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Explanation ~~of the mathematical addition of working voltages, insulation between circuits and use of PELV~~ and background information on electrical safety requirements in TC 34 standards

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Explanation ~~of the mathematical addition of working voltages, insulation between circuits and use of PELV~~ and background information on electrical safety requirements in TC 34 standards

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IEC TR 63139 has been prepared by IEC technical committee 34: Lighting. It is a Technical Report.

This second edition cancels and replaces the first edition published in 2018. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) new title and scope to enable the adding of further new subjects to the content of this document in the future;
b) new Clause 9 providing background information regarding the possible addition of currents in a lighting installation where luminaires are interconnected via their control ports;
c) new Clause 10 transferring Annex S of IEC 61347-1:2015 [1] (Examples of controlgear insulation coordination) from the controlgear safety standard into this document.

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

Draft	Report on voting
34/1416/DTR	34/1435/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

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

– reconfirmed,
– withdrawn, or
– revised.

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 Calculation of increased working voltage in case of insulation failure;

Clause 5 - Insulation between circuits following the circuits analysis in Clause 6;

Clause 7 - Use of protective extra low voltage (PELV);

Clause 8 - Insulation between LV supply and control line conductors;

Clause 9 - Summation of touch currents in a connected lighting system;

Clause 10 - Examples of insulation coordination situations between controlgear and luminaire.

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.

This document provides explanations and background information on electrical safety requirements in TC 34 standards.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

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4 Mathematical addition of working voltages Calculation of increased working voltage in case of insulation failure

Insulation requirements between live parts and accessible conductive parts as a 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 IEC 60598-1:2024 [2], Table T.1 and IEC 61347-1:2024 [3], Table M.1.

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~~ is 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~~ can result in a more complex summation due to the complexity of the oscillating circuit that ~~may~~ can 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~~ is 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~~ can 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~~ appropriate formula in Table 1 most of the expected failure cases are covered. Higher voltages occurring in very rare cases will not have any serious impact.

The formulas 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	See Formula (1)
AC	AC	Same frequency and with phase shift	See Formula (2)
AC	AC	Different frequency	See Formula (3)
AC	DC	No phase shift	See Formula (4)
DC	AC	No phase shift	See Formula (5)
DC	DC	No phase shift	See Formula (6)
NOTE 1 Voltages in this Table 1 are RMS values.			
NOTE 2 The AC and DC calculation is typical for LED applications.			

$$U = U_{AC1} + U_{AC2} \quad (1)$$

$$U = \sqrt{U_{AC1}^2 + U_{AC2}^2 + 2U_{AC1}U_{AC2}\cos\varphi} \quad (2)$$

$$U = \sqrt{U_{AC1}^2 + U_{AC2}^2} \quad (3)$$

$$U = \sqrt{U_{AC}^2 + U_{DC}^2} \quad (4)$$

~~$U = \sqrt{U_{AC}^2 + U_{DC}^2}$~~ $$U = \sqrt{U_{DC}^2 + U_{AC}^2} \quad (5)$$

$$U = U_{DC1} + U_{DC2} \quad (6)$$

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~~ can occur.

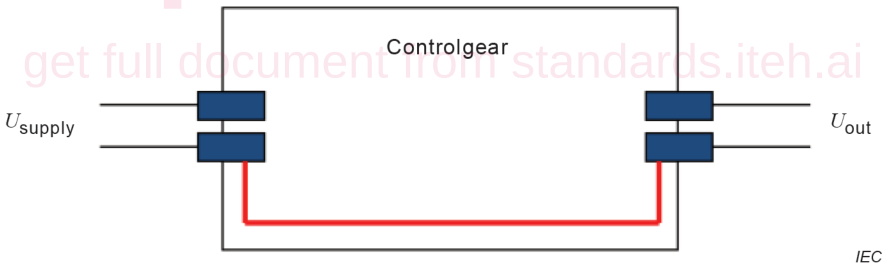


Figure 1 – Input/output failure simulation

For background information, Formula (4) and Formula (5) for the specific case of a combination of an AC and DC voltage are derived from the following Formula (7) to Formula (11). It ~~may~~ can be regarded as a showcase for any of the formulas from Table 1.

