IEC TR 63139

Edition 1.0 2018-10

TECHNICAL REPORT

colour inside

Explanation of the mathematical addition of working voltages, insulation between circuits and use of PELV in TC 34 standards

IEC TR 63139:2018-10(en)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - webstore.iec.ch/advsearchform
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 21 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
67 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC TR 63139

Edition 1.0 2018-10

TECHNICAL REPORT

Explanation of the mathematical addition of working voltages, insulation between circuits and use of PELV in TC 34 standards

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 29.140.01

ISBN 978-2-8322-6163-7

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

EXPLANATION OF THE MATHEMATICAL ADDITION OF WORKING VOLTAGES, INSULATION BETWEEN CIRCUITS AND USE OF PELV IN TC 34 STANDARDS

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.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

IEC TR 63139, which is a Technical Report, has been prepared by IEC technical committee 34: Lamps and related equipment.

The text of this Technical Report is based on the following documents:

DTR	Report on voting
34/415/DTR	34/493A/RVDTR

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

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

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

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

A bilingual version of this publication may be issued at a later date.

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 document provides background information to the following subjects being introduced into IEC TC 34 standards to cover new technologies associated with the use of LED light sources and controllable products.

This document consists of the following subdivisions:

Clause 4 – Mathematical addition of working voltages;

Clause 5 – Insulation between circuits;

Clause 6 – Use of protective extra low voltage (PELV);

Clause 7 – Insulation between LV supply and control line conductors.

EXPLANATION OF THE MATHEMATICAL ADDITION OF WORKING VOLTAGES, INSULATION BETWEEN CIRCUITS AND USE OF PELV IN TC 34 STANDARDS

1 Scope

This document is related to the insulation coordination in TC 34 standards and provides explanations on mathematical addition of working voltages, insulation between circuits, use of protective extra low voltage (PELV) and insulation between LV supply and control line conductors in order to cover new technologies associated with the use of LED light sources and controllable products.

It describes in which way the addition of supply voltages and working voltages can be arranged for an assessment of the electrical insulation requirements (e.g. creepage distances and clearances) in a system if a first failure occurs.

Furthermore the actual failure scenarios given in IEC 60598-1:2014 and IEC 60598-1:2014/AMD1:2017, Annex X and IEC 61347-1:2015, Clause 15 are explained in greater detail and the rationale behind the protective requirement for each situation is given (e.g. possible LV primary to ELV secondary does not lead to an overburden of the insulation in the second circuit).

This document also describes the possibility to increase immunity and reliability of electronic circuits, used in combination with LEDs, with the use of PELV and the associated safety consequences for this system.

The insulation between LV supply and control line conductors is also important and this document explains why this is an essential safety consideration for a complete installation system.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Mathematical addition of working voltages

Insulation requirements between live parts and accessible conductive parts as function of the controlgear input/output insulation classification and the insulation class of the luminaire are given in IEC 60598-1:2014, Table X.1 and IEC 61347-1:2015, Table 6.

Insulation requirements in TC 34 standards are based on a hazard assessment with the assumption that a certain failure will occur.

The required insulation is normally based on the working voltage U_{OUT}, but in some specific failure cases when the basic insulation between supply and output of a controlgear fails, the supply voltage should be added to U_{OUT}. For controlgear with double or reinforced insulation between primary (U_{SUPPLY}) and secondary (U_{OUT}) this type of failure is not expected.

In case of failure of the basic insulation within the controlgear the following assumptions are made:

- there is an increased output voltage,
- the luminaire remains working, and the increased voltage is present for a time long enough to create a conduction track across the insulation (known as tracking).

For 50/60 Hz transformers inside the controlgear, this failure condition results in the addition of the voltages that can be calculated by the simple summation of the two values. In electronic controlgear this situation may result in a more complex summation due to the complexity of the oscillating circuit that may influence the result.

The best method to check the output voltage in case of insulation failure is to measure the output voltage directly on a sample of controlgear with the fault simulated. The failure of the insulation and the output voltage should be measured against earth (or zero potential). This method has been found not to be practical due to the following reasons:

- differing supply conditions (voltage/frequency);
- difficulty in simulating exactly the failure condition;
- difficulty in making accurate and reproducible measurements.

For the above mentioned reasons the mathematical calculation of the sum of the voltages has been found to be more appropriate, reproducible and easy to calculate, even if the result may in some cases be lower than the real measurement. Designing and testing the insulation properties of the output circuit with an increased voltage value is considered as a necessary safety provision to cover this first failure condition which can occur inside basic insulated controlgear.

