BS EN 60990:2016

BSI Standards Publication

Methods of measurement of touch current and protective conductor current

National foreword

This British Standard is the UK implementation of EN 60990:2016. It is identical to IEC 60990:2016. It supersedes BS EN 60990:2000 which is withdrawn.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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Date	Text affected

EUROPEAN STANDARD
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EUROPÄISCHE NORM

EN 60990

September 2016

ICS 17.220; 35.020

Supersedes EN 60990:1999

English Version

Methods of measurement of touch current and protective conductor current (IEC 60990:2016)

Méthodes de mesure du courant de contact et du courant dans le conducteur de protection
(IEC 60990:2016)

Verfahren zur Messung von Berührungsstrom und Schutzleiterstrom
(IEC 60990:2016)

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

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CENELEC

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

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European foreword

The text of document 108/630/FDIS, future edition 3 of IEC 60990, prepared by IEC/TC 108 "Safety of electronic equipment within the field of audio/video, information technology and communication technology" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 60990:2016.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2017-04-04
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2019-07-04

This document supersedes EN 60990:1999

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Endorsement notice

The text of the International Standard IEC 60990:2016 was approved by CENELEC as a European Standard without any modification.

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

IEC 60065	NOTE	Harmonized as EN 60065.
IEC 60309-1:1999	NOTE	Harmonized as EN 60309-1:1999 (not modified).
IEC 60335-1	NOTE	Harmonized as EN 60335-1.
IEC 60364-1	NOTE	Harmonized as HD 60364-1.
IEC 60364-4-41:2005	NOTE	Harmonized as HD 60364-4-41:2007 (modified).
IEC 60601-1	NOTE	Harmonized in EN 60601-1 series.
IEC 60950-1	NOTE	Harmonized as EN 60950-1.
IEC 61010-1	NOTE	Harmonized as EN 61010-1.
IEC 62368-1	NOTE	Harmonized as EN 62368-1.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

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

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

Publication	Year	Title	EN/HD	Year
IEC/TS 60479-1	2005	Effects of current on human beings and livestock - Part 1: General aspects	-	-
IEC/TS 60479-2	2007	Effects of current on human beings and livestock - Part 2: Special aspects	-	-
IEC 61140	-	Protection against electric shock - Common aspects for installation and equipment	EN 61140	-
ISO/IEC Guide 51	2014	Safety aspects - Guidelines for their inclusion in standards	-	-
IEC Guide 104	2010	The preparation of safety publications and the use of basic safety publications and group safety publications	-	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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METHODS OF MEASUREMENT OF TOUCH CURRENT AND PROTECTIVE CONDUCTOR CURRENT

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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International Standard IEC 60990 has been prepared by TC 108: Safety of electronic equipment within the field of audio/video, information technology and communication technology.

This third edition cancels and replaces the second edition published in 1999. It constitutes a technical revision.

The principal changes in this edition as compared with the second edition are as follows:

- the effects names have been updated to reflect increased understanding of the range of effects and is in concert with present usage;
- the conditions of use invoking a GRIPPABLE PART have been reduced in the application of the requirements based upon the current understanding of this effect;
- the references to ISO 10012-1, which has been replaced by management standard of the same number, have been replaced with explanatory text, where needed to maintain the sense of the document;

- former informative Annex H (GRIPPABLE PART) has been deleted from this update as it does not properly represent the full set of conditions under which immobilization can occur. A new informative Annex H (Analysis of frequency filtered touch current circuits measurement) has been added;
- the Bibliography (formerly Annex M) has been updated with additional references for completeness.

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

FDIS	Report on voting
108/630/FDIS	108/640/RVD

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

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

In this standard, the following print types or formats are used:

- requirements proper and normative annexes: in roman type;
- compliance statements and test specifications: *in italic type*;
- notes/explanatory matter: in smaller roman type;
- normative conditions within tables: in smaller roman type;
- terms defined in Clause 3: SMALL CAPITALS.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC website 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This International Standard was developed as a response to concerns arising from the advent of electronic switching techniques being broadly applied to power systems and within EQUIPMENT, giving rise to high-frequency harmonic voltages and currents.

This standard is intended for the guidance of EQUIPMENT committees in preparing or amending the test specifications in their standards for measurement of leakage current. However the term "leakage current" is not used for reasons explained below.

This standard was initially prepared under the basic safety function assigned to TC 74 (now TC 108), as follows:

> Methods of measuring leakage current

This includes, for various types of EQUIPMENT, all aspects of what is referred to as "leakage current", including methods of measurement of current with regard to physiological effects and for installation purposes, under normal conditions and under certain fault conditions.

The methods of measurement of leakage current described herein result from the review of IEC TS 60479-1 and other publications, including descriptions of earlier methods of measurement.

The following conclusions were derived from a review of the effects of leakage current:

- the primary concern for safety involves possible flow of harmful current through the human body (this current is not necessarily equal to the current flowing through a protective conductor);
- the effect of electric current on a human body is found to be somewhat more complex than was assumed during the development of earlier standards in that there are several body responses which should be considered. The most significant responses for setting limits for continuous waveforms are
  - perception,
  - startle-reaction,
  - letgo-immobilization, and
  - ELECTRIC BURN.

Each of these four body responses has a unique threshold level. There are also significant differences in the manner in which some of these thresholds vary with frequency.

Two types of current have been identified as needing separate measuring methods: TOUCH CURRENT and PROTECTIVE CONDUCTOR CURRENT.

TOUCH CURRENT only exists when a human body or a body model is a current pathway.

It was also noted that the term "leakage current" has already been applied to several different concerns: TOUCH CURRENT, PROTECTIVE CONDUCTOR CURRENT, insulation properties, etc. Therefore, in this standard, the term "leakage current" is not used.

Measurement of TOUCH CURRENT

In the past, EQUIPMENT standards have used two traditional techniques for measurement of leakage current. Either the actual current in the protective conductor was measured, or a simple resistor-capacitor network (representing a simple body model) was used, the leakage current being defined as the current through the resistor.

This standard provides measuring methods for the four body responses to the electric current noted above, using a more representative body model.

This body model was chosen for most common cases of electric shock in the general sense. With respect to the path of current flow and conditions of contact, a body model approximating full hand-to-hand or hand-to-foot contact in normal conditions is used. For small areas of contact (for example, small, finger contact), a different model may be appropriate but is not covered here.

Of the four responses, startle-reaction and letgo-immobilization are related to the peak value of TOUCH CURRENT and vary with frequency. Traditionally, concerns for electric shock have dealt with sinusoidal waveforms, for which r.m.s. measurements are most convenient. Peak measurements are more appropriate for non-sinusoidal waveforms where significant values of TOUCH CURRENT are expected, but are equally suitable for sinusoidal waveforms. The networks specified for the measurement of startle-reaction and letgo-immobilization are frequency-responsive and are so weighted that single limit power-frequency values can be specified and referenced.

ELECTRIC BURNS, however, are related to the r.m.s. value of TOUCH CURRENT, and are relatively independent of frequency. For EQUIPMENT where ELECTRIC BURNS may be of concern (see 7.2), two separate measurements are made, one in peak value for electric shock and a second in r.m.s. value for ELECTRIC BURNS each using the appropriate test circuit.

EQUIPMENT committees should decide which physiological effects are acceptable and which are not, and then decide on limit values of current. Committees for certain types of EQUIPMENT may adopt simplified procedures based upon this standard. A discussion of limit values, based upon earlier work by various IEC EQUIPMENT committees, is provided in Annex D.

Measurement of PROTECTIVE CONDUCTOR CURRENT

In certain cases, measurement of the PROTECTIVE CONDUCTOR CURRENT of EQUIPMENT under normal operating conditions is required. Such cases include:

- selection of a residual current protection device,
- determination when a high integrity protective earth circuit is required,
- prevent excessive PROTECTIVE CONDUCTOR CURRENT overload in the electrical installation.

The PROTECTIVE CONDUCTOR CURRENT is measured by inserting an ammeter of negligible impedance in series with the EQUIPMENT protective earthing conductor.

METHODS OF MEASUREMENT OF TOUCH CURRENT AND PROTECTIVE CONDUCTOR CURRENT

1 Scope

This International Standard defines measurement methods for

- d.c. or a.c. current of sinusoidal or non-sinusoidal waveform, which could flow through the human body, and
- current flowing through a protective conductor.

The measuring methods recommended for TOUCH CURRENT are based upon the possible effects of current flowing through a human body. In this standard, measurements of current through networks representing the impedance of the human body are referred to as measurements of TOUCH CURRENT. These networks are not necessarily valid for the bodies of animals.

The specification or implication of specific limit values is not within the scope of this standard. IEC TS 60479 series provides information regarding the effects of current passing through the human body from which limit values may be derived.

This standard is applicable to all classes of EQUIPMENT, according to IEC 61140.

The methods of measurement in this standard are not intended to be used for

- TOUCH CURRENTS having less than 1 s duration,
- patient currents as defined in IEC 60601-1,
- a.c. at frequencies below 15 Hz, and
- currents above those chosen for ELECTRIC BURN limits.

This basic safety publication is primarily intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 104 and ISO/IEC Guide 51. It is not intended for use by manufacturers or certification bodies independent of product standards.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications in the preparation of its publications. The requirements, test methods or test conditions of this basic safety publication only apply when specifically referred to or included in the relevant publications.

2 Normative references

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

IEC TS 60479-1:2005, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC TS 60479-2:2007, *Effects of current on human beings and livestock – Part 2: Special aspects*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

ISO/IEC Guide 51:2014, *Safety aspects – Guidelines for their inclusion in standards*

IEC Guide 104:2010, *The preparation of safety publications and the use of basic safety publications and group safety publications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

TOUCH CURRENT

electric current through a human body or through an animal body when it touches one or more accessible parts of an installation or of EQUIPMENT

[SOURCE: IEC 60050-195:1998, 195-05-21]

3.2

PROTECTIVE CONDUCTOR CURRENT

current which flows in a protective conductor

3.3

EQUIPMENT

organized collection of electromechanical component parts and features to accomplish a defined task (as specified in the relevant product standard).

Note 1 to entry: If not specified in the relevant standard, see Annex A.

3.4

GRIPPABLE PART

part of the EQUIPMENT which could supply current through the human hand to cause muscular contraction around the part and an inability to let go

Note 1 to entry: Parts which are intended to be gripped with the entire hand are assumed to be grippable without further investigation.

3.5

ELECTRIC BURN

burning of the skin or of an organ, caused by passing an electric current across or through the surface

[SOURCE: IEC 60050-604:1987, 604-04-18]

4 Test site

4.1 Test site environment

Test site environmental requirements shall be as specified in the EQUIPMENT standard. If limit values of less than 70 μA r.m.s. or 100 μA peak are specified, or if the EQUIPMENT contains large shields which may be driven by high-frequency signals, product committees shall refer to Annex B.

4.2 Test transformer

The use of a test transformer for isolation is optional. For maximum safety, a test transformer for isolation (T2 in Figure 2, T in Figure 6 to Figure 14) shall be used and the main protective earthing terminal of the EQUIPMENT under test (EUT) earthed. Any capacitive leakage in the transformer shall then be taken into account. As an alternative to earthing the EUT, the test transformer secondary and the EUT shall be left floating (not earthed), in which case the capacitive leakage in the test transformer need not be taken into account.

If transformer T is not used, the EUT shall be mounted on an insulating stand and appropriate safety precautions taken, in view of the possibility of the body of the EUT being at hazardous voltage.

4.3 Earthed neutral conductor

EQUIPMENT intended for connection to a TT or TN power distribution system shall be tested with minimum voltage between neutral and earth.

NOTE Descriptions of various power distribution systems are given in Annex I.

The protective conductor and the earthed neutral conductor for the EUT should have a voltage difference of less than 1 % of line-to-line voltage (see example in Figure 1).

A local transformer, see 4.2, will achieve this requirement.

Alternatively, if the voltage difference is 1 % or more, the following are examples of methods which, in some cases, will avoid measurement errors due to this voltage:

- connecting the terminal B electrode of the measuring instrument network to the neutral terminal of the EUT instead of the protective earthing conductor (see 6.1.2) of the supply;
- connecting the earthing terminal of the EUT to the neutral conductor, instead of the protective earthing conductor, of the supply.

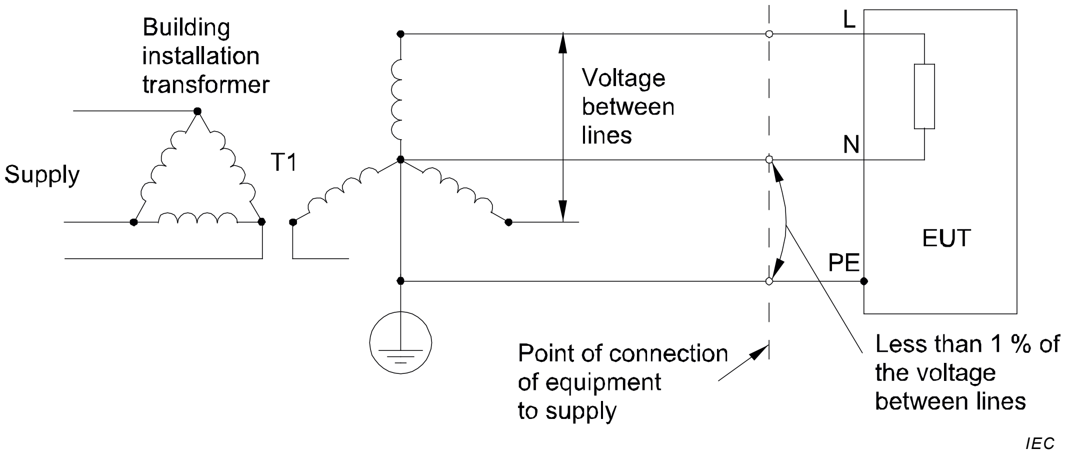


Figure 1 – Example of earthed neutral, direct supply

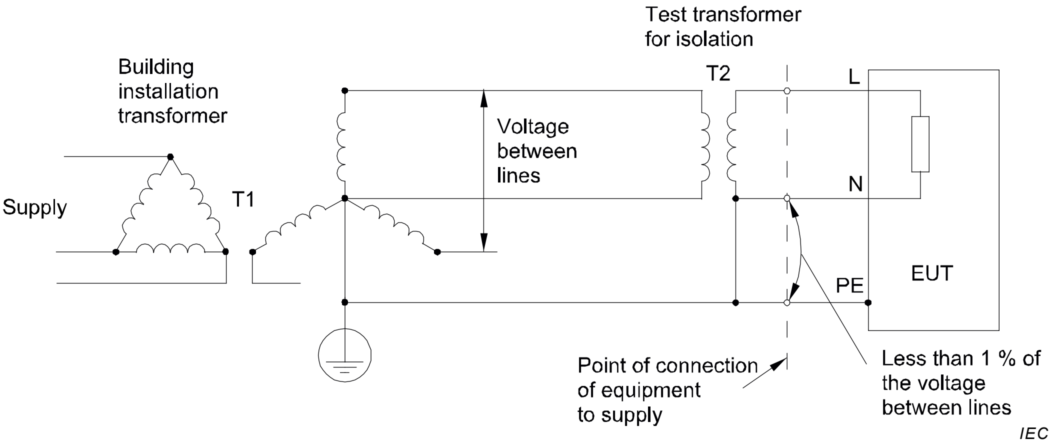


Figure 2 – Example of earthed neutral, with transformer for isolation

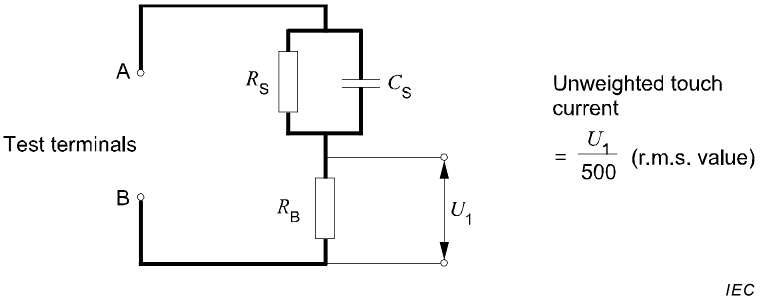
5 Measuring equipment

5.1 Selection of measuring network

5.1.1 General

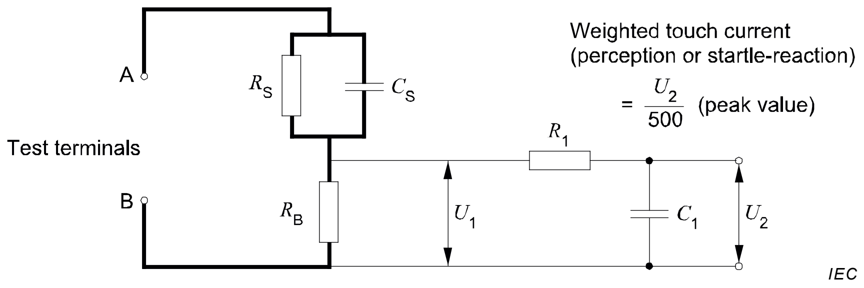
Measurements shall be made with one of the networks of Figure 3, Figure 4 and Figure 5.

