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## LIAISON STATEMENT

**For action to:** -

**For comment to:** -

**For information to:** IEEE 802.3 Ethernet Working Group; IEEE 802 LMSC

**Approval:** ITU-T Study Group 5 meeting (Sophia Antipolis, 22 November 2017)

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**Keywords:** Isolation; Insulation; Withstand:1.2/50; Rated: dielectric; Common-mode; Ethernet 802.3;



**Abstract:** This document uses material from an ITU-T SG5 primer on isolation transformers and insulation with specific regard to Ethernet transformers.


This liaison provides additional information on LS 76 (31 May 2011).

ITU-T Study Group 5 would like to thank the IEEE 802.3 Ethernet Working Group for establishing a liaison on Ethernet port isolation. At the system level the Ethernet connection is different to most telecommunication links in that the Ethernet link does not have a definite earth/ground connection — the link is floating. This situation has resulted in Ethernet ports being given dedicated tests in the ITU-T Recommendations on resistibility.

The following material was presented at the ITU-T SG5 meeting at Sophia Antipolis, 13-22 November 2017 and is directly relevant to the established IEEE 802.3 Working Group Ethernet port isolation liaison with ITU-T SG5.

### Introduction

People who are not familiar with insulation coordination often confuse isolation and insulation. This document tries to explain the meanings of both and how some of the confusion is caused by miss-interpretation in other IEC standards. The IEC committee charged with defining insulation co-ordination is TC 109

**TC 109**

IEC TC 109 *Insulation co-ordination for low-voltage equipment* has the responsibility to produce International Standards on the principles of insulation coordination applicable to all low-voltage equipment (powered by voltages up to and including 1 000 V a.c. and 1 500V d.c.). These standards shall provide IEC Technical Committees with:

- rules for the determination of voltage ratings for insulation coordination;

- physical data for dimensioning of insulations to given voltage rating; and

- guidance for determination of clearances, and creepage distances and requirements for solid insulation with respect to insulation coordination and safety aspects up to 2 000 V a.c and 3 000 V d.c operating voltage.

These standards shall provide horizontal safety function guidance to the IEC technical committees on insulation coordination for service voltages up to and including 1 000 V a.c. and 1 500 V d.c., including dimensioning of clearances, and creepage distances and requirements for solid insulation with respect to insulation coordination. This includes all methods of dielectric testing with respect to insulation coordination.

**Terms and definitions**

**isolating transformer:** transformer with protective separation between the input and output windings.

[IEC 60065, ed. 8.0 (2014-06)]

**insulation:** that part of an electrotechnical product which separates the conducting parts at different electrical potentials.

[IEC 60664-2-1, ed. 2.0 (2011-01)]

**insulation coordination:** mutual correlation of insulation characteristics of electrical equipment taking into account the expected micro-environment and other influencing stresses.

[IEC 60664-2-1, ed. 2.0 (2011-01)]

**insulation resistance:** resistance under specified conditions between two conductive elements separated by insulating materials.

[IEC 60050-151:2001]

**electrical breakdown:** failure of insulation under electric stress when the discharge completely bridges the insulation, thus reducing the voltage between the electrodes almost to zero.

[IEC 60664-1, ed. 2.0 (2007-04)]

**impulse withstand voltage:** highest peak value of impulse voltage of prescribed form and polarity which does not cause breakdown of insulation under specified conditions.

[IEC 60664-2-1, ed. 2.0 (2011-01)]

**rated impulse voltage:** impulse withstand voltage value assigned by the manufacturer to the equipment or to a part of it, characterizing the specified withstand capability of its insulation against transient over voltages.

[IEC 60664-1, ed. 2.0 (2007-04)]

**lightning overvoltage:** transient overvoltage at any point of the system due to a specific lightning discharge.

[IEC 60664-1, ed. 2.0 (2007-04)]

*Often it is assumed that the main component of insulation is the dielectric and so there are terms for dielectric as well. This results in some document clauses being named "dielectric test" rather than "insulation test".*

**dielectric:** material with a high resistance to the flow of direct current, capable of being polarized by an electrical field.

[IEC 60194, ed. 6.0 (2015-04)]

**dielectric breakdown:** complete failure of a dielectric material that is characterized by a disruptive electrical discharge through the material that is due to deterioration of material or due to an excessive sudden increase in applied voltage.

[IEC 60194, ed. 6.0 (2015-04)]

**dielectric withstand voltage tests:** tests made to determine the ability of insulating materials and spacings to withstand specified over voltages for a specified time without flashover or puncture.