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

~~$U = U_{RMS} = \sqrt{u^2(t)}$~~ $$U = \sqrt{\frac{\int_0^T u^2(t)dt}{T}} \quad (7)$$

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

$$U^2 = \frac{\int_0^T u^2(t)dt}{T} = \frac{\int_0^T (U_1 \sin(\omega t) + U_{DC})^2 dt}{T} = \frac{U_1^2}{T}\int_0^T \sin^2(\omega t)dt + \frac{2U_1U_{DC}}{T}\int_0^T \sin(\omega t)dt + \frac{1}{T}\int_0^T U_{DC}^2 dt \quad (8)$$

Evaluating this integral yields

$$U^2 = \frac{1}{2}\frac{U_1^2}{T}\left(t - \frac{1}{\omega}\sin(\omega t)\cos(\omega t)\right)\Big|_{t=0}^{t=T} - \frac{2U_1U_{DC}}{T\omega}\cos(\omega t)\Big|_{t=0}^{t=T} + \frac{1}{T}U_{DC}^2 T \quad (9)$$

$$U^2 = \frac{U_1^2}{2} + U_{DC}^2 \quad (10)$$

And thus,

$$U = \sqrt{\frac{U_1^2}{2} + U_{DC}^2} = \sqrt{U_{AC}^2 + U_{DC}^2} \quad (11)$$

5 Insulation between circuits

5.1 General

New requirements have been added to those in IEC 60598-1 [4] and IEC 61347-1 [5] concerning the requirements for insulation between different types of circuit and to conductive accessible parts. For insulation requirements between ~~active~~ live 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 secondary 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~~ must be able to cope with this higher voltage.

The explanations in the paragraph below 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~~ IEC 60598-1:2024 [2], Table T.1 and IEC 61347-1:2024 [3], Table M.1. A comparison with possible failure conditions is shown in Figure 3 to Figure 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~~ live parts and accessible conductive parts

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

Table 2 – Insulation requirements between ~~active~~ live parts and accessible conductive parts

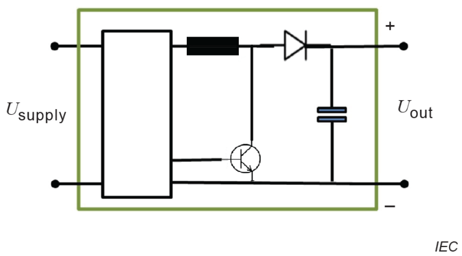
Controlgear		Required insulation between ~~active~~ live parts and accessible conductive parts		
Insulation between ~~LV~~ mains supply and secondary circuits	**Output voltage**	**Class I** **Insulation of accessible earthed conductive parts**	**Class II** **Insulation of one accessible conductive part or more than one with equipotential bonding**	**Class II** **Insulation of more than one accessible conductive part without equipotential bonding**
None	U_{out} > ~~LV_{supply}~~ mains supply	**(1)** Basic insulation complying with U_{out}	**(7)** Double or reinforced insulation complying with U_{out}	**(13)** Double or reinforced insulation complying with U_{out}
	U_{out} ≤ ~~Lv_{supply}~~ mains supply	**(2)** Basic insulation complying with ~~LV_{supply}~~ mains supply	**(8)** Double or reinforced insulation complying with ~~LV_{supply}~~ mains supply	**(14)** Double or reinforced insulation complying with ~~LV_{supply}~~ mains supply
Basic	Voltages above ELV	**(3)** Basic insulation complying with U_{out}	**(9)** Supplementary insulation complying with U_{out} ~~+ Lv_{supply}~~ added with mains supply	**(15)** Insulation has to fulfil the higher requirement of a) or b): a) Supplementary insulation complying with U_{out} ~~+ Lv_{supply}~~ added with mains supply b) Double or reinforced insulation complying with U_{out}
	ELV (FELV)	**(4)** Basic insulation complying with U_{out}	**(10)** Supplementary insulation complying with U_{out} ~~+ Lv_{supply}~~ added with mains supply	**(16)** Supplementary insulation complying with U_{out} ~~+ Lv_{supply}~~ added with mains supply
Double or reinforced	Voltages above ELV	**(5)** Basic insulation complying with U_{out}	**(11)** Basic insulation complying with U_{out}	**(17)** Double or reinforced insulation complying with U_{out}
	ELV (SELV)	**(6)** Basic insulation complying with U_{out} See also requirements in ~~IEC 60598-1:2014 and IEC 60598-1:2014/AMD1:2017, Sections 8, 10 and 11~~ IEC 60598-1:2024 [2], Clause 10, Clause 12 and Clause 13	**(12)** Basic insulation complying with U_{out} See also requirements in ~~IEC 60598-1:2014 and IEC 60598-1:2014/AMD1:2017, Sections 8, 10 and 11~~ IEC 60598-1:2024 [2], Clause 10, Clause 12 and Clause 13	**(18)** Basic insulation complying with U_{out} See also requirements in ~~IEC 60598-1:2014 and IEC 60598-1:2014/AMD1:2017, Sections 8, 10 and 11~~ IEC 60598-1:2024 [2], Clause 10, Clause 12 and Clause 13

