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SERIES K: PROTECTION AGAINST INTERFERENCE

ITU-T K.51 – Potential hazards of narrow pin spacing in connectors

ITU-T K-series Recommendations – Supplement 12

ITU-T

Supplement 12 to ITU-T K-series Recommendations

ITU-T K.51 – Potential hazards of narrow pin spacing in connectors

Summary

Supplement 12 to ITU-T K-series Recommendations addresses narrow pin spacing in connectors with limited creepage and clearance dimensions but high-power loading, which can potentially make them susceptible to high impedance shorts between connector pins or arcing during the connecting/disconnecting mating cycle. These shorts and arcs can result in thermal and fire hazards for such high-power connectors and negatively impact overall system reliability.

History

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Keywords

Arcing, fire hazard, high impedance short, high-power, narrow pin spacing, supplement, thermal hazard, USB Type C, RJ 45.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

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Supplement 12 to ITU-T K-series Recommendations

ITU-T K.51 – Potential hazards of narrow pin spacing in connectors

1 Scope

This supplement investigates the potential thermal and fire hazards for narrow pin spacing connectors such as USB 3.0 and RJ45 connectors. This informative Supplement then discusses various potential mitigation methods.

2 References

[ITU-T K.20] Recommendation ITU-T K.20 (2017), *Resistibility of telecommunication equipment installed in a telecommunication centre to overvoltages and overcurrents.*

[ITU-T K.21] Recommendation ITU-T K.21 (2017), *Resistibility of telecommunication equipment installed in customer premises to overvoltages and overcurrents.*

[ITU-T K.44] Recommendation ITU-T K.44 (2017), *Resistibility tests for telecommunication equipment exposed to overvoltages and overcurrents - Basic Recommendation.*

[ITU-T K.45] Recommendation ITU-T K.45 (2017), *Resistibility of telecommunication equipment installed in the access and trunk networks to overvoltages and overcurrents.*

[ITU-T K.51] Recommendation ITU-T K.51 (2016), *Safety criteria for telecommunication equipment.*

[ITU-T K.96] Recommendation ITU-T K.96 (2014), *Surge protective components: Overview of surge mitigation functions and technologies*.

[ITU-T K.126] Recommendation ITU-T K.126 (2017), *Surge protective component application guide – High frequency signal isolation transformers.*

[IEC 60512-99-001] IEC 60512-99-001:2012, *Connectors for electronic equipment – Tests and measurements – Part 99-001: Test schedule for engaging and separating connectors under electrical load – Test 99a: Connectors used in twisted pair communication cabling with remote power*.

[IEC 61000-4-2] IEC 61000-4-2:2008, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test.*

[IEC 62368-1] IEC 62368-1:2014, *Audio/video, information and communication technology equipment – Part 1: Safety requirements.*

[IEC 62680-1-3] IEC 62680-1-3:2016, *Universal serial bus interfaces for data and power – Part 1-3: Common components – USB Type C™ cable and connector specification.*

3 Definitions

This Supplement does not define any terms. Terms used in this Supplement are defined in the documents listed in clause 2 references.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

ECL Electronic Current Limiter

ESD Electro Static Discharge

MOV Metal Oxide Varistor

PCB Printed Circuit Board

PoE Power over Ethernet

PTC Positive Temperature Coefficient

SMD Surface Mount Device

USB Universal Serial Bus

5 Conventions

None.

6 USB Type C connector

6.1 Exposure of USB interfaces

Both [ITU-T K.20] and [ITU-T K.21] Recommendations contain surge testing for universal serial bus (USB) interfaces, thus indicating an exposure for these types of interfaces. These two Recommendations require a defined resistibility level for USB interfaces.

[IEC 60542-99-001] describes the aging of small form factor connectors (specifically RJ45 connectors, but similar parameters also apply to USB Type C connectors) due to multiple connecting and disconnecting cycles for these high-power applications and the consequent negative affect on system reliability.

6.2 USB Type C connector specification

The USB Type-C connector size and layout increases the risk of arcing or high-impedance shorting faults. This connector is used for both data and power transfer. The new Type C allows higher voltages and currents than previous USB versions but implements a new non-polarized connector that could lead to field failures and low reliability.

Figure 1 demonstrates how the highest voltage pins are near each other (V_{BUS} and V_{CONN}).