NOTE The purpose of the tests is to determine the adequacy against breakdown of insulating materials and spacings under normal or transient conditions.

[IEC 60076-21, ed. 1.0 (2011-12)]

## 60664-1 Ed.2.0 entry on voltage withstand

### 4.1.1.2.1 Impulse voltage dielectric test

The purpose of this test is to verify that clearances will withstand specified transient over-voltages. The impulse withstand test is carried out with a voltage having a 1,2/50 µs waveform with the values specified in table 5. For the waveform clauses 6.1 and 6.2 of IEC 61180-1 apply. It is intended to simulate over voltages of atmospheric origin and covers over voltages due to switching of low-voltage equipment.

Due to the scatter of the test results of any impulse voltage test, the test shall be conducted for a minimum of three impulses of each polarity with an interval of at least 1 s between pulses.

NOTE 1 The output impedance of the impulse generator should not be higher than 500 Ω. When carrying out tests on equipment incorporating components across the test circuit, a much lower virtual impulse generator impedance should be specified (see 9.2 in IEC 61180-2). In such cases, possible resonance effects, which can increase the peak value of the test voltage, should be taken into account when specifying test voltage values.

Technical committees may specify alternative dielectric tests according to 4.1.1.2.2.

### 4.1.1.2.2 Alternatives to impulse voltage dielectric tests

Technical Committees may specify an a.c. or d.c. voltage test for particular equipment as an alternative method.

NOTE While tests with a.c. and d.c. voltages of the same peak value as the impulse test voltage specified in table 5 of 4.1.1.2.1 verify the withstand capability of clearances, they more highly stress solid insulation because the voltage is applied for longer duration. They can overload and damage certain solid insulations. Technical Committees should therefore consider this when specifying tests with a.c. or d.c. voltages as an alternative to the impulse voltage test given in 4.1.1.2.1.

### 4.1.1.2.2.1 Dielectric test with AC voltage

The waveshape of the sinusoidal power frequency test voltage shall be substantially sinusoidal. This requirement is fulfilled if the ratio between the peak value and the r.m.s. value is $2^{0.5}$ ±3 %. The peak value shall be equal to the impulse test voltage of table 5 and applied for three cycles of the a.c. test voltage.

### 4.1.1.2.2.2 Dielectric test with DC voltage

The d.c. test voltage shall be substantially free of ripple. This requirement is fulfilled if the ratio between the peak values of the voltage and the average value is 1,0 ±3 %. The average value of the d.c. test voltage shall be equal to the impulse test voltage of table 5 and applied three times for 10 ms in each polarity.

**Test values in other standards**

Table 5 of 60664-1 Ed.2.0 has a preferred list of rated impulse voltages. Part of the preferred list are the impulse values of 1.5 kV. 2.5 kV, 4 kV and 6 kV. From clause 4.1.1.2.2.1 the corresponding AC rms voltage test values would be 1.1 kV, 1.8 kV, 2.8 kV and 4.2 kV. From clause 4.1.1.2.2.2 the corresponding DC voltage test values would be 1.5 kV. 2.5 kV, 4 kV and 6 kV.

Simply put the AC test voltage rms value should be 0.707 of the impulse test voltage peak and the DC test voltage value should be equal to the impulse test voltage peak. Depending on the insulation material some reduction in the AC and DC values can be made due to their longer application time to the insulation.

The specified impulse generator is the 1.2/50 detailed in IEC 60060-1 and the effective output impedance must be lower than 500 Ω and even lower still if voltage limiting surge protective components are likely to be present. The 1.2/50 impulse generator (circuit 2) specified in the IEC safety standards has an effective output resistance of about 40 Ω, which does not produce enough current to properly test voltage limiting surge protective components. A 1.2/50-8/20 combination wave generator with a 2 Ω effective impedance does have the required current capability to test voltage limiting surge protective components.

The missing information here is what impulse voltages appear on Ethernet systems? To set a "basic" level the ITU-T used the 2.4 kV peak value from the IEEE 802.3. As the ITU-T specifies the generator charging voltage, which is higher than the peak open-circuit voltage, for 2.4 kV output voltage, the generator charge voltage needs to be 2.5 kV. In severe electrical environments 2.5 kV rated transformers broke down and so a second "enhanced" rated level of 6 kV was defined.

