacerating injury, or expose class 3 hazards behind the glass.

Rationale: When it comes to glass, two hazards can be present in case the glass breaks:

- access to sharp edges from the broken glass itself
- exposure of class 3 energy hazards in case the glass is used as (part of) the **enclosure**.

Should the glass break during the impact test, T.9 is applied to ensure the expelled fragments will be at MS2 level or less.

Platen glass has a long history of being exempted, because it is quite obvious for people that, if broken, the broken glass is hazardous and contact should be avoided. There is no known history of serious injuries with this application. Platen glass is the glass that is typically used in scanners, copiers, etc. Accidents are rare, probably also because they are protected by an additional cover most of the time, which limits the probability that an impact will occur on the glass.

CRTs are exempted because they have separate requirements.

The test value for floor standing equipment is higher because it is more likely to be impacted by persons or carts and dollies at a higher force while in normal use.

The exemption for glass below certain sizes is taken over from IEC 60065. There is no good rationale to keep the exemption, other than that there are no serious accidents known from the field. The HBSDT decided that they want to keep the exemption in.

The flow chart in Figure 7 in this document shows the intent for the requirements.

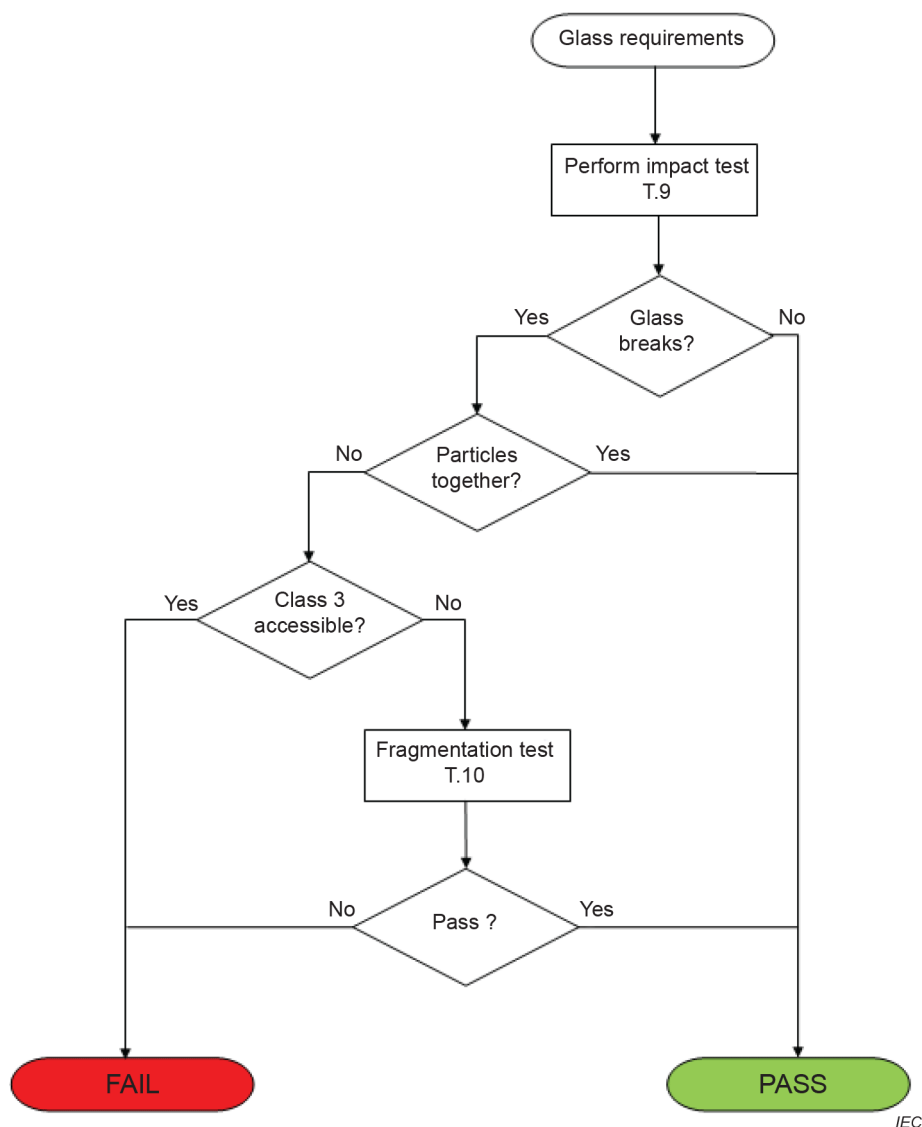


Figure 7 – Flow chart showing the intent of the glass requirements

4.4.3.10 Compliance criteria

The value of 30 g for the weight limit is chosen based on the maximum dimension of a side of 50 mm. A typical piece of glass with a size of 50 mm × 50 mm × 4 mm (roughly 2,80 g/cm³) would have a weight of around 30 g.

4.6 Fixing of conductors

Source: IEC 60950-1

Purpose: To reduce the likelihood that conductors could be displaced such that they reduce the **creepage distances** and **clearances**.

Rationale: These requirements have been successfully used for products in the scope of this document for many years.

4.7 Equipment for direct insertion into mains socket-outlets

Source: IEC 60065:2014, 15.5
 IEC 60950-1:2013, 4.3.6
 IEC 60335-1:2010, 22.3
 IEC 60884-1:2013, 14.23.2

Purpose: Determine that equipment incorporating integral pins for insertion into **mains** socket-outlets does not impose undue torque on the socket-outlet due to the mass and configuration of the equipment. This type of equipment often is known as Direct Plug-in Equipment or Direct Plug-in Transformers.

Rationale: Socket outlets are required to comply with the safety requirements in IEC 60884-1:2013, *Plugs and socket-outlets for household and similar purposes – Part 1: General requirements*, including subclause 14.23.2. The requirements result in socket designs with certain design limitations. Equipment incorporating integral pins for insertion into **mains** socket-outlets is not allowed to exceed these design limitations.

4.9 Likelihood of fire or shock due to entry of conductive objects

Purpose: The purpose of this subclause is to establish opening requirements that would minimize the risk of foreign conductive objects falling into the equipment that could bridge parts within class 2 or class 3 circuits, or between PS circuits that could result in ignition or electric shock.

It is considered unlikely that a person would accidentally drop something that could consequently fall into the equipment at a height greater than 1,8 m.

5 Electrically-caused injury

Purpose: Clause 5 classifies electrical energy sources and provides criteria for determining the energy source class of each conductive part. The criteria for energy source class include the source current-voltage characteristics, duration, and capacitance. Each conductive part, whether current-carrying or not, or whether earthed or not, shall be classed ES1, ES2, or ES3 with respect to earth and with respect to any other simultaneously **accessible** conductive part.

240 VA limit

IEC 62368-1 does not have requirements for a 240 VA energy hazard that was previously located in 2.1.1.5 of IEC 60950-1:2013.

The origin/justification of the 240 VA energy hazard requirement in the legacy documents was never precisely determined, and it appears the VA limits may have come from a manufacturer's specifications originally applied to exposed bus bars in mainframe computers back in the 1960's and concerns at the time service personnel inadvertently bridging them with a metal part.

However, when IEC TC 108 started the IEC 62368-1 project the intent was to take a fresh look at product safety using HBSE and only carry over a legacy requirement if the safety science and HBSE justified it. After considerable study by IEC TC 108, there was no support for carrying over the 240 VA requirement since:

- the requirements were not based on any proven science or sound technical basis;
- the 240 VA value was relatively arbitrary; and
- in practice the requirement was difficult to apply consistently (for example, on a populated printed board or inside a switch mode power supply).

In the meantime, there are energy limits for capacitors in Clause 5, which remains a more realistic concern and which were the second set of the energy hazard requirements in IEC 60950-1, the first being steady state 240 VA.

In addition, there are other requirements in IEC 62368-1 that will limit exposure to high levels of power (VA), including a VA limit for LPS outputs when those are required by Annex Q (for outputs connected to building wiring as required by 6.5.2).

Electric burn (eBurn)

Analysis of the body current generated by increasing frequency sinusoidal waveforms shows that the current continues to increase with frequency. The same analysis shows that the **touch current**, which is discounted with frequency, stabilizes.

The following paper describes the analysis fully: 'Touch Current Comparison, Looking at IEC 60990 Measurement Circuit Performance – Part 1: Electric Burn'; Peter E Perkins; IEEE PSES Product Safety Engineering Newsletter, Vol 4, No 2, Nov 2008.

The crossover frequency is different for the startle-reaction circuit than for the let go-immobilization circuit because of the separate Frequency Factor body response curves related to current levels; analysis identifies the crossover frequency where the eBurn current surpasses the **touch current**. Under these conditions, a person touching the circuit will become immobilized and will not be able to let go of the circuit. This crossover frequency is determined in the analysis. The person contacting the circuit should always be able to let go.

The general conditions that apply to eBurn circuits are:

- the eBurn limit only applies to HF sinusoidal signals;
- the area of contact should be limited to a small, fingertip contact (~ 1cm²);
- the contact time should be less than 1 s; at this short contact time, it is not reasonable to define different levels for various persons;

This requirement applies to **accessible** circuits that can be contacted at both poles, including all grounded circuits isolated from the **mains** and any isolated circuits where both contacts are easily available to touch.

A simplified application of these requirements in the documents limits the accessibility of HF sinusoidal currents above a specified frequency. The 22 kHz and 36 kHz frequency limits are where the eBurn current crosses the 5mA limit for the ES1 and ES2 measurement circuits. This will ensure that the person contacting the circuit will be able to remove themselves from the circuit under these conditions.