A12	A11	A10	A9	A8	A7	A6	A5	A4	A3	A2	A1
GND	RX2+	RX2–	V_{BUS}	SBU1	D–	D+	CC	V_{BUS}	TX1–	TX1+	GND
GND	TX2+	TX2–	V_{BUS}	V_{CONN}			SBU2	V_{BUS}	RX1–	RX1+	GND
B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	B12

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Figure 1 – USB Type-C functional signal plan

V_{BUS} can be 20 V max or 5A max (pins A9, B9, A4 and B4) for a 60W min/100W max delivery, while V_{CONN} can run as high as 5.5 V at 1.25A (pin B5). This B5 pin is close to the V_{BUS} (pin B4). Only one CC pin is connected through the cable to establish signal orientation and the other CC pin is repurposed as (B5 in the example shown above) V_{CONN} pin for powering electronics. Thus, these two high voltage pins are near each other. The cable is rated up to 3A while the connector is rated up to 5A (for contact resistance and possible thermal accumulation issues). Figure 1 also shows a USB 2.0 D+D-/ implementation where only a single set of D+/D- wires are implemented. Otherwise, B6 and B7 would be D+/D- respectively and used for full USB 3.1 data rates. Table 1 below shows the electrical parameters for Type C interfaces.

Table 1 – USB Type-C™ cable and connector specification [IEC 62680-1-3]

Mode of operation	Nominal voltage	Maximum current	Notes
USB Type-C current @ 1.5A	5 V	1.5 A	Supports higher power devices
USB Type-C current @ 3A	5 V	3 A	Supports higher power devices
USB PD	Up to 20V	Up to 5A	Directional control and power level management

6.3 USB Type C connector creepage and clearance dimensions

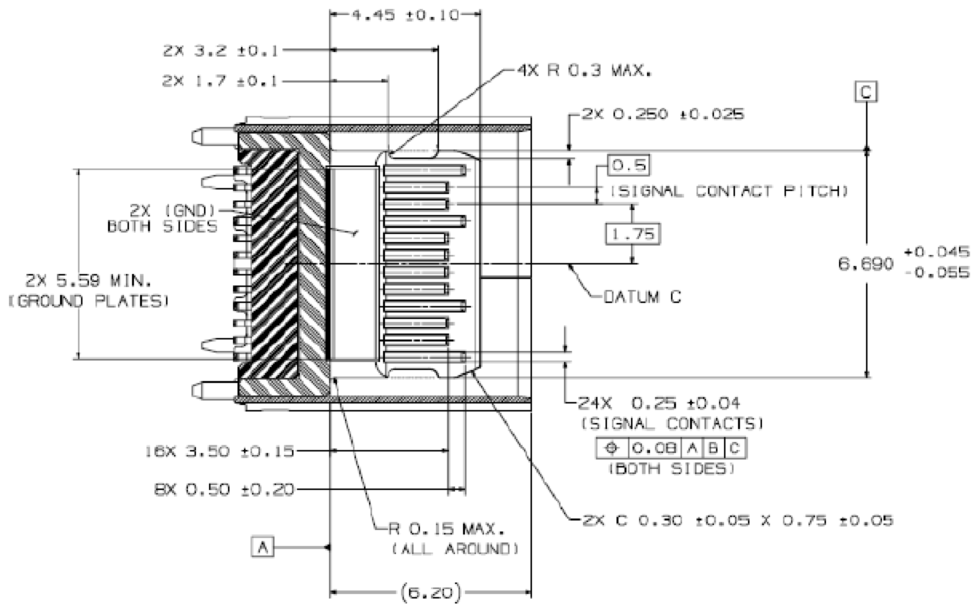

Figure 2 – USB Type C connector dimensions

Figure 2 shows a creepage distance between pins B4 and B5 of only 0.25 mm maximum.

6.4 Classifying a USB Type C connector

USB Type-C should be classified as a pollution degree 3 (currently it is typically classified as pollution degree 1) type application as defined in [IEC 62368-1] since this cord/connector may be carried around and subjected to:

1) potential pocket lint;

2) cable twist;

3) cable removal at an angle;

4) connector aging;

5) debris;

6) dust;

7) contamination;

8) low CTI PCB rating, etc.

Minimum creepage as defined by [IEC 62368-1] Table 23, pollution degree 3, material group I, II, or IIIa/IIIb (CTI based) for working voltage up to and including 10 V is a minimum of 1.0 mm. The Type C connector has a creepage distance of 0.25 mm, which is well below what is considered a safe level. For a 20 V working voltage, the minimum creepage distance is 1.2 mm.

If pollution degree 2 was considered, then the minimum [IEC 62368-1] creepage distance requirement would be 0.4 mm (10 V and below) and 0.48 mm (@ 20 V). This is much larger than the specified 0.25 mm of the Type C connector.

