EUROPEAN POWER SUPPLY MANUFACTURERS ASSOCIATION

Safety Approvals Guideline for Telecom Power Supplies

Guidelines to the Standards:

- IEC60950-1 amendement 1
- EN60950-1
- UL60950-1 Second edition

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This Guideline gives an overview of design issues, definitions and useable standards currently used in AC/DC and DC/DC power supplies for telecom applications. It should give a common understanding what safety rules and certifications should be used depending on the final application of the product.

Furthermore this paper gives a general interpretation how different standard requirements are applied to power supplies.

This paper does NOT intend to be a standard.

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The European Power Supply Manufacturers Association was established in 1995, to represent the European power supply industry. More information regarding the organisation can be found on the EPSMA website (www.epsma.org).

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1. Introduction

This paper aims to give an overview of the safety relevant aspects, which are needed to achieve safety approval according IEC/EN/UL60950-1 second edition, referred to elsewhere in this guideline as “the standards”. Especially for the less experienced engineer this document will give guidelines that facilitate the use and the understanding of the relatively complex matter of the standard and approval according to the standards.

2. Summary

It is important to understand that certified products have to comply with all applicable safety relevant aspects. This document will cover the majority:

- Electrical shock
- Energy related hazards
- Mechanical hazards
- Fire
- Heat related hazards
- Radiation
- Chemical hazards

2.1. Enclosure

The outer shell, called enclosure has to fulfill multiple functions:

- Fire enclosure
  Protects the environment from possible fire inside the unit
- Mechanical enclosure
  Protects from mechanical and other physical hazards
- Electrical enclosure
  Reduces the access to parts with hazardous voltages and energies
- Decorative part
  Part without safety function

3. Electrical Safety

3.1. Voltage potential description

- **Mains Supply**
  A power distribution system that is either an AC or DC mains supply
- **Live part**
  A part that is made of electrical conducting material and is connected to any of the system voltages but Protective Earth.
- **Primary**
  A part or circuit connected directly or indirectly to the mains input voltage.
- **Secondary**
  A part or circuit that has no direct connection to primary and is separated by a transformer, optocoupler or similar means of insulation.
- **Protective Earth**
  A part connected to the potential of the earth via a connector with a minimum cross section appropriate to the current and power level of the power supply.
- **Insulated part**
  Either a part made of non-conductive material or a conductive part that is isolated from any of the existing system voltages. One example would be a non conductive plastic enclosure of the power supply.
- **SELV Circuit**
  A secondary circuit that is so designed and protected that under normal operating conditions and single fault conditions its voltages do not exceed 42.4Vpk or 60Vdc, which is considered as a safe level.

3.2. Insulation type

- **Functional insulation**
  Lowest level of insulation, required for proper system operation, does not protect from electric shock, but may reduce risk of ignition and fire.
- **Basic insulation**
  Fundamental isolation against electric shock current
- **Supplementary insulation**
  Independent and additional isolation in order to avoid the risk of electric shock in case of basic insulation failure
- **Double insulation**
  Insulation comprising basic insulation and supplementary insulation
- **Reinforced insulation**
  Single insulation system that has the same performance as double insulation but cannot be separated into two individually testable basic/supplementary systems.

3.3. Protection class

- **Class I equipment**
  Device with basic insulation to exposed conductive surface, which is reliably connected to Protective Earth conductor.
- **Class II equipment**
  Device with double or reinforced insulation to exposed conductive surface. No Protective Earth connection required
- **Class III equipment**
  Device in which no hazardous voltages are being generated and that is supplied by an SELV circuit.

3.4. Pollution degree

- **Pollution degree 1**
  No pollution or only dry, non-conductive pollution, normally when equipment is encapsulated or hermetically sealed to exclude moisture and dust. Conformal safety standard compliant coating on PCBs or ingress protection above IP55 would be examples.
- **Pollution degree 2**
  Typical office environment, where there is only non-conductive pollution that might temporarily become conductive due to occasional condensation. It is generally appropriate for equipment covered by the scope of the standards.
- **Pollution degree 3**
  Typical industrial environment, where a local environment within the equipment is subject to conductive pollution or to dry non-conductive pollution which could become conductive due to expected condensation.