1 MHz limit

The effects of electric current on the human body are described in the IEC 60479 series and the requirements in IEC 62368-1 are drawn from there. The effects versus frequency are well laid out and properly accounted for in these requirements. The body effects move from conducted effects to surface radiofrequency burns at higher frequencies approaching 100 kHz. By long-term agreement, IEC safety documents are responsible for outlining the effects of current to 1 MHz, which are properly measured by the techniques given herein. Above the 1 MHz level, it becomes an EMC issue. Unless the current is provided as a principal action of the equipment operation, electric shock evaluation should not be needed above the 1 MHz level. Where it is fundamental to the equipment's operation, the high-frequency current levels shall be specially measured using proper high-frequency techniques, including classifying the circuits and, if necessary, appropriately protected to avoid any bodily injury.

5.2.1 Electrical energy source classifications

Source: IEC TS 60479-1:2005 and IEC 61201

Purpose: To define the line between hazardous and non-hazardous electrical energy sources for **normal operating conditions** and **abnormal operating conditions**.

Rationale: The effect on persons from an electric source depends on the current through the human body. The effects are described in IEC TS 60479-1.

IEC TS 60479-1 (see Figures 20 and 22, Tables 11 and 13); zone AC-1 and zone DC-1; usually no reaction (Figure 8 and Figure 9, Table 2 and Table 3 in this document) is taken as values for ES1.

IEC TS 60479-1 (see Figures 20 and 22; Tables 11 and 13); zone AC-2 and zone DC-2; usually no harmful physiological effects (see Figure 8 and Figure 9, Table 2 in this document) is taken as values for ES2.

IEC TS 60479-1; zone AC-3 and zone DC-3; harmful physiological effects may occur (see Figure 8 and Figure 9, Table 2 and Table 3 in this document) is the ES3 zone.

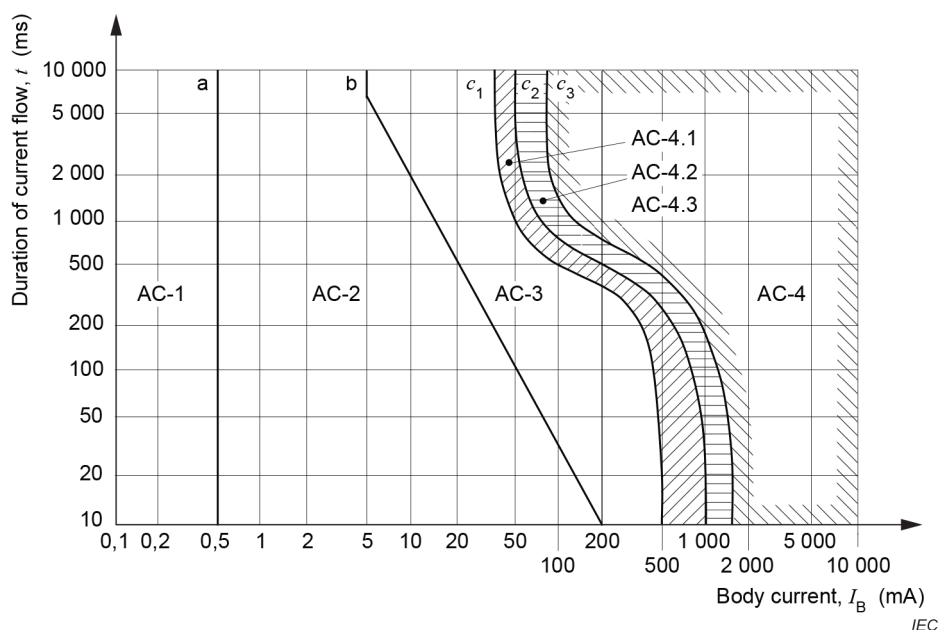


Figure 8 – Conventional time/current zones of effects of AC currents (15 Hz to 100 Hz) on persons for a current path corresponding to left hand to feet (see IEC TS 60479-1:2005, Figure 20)

**Table 2 – Time/current zones for AC 15 Hz to 100 Hz
for hand to feet pathway (see IEC TS 60479-1:2005, Table 11)**

Zones	Boundaries	Physiological effects
AC-1	up to 0,5 mA curve a	Perception possible but usually no startle reaction
AC-2	0,5 mA up to curve b	Perception and involuntary muscular contractions likely but usually no harmful electrical physiological effects
AC-3	Curve b and above	Strong involuntary muscular contractions. Difficulty in breathing. Reversible disturbances of heart function. Immobilisation may occur. Effects increasing with current magnitude. Usually no organic damage to be expected.
AC-4 ^a	Above curve c_1 $c_1 - c_2$ $c_2 - c_3$ Beyond curve c_3	Pathophysiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time. AC-4.1 Probability of ventricular fibrillation increasing up to about 5 %. AC-4.2 Probability of ventricular fibrillation up to about 50 %. AC-4.3 Probability of ventricular fibrillation above 50 %.
^a For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current that flows in the path left hand to feet. For other current paths, the heart current factor has to be considered.		

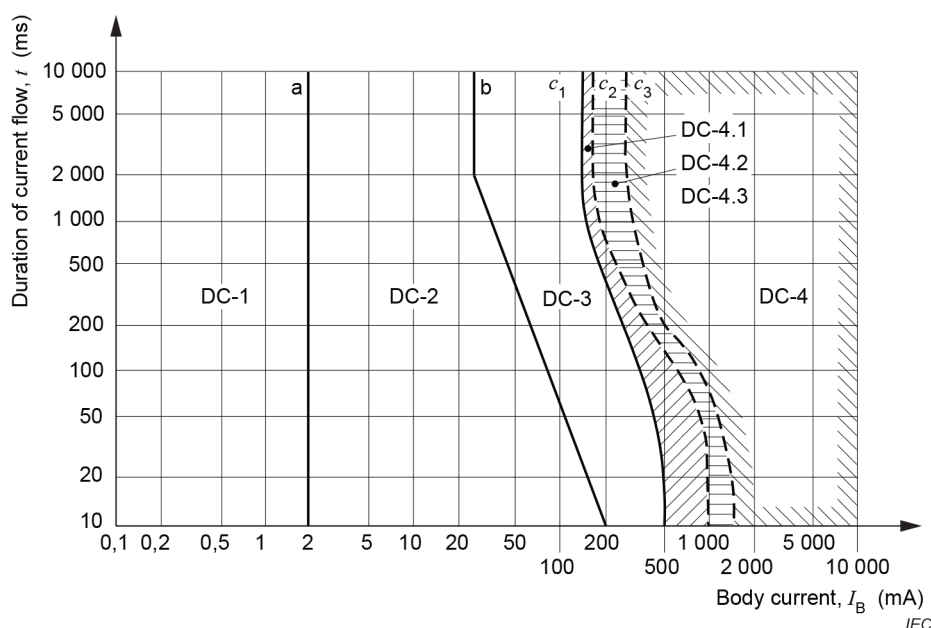


Figure 9 – Conventional time/current zones of effects of DC currents on persons for a longitudinal upward current path (see IEC TS 60479-1:2005, Figure 22)

**Table 3 – Time/current zones for DC for hand to feet pathway
(see IEC TS 60479-1:2005, Table 13)**

Zones	Boundaries	Physiological effects
DC-1	Up to 2 mA curve a	Slight pricking sensation possible when making, breaking or rapidly altering current flow.
DC-2	2 mA up to curve b	Involuntary muscular contractions likely, especially when making, breaking or rapidly altering current flow, but usually no harmful electrical physiological effects
DC-3	curve b and above	Strong involuntary muscular reactions and reversible disturbances of formation and conduction of impulses in the heart may occur, increasing with current magnitude and time. Usually no organic damage to be expected.
DC-4 ^a	Above curve c_1 $c_1 - c_2$ $c_2 - c_3$ Beyond curve c_3	Pathophysiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time. DC-4.1 Probability of ventricular fibrillation increasing up to about 5 %. DC-4.2 Probability of ventricular fibrillation up to about 50 %. DC-4.3 Probability of ventricular fibrillation above 50 %.
^a For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to feet and for upward current. For other current paths, the heart current factor has to be considered.		

The seriousness of an injury increases continuously with the energy transferred to the body. To demonstrate this principle Figure 8 and Figure 9 in this document (see IEC TS 60479-1, Figures 20 and 22) are transferred into a graph: effects vs energy (see Figure 10 in this document).

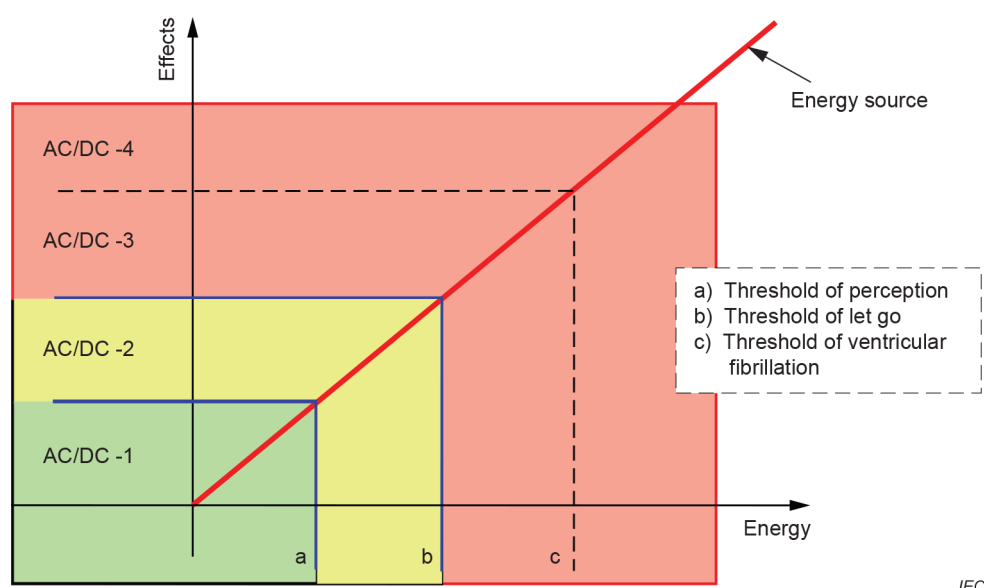


Figure 10 – Illustration that limits depend on both voltage and current

Within the document, only the limits for Zone 1 (green) and Zone 2 (yellow) will be specified.