Controlgear		Required insulation between ~~active~~ live parts and accessible conductive parts		
Insulation between ~~LV~~ mains supply and secondary circuits	Output voltage	Class I Insulation of accessible earthed conductive parts	Class II Insulation of one accessible conductive part or more than one with equipotential bonding	Class II Insulation of more than one accessible conductive part without equipotential bonding

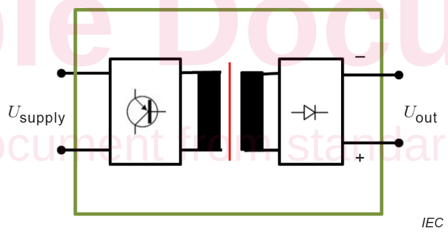
NOTE 1 The content of this Table 2 is identical to that of ~~IEC 60598-1:2014, Table X~~ IEC 60598-1:2024 [2], Table T.1. The corresponding Table ~~6~~ M.1 in ~~IEC 61347-1:2015~~ IEC 61347-1:2024 [3] is technically equivalent.

NOTE 2 The numbers in brackets are used as references in Table 3.

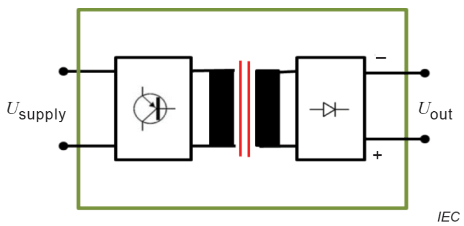
NOTE 3 For addition of voltages, see Table 1.



a) Controlgear without insulation between U_{supply} and U_{out}



b) Controlgear with basic insulation



c) Controlgear with double or reinforced insulation

NOTE One red line between the primary and secondary winding of the transformer stands for "basic insulation" and two red lines for "double or reinforced insulation".

Figure 2 – Examples of controlgear with different insulation systems

5.3 Possible failure conditions

Figure 3 to Figure 7 show detailed various failure conditions encountered in circuits for LED products.

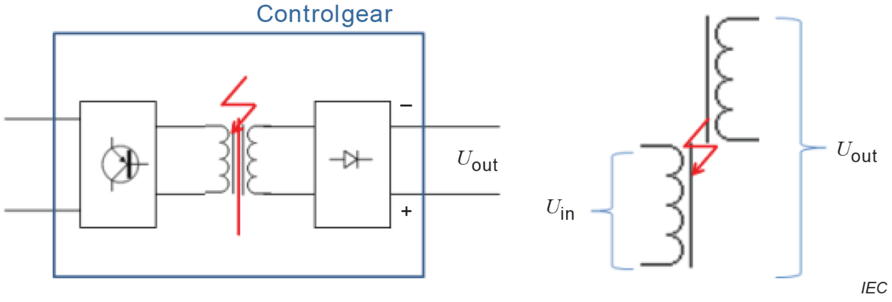


Figure 3 – Condition A: Failure between input and output circuits

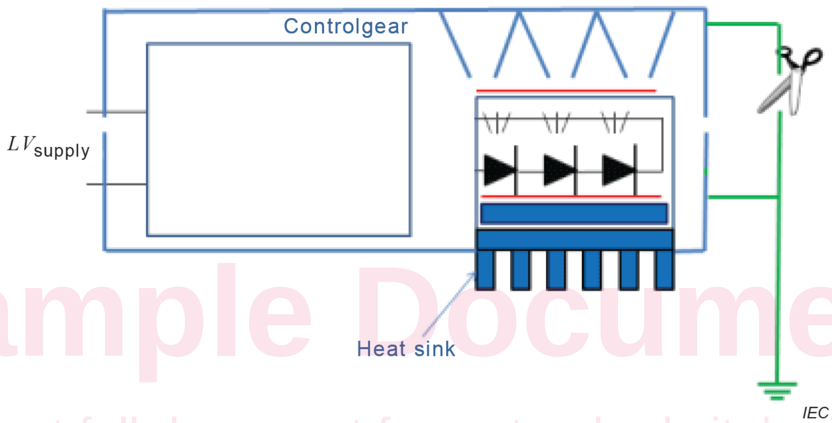


Figure 4 – Condition B: Earth failure/equipotential bonding failure (interruption of the connection continuity)