3.5. Connection to supply voltage

- Device with pluggable connection
  - Pluggable equipment type A: Connected by plug and socket outlet
  - Pluggable equipment type B: Connected by industrial connector
- Permanent connected equipment

3.6. AC mains transient voltages

There are four transient voltage classes depending on the exposure to external overvoltage.

- **Overvoltage category I**
  Signal level, special equipment or parts of equipment, especially on the secondary
- **Overvoltage category II**
  Local building branch circuit level, typical input levels for power supplies
- **Overvoltage category III**
  Distribution level, also used as more stringent level for PSUs

- **Overvoltage category IV**
  Primary supply level, overhead lines, outdoor cable systems and equipment

Clearances in equipment intended to be connected to the AC mains supply shall be designed for overvoltage category II (For usage in category III and IV additional external or internal protection equipment is required).

AC MAINS SUPPLY voltage [Vrms] a)	MAINS TRANSIENT VOLTAGE [Vpeak] b)			
	Overvoltage Category			
	I	II	III	IV
up to and including 50	330	500	800	1 500
over 50 up to and including 100	500	800	1 500	2 500
over 100 up to and including 150 c)	800	1 500	2 500	4 000
over 150 up to and including 300 d)	1 500	2 500	4 000	6 000
over 300 up to and including 600 e)	2 500	4 000	6 000	8 000

a) For equipment designed to be connected to a three-phase, three-wire supply,where there is no neutral conductor, the AC MAINS SUPPLY voltage is the line-to-line voltage.
In all other cases, where there is a neutral conductor, it is the line-to-neutral voltage.
b) The MAINS TRANSIENT VOLTAGE is always one of the values in the table. Interpolation is not permitted.
c) Including 120/208 V or 120/240 V.
d) Including 230/400 V or 277/480 V. e Including 400/690 V.

Figure 1: Mains transient voltage

3.7. Insulation material

These materials have to be operated within their specific ratings, mainly regarding temperature and voltage.

3.7.1. Material with specified voltage rating

If materials are used without minimum thickness requirement these have to be approved and tested up to a certain rated voltage. Typical examples are insulation tapes within magnetic components, specifically within isolation transformers. According to the required insulation type, one or more layers of such a material have to be used.

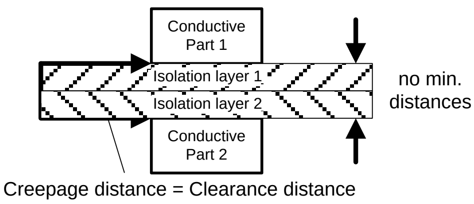

Figure 2: Voltage rated material

3.7.2. Material requiring minimum thickness

If the material does not have specific voltage rating, a minimum thickness of 0,4 mm is required for supplementary or reinforced insulation. For basic insulation no minimum is required and the thickness has to be chosen according to the material ratings. A typical example would be a bobbin of an isolation transformer

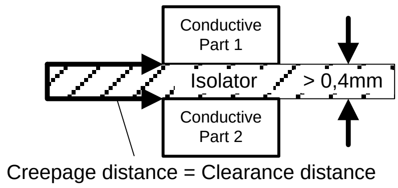

Figure 3: Minimum thickness insulation material

3.7.3. Printed circuit boards

On the surface area, i.e. top and bottom side (also known as component and solder side) the regular creepage and clearance distances according to 3.12 and 3.13 for pollution degree 2 or 3 apply.
If additionally protective coating is applied to achieve pollution degree 1, reduced distances are tolerated, however, PCB manufacturing is subject to special quality regulations according to the standards.
For inner layers there are special requirements for cemented joints. If the cemented joint meets different test requirements the joint is assessed either as distance through insulation, or as creepage/clearance in a pollution degree 1 environment. Otherwise the joint is assessed as creepage/clearance in the pollution degree 2 or 3 environment the equipment is designed to meet.
All the above requirements are also applicable to planar transformers.