NOTE See Annexes E, F and G for further explanation of the three networks.



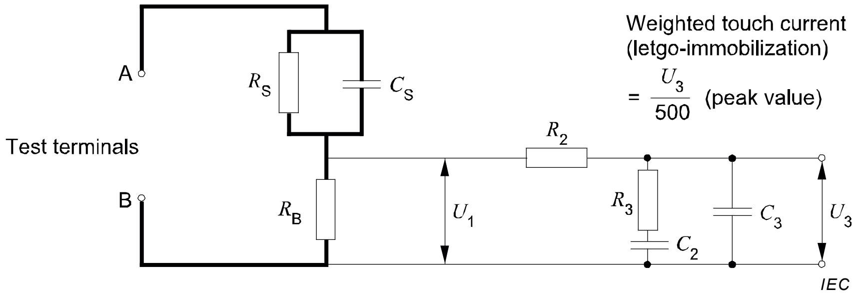
R_S	1 500 Ω
R_B	500 Ω
C_S	0,22 µF

Figure 3 – Measuring network, unweighted touch current



R_S	1 500 Ω	R_1	10 000 Ω
R_B	500 Ω	C_1	0,022 µF
C_S	0,22 µF		

Figure 4 – Measuring network, touch current weighted for perception or startle-reaction



R_S	1 500 Ω	R_3	20 000 Ω
R_B	500 Ω	C_2	0,006 2 µF
C_S	0,22 µF	C_3	0,009 1 µF
R_2	10 000 Ω		

NOTE For special conditions on the use of this network, see 5.1.2.

Figure 5 – Measuring network, touch current weighted for letgo-immobilization

5.1.2 Perception and startle-reaction

The network of Figure 4 shall be used for low level electric shock limits. This circuit is to be applied where the a.c. limit value in the product standard is up to 2 mA r.m.s. or 2,8 mA peak.

5.1.3 Letgo-immobilization

The network of Figure 5 shall be used for higher level electric shock limits. This circuit is to be applied where the a.c. limit value in the product standard is more than 2 mA r.m.s. or 2,8 mA peak.

5.1.4 Electric burn (a.c.)

The unweighted TOUCH CURRENT network of Figure 3 shall be used.

5.1.5 Ripple-free d.c.

Any one of the three networks shall be used. Unless otherwise specified in the EQUIPMENT standard, ripple-free d.c. means less than 10 % peak-to-peak ripple.

5.2 Test electrodes

5.2.1 Construction

Unless otherwise specified in the EQUIPMENT standard, the test electrodes shall be

- a test clip, or
- a 10 cm × 20 cm metal foil to represent the human hand. Where adhesive metal foil is used, the adhesive shall be conductive.

5.2.2 Connection

Test electrodes shall be connected to test terminals A and B of the measuring network.

5.3 Configuration

The EQUIPMENT under test (EUT) shall be fully assembled and ready for use in the maximum configuration; it shall be connected to external signal voltages where applicable, as specified by the manufacturer for a single EQUIPMENT.

EQUIPMENT which is designed for multiple power sources, only one of which is required at a time (for example, for backup), shall be tested with only one source connected.

EQUIPMENT requiring power simultaneously from two or more power sources shall be tested with all power sources connected but with not more than one connection to protective earth.

5.4 Power connections during test

5.4.1 General

NOTE Examples of power distribution systems are given in Annex I.

EQUIPMENT shall be connected in a test configuration as shown in Figure 6 to Figure 14, according to 5.4.2, 5.4.3 or 5.4.4, as appropriate.

EQUIPMENT committees should consider the possible need for the manufacturer to identify the power distribution system (TN, TT, IT) to which an EQUIPMENT is intended to be connected in its final application.

If the EUT is specified by the manufacturer for use only on certain power distribution systems, the EUT shall be tested only when connected to those systems.

EQUIPMENT to be connected only to TN or TT systems shall comply with 5.4.2. EQUIPMENT to be connected to IT systems shall comply with 5.4.3 and may also be connected to TN or TT systems.

For Class 0 and Class II EQUIPMENT (see IEC 61140), the protective conductors in Figure 6 through Figure 14 are ignored.

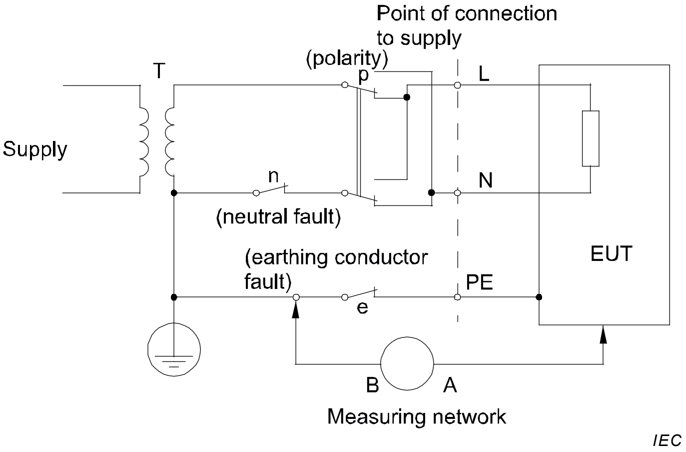
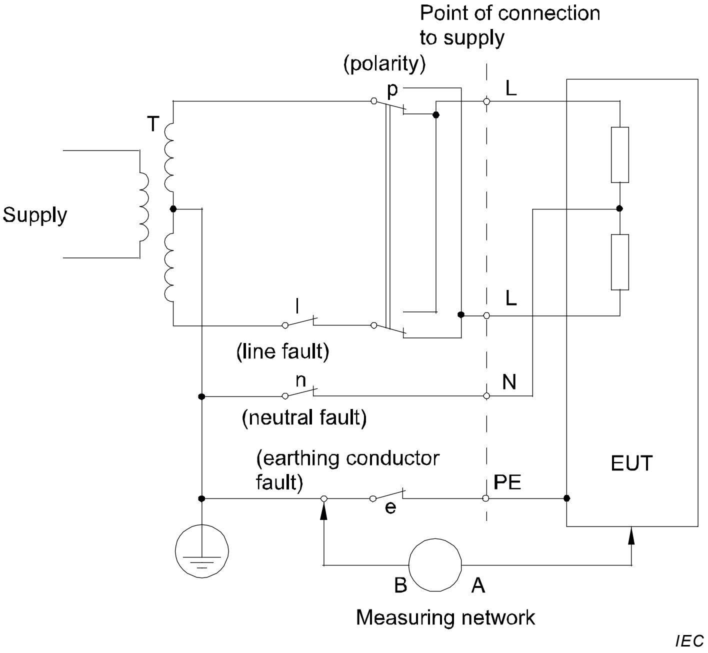


Figure 6 – Single-phase equipment on star TN or TT system



The centre-tapped winding may be one leg of a delta supply.

Figure 7 – Single-phase equipment on centre-earthed TN or TT system

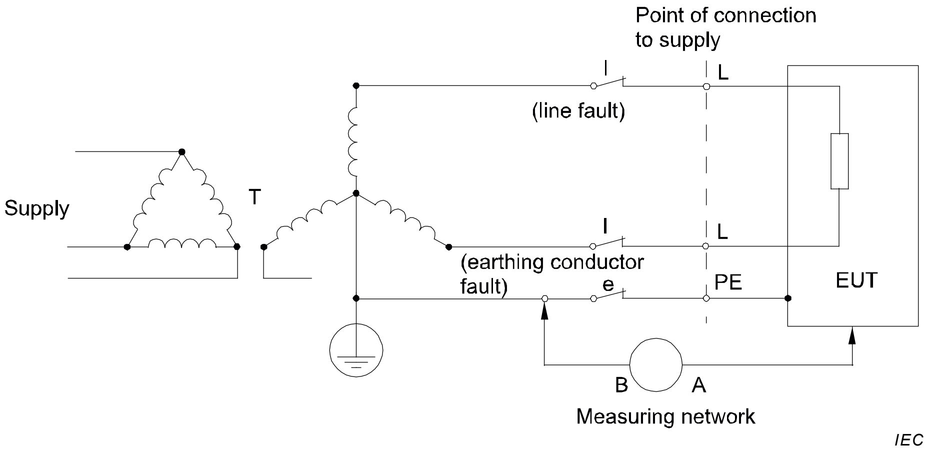
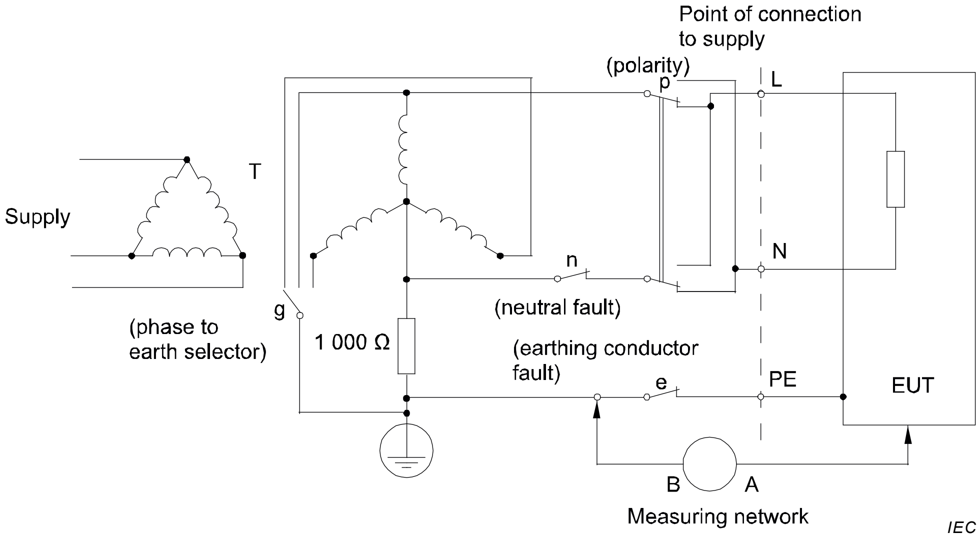
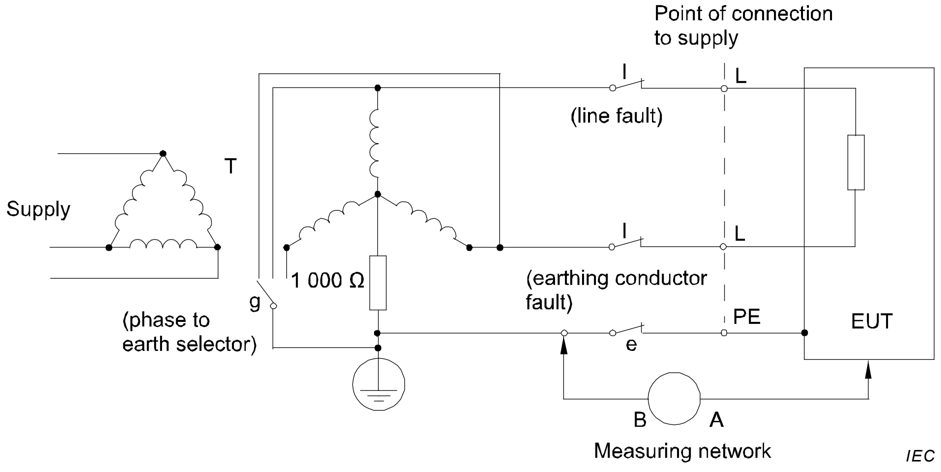


Figure 8 – Single-phase equipment connected line-to-line on star TN or TT system



The 1 000 Ω resistor should be rated for supply system faults.

Figure 9 – Single-phase equipment connected line-to-neutral on star IT system



The 1 000 Ω resistor should be rated for supply system faults.

Figure 10 – Single-phase equipment connected line-to-line on star IT system

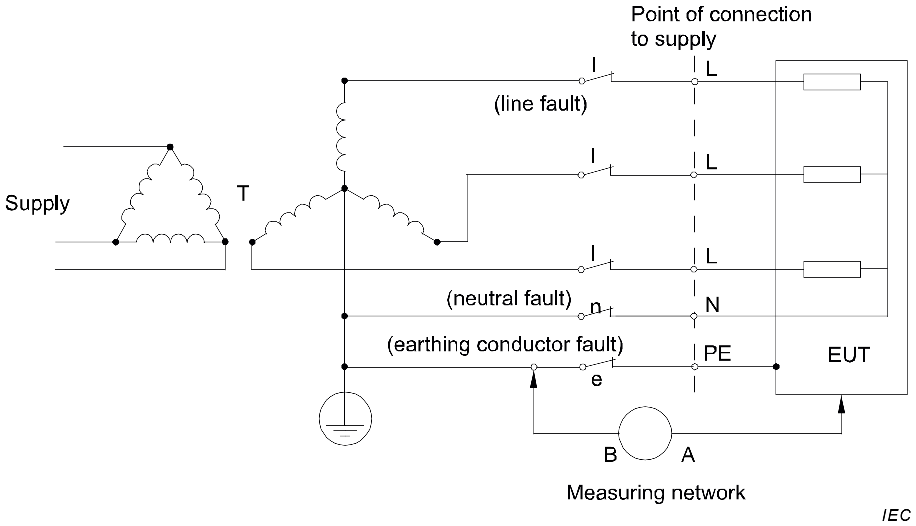
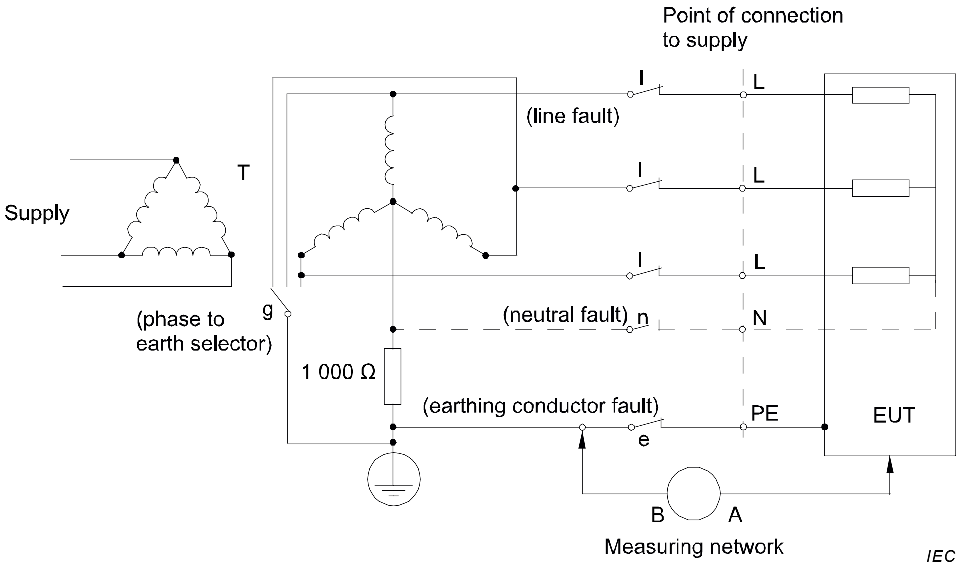


Figure 11 – Three-phase equipment on star TN or TT system



The 1 000 Ω resistor should be rated for supply system faults.