Curve “a” (limit of Zone 1) will be the limit for parts **accessible** by an **ordinary person** during normal use.

Curve “b” (limit of Zone 2) will be the limit for parts **accessible** by an **ordinary person** during (or after) a single fault.

IEC TC 108 regarded it not to be acceptable to go to the limits of either Zone 3 or 4.

In the document three (3) zones are described as electrical energy sources.

This classification is as follows:

- electrical energy source 1 (ES1): levels are of such a value that they do not exceed curve “a” (threshold of perception) of Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).
- electrical energy source 2 (ES2): levels are of such a value that they exceed curve “a”, but do not exceed curve “b” (threshold of let go) of Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).
- electrical energy source 3 (ES3): levels are of such a value that they exceed curve “b” of Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).

5.2.2.1 General

When classifying a circuit or part that is not **accessible**, that circuit or part shall be regarded as being **accessible** when measuring **prospective touch voltage** and **touch current**.

5.2.2.2 Steady-state voltage and current limits

Table 4 Electrical energy source limits for steady-state ES1 and ES2

Source: IEC TS 60479-1:2005, Dalziel, Effect of Wave Form on Let-Go Currents; AIEE Electrical Engineering Transactions, Dec 1943, Vol 62.

Rationale: The current limits of Table 4 line 1 and 2 are derived from curve a and b, Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).

The basis for setting limits for combined AC and DC **touch current** is from the work of Dalziel which provides clear data for men, women and children. In the current diagram (Figure 22), the AC current is always the peak value (per Dalziel). In the voltage diagram (Figure 23), the 30 V AC and 50 V AC points on the baseline are recognized as AC RMS values as stated in Table 4. Since IEC TC 108 is working with consumer appliances, there is a need to provide protection for children, who are generally considered the most vulnerable category of people. The formulas of IEC 62368-1:2018, Table 4 address the Dalziel investigations.

Under **single fault conditions** of a relevant **basic safeguard** or **supplementary safeguard**, **touch current** is measured according to 5.1.2 of IEC 60990:2016. However, this IEC 60990 subclause references both the IEC 60990 perception/reaction network (Figure 4) and the let-go network (Figure 5), selection of which depends on several factors. Figure 5 applies to **touch current** limits above 2 mA RMS. IEC TC 108 has decided that parts under **single fault conditions** of relevant **basic safeguards** or **supplementary safeguards** should be measured per Figure 5 (let-go immobilization network). Therefore, since 5.1.2 makes reference to both Figure 4 and Figure 5, for clarification Table 4 is mentioned directly in 5.2.2.2.

Because there is usually no reaction of the human body when touching ES1, access is permitted by any person (IEC TS 60479-1; zone AC-1 and zone DC-1).

Because there may be a reaction of the human body when touching ES2, protection is required for an **ordinary person**. One **safeguard** is sufficient because there are usually no harmful physiological effects when touching ES2 (IEC TS 60479-1:2005; zone AC-2 and zone DC-2).

Because harmful physiological effects may occur when touching ES3, (IEC TS 60479-1:2005; zone AC-3 and zone DC-3), protection is required for an **ordinary person** and an **instructed person**, including after a fault of one **safeguard**.

During the application of the electrical energy source limits for “combined AC and DC” in Table 4, if the AC component of a superimposed AC and DC energy source does not exceed 10 % of the DC energy, then the AC component can be disregarded for purposes of application of Table 4. This consideration is valid based on the definition of **DC voltage** in 3.3.14.1, which allows peak-to-peak ripple not exceeding 10 % of the average value to be integrated into **DC voltage** considerations. As a result, in such cases where AC does not exceed 10 % of DC, only the DC energy source limits in Table 4 need be applied.

When measuring combined AC and DC voltages and currents, both AC and DC measurements shall be made between the same points of reference. Do not combine common-mode measurements with differential-mode measurements. They shall be assessed separately.

In using Table 4, ES1 touch current measurement specifies the startle-reaction circuit ‘a’ intended for limits less than 2 mA RMS / 2,8 mA peak and ES2 touch current specifies the let-go-immobilization circuit ‘b’ intended for limits > 2 mA RMS / 2,8 mA peak. These circuits are adopted from IEC 60990:2016, Clause 5.

Normal operating conditions of equipment for touch current testing are outlined in 5.7.2 and Clause B.2 of IEC 62368-1:2018 and includes operation of all operator controls. **Abnormal operating conditions** are specified in Clause B.3 of IEC 62368-1:2018. **Single fault conditions** (within the equipment), specified in Clause B.4 of IEC 62368-1:2018, includes faults of a relevant **basic safeguard** or a **supplementary safeguard**.

5.2.2.3 Capacitance limits

Table 5 Electrical energy source limits for a charged capacitor

Source:	IEC TS 61201:2007 (Annex A)
Rationale:	Where the energy source is a capacitor, the energy source class is determined from both the charge voltage and the capacitance. The capacitance limits are derived from IEC TS 61201:2007, see Table 4 in this document.

The values for ES2 are derived from Table A.2 of IEC TS 61201:2007.

The values for ES1 are calculated by dividing the values from Table A.2 of IEC TS 61201:2007 by two (2).

Table 4 – Limit values of accessible capacitance (threshold of pain)

U V	C μF	U kV	C nF
70	42,4	1	8,0
78	10,0	2	4,0
80	3,8	5	1,6
90	1,2	10	0,8
100	0,58	20	0,4
150	0,17	40	0,2
200	0,091	60	0,133
250	0,061		
300	0,041		
400	0,028		
500	0,018		
700	0,012		

5.2.2.4 Single pulse limits**Table 6 Voltage limits for single pulses**

Rationale: The values are based on the DC current values of Table 4, assuming 25 mA gives a voltage of 120 V DC (body resistance of 4,8 kΩ). The lowest value is taken as 120 V because, under **single fault conditions**, the voltage of ES1 can be as high as 120 V DC without a time limit.

The table allows linear interpolation because the difference is considered to be very small. However, the following formula may be used for a more exact interpolation of the log-log based values in this table. The variable t or V is the desired unknown "in between value" and either may be determined when one is known:

$$V = \text{Antilog} \frac{\log V_2 + \log V_1 \times \frac{\log t_2 - \log t}{\log t - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t - \log t_1}}$$

and

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log V_2 - \log V}{\log V - \log V_1}}{1 + \frac{\log V_2 - \log V}{\log V - \log V_1}}$$

where:

t is the time duration that is required to be determined if U_{peak} voltage V is known (or t is known and V needs to be determined)

t_1 is the time duration adjacent to t corresponding to the U_{peak} voltage V_1

t_2 is the time duration adjacent to t corresponding to the U_{peak} voltage V_2

V is the U_{peak} voltage value that is known if time duration t is to be determined (or V is required to be determined if time duration t is known)

V_1 is the value of the voltage U_{peak} adjacent to V corresponding to time duration t_1

V_2 is the value of the voltage U_{peak} adjacent to V corresponding to time duration t_2

Table 7 **Current limits for single pulses**

Source: IEC TS 60479-1:2005

Rationale: For ES1, the limit of single pulse should not exceed the ES1 steady-state voltage limits for **DC voltages**.

For ES2, the voltage limits have been calculated by using the DC current values of curve b Figure 9 in this document and the resistance values of Table 10 of IEC TS 60479-1:2005, column for 5 % of the population (see Table 5 in this document).

The current limits of single pulses in Table 7 for ES1 levels are from curve a and for ES2 are from curve b of Figure 9 in this document.

The table allows linear interpolation because the difference is considered to be very small. However, the following formula may be used for a more exact interpolation of the log-log based values in this table. The variable t or I is the desired unknown "in between value" and either may be determined when one is known:

$$I = \text{Antilog} \frac{\log I_2 + \log I_1 \times \frac{\log t_2 - \log t}{\log t - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t - \log t_1}}$$

and

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log I_2 - \log I}{\log I - \log I_1}}{1 + \frac{\log I_2 - \log I}{\log I - \log I_1}}$$

where:

- t is the time duration that is required to be determined if the electric current I is known (or t is known and I needs to be determined)
- t_1 is the time duration adjacent to t corresponding to the electric current I_1
- t_2 is the time duration adjacent to t corresponding to the electric current I_2
- I is the value of the I_{peak} current that is known if time duration t is to be determined (or I is required to be determined if time duration t is known)
- I_1 is the value of the I_{peak} adjacent to I corresponding to time duration t_1
- I_2 is the value of the I_{peak} adjacent to I corresponding to time duration t_2

Table 5 – Total body resistances R_T for a current path hand to hand, DC, for large surface areas of contact in dry condition

Touch voltage V	Values for the total body resistance R_T (Ω) that are not exceeded for		
	5 % of the population	50 % of the population	95 % of the population
25	2 100	3 875	7 275
50	1 600	2 900	5 325
75	1 275	2 275	4 100
100	1 100	1 900	3 350
125	975	1 675	2 875
150	875	1 475	2 475
175	825	1 350	2 225
200	800	1 275	2 050
225	775	1 225	1 900
400	700	950	1 275
500	625	850	1 150
700	575	775	1 050
1 000	575	775	1 050
Asymptotic value	575	775	1 050
NOTE 1 Some measurements indicate that the total body resistance R_T for the current path hand to foot is somewhat lower than for a current path hand to hand (10 % to 30 %). NOTE 2 For living persons the values of R_T correspond to a duration of current flow of about 0,1 s. For longer durations R_T values may decrease (about 10 % to 20 %) and after complete rupture of the skin R_T approaches the initial body resistance R_o. NOTE 3 Values of R_T are rounded to 25 Ω.			

5.2.2.6 Ringing signals

Source: EN 41003

Purpose: To establish limits for analogue telephone network ringing signals.