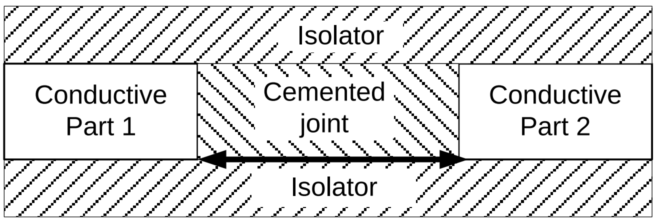

Figure 4: Insulation on the same PCB layer require regular creepage and clearance distances

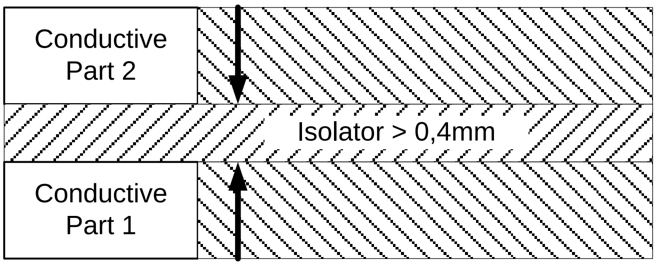

Figure 5: Insulation between different PCB layers is reinforced, if distance is > 0,4mm or meet criteria in table 2R of the standards (e.g. min 3 layers of prepreg)

3.7.4. Material groups

Insulation materials are classified into four groups according to their Comparative Tracking Index (CTI) values

- Material group I 600 ≤ CTI
- Material group II 400 ≤ CTI < 600
- Material group IIIa 175 ≤ CTI < 400
- Material group IIIb 100 ≤ CTI < 175

3.8. Electrical safety hazards

- **Voltage hazard**
  Any voltage that exceeds SELV is treated as voltage hazard.
- **Energy hazard**
  Even for low voltages that are treated as SELV, there can be so much current

available that the power exceeds 240VA. In this case protection criteria apply to prevent exposure of the metal parts and the risk of a short circuit.

3.8.1. ELV circuit

Secondary "*Extra Low Voltage"* circuit. The maximum voltage is 42,4V_{peak} or 60Vdc between any pair of the conductors and between any conductor and Protective Earth (PE) under normal operating conditions.

3.8.2. SELV circuit

Secondary *"Safe extra low voltage".* The voltage does not exceed the safe limit of V_1 of <42,4Vp or < 60Vdc in normal operating conditions, however, voltages up to V_2 are tolerated as follows

if $t_1 \leq 20ms$, $t_2 > 1s$

if $t_1 > 20ms$, $t_2 > 3s$ and $t_1 \leq 200ms$

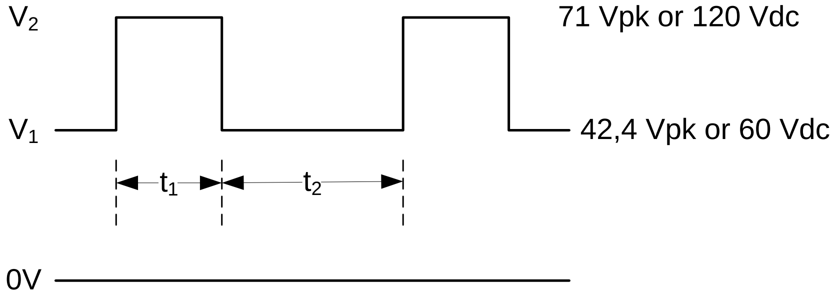

Figure 6: Maximum SELV voltages

3.8.3. TNV circuit

A circuit in the equipment to which the accessible area of contact is limited and that is designed and protected in a way that under normal operating and single fault conditions, the voltages do not exceed specified limit values.