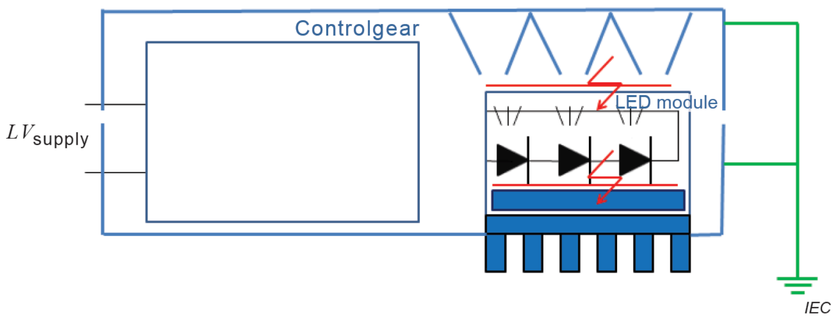


Figure 5 – Condition C: Insulation failure between output circuits and accessible earthed metal part

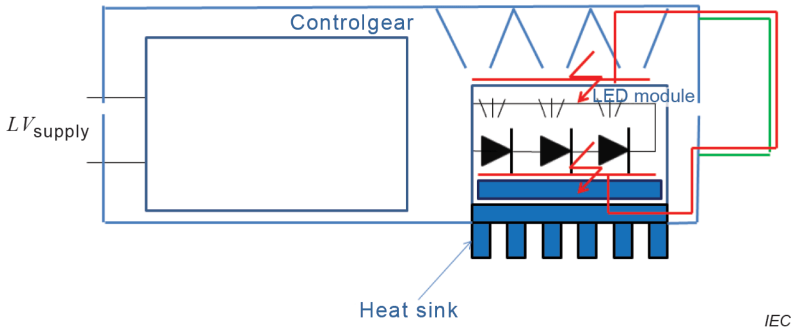


Figure 6 – Condition D: Insulation failure between output circuit to conductive parts which are connected together (equipotential bonding)

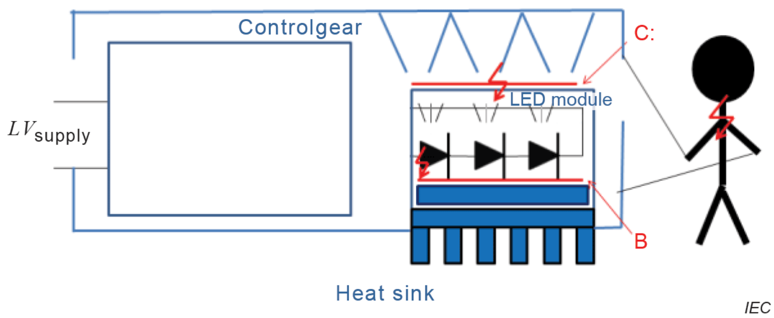


Figure 7 – Condition E: Insulation failure between output circuit and different conductive parts not connected together (no equipotential bonding)

6 Circuits analysis

Table 3 provides an overview of the possible hazard related to the failure conditions described in 5.3. Each combination has been evaluated and the consequences are listed with the requirements for the insulation introduced in IEC 60598 series which are needed for each numbered case in Table 2.

Table 3 – Circuit analysis overview

Table 2 references	Failure conditions (see 5.3)	Consequential circuit analysis
(1) and (2)	A	NA
	B	The second line of defence is the basic insulation.
	C	The second line of defence is the earth connection.
	D	NA
	E	NA
(3) and (4)	A	The second line of defence is the earth connection. (Consequential failures due to high voltage also protected by earth connection).
	B	The second line of defence is the basic insulation. (Otherwise different conductive parts which become unbounded ~~may~~ can have different potentials).
	C	The second line of defence is the earth connection.
	D	NA
	E	NA