Rationale: For details see rationale for Annex H. Where the energy source is an analogue telephone network ringing signal as defined in Annex H, the energy source class is taken as ES2 (as in IEC 60950-1:2005, Annex M).

5.2.2.7 Audio signals

Source: IEC 60065:2014

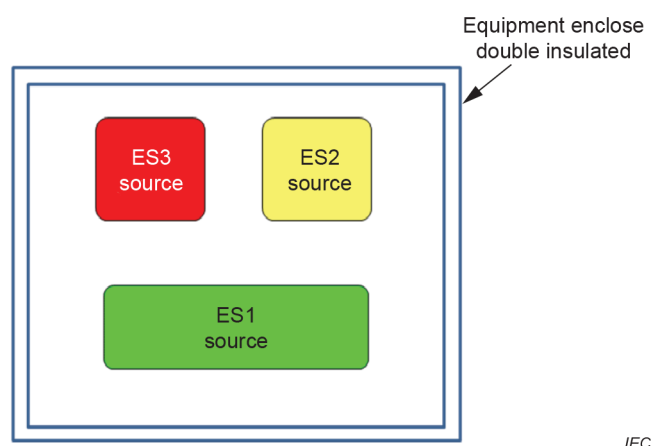
Purpose: To establish limits for touch voltages for audio signals.

Rationale: The proposed limits for touch voltages at terminals involving audio signals that may be contacted by persons have been extracted without deviation from IEC 60065. Reference: IEC 60065:2014, 9.1.1.2 a). Under **single fault conditions**, 10.2 of IEC 60065:2014 does not permit an increase in acceptable touch voltage limits.

The proposed limits are quantitatively larger than the accepted limits of Tables 5 and 6, but are not considered dangerous for the following reasons:

- the output is measured with the load disconnected (worst case load);
- defining the contact area of connectors and wiring is very difficult due to complex shapes. The area of contact is considered small due to the construction of the connectors;
- normally, it is recommended to the user, in the instruction manual provided with the equipment, that all connections be made with the equipment in the “off” condition;
- in addition to being on, the equipment would have to be playing some program at a high output with the load disconnected to achieve the proposed limits (although possible, highly unlikely). Historically, no known cases of injury are known for amplifiers with non-clipped output less than 71 V RMS;
- the National Electrical Code (USA) permits **accessible** terminals with maximum output voltage of 120 V RMS.

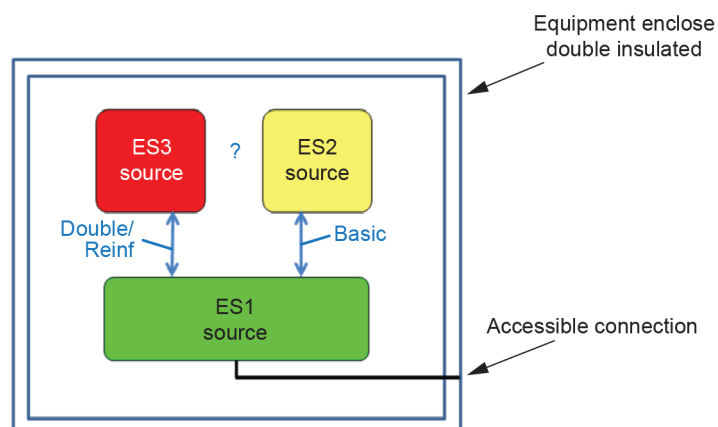
5.3.2 Accessibility to electrical energy sources and safeguards



IEC

What are the requirements between the non-**accessible** sources?

Answer: None. As the **enclosure** is double insulated, the sources are not **accessible**.

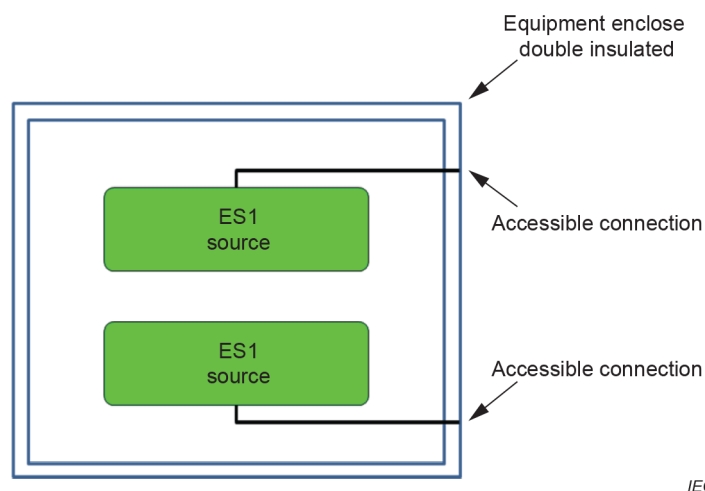


IEC

Now there is an **accessible** connection. What are the requirements between the sources in this case?

Answer:

- **Basic insulation** between ES1 and ES2
- **Double insulation** or **reinforced insulation** between ES1 and ES3
- The insulation between ES2 and ES3 depends on the insulation between the ES1 and ES2



Now there are two **accessible** connections from independent sources. What are the requirements between the sources in this case?

Answer:

- According to Clause B.4, the insulation or any components between the sources need to be shorted
- If one of the two ES1 sources would reach ES2 levels ⇒ **basic safeguard**
- If both ES1 sources stay within ES1 limits ⇒ no **safeguard (functional insulation)**

For **outdoor equipment**, lower voltage limits apply because the body impedance is reduced to half the value when subjected to wet conditions as described in IEC TS 60479-1 and IEC TS 61201.

Where **Class III equipment** is acceptable in an indoor application, this outdoor application does not introduce additional **safeguard** requirements.

5.3.2.2 Contact requirements

Source: IEC 61140:2001, 8.1.1

Purpose: Determination of **accessible** parts for adults and children. Tests are in IEC 62368-1:2018, Annex V.

Rationale: According to Paschen's Law, air breakdown does not occur below 323 V peak or DC (at sea level). IEC 62368-1:2018 uses 420 V peak (300 V RMS) to add an additional safety margin.

5.3.2.3 Compliance criteria

The reason for accepting different requirements for components is because you cannot expect your supplier to make different components for each end application.

5.3.2.4 Terminals for connecting stripped wire

Source: IEC 60065

Purpose: To prevent contact of ES2 or ES3 parts.

Rationale: Accepted constructions used in the audio/video industry for many years.

5.4 Insulation materials and requirements

Rationale: The requirements, test methods and compliance criteria are taken from the actual outputs from IEC TC 108 MT2 (formerly WG6) as well as from IEC TC 108 MT1.

- The choice and application of components shall take into account the needs for electrical, thermal and mechanical strength, frequency of the **working voltage** and working environment (temperature, pressure, humidity and pollution).
- Components shall have the electric strength, thermal strength, mechanical strength, dimensions, and other properties as specified in the document.
- Depending on the grade of **safeguard** (**basic safeguard**, **supplementary safeguard**, **reinforced safeguard**) the requirements differ.
- Components complying with their component documents (for example, IEC 60384-14 for capacitances) have to be verified for their application.
- The components listed in this subclause of the new document have a separation function.

5.4.1.1 Insulation

Source: IEC 60664-1

Purpose: Provide a reliable **safeguard**

Rationale: Solid **basic insulation**, **supplementary insulation**, and **reinforced insulation** shall be capable of durably withstanding electrical, mechanical, thermal, and environmental stress that may occur during the anticipated lifetime of the equipment.

Clearances and **creepage distances** may be divided by intervening unconnected (floating) conductive parts, such as unused contacts of a connector, provided that the sum of the individual distances meets the specified minimum requirements (see Figure O.4).

5.4.1.4 Maximum operating temperatures for materials, components and systems

Source: IEC 60085, IEC 60364-4-43, ISO 306, IEC 60695-10-2

Rationale: Temperature limits given in Table 9:

- limits for insulation materials including electrical insulation systems, including winding insulation (Classes A, E, B, F, H, N, R and 250) are taken from IEC 60085;
- limits for insulation of internal and external wiring, including power supply cords with temperature marking are those indicated by the marking or the rating assigned by the (component) manufacturer;
- limits for insulation of internal and external wiring, including power supply cords without temperature marking of 70 °C are referenced in IEC 60364-4-43 for an ambient temperature of 25 °C;
- limits for thermoplastic insulation are based on:
 - data from Vicat test B50 of ISO 306;
 - ball pressure test according to IEC 60695-10-2;
 - when it is clear from the examination of the physical characteristics of the material that it will meet the requirements of the ball pressure test;

- experience with 125 °C value for parts in a circuit supplied from the **mains**.

5.4.1.4.3 Compliance criteria

Table 9 Temperature limits for materials, components and systems

Rationale Regarding condition “a”, it has been assumed by the technical committee for many years that the thermal gradient between outer surface and inner windings will be limited to 10 °C differential as an average. As a result, the temperature limits for outer surface insulation measured via thermocouple is 10 °C lower than similar measurement with a thermocouple embedded in the winding(s), with both limits at least 5 °C less than the hot-spot temperature allowed per IEC 60085 as an additional safety factor. However, some modern transformer constructions with larger power densities may have larger thermal gradients, as may some outer surface transformer insulation thermal measurements in the equipment/system be influenced by forced cooling or similar effects. Therefore, if thermal imaging, computer modeling, or actual measurement shows a thermal gradient greater than 10 °C average between transformer surface temperature and transformer winding(s), the rise of resistance temperature measurement method and limits for an embedded thermocouple should be used (for example, 100 °C maximum temperature for Class 105 (A)) for determining compliance of a transformer with Table 9 since the original assumptions do not hold true.

As an example, a material rated for 124 °C using the rise of resistance method is considered suitable for classes whose temperature is lower (class with letter codes E and A) and not for classes whose temperature is higher (class with letter codes B, F, H, N, R and 250).