This defined Type C dimension ONLY complies with a pollution degree 1 status, which has creepage requirements of 0.08 mm (10 V and below) and 0.11 mm (@ 20 V). However, pollution degree 1 is defined as no pollution or only dry, non-conductive pollution; typically found only in equipment that is sealed to exclude dust and moisture.

[ITU-T K.51] *Safety criteria for telecommunication equipment* refers to both [IEC 60950-1] and [IEC 62368-1]. These two safety documents address creepage and clearance dimensions to reduce potential hazards. [ITU-T K.51] clause 5.2.2 *Interconnection of equipment* missed the opportunity to include a related connector/plug alignment type test and a minimum creepage distance; therefore, it should refer to clause 7 below.

7 Connector/plug alignment testing

7.1 IEC 62368-1 connector testing

All small form factor connectors/plugs shall comply with the connector 10 N test condition T.2 of [IEC 62368-1] having a steady force of 10 N applied for approximately 5 s without any shorting of pins, fire, or other safety related hazard.

All small form factor connectors/plugs shall comply with test method 3 of [IEC 62368-1] (V.1.4) having a blunt probe applied without appreciable force in any possible position to the connector/plug without any shorting of pins, fire, or other safety related hazard occurring.

All small form factor connectors/plugs shall not experience any shorting of pins, fire, or other safety related hazard after/during 10 repeated insertions and removals.

These small form factor connectors should also be subjected to the testing outlined in [IEC 60512-99-001] for aging and loading considerations, steps one through six as summarized in clause 8.

8 RJ45 connector aging (engaging and disengaging testing)

8.1 IEC 60512-99-001 compliance testing

To protect against the possibility of arcing between the plug contact of a patch cord and the RJ45 connector contact, [IEC 60512-99-001] was created. This standard contains tests that simulate power over ethernet (PoE) + (also known as Type 2, 3, and 4) aging and capacity loading. Adherence to this standard increases the overall reliability of system connection points.

Due to the relative high loading characteristics of PoE + (Type 2, 3 or 4), an electric arc may appear during the disconnection process and damage or corrode the contacts. Therefore, [IEC 60512-99-001] standard ensures a minimal number of connection/disconnection occurrences. This standard has essentially six steps of testing:

1) Initial state (parameter measurements such as contact resistance, insulation resistance, etc.);
2) Mechanical operation under load (total of fifty mating cycles);
3) Aging process simulation (exposed to a flowing mixture of H2S and SO2 gases);
4) Parameter measurements;
5) Mechanical operation under load (total of fifty mating cycles);
6) Parameter measurements.

The connector is tested to the maximum current level as specified for each PoE Type. However, due to the high probability that one contact will disconnect before the other in the same pair, the second contact is required to support twice the usual power level.
The aging simulation is intended to mimic mild environments, such as a typical office area. The connectors are placed in to a special tank for four days for this simulation.

Following the mechanical operations and aging process, a new round of parameter readings is conducted to validate that samples have not been negatively impacted. For example, if the contact resistance has changed by more than 20 mΩ between the first step and the third step, the samples are deemed non-compliant with this standard.

If the samples remain in compliance after step four, the samples are again subjected to the same mechanical operations under load tests and again parameters are measured. These parametric values are compared with the initial state values again, with a limit of 20 mΩ change in the contact resistance between step 1 and step 6.

9 Narrow pitch mitigation methods

These narrow pitch pin connectors/plugs may be susceptible to the high impedance shorts as outlined in clause 6. These connectors/plugs may also be exposed to electro-static discharge (ESD) or surge events.

The high impedance short issue may be addressed with several approaches:

1) Increasing creepage distances as much as possible;
2) Use a non-conducting conformal coating on connectors/plugs and printed circuit boards (PCBs) to make the application a pollution degree 1 environment;
3) Inserting over-current protectors such as positive temperature coefficient (PTC) components, electronic current limiters (ECLs), or fuses in series with the connected line;
4) Other thermally triggered methods that open the circuit path while high impedance shorts draw less than the current needed to activate protectors in #3 above;
5) Implementing over-voltage clamping or crowbarring components across narrowly spaced connections/pins.

10 ESD mitigation methods

ESD testing and immunity is covered in [IEC 61000-4-2]. Implementing low off-state capacitance ESD protectors within the small form factor connector/plug may not be practical but using such protectors on the cables or PCBs that connect to these connectors and plugs may prove to be useful. Avalanche breakdown based silicon protection arrays, Zener type diodes, surface-mount device

(SMD) metal oxide varistors (MOVs), or thyristor based protectors connected between signal pin and earth reference are potential solutions for ESD mitigation.