Figure 12 – Three-phase equipment on star IT system

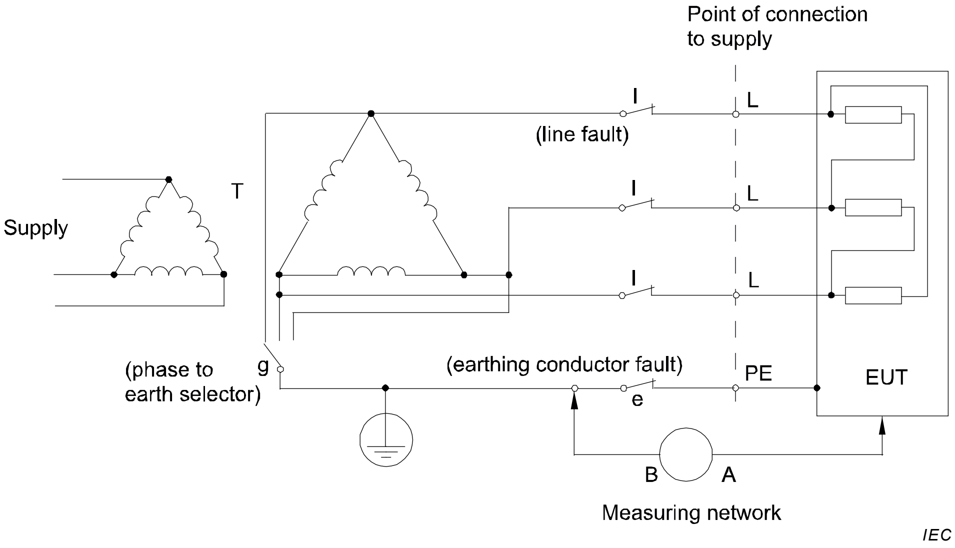
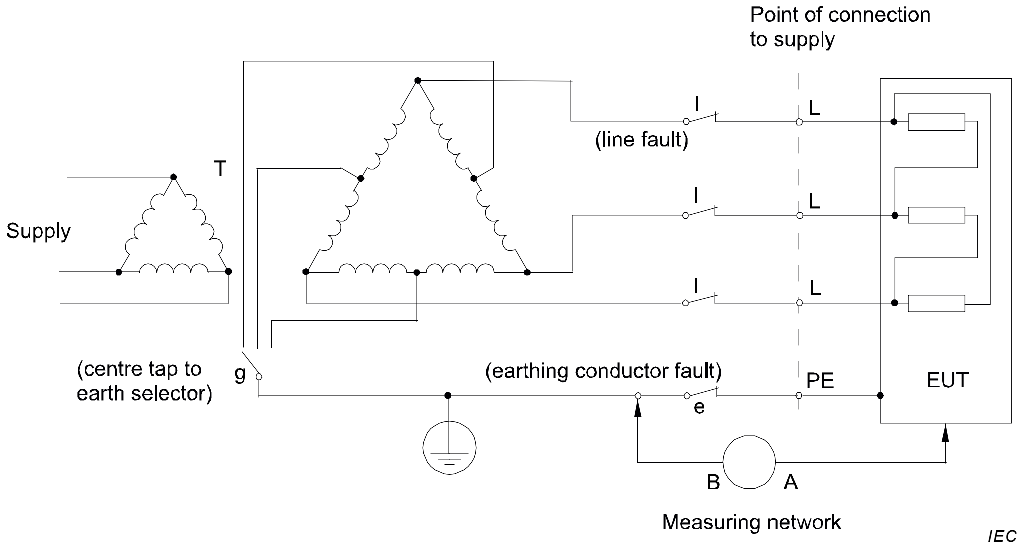


Figure 13 – Unearthed delta system



Where an EQUIPMENT contains both a three-phase load and a centre-earthed single-phase load, and the earthed side is identified, switch g shall remain in the position identified as the earthed side.

Figure 14 – Three-phase equipment on centre-earthed delta system

5.4.2 Equipment for use only on TN or TT star power distribution systems

Three-phase EQUIPMENT shall be connected to a three-phase star power distribution system, with earthed neutral. Single-phase EQUIPMENT shall be connected between phase and neutral of an earthed neutral power distribution system or, where specified by the manufacturer to operate in such a manner, line-to-line on a centre-earthed three-phase star power distribution system (see Figure 6, Figure 8 and Figure 11).

5.4.3 Equipment for use on IT power distribution systems including unearthed delta systems

Three-phase EQUIPMENT shall be connected to an appropriate three-phase IT power supply system. Single-phase EQUIPMENT shall be connected between phase and neutral or, where specified by the manufacturer to operate in such a manner, line-to-line (see Figure 9, Figure 10, Figure 12 and Figure 13).

5.4.4 Equipment for use on single-phase centre-earthed power supply systems or on centre-earthed delta power supply systems

Single-phase EQUIPMENT shall be connected to a supply having its centre tap earthed (see Figure 7 and Figure 14).

Three-phase EQUIPMENT shall be connected to the appropriate delta supply (see Figure 14).

5.5 Supply voltage and frequency

5.5.1 Supply voltage

Supply voltage shall be measured at the EQUIPMENT supply terminals.

Traditionally, TOUCH CURRENT was at its maximum at the highest supply voltage. Modern electronic power supplies will not always provide maximum TOUCH CURRENT under this supply condition. TOUCH CURRRENT may be maximized at the lowest voltage, i.e. maximum current draw, or under some other condition. Electric shock protection shall be provided under the worst case operating condition.

EQUIPMENT rated for a single voltage shall be tested at its rated voltage plus an appropriate working tolerance to allow for supply variations.

EQUIPMENT rated for a nominal voltage range shall be tested at the extremes of the voltage range, plus an appropriate working tolerance to allow for supply variations. The working tolerance is determined by the EQUIPMENT committee or by the manufacturer if necessary (for example, 0 %, -10 %/+6 % or +10 %).

EQUIPMENT rated for different nominal voltages or voltage ranges, using a voltage selector, shall be set for the highest nominal voltage or voltage range and then treated as above. Where voltage selection involves more complex switching than a rearrangement of transformer windings, additional tests may be necessary to determine the worst case.

If it is inconvenient to test EQUIPMENT at the specified voltage, it is permitted to test it at any available voltage within the rating of the EQUIPMENT and then calculate the results.

5.5.2 Supply frequency

Supply frequency shall be the maximum rated nominal frequency, or alternatively, measurements may be corrected by calculation for estimation of the worst case current.

6 Test procedure

6.1 General

6.1.1 Touch current measurements

Product committees may wish to exclude measurement of TOUCH CURRENT at some accessible parts, based upon the principle of limitation of voltage (see IEC 60364-4-41). If so, measurements shall be made for accessible voltage and then, if required, for weighted or unweighted TOUCH CURRENT according to Clause 6.

Concern for ELECTRIC BURN effects may arise with d.c. or at high frequencies (for example, above 30 kHz for 3,5 mA TOUCH CURRENT). At lower frequencies, startle-reaction and letgo-immobilization will be the dominant considerations. Where there is such a concern, the unweighted r.m.s. value of TOUCH CURRENT shall be measured (Figure 3), in addition to measurement for either startle-reaction (Figure 4), or inability to let go (Figure 5).

6.1.2 Control switches, equipment and supply conditions

During TOUCH CURRENT measurements, the test environment, configuration, earthing and supply system shall be according to 5.3, 5.4 and 5.5.

In order to maximize the current values during measurements, the configuration shall be varied by connection and disconnection of units that are part of the EQUIPMENT, as permitted by the manufacturer's operating and installation instructions.

Control switches e, g, l, n and p in Figure 6 to Figure 14 shall be manipulated as described in 6.2, while the conditions listed in this subclause and 6.2.1 are independently varied so as to give the maximum measured value or values. Product committees shall make an appropriate selection of these variables. Recent addition of ABNORMAL OPERATION as an operating condition in product standards as related to the electrical installation (e.g. the loss of PE or the inability to ensure polarity of supply) clarifies the test conditions under NORMAL operation and FAULT CONDITIONS to then be applied.

6.1.3 Use of measuring networks

Appropriate measuring electrodes (see 5.2), measuring network (see 5.1) and measuring device (see G.4) shall be used in accordance with the appropriate systems of Figure 6 to Figure 14 (see 5.4) to make measurements of TOUCH CURRENT between simultaneously accessible parts, and between accessible parts and earth.

The terminal A electrode shall be applied to each accessible part in turn.

For each application of the terminal A electrode, the terminal B electrode shall be applied to earth, then applied to each of the other accessible parts in turn.

For power systems with an earthed power conductor, the terminal B electrode may be connected directly to the earthed power conductor at the interface of the EUT and the power supply, instead of being connected to the protective conductor. This connection may be used even though the voltage difference between the protective conductor and the earthed power conductor is more than 1 % of the line-to-line voltage (see 4.2).

6.2 Normal and fault conditions of equipment

6.2.1 Normal operation of equipment

The test is carried out with terminal A of the measuring network connected to each unearthed or conductive accessible part and circuit in turn, with all test switches l, n and e closed.

Measurements shall be made in all applicable conditions of normal operation.

Examples of normal operation include mains switch on, mains switch off, standby, start-up, heating and any setting of operator controls except supply-voltage-setting controls.

Single-phase EQUIPMENT shall be tested in normal and reverse polarity (switch p).

Three-phase EQUIPMENT shall be tested with phase reversals, unless EQUIPMENT operation is dependent on phasing.

6.2.2 Equipment and supply fault conditions

6.2.2.1 General

For EQUIPMENT having no connection to earth, 6.2.2 does not apply.

For EQUIPMENT having a protective earthing connection or a functional earthing connection, terminal A of the measuring network is connected to the EQUIPMENT earthing terminal of the EUT.

Measurements shall be made with each of the applicable fault conditions specified in 6.2.2.2 to 6.2.2.9. The faults shall be applied one at a time, but shall include any faults which are a logical result of the first fault. Before applying any fault, the EQUIPMENT shall be restored to its original condition (for example, without faults or consequential damage).

Where a balanced line filter is used on three-phase EQUIPMENT, the net current to earth is theoretically zero. However, it is normal for component and voltage unbalance to produce a finite value of net current, the maximum value of which may not be measured during type testing. Larger unbalanced currents will result from a failed capacitor in one phase. EQUIPMENT committees should consider including a test for such EQUIPMENT, involving the substitution of a deliberately faulted filter (one capacitor removed), together with a loss of protective earth connection (see 6.2.2.2).

Similar considerations apply to a balanced arrangement of other components, such as surge arrestors, connected between mains and earth.

Three-phase EQUIPMENT shall be tested with phase reversals unless EQUIPMENT operation is dependent on phasing.

6.2.2.2 Fault condition No. 1

Depending on the kind of EQUIPMENT, several safety degrees of the protective conductor are to be distinguished (see IEC 61140).

Single-phase EQUIPMENT not reliably earthed shall be tested with loss of protective earth connection (switch e) in combination with normal and reverse polarity (switch p).

Three-phase EQUIPMENT not reliably earthed shall be tested with loss of protective earth connection (switch e).

Unless decided otherwise by the product committee, the requirements of this subclause do not apply to reliably earthed EQUIPMENT which is connected to the supply either permanently, or by means of plugs and sockets which are of industrial grade (for example, connectors specified in IEC 60309-1 or a comparable national standard).

6.2.2.3 Fault condition No. 2

Single-phase EQUIPMENT shall be tested with neutral open (switch n), with earth intact and in normal polarity, and again in reverse polarity (switch p).

6.2.2.4 Fault condition No. 3

EQUIPMENT for use on IT systems shall be tested with each phase conductor faulted to earth, one at a time (switch g).

6.2.2.5 Fault condition No. 4

Three-phase EQUIPMENT shall be tested with each phase conductor open, one at a time (switches l).

6.2.2.6 Fault condition No. 5

Single-phase EQUIPMENT for use on IT power systems or on three-phase delta systems shall be tested with a three-phase power system, with each phase faulted to earth, one at a time (switch g), in combination with normal and reverse polarity (switch p) and separately with each phase conductor open one at a time (switches l), and in combination with normal and reverse polarity (switch p).

6.2.2.7 Fault condition No. 6

Three-phase EQUIPMENT for use on centre-earthed delta supply systems shall be tested on a delta supply system with each delta-leg centre-earthed, one at a time (switch g).

EQUIPMENT containing both three-phase and centre-earthed circuits which cannot be installed independently and which have an identified earthed leg shall be tested with switch g on the identified earth-leg position only.

6.2.2.8 Fault condition No. 7

Other faults as specified by the product committee shall be simulated if they are likely to increase TOUCH CURRENT.

6.2.2.9 Fault condition No. 8

Accessible conductive parts which are only incidentally electrically connected to other parts shall be tested both when connected electrically to the other part(s) and when disconnected electrically from the other part(s). See Annex C regarding incidentally connected parts.

7 Evaluation of results

7.1 Perception, startle-reaction and letgo-immobilization

Voltages U_2 and U_3 of Figure 4 and Figure 5 are frequency-weighted values of U_1, such that a single, low-frequency equivalent indication of TOUCH CURRENT results for all frequencies present above 15 Hz. These weighted values of TOUCH CURRENT are taken as the highest values of U_2 and U_3 measured during the procedure of Clause 6, divided by 500 Ω. The maximum values are compared with the limits for perception or startle-reaction and letgo-immobilization specified for the EQUIPMENT (for example, a 50 Hz or 60 Hz limit value).

Measurements for d.c. limits are made in a like manner, but taken as U_1 divided by 500 Ω (see also Annex G).

7.2 Electric burn

Where there is concern for ELECTRIC BURN effects (see 6.1), the unweighted r.m.s. or d.c. value of TOUCH CURRENT is measured. This is calculated from the r.m.s. voltage U_1, measured across the 500 Ω resistor of the measuring network of Figure 3.

The effect of TOUCH CURRENT is also related to the area of contact with the human body and the duration of contact. The relationship between these parameters and the establishment of TOUCH CURRENT limits are not in the scope of this standard (see also Clause D.3).

NOTE ELECTRIC BURNS result from the power dissipated as current flows through the resistance of the human skin and body. Other forms of burn can result from electrical EQUIPMENT, for example due to arcing or the by-products of arcing.

8 Measurement of protective conductor current

8.1 General

Current requirements and values for protective conductors are not related to TOUCH CURRENT concerns and, therefore, such limits and methods of measurement are dealt with separately.

8.2 Multiple equipment

Within any shared earthing system, the PROTECTIVE CONDUCTOR CURRENTS of individual EQUIPMENT combine in a non-arithmetic manner. Therefore, THE PROTECTIVE CONDUCTOR CURRENT of a group OF EQUIPMENT earthed by a single protective earthing conductor cannot be reliably predicted from knowledge of individual EQUIPMENT PROTECTIVE CONDUCTOR CURRENTS. Consequently, measurements made on individual EQUIPMENT are of limited use, and the PROTECTIVE CONDUCTOR CURRENT for that group of EQUIPMENT shall be measured in the shared protective earthing conductor.

8.3 Measuring method

The installation PROTECTIVE CONDUCTOR CURRENT shall be measured after installation by inserting an ammeter of negligible impedance (for example, 0,5 Ω) in series with the protective conductor. Measurement of PROTECTIVE CONDUCTOR CURRENT is made with the EQUIPMENT and power distribution system running in all normal operating modes.

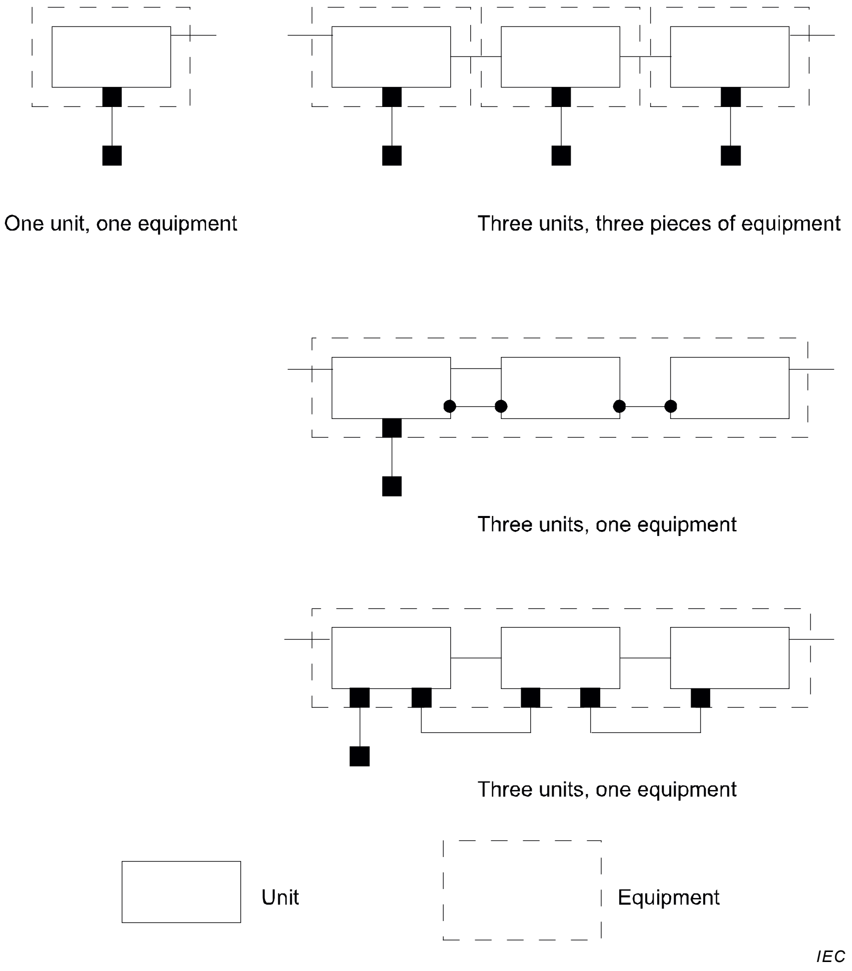
Annex A
(normative)

Equipment

Unless otherwise defined in the EQUIPMENT standard, an EQUIPMENT is identified as having a single connection to a supply of electricity.