5.4.1.5 Pollution degrees

Source: IEC 60664-1

Rationale: No values for PD 4 (pollution generates persistent conductivity) are included, as it is unlikely that such conditions are present when using products in the scope of the document.

5.4.1.5.2 Test for pollution degree 1 environment and for an insulating compound

The compliance check made by visual inspection applies both to single layer and multi-layer boards without the need for sectioning to check for voids, gaps, etc.

5.4.1.6 Insulation in transformers with varying dimensions

Source: IEC 60950-1

Purpose: To consider actual **working voltage** along the winding of a transformer.

Rationale: Description of a method to determine adequacy of **solid insulation** along the length of a transformer winding.

5.4.1.7 Insulation in circuits generating starting pulses

Source: IEC 60950-1, IEC 60664-1

Purpose: To avoid insulation breakdown due to starting pulses.

Rationale: This method has been successfully used for products in the scope of this document for many years.

5.4.1.8 Determination of working voltage

Source: IEC 60664-1:2007, 3.5; IEC 60950-1

Rationale: The **working voltage** does not include short duration signals, such as transients. Recurring peak voltages are not included. Transient overvoltages are covered in the **required withstand voltage**. Ringing signals do not carry external transients.

5.4.1.8.1 General

Rationale: **Functional insulation** is not addressed in Clause 5, as it does not provide protection against electric shock. Requirements for **functional insulation** are covered in Clause 6, which addresses protection against electrically caused fire.

Source: IEC 60664-1:2007, 3.8

Rationale: In IEC 62368-1, “Circuit supplied from the **mains**” is used for a “primary circuit”. “Circuit isolated from the **mains**” is used for a “secondary circuit”.

“**External circuit**” is defined as **external** to the equipment. ES1 can be external to the equipment.

For an **external circuit** operating at ES2 level and not exiting the building, the transient is 0 V. Therefore, in this case, ringing peak voltage needs to be taken into account.

5.4.1.8.2 RMS working voltage

Source: IEC 60664-1:2007, 3.5

Rationale: RMS **working voltage** is used when determining minimum **creepage distance**. Unless otherwise specified, working voltage is the RMS value.

5.4.1.10 Thermoplastic parts on which conductive metallic parts are directly mounted

Source: ISO 306 and IEC 60695-2 series

Rationale: The temperature of the thermoplastic parts under **normal operating conditions** shall be 15 K less than the softening temperature of a non-metallic part. Supporting parts in a circuit supplied from the **mains** shall not be less than 125 °C.

5.4.2 Clearances

5.4.2.1 General requirements

Source: IEC 60664-1:2007

Rationale: The dimension for a **clearance** is determined from the required impulse withstand voltage for that **clearance**. This concept is taken from IEC 60664-1:2007, 5.1. In addition, **clearances** are affected by the largest of the determined transients. The likelihood of simultaneous occurrence of transients is very low and is not taken into account.

Overvoltages and transients that may enter the equipment, and peak voltages that may be generated within the equipment, do not break down the **clearance** (see IEC 60664-1:2007, 5.1.5 and 5.1.6).

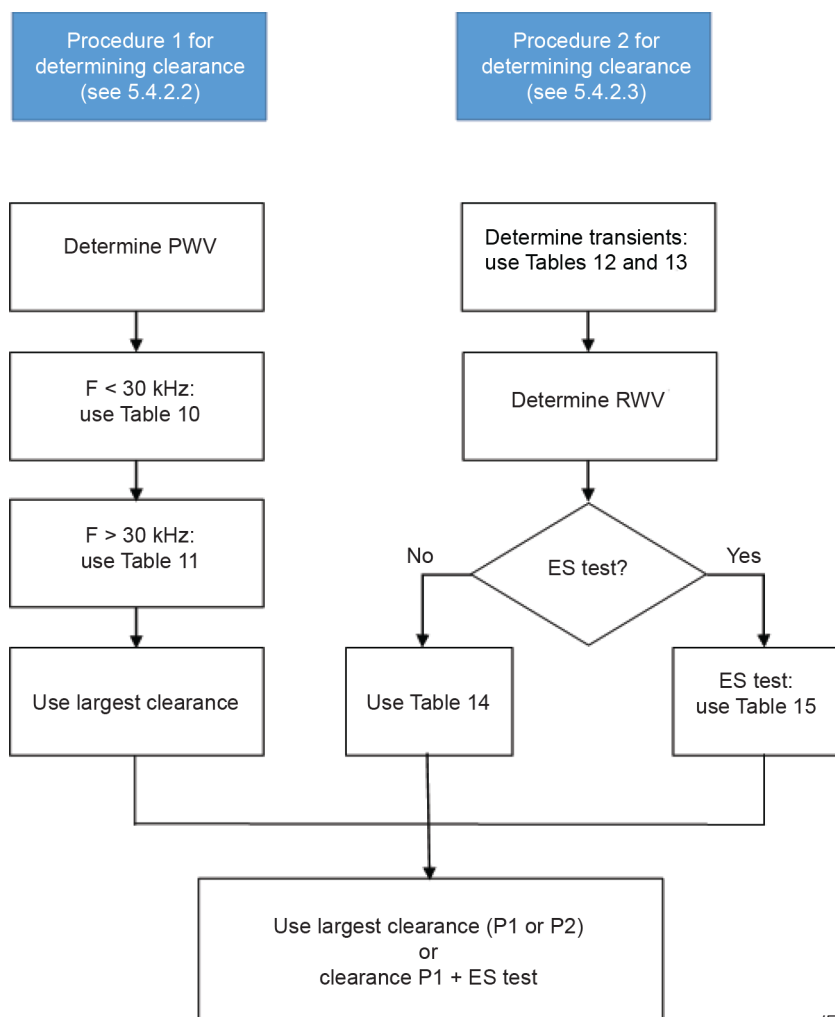
Minimum **clearances** of safety components shall comply with the requirements of their applicable component safety document.

Clearances between the outer insulating surface of a connector and conductive parts at ES3 voltage level shall comply with the requirements of **basic insulation** only, if the connectors are fixed to the equipment, located internal to the outer **electrical enclosure** of the equipment, and are **accessible** only after removal of a sub-assembly that is required to be in place during normal operation.

It is assumed that the occurrence of both factors, the sub-assembly being removed and the occurrence of a transient overvoltage, have a reduced likelihood and hazard potential.

Source: IEC 60664-2 series, *Application guide*

Rationale: The method is derived from the IEC 60664-2 series, *Application guide*.



IEC

Example:

Assuming:

- an SMPS power supply,
- connection to the AC **mains**,
- a peak of the working voltage (PWV) of 800 V,
- frequencies above and below 30 kHz,
- reinforced **clearances** required,
- **temporary overvoltages**: 2 000 V

Procedure 1:

Table 10 requires 2,54 mm

Table 11 requires 0,44 mm

Result is 2,54 mm

NOTE All PWV below 1 200 V have **clearance** requirements less than 3 mm for both Table 10 and Table 11

Final result:

- 3,0 mm or
- ES test at 4,67 KV and 2,54 mm

Procedure 2:

Transients (OVC 2): 2 500 V

RWV = 2 500 V

Table 14 requires 3,0 mm

The required ES test voltage according to Table 15 is 4,67 KV

Result is 3,0 mm or ES test at 4,67 KV

ATTENTION:

For a product with connection to coax cable, different values are to be used since a different transient and **required withstand voltage** is required.

5.4.2.2 Procedure 1 for determining clearance

Rationale: Related to the first dash of 5.4.2.2, it is noted that an example of a cause of determination of the peak value of steady state voltages that are below the peak voltage of the **mains** includes, for example, a determination in accordance with the 2nd and 3rd dash of 5.4.2.3.3 where filtering is in place to lower expected peak voltages.

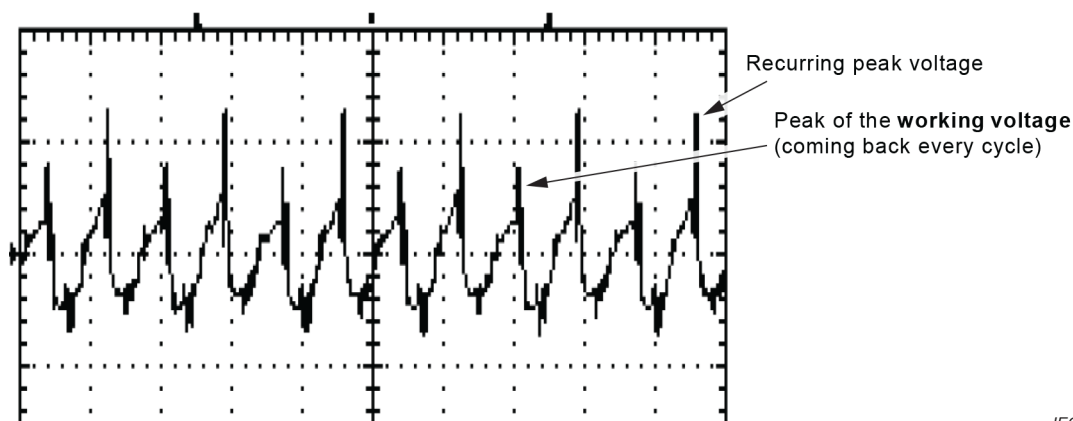
Similarly, related to the second dash of 5.4.2.2, an example of this case where the recurring peak voltage is limited to 1,1 times the **mains** voltage may be use of certain forms of surge protection devices that reduce overvoltage category.

Peak of the working voltage versus recurring peak voltage.

There has been some discussion between the two terms. The peak of the **working voltage** is the peak value of the waveform that occurs each cycle, and therefore is considered to be a part of the **working voltage**.

A recurring peak voltage is a peak that does not occur at each cycle of the waveform, but that reoccurs at a certain interval, usually at a lower frequency than the waveform frequency.

Figure 11 in this document gives an example of a waveform where the recurring peak voltage occurs every two cycles of the main waveform.