11 Surge descriptions and surge mitigation examples

There are two types of surges; common-mode and differential-mode. Most surges are coupled in common-mode, but insulation breakdown and voltage-limiting type protector operation can convert a common-mode surge into a differential surge. Common mode events result in all service conductors having the same surge level (equipotential). Figure 3 shows several mitigation options for a common-mode surge:

a) voltage limit the surge voltage from a reference potential (usually earth) by using voltage limiting components;

b) block the voltage surge with an isolating transformer, (not applicable for telecommunication services carry DC voltage such as PoE);

c) filter out the surge frequencies if the service and lightning spectrums do not overlap;

d) use a common-mode choke, which has a high impedance to common-mode surge and a low impedance to the differential signal;

e) use a series current limiter. Thermally operated current limiters will not normally operate under surge conditions, but electronic current limiters will.

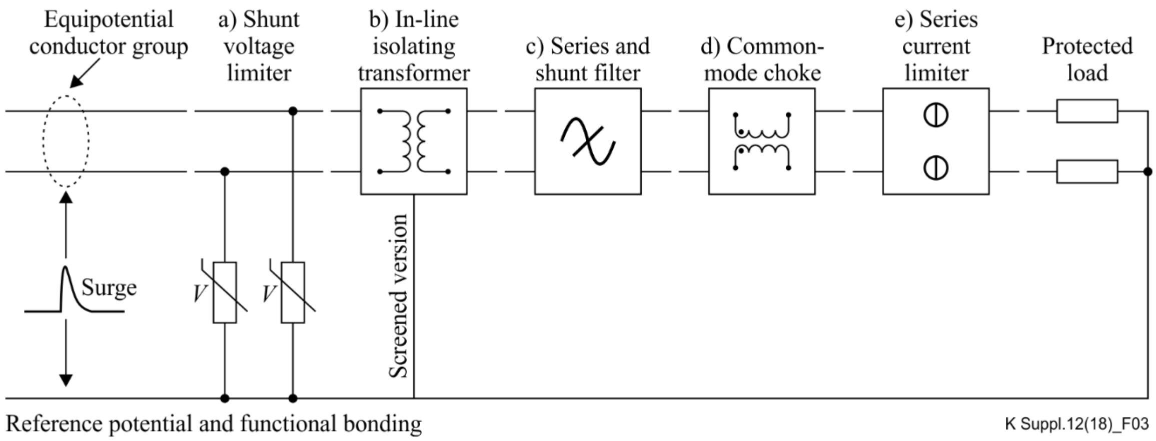

Figure 3 – Common-mode surge mitigation options

The description and operation of protection technologies is covered in [ITU-T K.96].

Differential mode means that the surge voltage is developed between the service conductors. Figure 4 shows several mitigation options for a differential-mode surge.

a) voltage limit the surge voltage between the conductors by using voltage limiting components;

b) if the signal transformer core saturates, stopping transformer action, surge truncation will occur, see [ITU-T K.126];

c) filter out the surge frequencies if the service and lightning spectrums do not overlap;

d) use a series current limiter. Thermally operated current limiters will not normally operate under surge conditions, but electronic current limiters will.

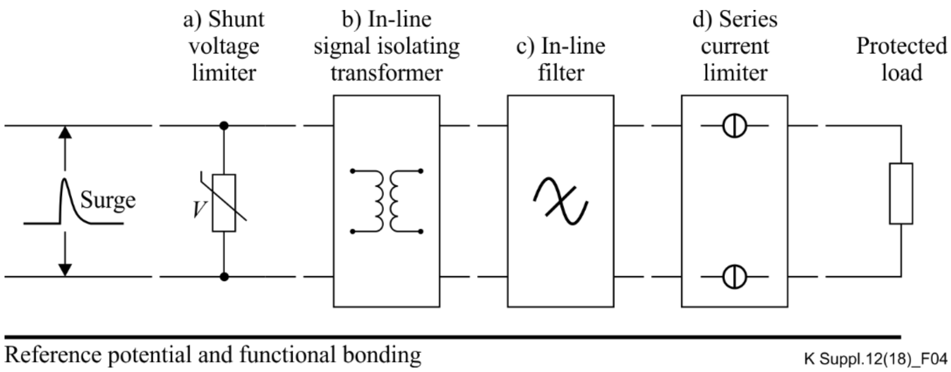

Figure 4 – Differential-mode surge mitigation options

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