An EQUIPMENT may be a single unit or may consist of physically separate, electrically interconnected units (see Figure A.1). The source of electricity may be contained within the EQUIPMENT (for example, solar or battery power).

The connection of signal cables shall be considered as part of the EQUIPMENT, in accordance with 5.4.



One unit, one equipment

Three units, three pieces of equipment

Three units, one equipment

Three units, one equipment

Key

■—■ Supply connection compatible with local supply

●—● Supply connection not designed to be connected directly to local supply

—— Other connections

Figure A.1 – Equipment

Annex B
(normative)

Use of a conductive plane

Where limits for TOUCH CURRENT (with or without frequency weighting) less than 70 μA r.m.s. or 100 μA peak are specified, or where an EQUIPMENT is tested that has large capacitive coupling to outer surfaces which may be driven at high frequencies (for example, high-frequency signal generators and voltage measuring instruments), it is appropriate to measure the current which is coupled capacitively into a conductive surface placed beneath or against a surface of the EQUIPMENT. If the EQUIPMENT is to be tested in this manner, it shall be placed on a conductive plane which is in turn placed on an insulating surface (see Figure B.1).

The conductive plane shall be equal to or greater than the adjacent EQUIPMENT surface in area and perimeter.

Measurements shall be according to Clause 6, with the conductive plane tested as an accessible part.

The measurements shall be repeated with the conductive plane placed against any other surface of the EQUIPMENT which may become adjacent to an outside conductive plane.

For purposes of isolation from electromagnetic interference, it may be necessary to place the EQUIPMENT (including the conductive plane, if used) 0,5 m or more from other conductors or EQUIPMENT.

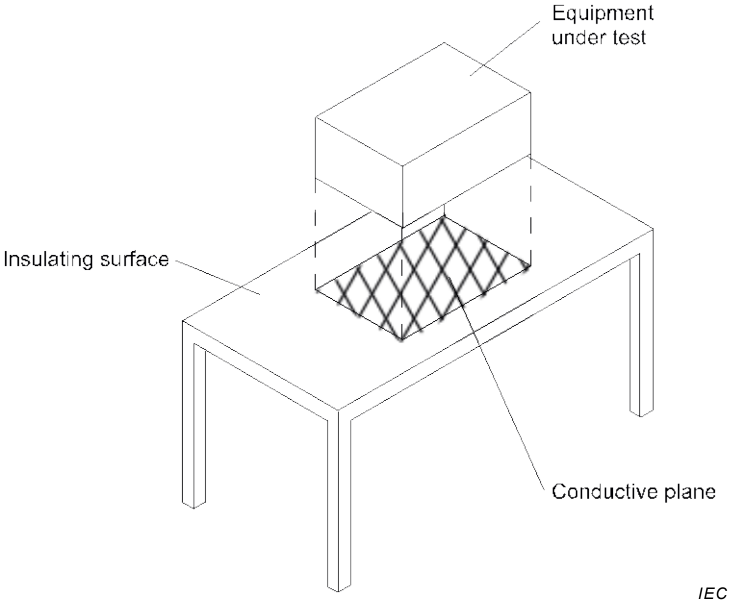


Figure B.1 – Equipment platform

Annex C
(normative)

Incidentally connected parts

Incidentally connected parts are accessible conductive parts which are neither reliably connected to, nor positively isolated from, earth or any specified voltage.

Examples of incidentally connected parts include

- doors and assemblies attached by metal hinges,
- adhesively-bonded labels which have an accessible conductive part (for example, metal foil),
- parts which are attached to painted or anodised surfaces,
- control handles.

Some production samples of the EQUIPMENT may have an incidentally connected part effectively connected to earth or to another circuit. In other samples, the same part may be isolated from earth and other circuits. Since, in general, it is not clear which case will produce the higher TOUCH CURRENT, 6.2.2 requires TOUCH CURRENT to be measured for both cases in order to find the worst case. However, where the predominant frequency is below 100 Hz, the worst case is most likely to be that in which the incidentally connected part is connected to the other parts.

Annex D

(informative)

Choice of current limits

D.1 General

When drafting the procedures specified in this standard, certain assumptions were made about the current limits which product committees would use. This was necessary in order to select the appropriate data from IEC TS 60479-1 for design of the measuring networks in Figure 3, Figure 4 and Figure 5.

These assumptions were based on earlier IEC publications. Current values given in this annex are examples only. They are given below for the assistance of product committees when selecting current limits.

D.2 Limit examples

D.2.1 Ventricular fibrillation

No limit assumed.

It is assumed that the limits chosen for TOUCH CURRENTS will be well below the threshold for ventricular fibrillation.

D.2.2 Inability to letgo-immobilization

The method of measurement is specified in this standard.

IEC TS 60479-1 assumes 10 mA r.m.s. as the approximate average threshold level of letgo-immobilization current, whereas 5 mA r.m.s. as proposed for IEC TS 60479-1, would include the entire adult population. See Figure F.3 for the effects of frequency.

D.2.3 Startle-reaction

The method of measurement is specified in this standard.

The startle-reaction threshold given in IEC TS 60479-1 is approximately 0,5 mA r.m.s. for low frequencies. Various limits are in use between the thresholds for startle-reaction and letgo-immobilization.

D.2.4 Perception threshold

TOUCH CURRENT can be perceived at levels as low as a few microamperes. Unless the current is high enough to produce involuntary startle-reaction that might result in harmful effects, these small touch currents are not considered hazardous and not usually measured by these methods.

D.2.5 Special applications

The method of measurement specified in this standard can be used, unless otherwise specified in the applicable standard for the particular product.

0,25 mA r.m.s. (one half of the startle-reaction threshold) is used for Class II EQUIPMENT in product standards such as IEC 60065, IEC 60335-1, IEC 60950-1 and IEC 62368-1. See Figure F.2 for frequency effects.

Limits lower than 0,25 mA r.m.s. are specified for some medical applications. For such applications the method of measurement in this standard may not provide an appropriate body impedance model (see Clause E.1).

D.3 Choice of limits

Consideration should be given to the need to specify different limits for (1) normal operating conditions and (2) fault conditions.

See IEC TS 60479 series for guidance on the effects of current passing through the human body.

Limits are normally expressed in terms of maximum values of d.c. and a.c. at frequencies up to 100 Hz. The methods of measurement specified in this standard are the same for letgo-immobilization, startle-reaction and some special applications. Measuring networks take into account the effect of higher-frequency current on the body and simulate lowering of body impedance as frequency increases. Letgo-immobilization, startle-reaction and perception are determined by peak values of current, weighted for frequency. For ELECTRIC BURN, r.m.s. values are significant. For the scope of this standard, the effects of frequency on ELECTRIC BURNS are negligible, since the predominant effect at low frequency is startle-reaction or letgo-immobilization.

Limits based upon ventricular fibrillation (see D.2.1) are not necessary for most EQUIPMENT, since the lower TOUCH CURRENT limits for startle-reaction or letgo-immobilization almost always prevent ventricular fibrillation. An exception (discussed in IEC TS 60479-1) is where a short-duration current impulse can flow through the body (too short an impulse to cause inability to let go), and startle-reaction from the current impulse is not considered hazardous.

Inability to let-go has traditionally focused on GRIPPABLE PARTS but this is now understood to be a simplistic view. Under this condition the highest limit value for continuous current is the same as letgo-immobilization (see D.2.2), except for consideration of ELECTRIC BURN. However, ELECTRIC BURN only becomes the predominant factor at high frequencies. In the range of the limits for startle-reaction and letgo-immobilization, there may be a secondary safety hazard due to surprise or involuntary muscle reaction, but no direct injury is expected due to current through the body. Such a current may be considered acceptable under single fault conditions, if so product committees should specifically provide an exemption.

For short-duration current, a limit value higher than that for letgo-immobilization is sometimes used, provided that it is sufficiently below the ventricular fibrillation and ELECTRIC BURN threshold. The network of Figure F.3 might be specified by product committees for such a.c. measurements where small area contact is expected.

The startle-reaction network of Figure 4 should be used for measurements where the startle-reaction limit is used for small area contact.

It is understood that the limit values for low-frequency TOUCH CURRENT in other IEC publications are based upon the following considerations.

- Limits for startle-reaction and lower limits:
  - need to avoid involuntary startle-reaction, where severe consequences may result (for example, falling from a ladder or dropping EQUIPMENT);
  - the limit for startle-reaction is generally 0,5 mA r.m.s. or 0,7 mA peak for a sinusoidal current;
  - a limit lower than 0,25 mA r.m.s. (0,35 mA peak) is indicated where the user is particularly sensitive or at risk due to environmental or biological reasons.
- Letgo-immobilization:

- startle and some reaction are acceptable as an indication of a first fault, when the letgo-immobilization limit is applied;
- men and women are estimated to have an average letgo-immobilization threshold of 16 mA r.m.s. and 10,5 mA r.m.s. respectively;
- some people have a lower threshold, for example the 99,5 percentiles of men and women have been reported as 9 mA r.m.s. and 6 mA r.m.s. respectively, and the threshold values for children are expected to be lower;
- certain single fault conditions may justify letgo-immobilization limits, with startle-reaction limits applying for normal (non-fault) conditions.

Certain EQUIPMENT types may have high initial TOUCH CURRENT when first switched on, which diminishes rapidly as EQUIPMENT is operated. This is normally ignored in setting EQUIPMENT limits when specified by the product committee.

D.4 Electric burn effects of touch current

There is no generally accepted limit value of TOUCH CURRENT which will prevent ELECTRIC BURNS in all cases. Other parameters, such as the area of contact with the human body and the duration of contact, are known to be relevant. The relationship between these parameters needs further study. When safe limits are established, they may be in terms of two or more of these parameters.

The method of measurement of TOUCH CURRENT for consideration of ELECTRIC BURN effects is specified in this standard (see 7.2).

The following limit has been used in an IEC standard:

– IEC 61010-1: 500 mA r.m.s. (under fault conditions).

It is reported that skin burns begin to occur at current densities of about 300 mA r.m.s./cm^2 to 400 mA r.m.s./cm^2 (Becker, Malhotra and Hedley-Whyte).

Analysis of conditions leading to ELECTRIC BURN has shown that there is a crossover frequency where ELECTRIC BURN exceeds letgo-immobilization and product requirements should reflect the need for making the correct measurement to provide the proper protection. IEC 62368-1 reflects one approach to defining such a requirement.

Annex E
(informative)

Networks for use in measurement of touch current

E.1 General

Current values given in this annex are only examples.

The networks of Figure 3, Figure 4 and Figure 5 are intended for TOUCH CURRENT measurements using limits in general use by product committees: for example, from 100 μA r.m.s./140 μA peak up to approximately 10 mA r.m.s./14 mA peak for a.c. and d.c. currents, and covering a frequency range to 1 MHz for sinusoidal, mixed frequency and non-sinusoidal waveforms.

E.2 Body impedance network – Figure 3

The purpose of the network of Figure 3 is to

- simulate the impedance of the human body,
- provide a measurement indicating the level of current which can flow through a human body if the body contacts the EQUIPMENT in a like manner.

R_B models the internal impedance of the human body.

R_S and C_S model the total skin impedance of two points of contact. The value of C_S is determined from the area of skin contact. For larger areas of contact, a larger value (for example, 0,33 μF) may be used.

NOTE The human body model of Figure 3 with the R and C values used herein has traditionally been used in product safety standards for 50 years or more; it has a long history of adequacy for this measurement.

TOUCH CURRENT with regard to ELECTRIC BURN is equal to U_1 r.m.s. divided by 500 Ω.

E.3 Startle-reaction (and body impedance) network – Figure 4

Startle-reaction by the human body is the result of current flowing in the internal portions of the body.

Consideration of, and compensation for, the frequency variation of startle-reaction are required for accurate measurement of this effect. The network of Figure 4 simulates body impedance and provides weighting to follow the frequency characteristics of the body for current causing involuntary startle-reaction. It has been assumed that the shape of the frequency characteristic is the same for reaction and startle, and the data establishing the frequency characteristic was actually obtained through tests on the threshold of startle.

The measurement network is usable for current limits up to the weighted equivalent of about 2 mA r.m.s. at 50 Hz and 60 Hz. The use of this network for measurement of higher level limits is restricted by the consideration of letgo-immobilization and the need for different frequency weighting where the inability to let go is of concern above these levels (see Clause E.4).

The a.c. or d.c. TOUCH CURRENT with regard to startle-reaction is equal to U_2 peak divided by 500 Ω.

E.4 Letgo-immobilization (and body impedance) network – Figure 5

Immobilization or the inability to let go of an object is caused by current flow internal to the body (for example, through muscles). The measurement network is suitable for current limits above the weighted equivalent of about 2 mA r.m.s. at 50 Hz and 60 Hz.

The effect of frequency on letgo-immobilization limits is different from its effect on startle-reaction, or on ELECTRIC BURN. This is especially true for frequencies above 1 kHz where the filter design takes this into account.

The network of Figure 5 simulates body impedance and is weighted to follow the frequency response of the body to currents which can cause tetanization of muscles (involuntary muscular contraction) and, thereby, an inability to let go. TOUCH CURRENT with regard to the letgo-immobilization is equal to U_3 peak divided by 500 Ω.

Annex F
(informative)

Measuring network limitations and construction

The networks of Figure 3, Figure 4 and Figure 5 are intended to produce a measurable voltage response which approximates the curves given in Figure F.1, Figure F.2 and Figure F.3. The networks and reference curves provided are in general agreement with those published in IEC TS 60479-1 and IEC TS 60479-2, except that, for simplicity of measurement circuits, slight deviations are allowed at the curve inflections between 300 Hz and 10 kHz.

Where limits for ELECTRIC BURN are specified, TOUCH CURRENT is also measured without frequency weighting. The criteria established for ELECTRIC BURN will override criteria for startle-reaction or letgo-immobilization if the r.m.s. current limit for ELECTRIC BURN is exceeded before the weighted peak current limits for startle-reaction and letgo-immobilization are reached. If this occurs, it will usually be in the range of 30 kHz to 500 kHz, depending upon the waveform of the current and limit values used. Unless such frequencies are predominant, no measurement for ELECTRIC BURN limit is necessary.