The approximation given by the mathematical calculation is considered to provide sufficient severity, compared to the possible practical failure voltage, to ensure the safety of the product through its lifetime. With the selected formula most of the expected failure cases are covered. Higher voltages occurring in very rare cases will not have any serious impact.

The formulas to be used for combining the input and output voltages of the controlgear, with basic insulation between supply and output, are given in Table 1.

Table 1 – Addition of voltages

U_{supply}	U_{OUT}	Phase relationship	Voltage calculation for insulation design
AC	AC	Same frequency and no phase shift	$U = U_{AC1} + U_{AC2}$
AC	AC	Same frequency and with phase shift	$U = \sqrt{U_{AC1}^2 + U_{AC2}^2 + 2\, U_{AC1}\, U_{AC2} \cos\varphi}$
AC	AC	Different frequency	$U = \sqrt{U_{AC1}^2 + U_{AC2}^2}$
AC	DC	No phase shift	$U = \sqrt{U_{AC}^2 + U_{DC}^2}$
DC	AC	No phase shift	$U = \sqrt{U_{AC}^2 + U_{DC}^2}$
DC	DC	No phase shift	$U = U_{DC1} + U_{DC2}$

NOTE 1 Voltages in the table are RMS values.

NOTE 2 The AC and DC calculation is typical for LED applications.

Figure 1 shows the simulation of the possible fault between input and output terminals (red line) with the mathematical calculation providing the expected output voltage that may occur.

Figure 1 – Input/output failure simulation

For background information, the formula $U = \sqrt{U_{AC}^2 + U_{DC}^2}$ (line 4 of Table 1) for the specific case of a combination of an AC and DC voltage is derived from the following Formulas (1) to (5). It may be regarded as a showcase for any of the formulas from Table 1.

U is the RMS value (U_{RMS}) of the voltage $u(t)$

$$U = U_{RMS} = \sqrt{u^2(t)} \tag{1}$$

In the particular case given, $u(t)$ consists of an AC (sinusoidal) part with peak voltage U_1 and frequency ω and a DC part U_{DC}. It can be derived that

$$U^2 = u^2(t) = \frac{\int_0^T u^2(t)\,dt}{T} = \frac{\int_0^T (U_1 \sin(\omega t) + U_{DC})^2\,dt}{T} =$$

$$\frac{U_1^2}{T}\int_0^T \sin^2(\omega t)\,dt + \frac{2U_1U_{DC}}{T}\int_0^T \sin(\omega t)\,dt + \frac{1}{T}\int_0^T U_{DC}^2\,dt \tag{2}$$

Evaluating this integral yields

$$U^2 = \frac{1}{2}\frac{U_1^2}{T}\left(t - \frac{1}{\omega}\sin(\omega t)\cos(\omega t)\right)\Big|_{t=0}^{t=T} - \frac{2\,U_1 U_{\mathrm{DC}}}{T\omega}\cos(\omega t)\Big|_{t=0}^{t=T} + \frac{1}{T}U_{\mathrm{DC}}^2 T \qquad (3)$$

$$U^2 = \frac{U_1^2}{2} + U_{\mathrm{DC}}^2 \qquad (4)$$

And thus,

$$U = \sqrt{\frac{U_1^2}{2} + U_{\mathrm{DC}}^2} = \sqrt{U_{\mathrm{AC}}^2 + U_{\mathrm{DC}}^2} \qquad (5)$$

5 Insulation between circuits

5.1 General

New requirements have been added to those in IEC 60598-1 and IEC 61347-1 concerning the requirements for insulation between different types of circuit and to conductive accessible parts. For insulation requirements between active parts and accessible conductive parts and examples of controlgear with different insulation systems see Table 2 and Figure 2.

In case of a failure in the basic insulation, with the assumptions made in Clause 4, between the supply voltage and the output circuit, the insulation in the second circuit will have an increase chance of failing; this can be regarded as a follow up failure, which is by definition still a single fault. This means that the insulation in the secondary circuit should be able to cope with this higher voltage.

The following explanations provide information regarding the technical rationale associated with these requirements.

The numbers in brackets (1) to (18) detailed in Table 2 refer to the content of IEC 60598-1:2014, Table X.1 and IEC 61347-1:2015, Table 6. A comparison with possible failure conditions is shown in Figures 3 to 7. Each combination has been evaluated and the consequences are listed in 5.3 with the requirements for the insulation which is needed for each numbered case.

5.2 Insulation requirements between active parts and accessible conductive parts

Explanations to the application of the insulation requirements are given in Table 2 and Figure 2.