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Figure 11 – Illustration of working voltage

Table 10 Minimum clearances for voltages with frequencies up to 30 kHz

Rationale: IEC TC 108 noted that, if the rules of IEC 60664-1 are followed, for reinforced **clearance**, some values were more than double the requirements for **basic insulation**. IEC TC 108 felt that this should not be the case and decided to limit the requirement for **reinforced insulation** to twice the value of **basic insulation**, thereby deviating from IEC 60664-1.

In addition, normal rounding rules were applied to the values in the table.

5.4.2.3.2.2 Determining AC mains transient voltages

Source: IEC 60664-1:2007, 4.3.3.3

Rationale: Table 12 is derived from Table F.1 of IEC 60664-1:2007.

The term used in IEC 60664-1 is 'rated impulse voltage'. Products covered by IEC 62368-1 are also exposed to transients from **external circuits**, and therefore another term is needed, to show the different source.

Outdoor equipment that is part of the building installation, or that may be subject to transient overvoltages exceeding those for Overvoltage Category II, shall be designed for Overvoltage Category III or IV, unless additional protection is to be provided internally or externally to the equipment. In this case, the installation instructions shall state the need for such additional protection.

5.4.2.3.2.3 Determining DC mains transient voltages

Rationale: Transient overvoltages are attenuated by the capacitive filtering.

5.4.2.3.2.4 Determining external circuit transient voltages

Source: ITU-T K.21

Rationale: Transients have an influence on circuits and insulation, therefore transients on **external circuits** need to be taken into account. Transients are needed only for the dimensioning **safeguards**. Transients should not be used for the classification of energy sources (ES1, ES2, etc.).

It is expected that **external circuits** receive a transient voltage of 1,5 kV peak with a waveform of 10/700 μ s from sources outside the building.

The expected transient is independent from the application (telecom; LAN or other). Therefore, it is assumed that for all kinds of applications the same transient appears. The value 1,5 kV 10/700 μ s is taken from ITU-T K.21.

It is expected that **external circuits** using earthed coaxial cable receive no transients that have to be taken into account from sources outside the building.

Because of the earthed shield of the coaxial cable, a possible transient on the outside cable will be reduced at the earthed shield at the building entrance of the cable.

It is expected that for **external circuits** within the same building no transients have to be taken into account.

The transients for an interface are defined with respect to the terminals where the voltage is defined. For the majority of cases, the relevant voltages are common (U_c) and differential mode (U_d) voltages at the interface. For **hand-held** parts or other parts in extended contact with the human body, such as a telephone hand set, the voltage with respect to local earth (U_{ce}) may be relevant. Figure 12 in this document shows the definition of the various voltages for paired-conductor interface.

The transients for coaxial cable interfaces are between the centre conductor and shield (U_d) of the cable if the shield is earthed at the equipment. If the shield is isolated from earth at the equipment, then the shield-to-earth voltage (U_s) is important. Earthing of the shield can consist of connection of the shield to the **protective earthing**, functional earth inside or immediately outside the equipment. It is assumed that all earths are bonded together. Figure 13 in this document shows the definition of the various voltages for coaxial-cable interfaces.

An overview of insulation requirements is given in Table 6 in this document.

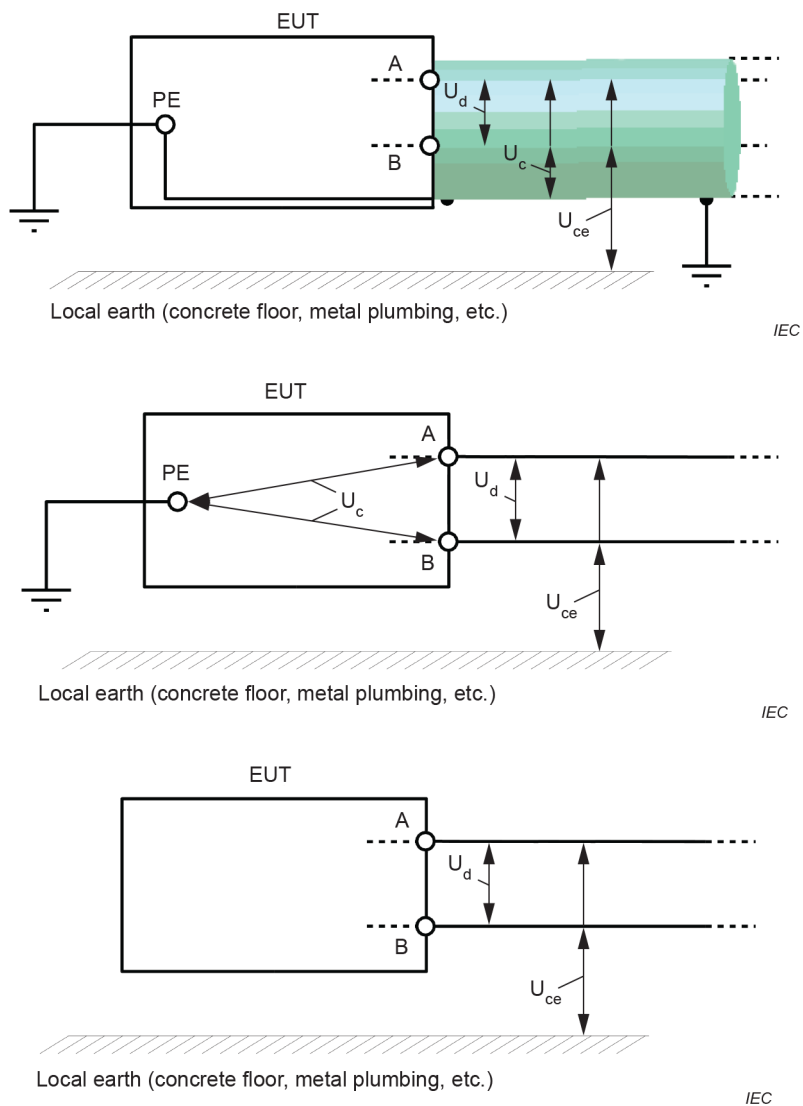


Figure 12 – Illustration of transient voltages on paired conductor external circuits

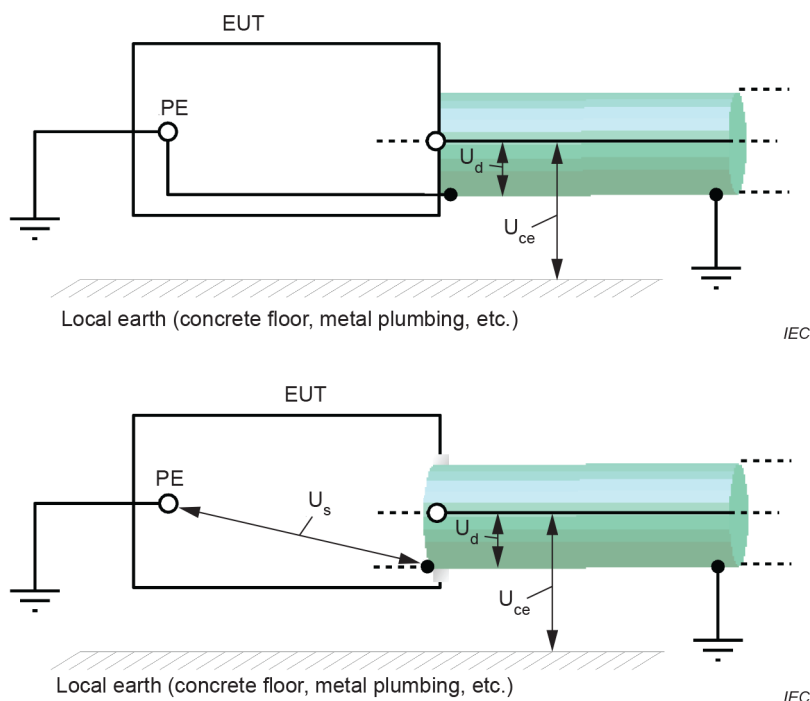


Figure 13 – Illustration of transient voltages on coaxial-cable external circuits

Table 6 – Insulation requirements for external circuits

External Circuit under consideration	Insulation	Requirement
ES1 earthed	None	None
ES1 unearthed	Separation (to floating metal parts and other floating ES1 circuits)	Electric strength test (using Table 15) between unearthed ES1 and other unearthed ES1 and floating parts
ES2	Basic insulation (to ES1 and metal parts)	Clearances; creepage distance; and solid insulation and by electric strength test (using Table 15) between ES2 and ES1 and metal parts
ES3	Double insulation or reinforced insulation (to ES1, ES2 and metal parts)	Clearances; creepage distance; and solid insulation requirements including electric strength test (using Table 15)

Table 13 External circuit transient voltages

Rationale: When the DC power distribution system is located outside the building, transient over-voltages can be expected. Transients are not present if the DC power system is connected to **protective earthing** and is located entirely within a single building.

5.4.2.3.2.5 Determining transient voltage levels by measurement

Source: Test method is taken from IEC 60950-1:2013, Annex G.

5.4.2.3.4 Determining clearances using required withstand voltage

Source: IEC 60664-1:2007, Table F.2 Case A (inhomogeneous field) and Case B (homogeneous field)

Rationale: Values in Table 14 are taken from IEC 60664-1:2007 Table F.2 Case A (inhomogeneous field) and Case B (homogeneous field) and include explicit values for **reinforced insulation**. **Clearances** for **reinforced insulation** have been calculated in accordance with 5.1.6 of IEC 60664-1:2007. For **reinforced insulation** 5.1.6 states **clearance** shall be to the corresponding rated impulse voltage that is one step higher for voltages in the preferred series. For voltages that are not in the preferred series, the **clearance** should be based on 160 % of the **required withstand voltage** for **basic insulation**.

When determining the **required withstand voltage**, interpolation should be allowed when the internal repetitive peak voltages are higher than the **mains** peak voltages, or if the **required withstand voltage** is above the **mains** transient voltage values.