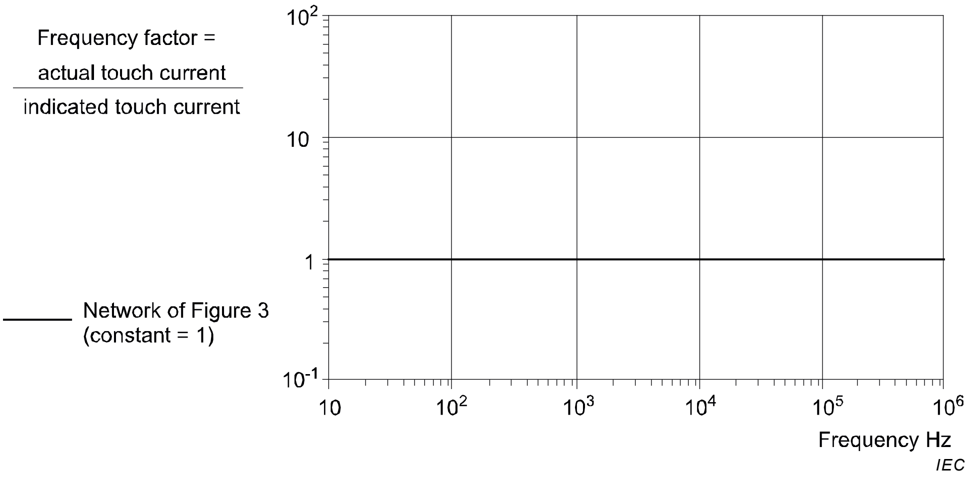


Figure F.1 – Frequency factor for electric burn

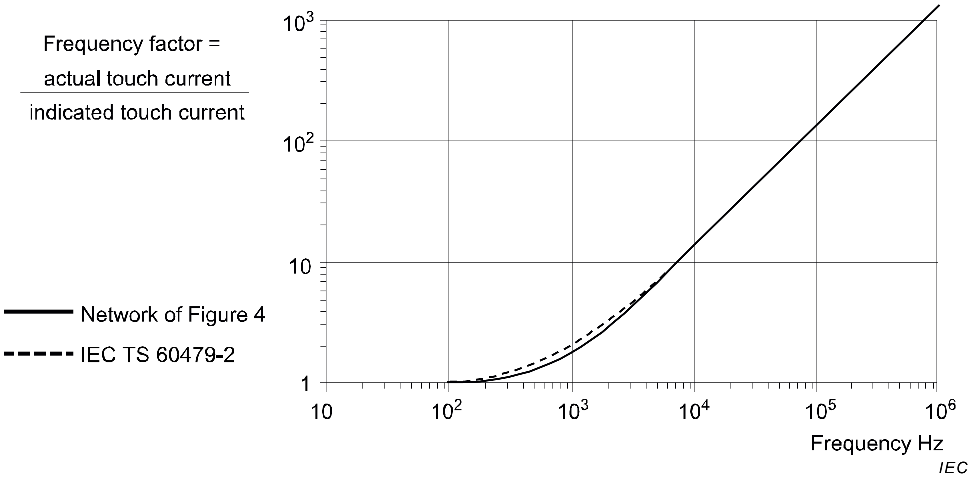


Figure F.2 – Frequency factor for perception or startle-reaction

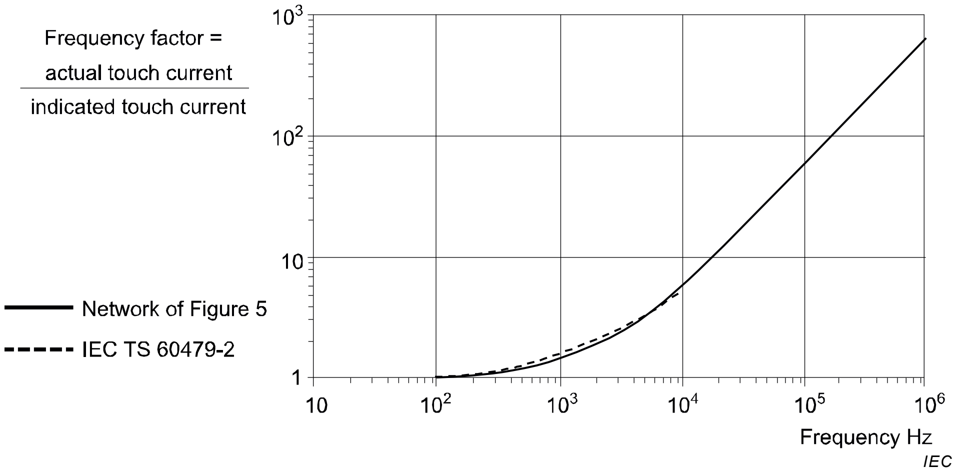


Figure F.3 – Frequency factor for letgo-immobilization

Annex G
(informative)

Construction and application of touch current measuring instruments

G.1 Considerations for selection of components

G.1.1 General

The selection of components for the TOUCH CURRENT measuring networks in Figure F.3, Figure 4 and Figure 5 can be greatly affected by the application, for example, by the current levels and frequencies that are to be measured, and by the tolerances and power handling capability to be considered.

The measuring networks and instruments and the performance specifications discussed in this standard are appropriate for both sinusoidal TOUCH CURRENT waveforms from simple EQUIPMENT and for non-sinusoidal TOUCH CURRENT waveforms from sophisticated products that can generate high frequencies. However, for a limited application, it may not be necessary for a network to cover the complete range of d.c. to 1 MHz, nor to withstand power input levels that are unlikely in the particular application. Simpler current measuring networks and instruments can be substituted for the specified networks and instruments, provided that circuit conditions are such that the readings would be the same.

Information provided here is intended to point out the factors to be considered for each component, so that appropriate decisions can be made for particular applications.

G.1.2 Power rating and inductance for R_S and R_B

Power in R_S and R_B is determined by two factors. One is the possibility of overload at d.c. or low frequencies. If, for example, a 240 V 50 Hz/60 Hz overload capability is desired, R_S shall tolerate 21,6 W and R_B 7,2 W for at least a short time, without shift in value. However, if overloads are not a concern, then 1/2 W or 1 W metal film resistors can provide adequate accuracy, together with a low temperature coefficient and long-term stability.

Based on the above choices, the measuring network should be appropriately marked, unless it is capable of withstanding continuous overloads.

R_B may also dissipate power from high-frequency currents in some applications. For example, if a current at a burn hazard of 500 mA is to be measured, a power of 125 W would be dissipated in R_B. Although this is unlikely, a resistor with this capability could be chosen.

Wire wound power resistors are available to handle the power, if other factors such as accuracy and inductive errors are controlled to acceptable levels for the application. Power resistors with an accuracy of ± 1 % and ± 5 % are readily available. Inductance has been measured on typical 12 W and 20 W wire wound resistors and found to be about 30 μH in a 1 000 Ω value. Two such resistors in parallel give 500 Ω and the inductance would cause a 2 % increase in impedance to 510 Ω at 1 MHz. The values of resistor R_S and capacitor C_S control the high-frequency performance of the R_S/R_B network. An inductance of 1 mH, which is much higher than would be expected, in series with R_S (1 500 Ω), causes less than 0,2 % at 1 MHz.

G.1.3 Capacitor C_S

Film capacitors with extended foil construction are recommended. Capacitor C_S may require a voltage rating capable of withstanding short-term overload, for example 250 V a.c., or perhaps 400 V d.c. or 600 V d.c. Film capacitors rated for d.c. will usually tolerate an a.c. peak voltage equal to the d.c. rating for short periods without failure. If the inductance of C_S

and its wiring is to be controlled for performance at 1 MHz, two or three capacitors in parallel may be necessary to achieve accuracy and frequency response.

0,1 μF film capacitors rated 250 V a.c. have been measured for resonance at about 3 MHz. Errors of approximately 3 % at 1 MHz can be expected due to the inductance of such components. Capacitors of lower value than 0,1 μF can be connected in parallel to reduce the inductive error.

G.1.4 Resistors R1, R2 and R3

Metal film resistors will give adequate performance under overload and at frequencies up to 1 MHz. If overload capability is desired (see G.1.2), R1 and R2 should be rated 1 W.

G.1.5 Capacitors C1, C2 and C3

Film type capacitors of extended foil construction are recommended. The inductance of capacitors in this range will generally not result in significant errors up to 1 MHz. Capacitors can be adjusted for tolerance by connecting two or more smaller capacitors in parallel.

G.2 Voltmeter

For full performance up to 1 MHz, the device used for measuring U_1, U_2, and U_3 should be a voltage measuring instrument which

- responds to
  - d.c. for d.c. measurements,
  - true r.m.s. for r.m.s. measurements, and
  - peak for peak measurements;
- has an input resistance not less than 1 MΩ;
- has an input capacitance not more than 200 pF for a.c. measurements;
- has a frequency range for a.c. measurements from 15 Hz to 1 MHz, or more if higher frequencies are involved;
- has floating or differential input with common mode rejection of at least 40 dB up to 1 MHz.

See Clause G.1 regarding the use of simpler instruments for particular applications.

G.3 Accuracy

The overall accuracy of the TOUCH CURRENT measuring network and its voltmeter is influenced by the accuracy of resistors and capacitors, and the frequency response, impedance and accuracy of the voltmeter. Intercomponent capacity and lead inductance also affect the accuracy of a measurement.

NOTE Analysis of the effects of tolerances on the measured TOUCH CURRENT for the specified R and C components in the TOUCH CURRENT meter circuits shows that tolerance of the resistors R_S and R_B primarily affect the measurement results. The effects of the other component tolerances are an order of magnitude lower.

A voltmeter has both an input resistance and an input capacitance. At d.c. or low frequencies, a voltmeter having an input resistance of 1 MΩ used with the measuring network of Figure 4 or Figure 5 will indicate 1 % low due to voltage division with the 10 000 Ω resistor in the measuring network. At high frequencies, the input capacitance of the voltmeter, typically 30 pF, being directly in parallel with the output capacitor of the measuring network, can cause an indication that is 0,15 % low in the network of Figure 4 and 0,33 % low in the network of Figure 5.

G.4 Calibration and application of measuring instruments

NOTE A definition of calibration is to correlate the readings of an instrument with those of a standard in order to check the instrument.

The performance of an assembled TOUCH CURRENT measuring network or TOUCH CURRENT measuring instrument can be determined by comparing its readings with calculated ideal values throughout the frequency range of interest (see Clause K.1). The error at each frequency of measurement should be noted for many specimens of each instrument. A compilation of error data should be used to establish guard bands within which future measurements are likely to occur. Statistical confidence in the statement regarding the width of the guard bands can be specified. If only one specimen of a particular design of instrument is built, the guard band can be the actual error data.

The establishment of guard bands ensures that measurements can reproducibly indicate whether the EQUIPMENT being tested is within the TOUCH CURRENT limits, when used in the following way.

For equipment manufacturers, the guard band should be added to the reading, and the sum compared to the limit. This ensures that EQUIPMENT indicated as complying with the TOUCH CURRENT limit will not be rejected by the testing laboratory. For testing laboratories, the guard band should be algebraically subtracted from the reading and the difference compared to the limit. This ensures that the testing laboratory will not reject EQUIPMENT that actually complies with the limit. The tolerances for instruments used by a testing laboratory should be sufficiently low to be accommodated by the difference between the limit value and the threshold of the unwanted physiological effect (see IEC TS 60479-1).

If necessary, the guard band of a measuring network can be made narrower, for example by

- selection of components,
- trimming of component values by connecting one or more components in parallel,
- minimizing lead length and sharp bends in leads (to reduce inductance),
- minimizing areas of parts in proximity (to reduce intercomponent capacitances).

It is recommended that equipment manufacturers minimize TOUCH CURRENT levels. The design of EQUIPMENT having current levels close to TOUCH CURRENT limit values is considered to be poor practice, due to the effects of component tolerance, ageing, use and environment on TOUCH CURRENT. When the TOUCH CURRENT from the EQUIPMENT is close to the limit value, special care should be taken in measurement precision and calibration of the test EQUIPMENT. If the TOUCH CURRENT is not close to the limit value, a wider guard band will be acceptable for instruments used by a manufacturer.

G.5 Records

For each measuring instrument, records should be established containing periodic measurements of the measuring system. These records will provide data for subsequent confirmation systems (see Clause G.6) and about any limitations in use.

G.6 Confirmation systems

NOTE A definition of metrological confirmation (shortened to “confirmation” in this standard) is given in many quality standards.

Measuring instruments used for EQUIPMENT certification should be subjected to routine confirmation of their accuracy (see Clause K.2).

Annex H
(informative)

Analysis of frequency filtered touch current circuit measurements

Annex H demonstrates the method of measurement of complex waveforms in accordance with IEC TS 60479 series.

Modern oscilloscopes provide accurate numeric value measurement information of waveforms during measurement. Common measurements are r.m.s., peak and peak-to-peak measurements of the waveforms. This annex will show how to use that data to properly develop the needed resulting value which is to be compared to the limit specified in the product standard.

IEC TS 60479-2, special aspects, deals with the complexity of waveforms developed by modern electronic EQUIPMENT that easily switches significant voltages to develop voltages or current adapted for specialized use within EQUIPMENT.

IEC TS 60479-2:2007, 5.2 excerpt: 'Most physiological effects are related to the filtered peak current (in magnitude and duration) with the natural body filter defined by the frequency factor F. The peak value of the current should be used in all cases except ... (when) pure sinusoidal current.'

The frequency factor filters developed for IEC 60990 fit the frequency factor curves of IEC TS 60479-2 extended to 1 MHz, the long standing dividing frequency between electrical safety and EMC, as shown in Annex F. This extension is based upon a general medical understanding of the conduction of current within the body by including a continual increase in the allowed current to the end frequency carrying on the same reduction in effects specifically measured. These filters are implemented as an inverse of the frequency factor curves to aid in simplifying the measurements.

To implement the measurement of TOUCH CURRENT according to IEC TS 60479 series, including the frequency factor provisions, IEC 60990 provides two TOUCH CURRENT measurement circuits which meet the frequency factor curves of IEC TS 60479-2 under the following conditions:

- A circuit weighted for startle-reaction (formerly called perception-reaction) – Figure 4.
- A circuit weighted for letgo-immobilization (formerly called let-go) – Figure 5.

SPICE analysis was done for the frequency filtered circuits of Figure 4 and Figure 5 using common waveshapes straightforward for analysis and the results are discussed below. Although only a couple of cycles are shown, this analysis applies to continuous TOUCH CURRENT waveforms. The TOUCH CURRENT is calculated in the analysis and is V(output) / 500 Ω which is shown in the plot. The calculation leads to the mV/Ω units (=mA) attached to the TOUCH CURRENT Y / vertical / ordinate axis.

NOTE SPICE output waveform naming explained: (V(output)/500 Ω) = weighted touch current and xmV/Ω = *x*mA touch current calculated using the voltage output from the startle-reaction/Figure 4 or the letgo-immobilization/Figure 5 filtered circuit.

Bipolar waveform examples

Bipolar alternating current wavefoms include:

- sinusoidal waves (the most common example); and
- non-sinusoidal waveforms developed by electronic switching within products for power distribution and utilization.

A simple example is that of a 50 Hz (20 ms) triangular waveform shown in Figure H.1 and Figure H.2.

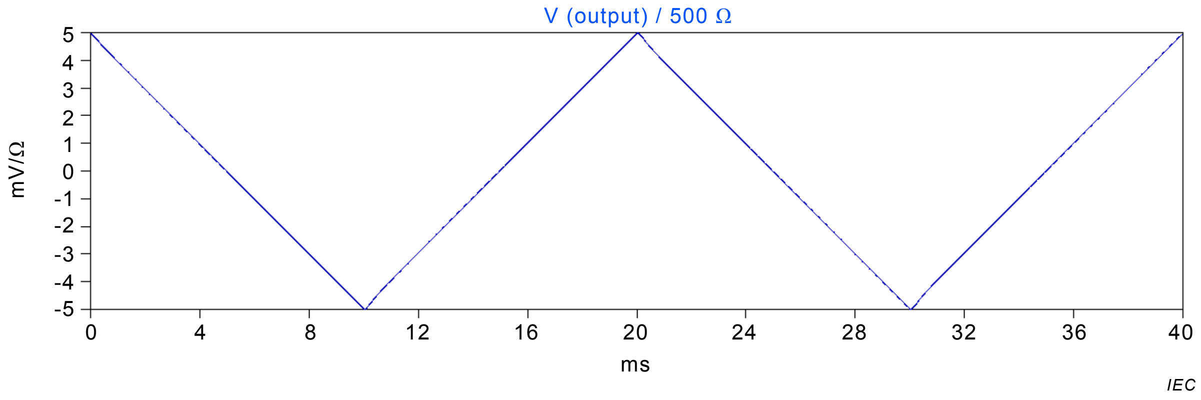


Figure H.1 – Triangular waveform touch current, startle-reaction

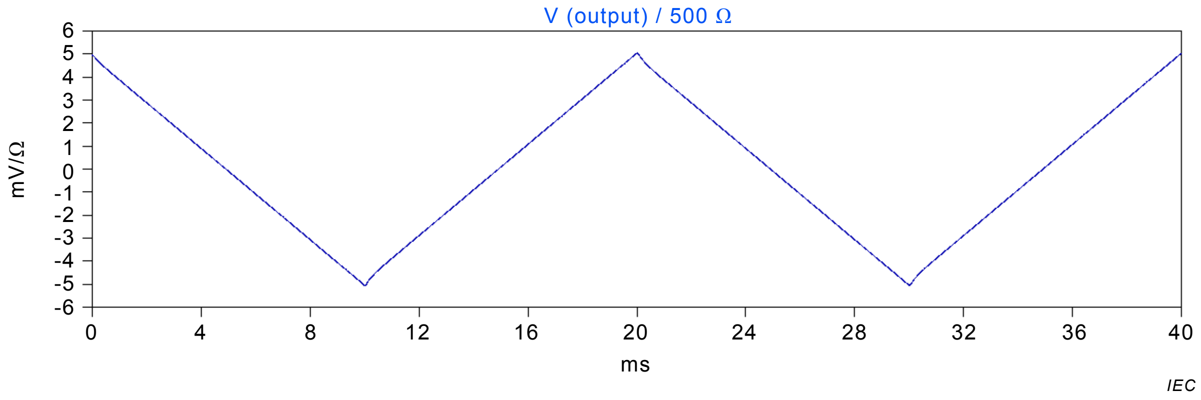


Figure H.2 – Triangular waveform touch current, letgo-immobilization

The input conditions are the same as for an equivalent sinusoidal waveform the results are not the same. The peak value shown in Table H.1 is the peak-to-peak value divided by 2. The peak current is at the 5 mA peak level but the r.m.s. value is below the 3,5 mA level of the example above. The peak measurement be used to adequately compare the level of TOUCH CURRENT hazard to the body. In this case the r.m.s. value when used as a measure of adequacy would indicate a margin below that of a sinusoidal limit value which is an unwarranted sense of protection available.

Table H.1 – Triangular waveform response comparison

Circuit / TOUCH CURRENT response	Peak	r.m.s
Startle-reaction circuit TOUCH CURRENT I [V(output) / 500 Ω]	4,98 mA	2,868 mA
Letgo-immobilization circuit TOUCH CURRENT I [V(output) / 500 Ω]	5,05 mA	2,869 mA

The filter circuit component of the TC circuits properly acts on the high frequency components of each waveform.