The IEEE Std. 802.3 has some 10 sub-clauses entitled "Electrical isolation", which should really be titled "Insulation withstand of electrical isolation" as it is insulation that is tested and not isolation. The IEC 60950 safety standard of various dates is used as reference for the test voltage values the insulation. There are consistent values for AC and DC voltage testing; 1500 V rms and 2250 V d.c. The relationship of AC/DC is 0.6, which is not consistent with the 0.707 IEC 60664-1 Ed.2.0 value. High level AC or DC voltage testing does not reflect the actual electrical environment experienced by the Ethernet port. Two impulse test options are given; 1.5 kV 10/700 and 2.4 kV 1.2/50.

Anyone familiar with telecommunication port surge testing will recognise that 1.5 kV 10/700 is used for ports connected to long external lines, which usually have an earth reference, and is inappropriate for floating short distance Ethernet lines. The much shorter 1.2/50 is standard to IEC 60664-1 Ed.2.0 and a better representation of the short line electrical environment.

The insulation resistance test at 500 V d.c. and not less than 2 MΩ verifies the insulation after the impulse test. Conveniently the insulation resistance test voltage removes the need to test for AC mains power contact, because even if it did happen the peak AC mains voltage will be less than 400 V, which is lower than the 500 V d.c. insulation test voltage.

There has been a great deal of controversy over situations where the Ethernet port has voltage limiting components that bridge the insulation. The IEC 60950-1 indicated that these limiters could be removed for testing. However, this situation is not quite so clear when you study IEC 62368-1 hazard based safety standard, which is the intended replacement for the IEC 60950-1, the prescriptive safety standard. IEC 62368-1 edition 1 was rapidly followed by edition 2 and edition 3 is currently being worked on. IEC 62368-1 has not been widely accepted as it is a major concept change. To help explain what the IEC 62368-1 means, the IEC 62368-2 was produced (currently in edition 2). A full review of IEC 62368-1 implications will be done once edition 3 is published.

Summary

For the reasons given the ITU-T uses a 1.2/50-8/20 generator charged to 2.5 kV for basic and 6 kV for enhanced insulation voltage withstand testing of an isolated Ethernet port, followed by a 500 V d.c. test to verify the insulation is still good. Any voltage limiters that bridge the insulation shall not be removed for testing.

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## Bibliography (Annotated)

*Lightning Surge Damage to Ethernet and POTS Ports Connected to Inside Wiring*

This paper was presented at the 2014 IEEE Symposium on Product Compliance Engineering, where it received the Best Paper award. The paper discusses lightning damage to Ethernet and POTS ports connected to cables routed entirely within the same building. Manufacturers in both the USA and Japan have reported surprisingly high rates of lightning damage to ports on optical network terminals used for fiber-to-the-home delivery of telecom services. Similar damage has been reported on VOIP PBXs. While there are three known mechanisms by which lightning can couple onto inside wiring, their occurrence is believed to be statistically infrequent. The paper discusses these three known mechanisms as well as three new theories that are currently under study. All three of the new theories are based on the notion that surges on the AC mains are being coupled onto inside wiring communication cables. While research on these new theories continues, some guidelines are provided for manufacturers who wish to implement enhanced surge protection on Ethernet and POTS ports connected to inside wiring.

http://www.randolph-telecom.com/articles/Lightning%20Surge%20Damage%20to%20Ethernet%20and%20POTS%20Ports%20Connected%20to%20Inside%20Wiring.pdf

*Magnetically induced voltages and currents in Ethernet cables due to lightning strokes*

This report discusses the currents and voltages that are magnetically induced in Ethernet cables due to nearby lightning strokes and their interaction with Surge Protective Devices, SPDs, or Ethernet port Surge Protective Components, SPCs.

http://pes-spdc.org/system/files/filedepot/387/magnetically_induced_voltages_and_currents_in_ethernet_cables-rev3.pdf

*Guide to the electrical parameter classifications of IEC 60950 and IEC 62368 safety standards*

This document compares the terms, definitions and parameters of the IEC 60950-1 and IEC 62368-1. Ultimately IEC 60950-1 should be replaced by the IEC 62368-1 hazard-based safety standard and so it is important to understand the relationships between the established and hazard-based terminology.

https://pes-spdc.org/sites/default/files/guide-to-iec-tc108-safety-standards-parameters.pdf

*ITU-T K.126 (07/2017): Surge protective component application guide - High frequency signal isolation transformers*

Failures of Ethernet local area network (LAN) ports have been attributed to use of inappropriate surge protective devices (SPDs), lack of insulation coordination and inappropriate wiring, which causes the failure of transformers, associated wiring, components and connectors. Recommendation K.126 discusses isolation transformer parameters and how they influence the equipment common-mode and differential-mode surge performance. Access to the full text of [ITU-T K.95] is necessary to fully understand this document.

https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-K.126-201707-I!!PDF-E&type=items