No values for PD 4 (pollution generates persistent conductivity) are included, as it is unlikely that such conditions are present when using products in the scope of the document.

Table 14 Minimum clearances using required withstand voltage

Rationale: IEC 62368-1 follows the rules and requirements of IEC basic safety publications, one of which is the IEC 60664 series. IEC 60664-1 specifies **clearances** for **basic insulation** and **supplementary insulation**. **Clearances** for **reinforced insulation** are not specified. Instead, 5.1.6 specifies the rules for determining the reinforced **clearances**.

The reinforced **clearances** in Table 14 have a varying slope, and include a “discontinuity”. The values of Table 14 are shown in Figure 14 in this document.

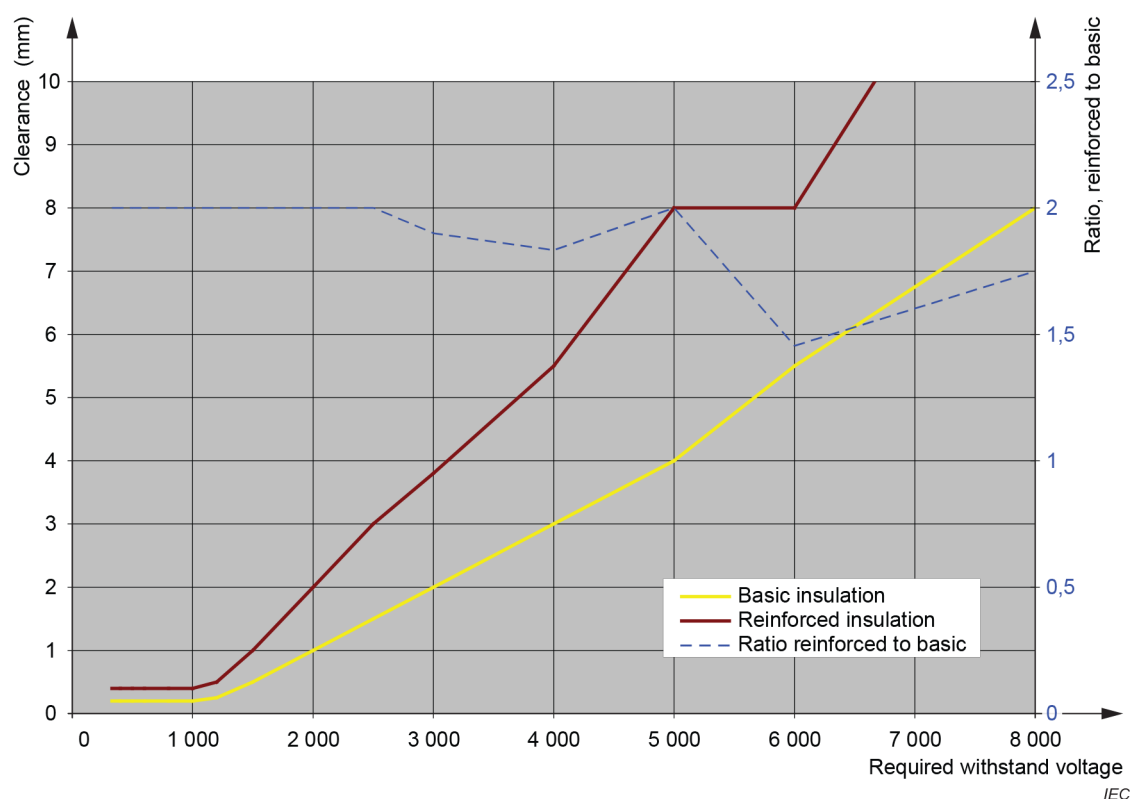


Figure 14 – Basic and reinforced insulation in Table 14 of IEC 62368-1:2018; ratio reinforced to basic

The brown line, reinforced **clearance**, is not a constant slope as is the yellow line, basic **clearance**. The ratio of reinforced to basic (blue line) varies from a maximum of 2:1 to a minimum of 1,49:1. Physically, this is not reasonable; the ratio should be nearly constant.

In IEC 60664-1:2007, the values for **basic insulation** are given in Table F.2. No values are given for **reinforced insulation**. Table F.2 refers to 5.1.6 for **reinforced insulation**.

Rule 1, preferred series impulse withstand voltages

Subclause 5.1.6 of IEC 60664-1:2007 states:

*“With respect to impulse voltages, clearances of reinforced insulation shall be dimensioned as specified in Table F.2 corresponding to the rated impulse voltage but one step higher in the preferred series of values in 4.2.3 than that specified for **basic insulation**.”*

NOTE 1 IEC 62368-1 uses the term “**required withstand voltage**” instead of the IEC 60664-1 term “required impulse withstand voltage.”

NOTE 2 IEC 62368-1 uses the term “**mains transient voltage**” instead of the IEC 60664-1 term “rated impulse voltage.”

The preferred series of values of rated impulse voltage according to 4.2.3 of IEC 60664-1:2007 is: 330 V, 500 V, 800 V, 1 500 V, 2 500 V, 4 000 V, 6 000 V, 8 000 V, 12 000 V

Applying Rule 1, the reinforced **clearance** (inhomogeneous field, **pollution degree 2**, Table F.2) for:

- 330 V would be the **basic insulation clearance** for 500 V: 0,2 mm
- 500 V would be the **basic insulation clearance** for 800 V: 0,2 mm
- 800 V would be the **basic insulation clearance** for 1 500 V: 0,5 mm
- 1 500 V would be the **basic insulation clearance** for 2 500 V: 1,5 mm
- 2 500 V would be the **basic insulation clearance** for 4 000 V: 3,0 mm
- 4 000 V would be the **basic insulation clearance** for 6 000 V: 5,5 mm
- 6 000 V would be the **basic insulation clearance** for 8 000 V: 8,0 mm
- 8 000 V would be the **basic insulation clearance** for 12 000 V: 14 mm
- 12 000 V is indeterminate because there is no preferred voltage above 12 000 volts.

Rule 2, 160 % of impulse withstand voltages other than the preferred series

With regard to non-**mains** circuits, subclause 5.1.6 of IEC 60664-1:2007 states:

“If the impulse withstand voltage required for basic insulation according to 4.3.3.4.2 is other than a value taken from the preferred series, reinforced insulation shall be dimensioned to withstand 160 % of the value required for basic insulation.”

The impulse withstand voltages other than the preferred series (in IEC 60664-1:2007, Table F.2) are: 400 V, 600 V, 1 200 V, 2 000 V, 3 000 V, 10 000 V, and all voltages above 12 000 V.

Applying Rule 2, the reinforced **clearance** (inhomogeneous field, **pollution degree 2**, Table F.2) for:

400 V x 1,6 = 640 V interpolated to 0,20 mm.

Since 640 V is not in the list, the **reinforced insulation** is determined by interpolation. Interpolation yields the reinforced **clearance** as 0,2 mm.

Applying Rule 2 to the impulse withstand voltages in Table F.2 that are not in the preferred series:

- $400\text{ V} \times 1,6 = 640\text{ V}$ interpolated to 0,20 mm
- $600\text{ V} \times 1,6 = 960\text{ V}$ interpolated to 0,24 mm
- $1\,200\text{ V} \times 1,6 = 1\,920\text{ V}$ interpolated to 0,92 mm
- $2\,000\text{ V} \times 1,6 = 3\,200\text{ V}$ interpolated to 2,2 mm
- $3\,000\text{ V} \times 1,6 = 4\,800\text{ V}$ interpolated to 3,8 mm
- $10\,000\text{ V} \times 1,6 = 16\,000\text{ V}$ interpolated to 19,4 mm
- $15\,000\text{ V}$ to $100\,000\text{ V} \times 1,6$ and interpolated according to the rule.

Clearance differences for Rules 1 and 2

The two rules, Rule 1 for impulse withstand voltages of the preferred series, and Rule 2 for impulse withstand voltages other than the preferred series, yield different **clearances** for the same voltages. These differences occur because the slope, mm/kV, of the two methods is slightly different. The slope for Rule 1 is not constant. The slope for Rule 2 is nearly constant. Figure 15 in this document illustrates the differences between Rule 1, Rule 2 and Table 14 of IEC 62368-1:2018.