Another simple circuit of interest is a 50 Hz square wave shown in Figure H.3 and Figure H.4.

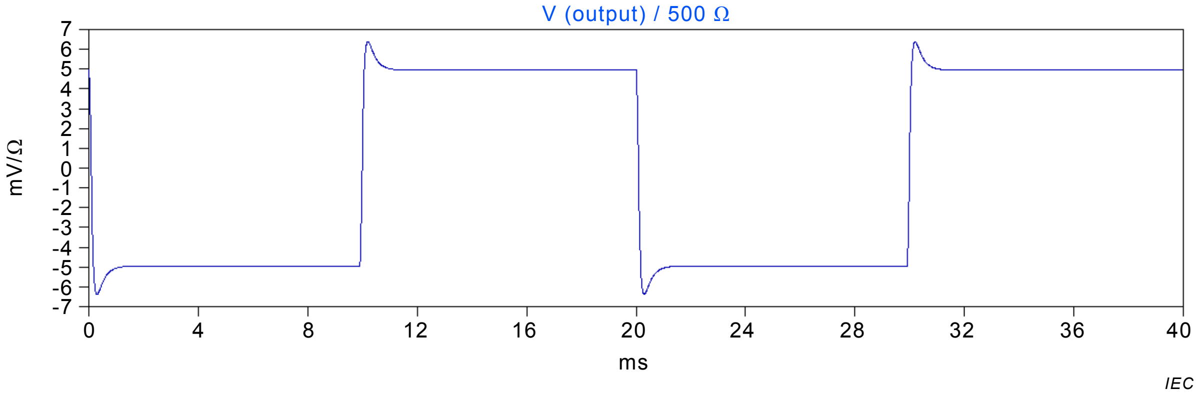


Figure H.3 – 1 ms rise time pulse response, startle-reaction

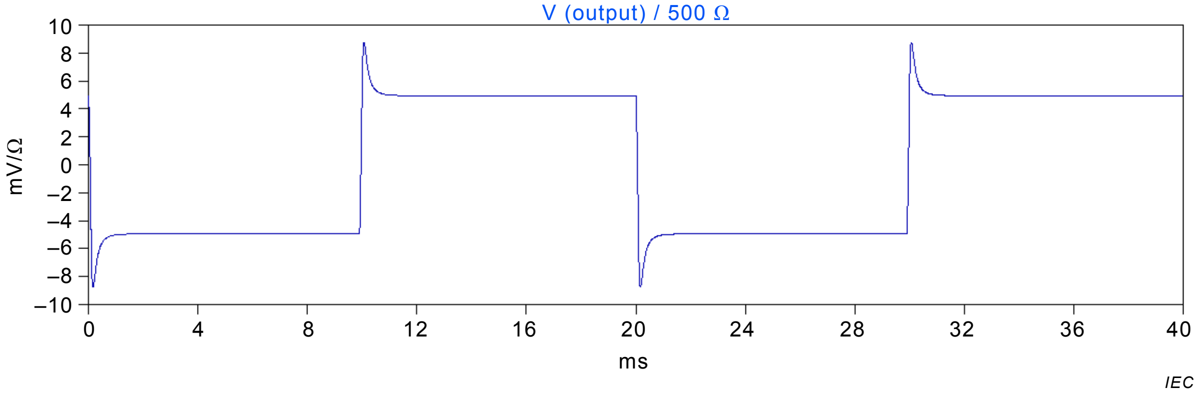


Figure H.4 – 1 ms rise time pulse response, letgo-immobilization

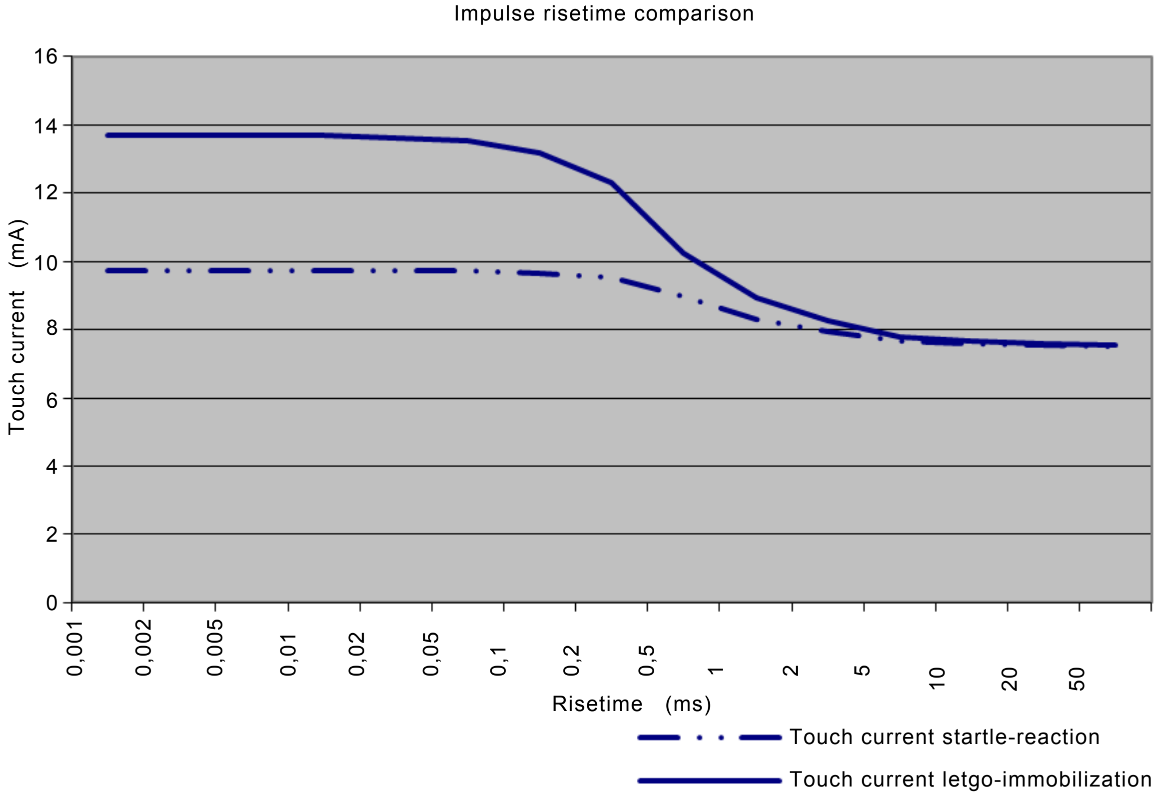
The steady value is 5 mA but the peak value (= peak-to-peak / 2) is higher in each case as shown in Table H.2.

Table H.2 – Square wave touch current response

Circuit / TOUCH CURRENT response	Peak	r.m.s
Startle-reaction circuit TOUCH CURRENT I [V(output) / 500 Ω]	6,39 mA	4,991 mA
Letgo-immobilization circuit TOUCH CURRENT I [V(output) / 500 Ω]	8,758 mA	5,054 mA

The letgo-immobilization circuit allows more high frequency current through the filter, therefore the peak value is higher.

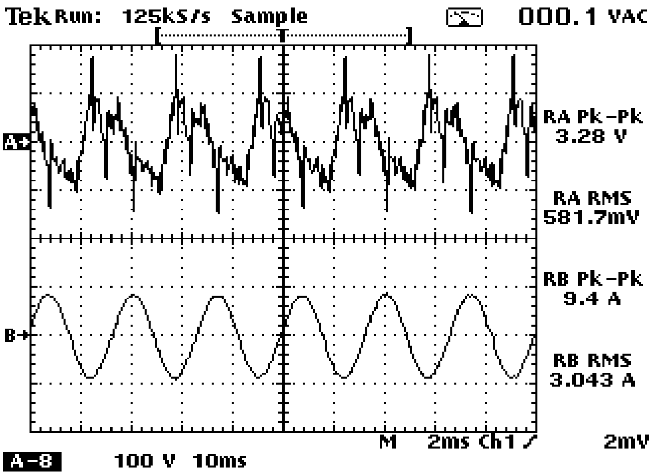
The rise time is a key factor in the peak TOUCH CURRENT for a fast rising waveform. For this type of waveform, the rise time affects the TOUCH CURRENT by up to a factor of 2 as shown in the TOUCH CURRENT versus rise time plot as shown in Figure H.5.



IEC

Figure H.5 – Touch current vs. rise time plot, 20 ms square wave

TOUCH CURRENT waveforms have been published for dozens of pieces of modern EQUIPMENT[1]. The use of mains switching devices including efforts to restore sinusoidal input current (power factor correction = PFC) and, more recently, to add higher energy efficiency to Switch Mode Power Supplies (SMPS) has led to more complicated TOUCH CURRENT waveforms. One of the more complicated waveforms that has been seen is shown in waveform A of Figure H.6.



IEC

Figure H.6 – PFC SMPS touch current waveform

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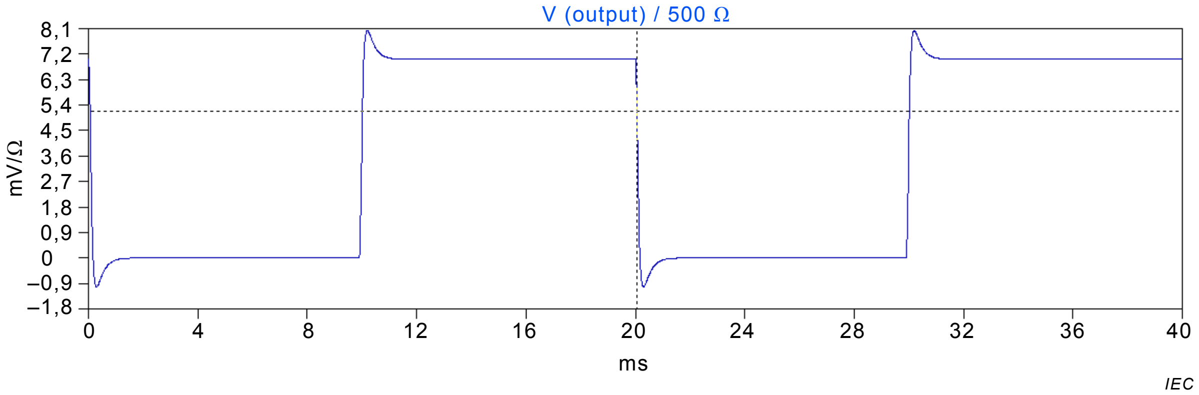
[1] 'Touch current comparison data'; Perkins, 2006. A collection of more than two dozen touch current waveforms from a variety of equipment; posted on www.safetylink.com, search on perkins.

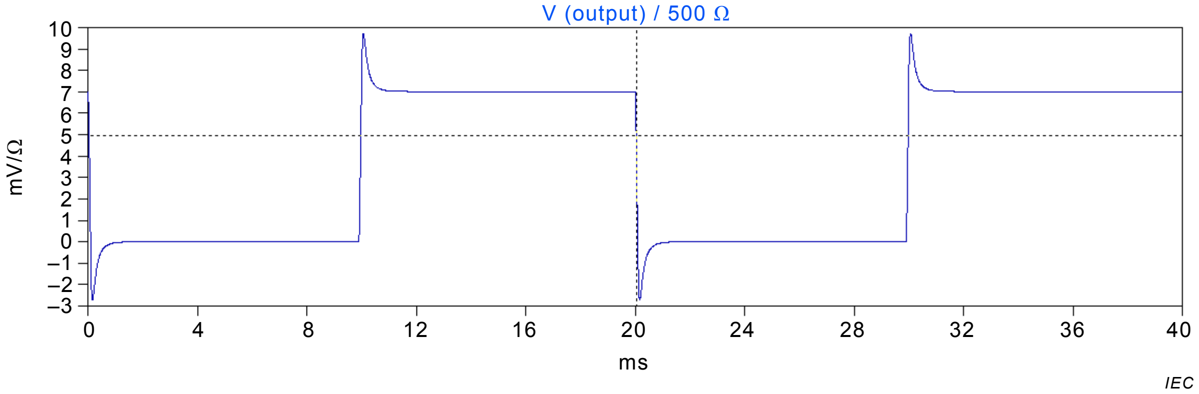
Monopolar waveform example

DC applications are the most common examples of monopolar waveforms. Of specific interest are switched d.c. applications that are discussed here and shown in Figure H.7 and Figure H.8.



r.m.s. value indicated

Figure H.7 – 50 Hz square wave, 0,1 ms rise time, startle-reaction



r.m.s. value indicated

Figure H.8 – 50 Hz square wave, 0,1 ms rise time, letgo-immobilization

For monopolar waveforms the peak value of the TOUCH CURRENT is used. The overshoot on top of the d.c. pulse is included in the measurement, the undershoot is not included.

Table H.3 – Square wave monopolar touch current response

Circuit / TOUCH CURRENT response	Peak	r.m.s.
Startle-reaction circuit TOUCH CURRENT I [V(output) / 500 Ω]	8,031 mA	5,006 mA
Letgo-immobilization circuit TOUCH CURRENT I [V(output) / 500 Ω]	9,716 mA	5,037 mA

As before, the rise time of the waveform affects the overshoot and the peak value of the TOUCH CURRENT as shown in Table H.3.

Mixed a.c./d.c. examples

IEC TS 60479-2:2007, Figure 7 shows the let-go threshold expressed in peak mA for the combinations of 50/60 Hz sinusoidal alternating current and direct current. The peak of the composite a.c. and d.c. wave in mA at the let-go threshold estimated for the population of humans including children is shown as a function of the direct current component in mA.

IEC TS 60479-2:2007, Figure 7 is represented by the equation for the composite current:

$$\mathrm{ACpk{+}DC} = 7{,}176^{(-0{,}143\,4 \times \mathrm{DC})} - 0{,}106\,1 + \mathrm{DC}$$

These effects are related to the peak value of the current and they have to be combined frequency per frequency to estimate the total effect. A measurement circuit is described in this standard.

Herein is shown to the use of IEC 60990 circuits to make measurement of mixed a.c./d.c. TOUCH CURRENTS and properly evaluate them against the equation above. The IEC TS 60479-2:2007, Figure 7 is repeated in Figure H.9 and annotated with some additional data from the waveforms discussed in this annex.

NOTE The composite waveform shown in IEC TS 60479-2:2007, Figure 7 is named ACpknDC in the plot of Figure 9 below. The examples are ACpknDCex1 and ACpknDCex2; the DC values are similarly named as explained in the text following.

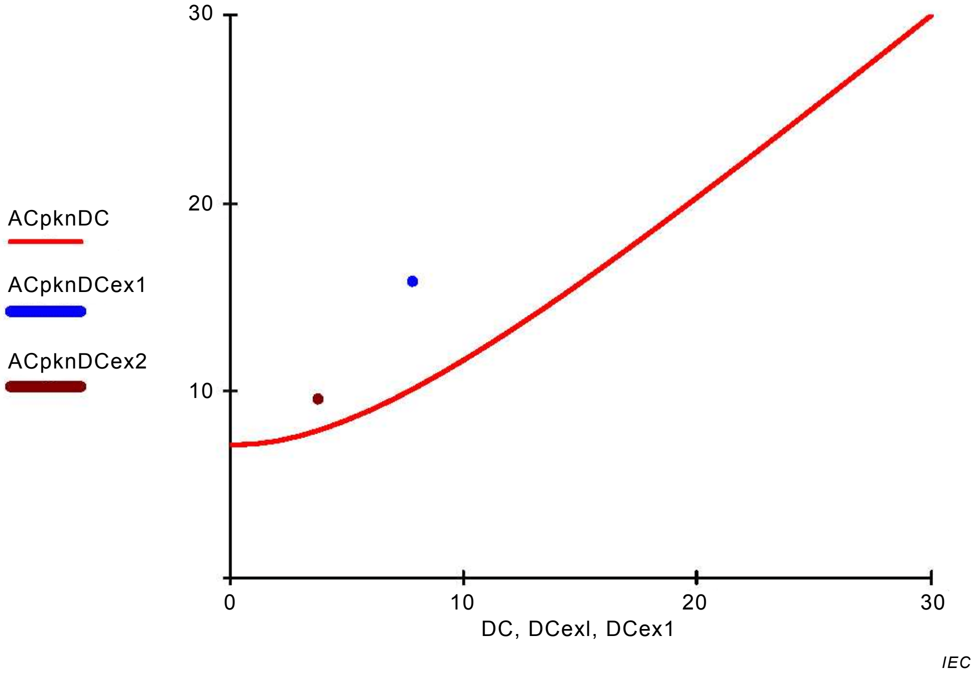


Figure H.9 – IEC TS 60479-2 let-go threshold for AC and DC combinations augmented by additional data, mA each axis

The procedure is as follows. The maximum peak absolute value of the composite waveform is selected (**bold values** of TOUCH CURRENT in the tables) to be plotted as ACpknDC. The peak-equivalent (pk-ev) value is calculated from the r.m.s. value; this is subtracted from the maximum peak value to get the DC value needed for the plot. The values derived from the measurements can be plotted on the same graph as the curve to compare as is done here or, alternatively, the DC value can be entered into the equation for the composite current to calculate the ACpk+DC and compared to the measurement derived value called ACpknDC.

Example 1 (ex1):

The first example (shown in Figure H.10) analyzed for letgo-immobilization.

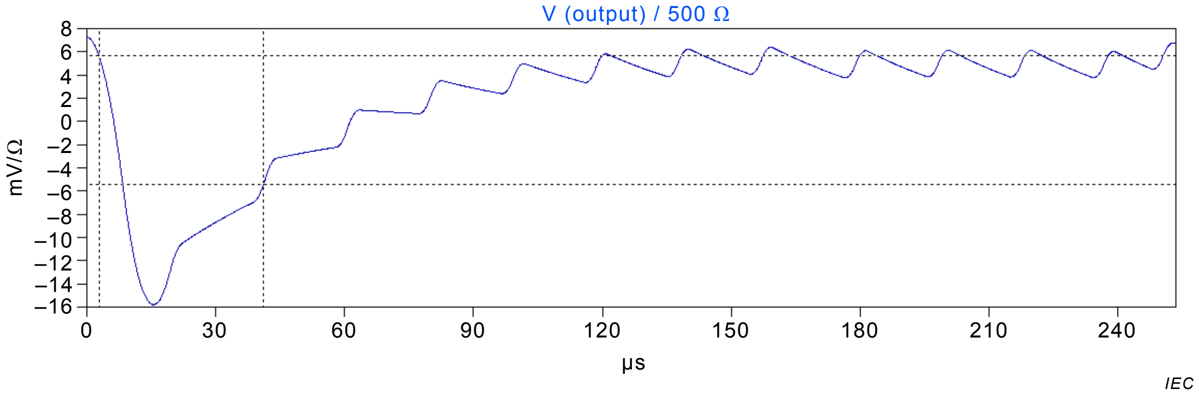


Figure H.10 – Ex1 case: showing r.m.s. window

For the ex1 case shown above, see Table H.4.

Table H.4 – Mixed ACnDC waveform evaluation, ex1

	TOUCH CURRENT peak	TOUCH CURRENT r.m.s.
Letgo-immobilization case	+7,281 96 / **-15,788 2** mA peak	5,644 6 mA r.m.s. Pk-ev: 5,644 6 × 1,414 = 8 mA peak 15,79 − 8 = **7,79** mA d.c.
The values in bold in the table correspond to the plotted values (with rounding included in the latter) of Figure H.10.		

The values to be plotted for graphical evaluation are:

ACpknDCex1 = 15,8, DCex1 = 7,79

Example 2 (ex2):

Another mixed case, ex2, is shown in Figure H.11 and Table H.5.

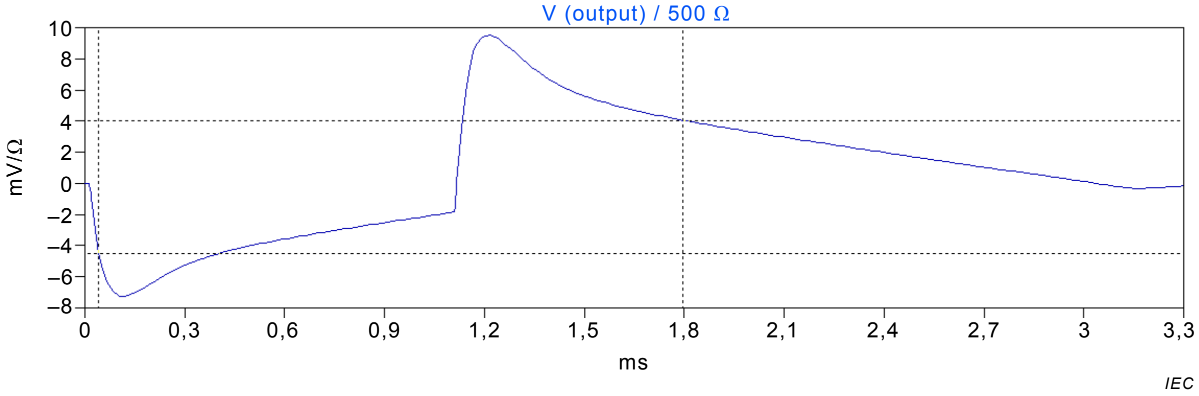


Figure H.11 – Waveform ex2 case: showing r.m.s. window

Table H.5 – Mixed ACnDC waveform evaluation, ex2

	TOUCH CURRENT **peak**	TOUCH CURRENT **r.m.s**
Letgo-immobilization case	**9,524 69** / -7,247 19 mA peak	4,085 4 mA r.m.s. Pk-ev: 4,085 4 × 1,414 = 5,777 6 mA peak 9,524 7 − 5,777 6 = **3,747 1** mA d.c.
The values in bold in the table correspond to the plotted values (with rounding included in the latter) of Figure H.11.		

The values to be plotted for graphical evaluation are:

ACpknDCex2 = 9,52,   DCex2 = 3,75

Each example falls above the letgo-immobilization curve and fails to meet a letgo-immobilization TOUCH CURRENT limit of 5 mA r.m.s. / 7 mA peak as described in IEC TS 60479-2.

Annex I
(informative)

AC power distribution systems (see 5.4)

I.1 General

In IEC 60364-1, a.c. power distribution systems are classified TN, TT and IT, depending on the arrangement of current-carrying conductors and on the method of earthing. The classes and codes are explained in this annex. Some examples of each class are given in the Figure I.1 to Figure I.8; other configurations also exist.

In the figures:

– in most cases, the power systems apply for single-phase and three-phase EQUIPMENT but, for simplicity, only single-phase EQUIPMENT is illustrated;

– the power sources may be transformer secondaries, motor-driven generators or uninterruptible power systems;

– for transformers within a user's building, some of the figures apply, and the building boundary represents a floor of the building;

– some power systems are earthed at additional points, for example at the power entry points of users' buildings (see IEC 60364-4-41:2005).

The following types of EQUIPMENT connection are taken into account; the numbers of wires mentioned do not include conductors used exclusively for earthing:

– single-phase, 2-wire;

– single-phase, 3-wire;

– two-phase, 3-wire;

– three-phase, 3-wire;

– three-phase, 4-wire.

The system codes used have the following meaning.

– First letter: relationship of the power system to earth
  - T means direct connection of one pole to earth;
  - I means system isolated from earth, or one point connected to earth through an impedance.

– Second letter: earthing of the EQUIPMENT
  - T means direct electrical connection of the EQUIPMENT to earth, independently of the earthing of any point of the power system;
  - N means direct electrical connection of the EQUIPMENT to the earthed point of the power system (in a.c. systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a phase conductor).

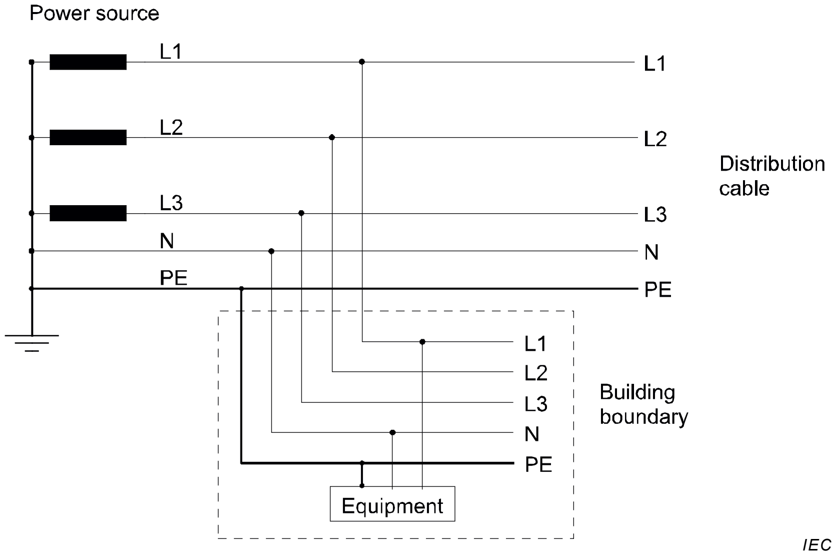
– Subsequent letters, if any: arrangement of neutral and protective conductors
  - S means the protective function is provided by a conductor separate from the neutral or from earthed line (or, in a.c. systems, earthed phase) conductor;
  - C means the neutral and protective functions are combined in a single conductor (PEN conductor).

I.2 TN power systems

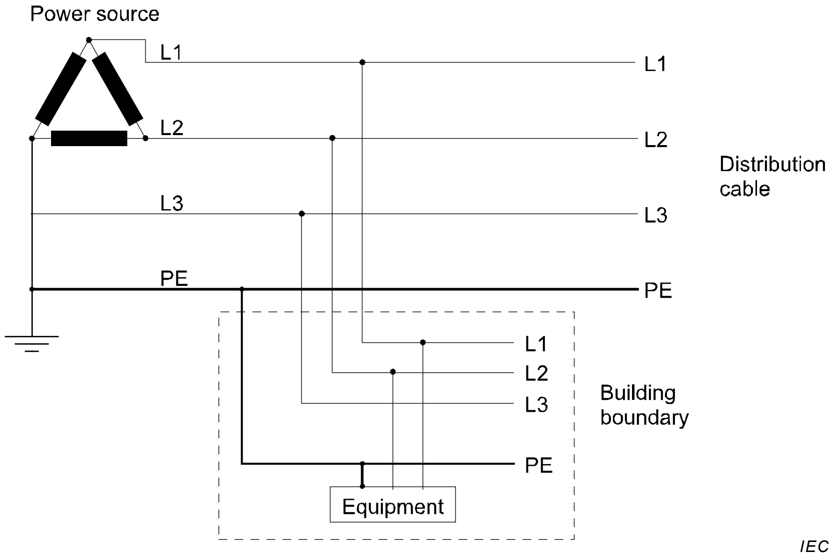
TN power systems are directly earthed, the parts of the EQUIPMENT required to be earthed being connected by protective earthing conductors. Three types of TN power systems are considered:

- TN-S power system: in which a separate protective conductor is used throughout the system;
- TN-C-S power system: in which neutral and protective functions are combined in a single conductor in part of the system;
- TN-C power system: in which neutral and protective functions are combined in a single conductor throughout the system.

Some TN power systems are supplied from a secondary winding of a transformer that has an earthed centre tap (neutral). Where the two phase conductors and the neutral conductor are available, these systems are commonly known as single-phase, 3-wire power systems.

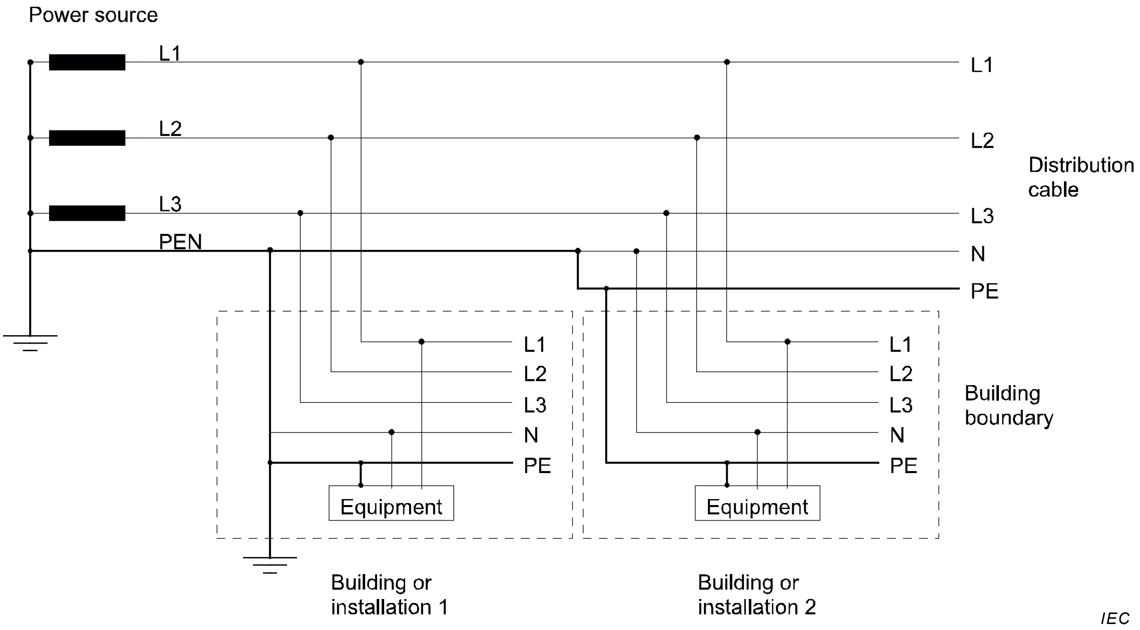


Separate neutral and protective conductors



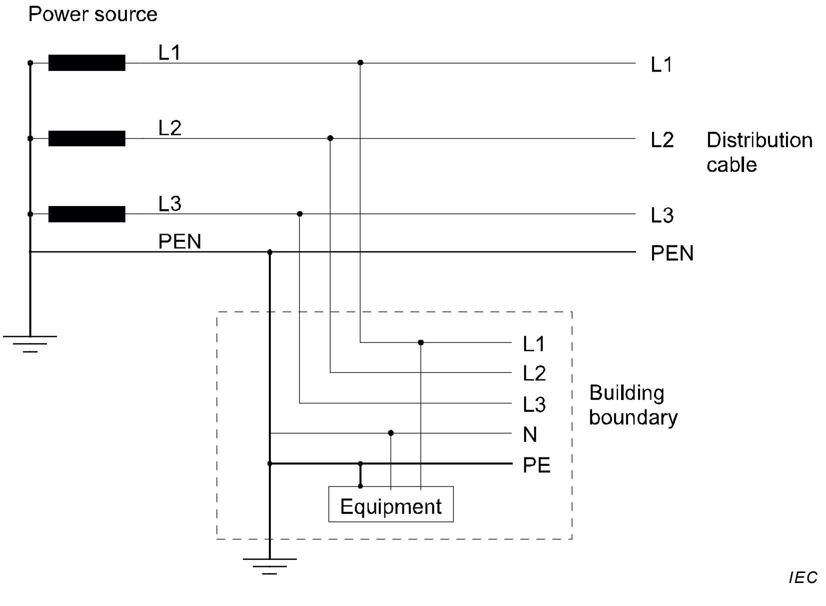
Earthed line conductor

Figure I.1 – Examples of TN-S power system



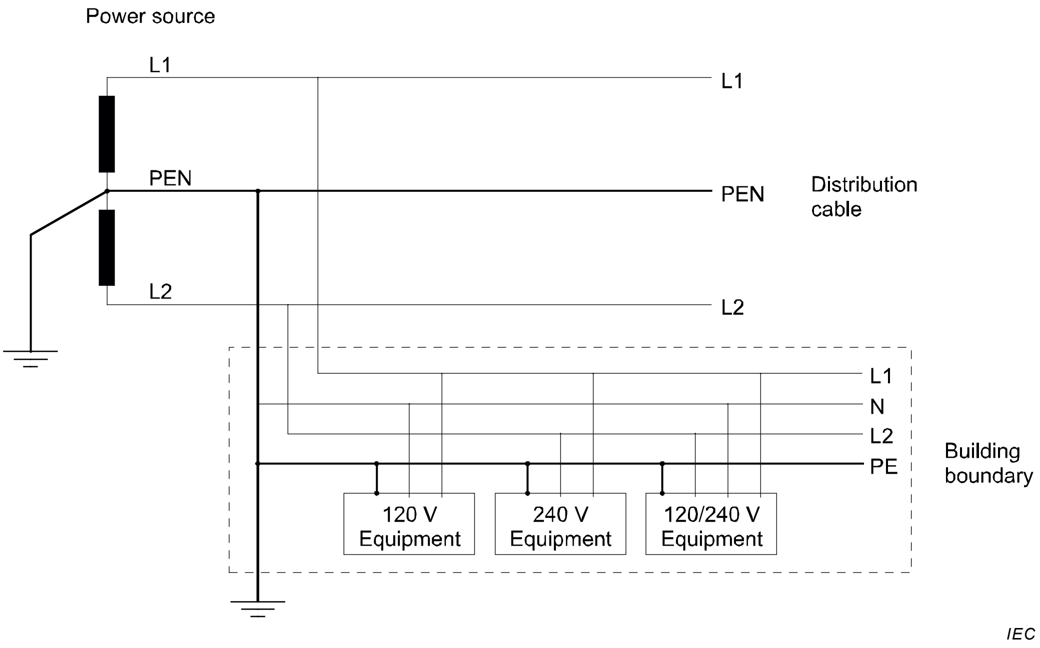
The point at which the PEN conductor is separated into protective earth and neutral conductors may be at the building entrance or at distribution panels within the building.