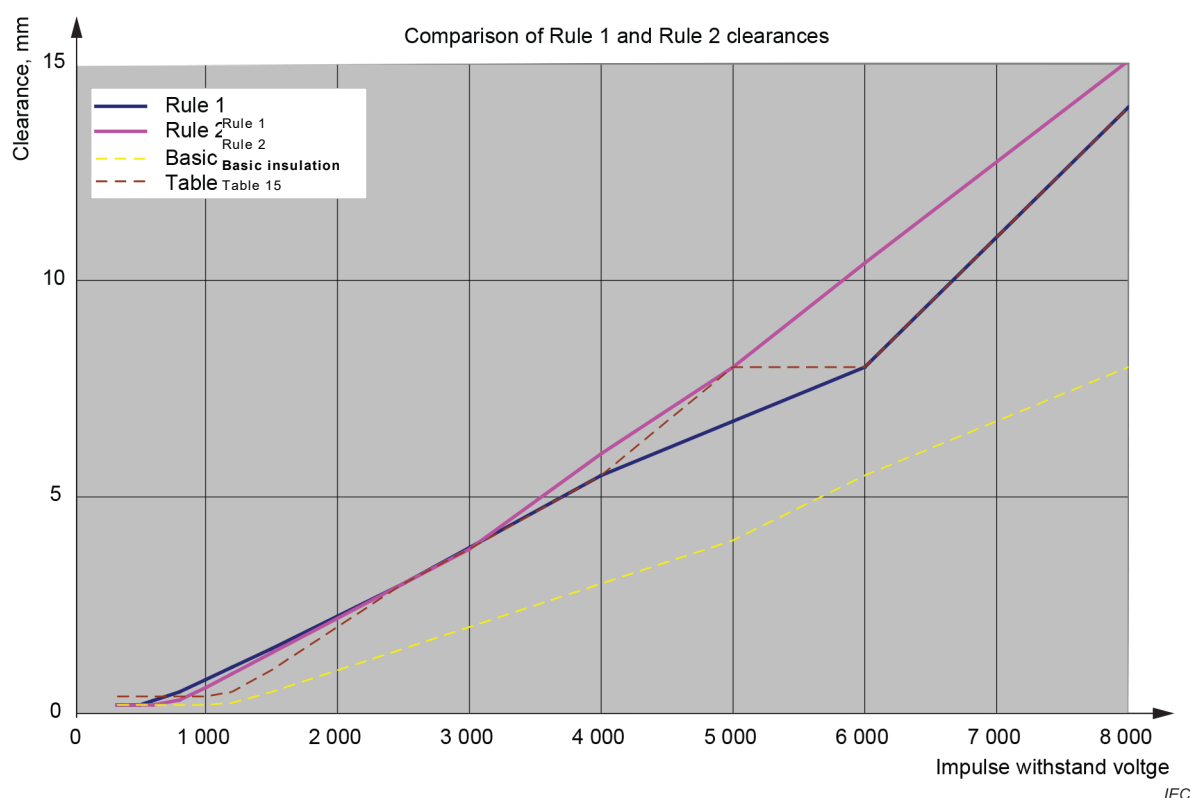


Figure 15 – Reinforced clearances according to Rule 1, Rule 2, and Table 14

If the two values for Rules 1 and 2 are combined into one set of values, the values are the same as in existing Table 14 (the brown line in Figure 14 and Figure 15 in this document). According to IEC 60664-1:2007, 5.1.6, only the impulse withstand voltages “other than a value taken from the preferred series...” are subject to the 160 % rule. Therefore, the **clearances** jump from Rule 1 criteria to Rule 2 criteria and back again. This yields the radical slope changes of the Table 14 reinforced **clearances** (brown) line.

Physically, the expected **reinforced insulation clearances** should be a constant proportion of the **basic insulation clearances**. However, the proportion between steps of Rule 1 (preferred series of impulse withstand voltages) are:

– 330 V to 500 V:	1,52
– 500 V to 800 V:	1,60
– 800 V to 1 500 V:	1,88
– 1 500 V to 2 500 V:	1,67
– 2 500 V to 4 000 V:	1,60
– 4 000 V to 6 000 V:	1,50
– 6 000 V to 8 000 V:	1,33
– 8 000 V to 12 000 V:	1,50
Average proportion, 330 to 12 000:	1,57

For Rule 2, all of the **clearances** for **reinforced insulation** are based on exactly 1,6 times the non-preferred series impulse withstand voltage for **basic insulation**.

The two rules applied in accordance with 5.1.6 of IEC 60664-1:2007 result in the variable slope of the **clearance** requirements for **reinforced insulation** of IEC 62368-1.

IEC TC 108 noted that, if the rules of IEC 60664-1 are followed, for **clearances** for **reinforced insulation**, some values were more than double the requirements for **basic insulation**. IEC TC 108 felt that this should not be the case and decided to limit the requirement for **reinforced insulation** to twice the value of **basic insulation**, thereby deviating from IEC 60664-1.

In addition, normal rounding rules were applied to the values in the table.

5.4.2.4 Determining the adequacy of a clearance using an electric strength test

Source: IEC 60664-1:2007, Table F.5

Purpose: Tests are carried out by either impulse voltage or AC voltage with the values of Table 15.

Rationale: The impulse test voltages in Table 15 are taken from IEC 60664-1:2007, Table F.5. The calculation for the AC RMS values as well as the DC values are based on the values given in Table A.1 of IEC 60664-1:2007 (see Table 7 in this document for further explanation).

This test is not suited for homogenous fields. This is for an actual design that is within the limits of the homogenous and inhomogeneous field.

Calculations for the voltage drop across an air gap during the electric strength test may be rounded up to the next higher 0,1 mm increment. In case the calculated value is higher than the value in the next row, the next row may be used.

Enamel Material: Most commonly used material is polyester resin or polyester

Dielectric constant for Polyester: 5 (can vary)

Dielectric constant for air: 1

Formula used for calculation (voltage divides inversely proportional to the dielectric constant)

Transient = 2 500 V = 2 500 (thickness of enamel / 5 + air gap / 1) = 2 500 (0,04 / 5 + 2 / 1 for 2 mm air gap) = 2 500 (0,008 + 2) = (10 V across enamel + 2 490 V across air gap)

Related to condition a of Table 15, although U is any **required withstand voltage** higher than 12,0 kV, there is an exception when using Table F.5 of IEC 60664-1:2007.

Table 7 – Voltage drop across clearance and solid insulation in series

Enamel thickness mm	Air gap mm	Transient on 240 V system	Transient voltage across air gap	Transient voltage across enamel	Peak impulse test voltage for 2 500 V peak transient from Table 16	Test voltage across air gap	Test voltage across enamel
Material: Polyester, dielectric constant = 5							
0,04	2	2 500	2 490	10	2 950	12	2 938
0,04	1	2 500	2 480	20	2 950	24	2 926
0,04	0,6	2 500	2 467	33	2 950	39	2 911
For 2 500 V peak impulse (transient for 230 V system), the homogenous field distance is 0,6 mm (from Table A.1 of IEC 60664-1:2007). Our test voltage for 2 500 V peak is 2 950 V peak from Table 15. This means that a minimum distance of 0,79 mm through homogenous field needs to be maintained to pass the 2 950 V impulse test. This gives us a margin of $(0,19/0,6) \times 100 = 3,2 \%$. In actual practice, the distance will be higher as it is not a true homogenous field. Therefore, we do not need to verify compliance with Table 14. We are always on the conservative side.							
Material: Polyamide, dielectric constant = 2,5							
0,04	2	2 500	2 480	20	2 950	23	2 927
0,04	1	2 500	2 460	40	2 950	46	2 904
0,04	0,6	2 500	2 435	65	2 950	76	2 874
For 2 500 V peak impulse (transient for 230 V system), the homogenous field distance is 0,6 mm (from Table A.1 of IEC 60664-1:2007). Our test voltage for 2 500 V peak is 2 950 V peak from Table 15. This means that a minimum distance of 0,78 mm through homogenous field needs to be maintained to pass the 2 950 V impulse test. This gives us a margin of $(0,18/0,6) \times 100 = 3,0 \%$. In actual practice, the distance will be higher, as it is not a true homogenous field. Therefore, we do not need to verify compliance with Table 14. We are always on the conservative side.							

5.4.2.5 Multiplication factors for altitudes higher than 2 000 m above sea level

- Source: IEC 60664-1:2007, curve number 2 for case A using impulse test.
- Purpose: Test is carried out by either impulse voltage or AC voltage with the values of Table 16 and the multiplication factors for altitudes higher than 2 000 m.
- Rationale: Table 16 is developed using Figure A.1 of IEC 60664-1:2007, curve number 2 for case A using impulse test.

5.4.2.6 Compliance criteria

- Source: IEC 60664-1:2007, 5.1.1
- Rationale: IEC 62368-1:2018, Annex O figures are similar/identical to figures in IEC 60664-1:2007.

Tests of IEC 62368-1:2018, Annex T simulate the occurrence of mechanical forces:

- 10 N applied to components and parts that may be touched during operation or servicing. Simulates the accidental contact with a finger or part of the hand;
- 30 N applied to internal **enclosures** and barriers that are **accessible to ordinary persons**. Simulates accidental contact of part of the hand;

- 100 N applied to external **enclosures** of **transportable equipment** and handheld equipment. Simulates expected force applied during use or movement;
- 250 N applied to external **enclosures** (except those covered in T.4). Simulates expected force applied by a body part to the surface of the equipment. It is not expected that such forces will be applied to the bottom surface of heavy equipment (> 18 kg).

During the force tests metal surfaces shall not come into contact with parts at ES2 or ES3 voltage.

5.4.3 Creepage distances

Source: IEC 60664-1:2007, 3.3

Purpose: To prevent flashover along a surface or breakdown of the insulation.

Rationale: Preserve **safeguard** integrity.

In IEC 60664-1:2007, Table F.4 columns 2 and 3 for printed wiring boards are deleted, as there is no rationale for the very small **creepage distances** for printed wiring in columns 2 and 3 (the only rationale is that it is in the basic safety publication IEC 60664-1).

However, there is no rationale why the **creepage distances** are different for printed wiring boards and other isolation material under the same condition (same PD and same CTI).

Moreover the **creepage distances** for printed boards in columns 2 and 3 are in conflict with the requirements in G.13.3 (Coated printed boards). Consequently the values for voltages up to 455 V in Table G.16 were replaced.

Creepage distances between the outer insulating surface of a connector and conductive parts at ES3 voltage level shall comply with the requirements of **basic insulation** only, if the connectors are fixed to the equipment, located internal to the outer **electrical enclosure** of the equipment, and are **accessible** only after removal of a sub-assembly which is required to be in place during normal operation.

It is assumed that the occurrence of both factors, the sub-assembly being removed, and the occurrence of a transient overvoltage have a reduced likelihood and hazard potential.

5.4.3.2 Test method

Source: IEC 60664-1:2007, 3.2

Purpose: Measurement of **creepage distance**.

Rationale: To preserve **safeguard** integrity after mechanical tests.

Annex O figures are similar/identical to figures in IEC 60950-1 and IEC 60664-1.

Tests of Annex T simulate the occurrence of mechanical forces:

- 10 N applied to components and parts that are likely to be touched by a **skilled person** during servicing, where displacement of the part reduces the **creepage distance**. Simulates the accidental contact with a finger or part of the hand.
- 30 N applied to internal **enclosures** and barriers that are **accessible** to **ordinary persons**. Simulates accidental contact of part of the hand.
- 100 N applied to external **enclosures** of **transportable equipment** and **hand-held equipment**. Simulates expected force applied during use or movement.