Figure I.2 – Example of TN-C-S power system



Neutral and protective functions combined in one conductor (PEN)

Figure I.3 – Example of TN-C power system



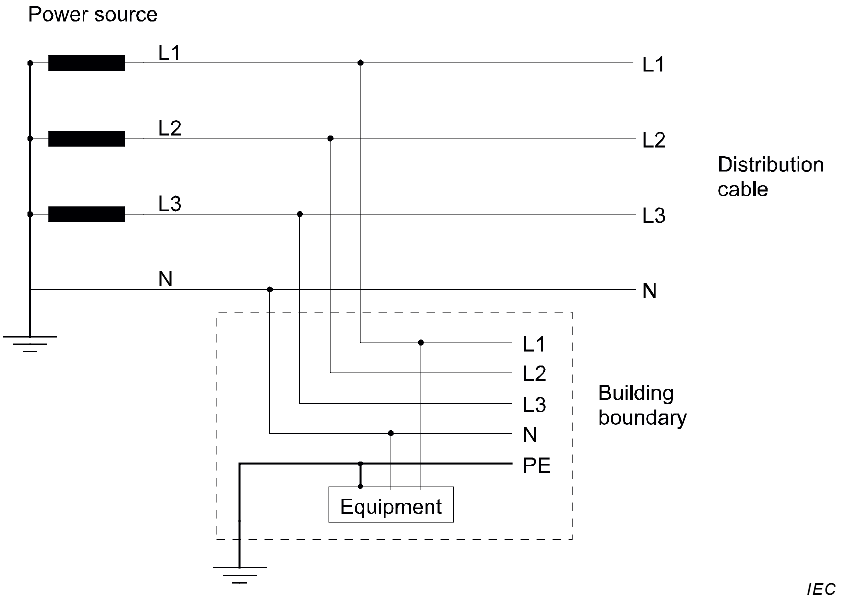
Protective and neutral functions combined in one conductor (PEN)

This system is widely used in North America at 120/240 V.

Figure I.4 – Example of single-phase, 3-wire TN-C power system

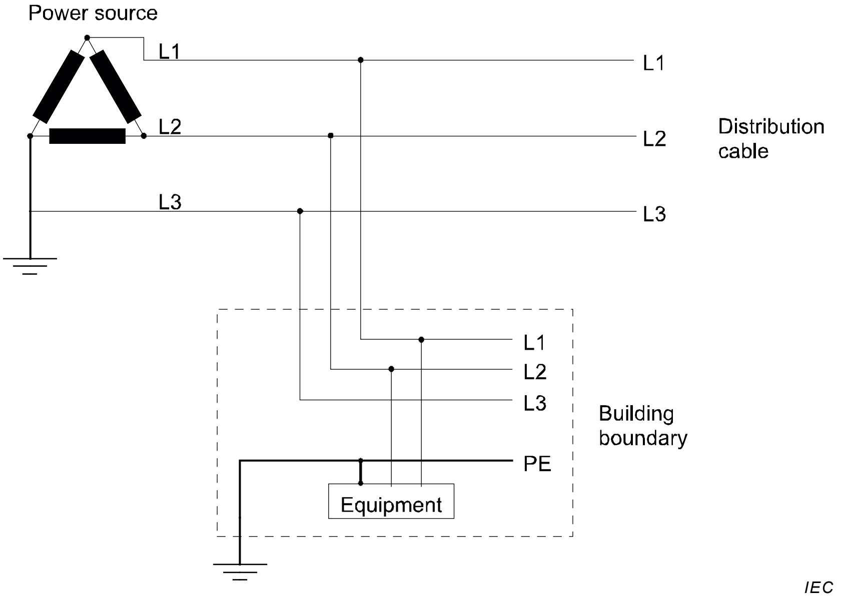
I.3 TT power systems

TT power systems have one point directly earthed, the parts of the equipment required to be earthed being connected at the user's premises to earth electrodes that are electrically independent of the earth electrodes of the power distribution system.



Earthed neutral and independent earthing of EQUIPMENT

Figure I.5 – Example of 3-line and neutral TT power system

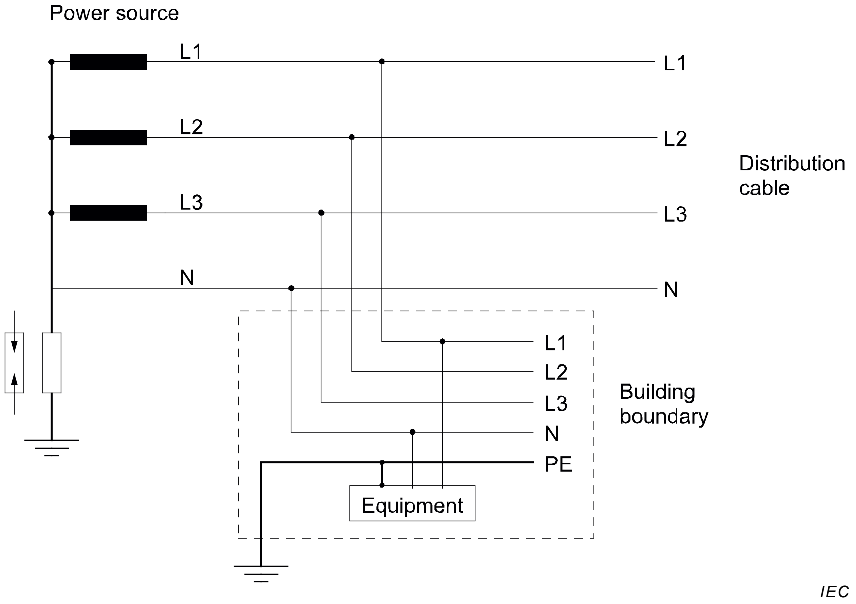


Earthed line and independent earthing of EQUIPMENT

Figure I.6 – Example of 3-line TT power system

I.4 IT power systems

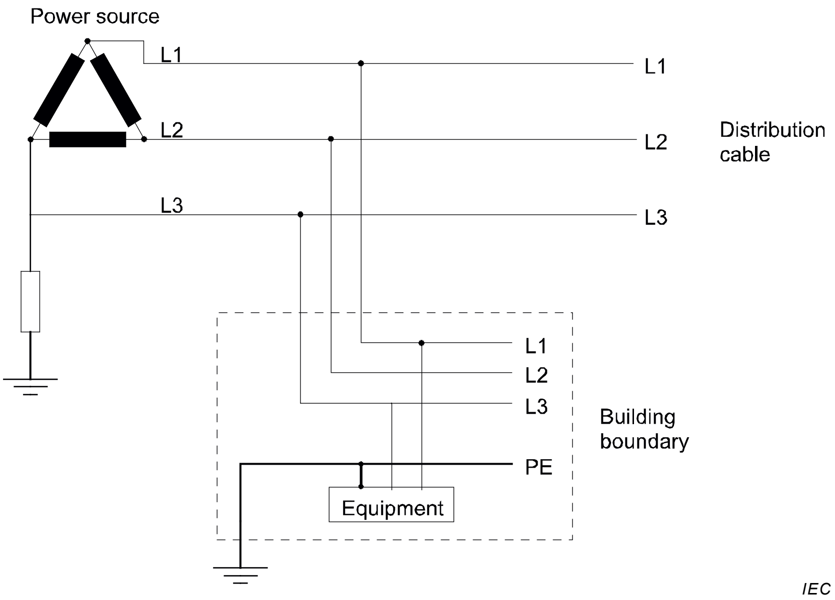
IT power systems are isolated from earth, except that one point may be connected to earth through an impedance or a voltage limiter. The parts of the EQUIPMENT required to be earthed are connected to earth electrodes at the user's premises.



The neutral may be connected to earth through an impedance or a voltage limiter, or isolated from earth.

This system is widely used isolated from earth, in some installations in France, with impedance to earth, at 230/400 V, and in Norway, with a voltage limiter, neutral not distributed, at 230 V line-to-line.

Figure I.7 – Example of 3-line (and neutral) IT power system



The system may be isolated from earth.

Figure I.8 – Example of 3-line IT power system

Annex J
(informative)

Routine and periodic touch current tests, and tests after repair or modification of mains operated equipment

This annex defines methods and procedures to perform tests which reverify TOUCH CURRENT according to design requirements from the product standard, during production (routine test), after repair or modification and at periodic intervals during use.

The objective is to have the test performed by technicians or other instructed persons, using simple procedures to achieve sufficient accuracy. Measuring results should be easy to interpret. Measuring equipment should be economical and easy to use under practical field conditions.

Method

Tests are to be carried out using the procedures of this standard with the appropriate measuring network. Tests are to be performed under the environmental conditions of an appropriate field or factory location.

The EQUIPMENT is to be tested in a stand-alone configuration without external connections, except for the mains supply.

TOUCH CURRENT is to be measured and shall be at or below the limit defined in the EQUIPMENT standard as follows:

- if the limit is given as d.c. current, measure the d.c. and compare with the limit;
- if the limit is given in peak current, measure the peak current and compare with the peak limit;
- if the limit is given in r.m.s. current, measure the r.m.s. current and compare with the r.m.s. limit.

No routine or periodic test is required for ELECTRIC BURN currents unless specified by the EQUIPMENT standard.

Annex K
(normative)

Network performance and calibration

K.1 Network or instrument performance and initial calibration

Measured ratios of input voltage to input current (input impedance) and output voltage to input current (transfer impedance or network response) are compared with ideal values calculated from the nominal component values specified in Figure 3, Figure 4 and Figure 5. Care is taken in the arrangement of the test equipment circuitry so that intercomponent capacitance, lead inductance and characteristics of the voltage measuring device do not significantly affect the voltage-current ratios.

A guard band indicating the uncertainty of measurement at various frequencies is specified for each instrument. The performance of measuring networks can, if necessary, be adjusted to make the guard band narrower.

NOTE 1 A definition of uncertainty of measurement is the characterization of the range within which the true value of a measurement is estimated to lie; this is a common term in metrology and calibration.

NOTE 2 Guidance on adjusting the performance of measuring networks is given in G.4.

The performance of a measuring network is checked by passing variable frequency sinusoidal current through the input of the instrument, test terminals A and B in Figure 3, Figure 4 and Figure 5. The input current (I), input voltage (U) and output voltage (U_1, U_2 or U_3) are measured at various frequencies. If possible, the output voltage is measured by the same voltmeter as will be used during all measurements on the EQUIPMENT for product certification purposes and for all confirmation procedures (see Clause K.2).

Table K.1 – Calculated input impedance and transfer impedance for unweighted touch current measuring network (Figure 3)

Frequency Hz	**Input impedance** U / I	**Transfer impedance** U_1 / I
20	1 998	500
50	1 990	500
60	1 986	500
100	1 961	500
200	1 857	500
500	1 434	500
1 000	979	500
2 000	675	500
5 000	533	500
10 000	509	500
20 000	502	500
50 000	500	500
100 000	500	500
200 000	500	500
500 000	500	500
1 000 000	500	500

Table K.2 – Calculated input impedance and transfer impedance for startle-reaction touch current measuring network (Figure 4)

Frequency Hz	**Input impedance** U / I	**Transfer impedance** U_2 / I
20	1 998	500
50	1 990	499
60	1 986	498
100	1 961	495
200	1 857	480
500	1 433	405
1 000	973	284
2 000	661	162,9
5 000	512	68,3
10 000	485	34,4
20 000	479	17,21
50 000	477	6,89
100 000	476	3,45
200 000	476	1,722
500 000	476	0,689
1 000 000	476	0,345

Table K.3 – Calculated input impedance and transfer impedance for letgo-immobilization current measuring network (Figure 5)

Frequency Hz	**Input impedance** U / I	**Transfer impedance** U_3 / I
20	1 998	500
50	1 990	499
60	1 986	499
100	1 961	496
200	1 858	484
500	1 434	427
1 000	976	340
2 000	667	251
5 000	515	144,3
10 000	487	79,9
20 000	479	41,2
50 000	477	16,63
100 000	476	8,32
200 000	476	4,16
500 000	476	1,666
1 000 000	476	0,833

K.2 Calibration in a confirmation system

K.2.1 General

NOTE A definition of metrological confirmation (shortened to "confirmation" in this standard) is a set of operations required to ensure that a measuring equipment is in a state of compliance with requirements for its intended use.

Each instrument that is used to determine acceptability for the purpose of certification of EQUIPMENT shall be routinely calibrated in a confirmation system to ensure that no drift of its performance outside the limits of permissible error has occurred. Reference is necessary to the guard band and other data recorded for the particular measuring instrument during its initial calibration (see Clause K.1).

If a particular measuring instrument has drifted outside permissible limits, measurements made on the EQUIPMENT with that instrument since the last confirmation calibration shall be reviewed to check their validity.

Calibration in a confirmation system is carried out in two steps.

K.2.2 Measurement of input resistance

The d.c. input resistance is measured and its value is checked against the ideal value (2 000 Ω) and the value determined during initial calibration.

NOTE This measurement guards against the possibility that a shift in input impedance has occurred at the same time that a shift occurs in the instrument response, resulting in addition or cancellation of errors.

K.2.3 Measurement of instrument performance

The input voltage and the output voltage (or milliamperes as indicated on the meter) are measured at various frequencies and the ratios compared to the data in Table K.4, Table K.5 or Table K.6, as appropriate. If possible, the output voltage is measured by the same voltmeter as will be used for initial calibration and during all measurements on the EQUIPMENT for product certification purposes. It is sufficient to carry out the measurements at a few frequencies over the whole frequency range of interest as long as attention is given to the higher frequencies. The input voltages used should be such as to produce output indications in the range of the TOUCH CURRENT limit values for which the measuring instrument is intended, subject to observing the power rating of internal components.

NOTE Table K.4, Table K.5 and Table K.6 are derived from Table K.1, Table K.2 and Table K.3 respectively but, in order to simplify the confirmation procedure, the presentation of the data avoids the need to measure input current at high frequencies.

Table K.4 – Output voltage to input voltage ratios for unweighted touch current measuring network (Figure 3)

Frequency Hz	Output voltage to input voltage ratio	Input voltage to output voltage ratio	Input voltage per milliampere indication
20	0,250	4,00	2,00
50	0,251	3,98	1,99
60	0,252	3,97	1,99
100	0,255	3,92	1,96
200	0,269	3,72	1,86
500	0,349	2,87	1,43
1 000	0,511	1,96	0,979
2 000	0,740	1,35	0,675
5 000	0,937	1,07	0,533
10 000	0,983	1,02	0,509
20 000	0,996	1,00	0,502
50 000	0,999	1,00	0,500
100 000	1,00	1,00	0,500
200 000	1,00	1,00	0,500
500 000	1,00	1,00	0,500
1 000 000	1,00	1,00	0,500

Table K.5 – Output voltage to input voltage ratios for startle-reaction measuring network (Figure 4)

Frequency Hz	Output voltage to input voltage ratio	Input voltage to output voltage ratio	Input voltage per milliampere indication
20	0,250	4,00	2,00
50	0,251	3,99	2,00
60	0,251	3,99	1,99
100	0,252	3,96	1,98
200	0,259	3,87	1,93
500	0,282	3,54	1,77
1 000	0,292	3,43	1,71
2 000	0,246	4,06	2,03
5 000	0,133	7,50	3,75
10 000	0,070 8	14,1	7,06
20 000	0,036 0	27,8	13,9
50 000	0,014 5	69,2	34,6
100 000	0,007 23	138	69,1
200 000	0,003 62	277	138
500 000	0,001 45	691	346
1 000 000	0,000 723	1 382	691

Table K.6 – Output voltage to input voltage ratios for letgo-immobilization measuring network (Figure 5)

Frequency Hz	Output voltage to input voltage ratio	Input voltage to output voltage ratio	Input voltage per milliampere indication
20	0,250	4,00	2,00
50	0,251	3,99	1,99
60	0,251	3,98	1,99
100	0,253	3,95	1,98
200	0,261	3,83	1,92
500	0,298	3,36	1,68
1 000	0,348	2,87	1,44
2 000	0,377	2,65	1,33
5 000	0,280	3,57	1,79
10 000	0,164	6,09	3,04
20 000	0,086 0	11,6	5,81
50 000	0,034 9	28,7	14,3
100 000	0,017 5	57,2	28,6
200 000	0,008 74	114	57,2
500 000	0,003 50	286	143
1 000 000	0,001 75	572	286

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