- TNV-1 Circuit
  A circuit, whose normal operating voltages do not exceed the limits for a SELV circuit under normal operating conditions, but may have overvoltages from telecommunication networks and cable distribution systems.
- TNV-2 Circuit
  A circuit, whose normal operating voltages exceed the limits for a SELV circuit under normal operating conditions, but it's not subject to overvoltages from telecommunication networks
- TNV-3 Circuit
  A circuit, whose normal operating voltages exceed the limits for a SELV circuit under normal operating conditions and on which overvoltages from telecommunication networks and cable distribution systems are possible

		Normal operating voltages	
Overvoltages from TELECOMMUNICATION NETWORKS possible?	**Overvoltages from CABLE DISTRIBUTION SYSTEMS possible?**	**Within SELV CIRCUIT limits**	**Exceeding SELV CIRCUIT limits but within TNV CIRCUIT limits**
Yes	Yes	TNV-1 CIRCUIT	TNV-3 CIRCUIT
No	N/A	SELV CIRCUIT	TNV-2 CIRCUIT

3.8.3.1. TNV voltages

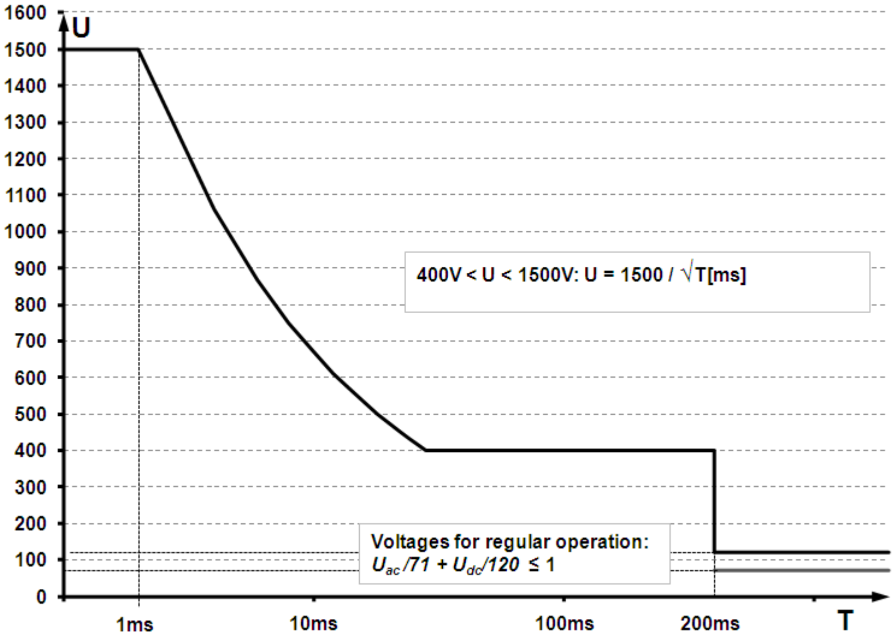

Figure 7: Maximum voltage permitted after single fault

3.9. Safety relevant components

3.9.1. Optocoupler

A component to be used across an insulation barrier. This part has to have safety approvals according UL1577, DIN EN 60747-5-5 or similar. Especially for smaller, surface mounted components, creepage and clearance distances have to be checked and matched with the respective design requirements of the standards.

3.9.2. Transformer

The transformer is used to transfer energy across an isolation barrier, usually from primary to secondary. The typical insulation type for a transformer is double/reinforced. Figure 8 illustrates, for convenience, two methods of insulation on one bobbin.
Cross section "A" shows a solution with an insulated secondary, "B" shows the primary insulated. Note that each insulation function has to use at least 2 layers of tape plus overlap.
Creepage and clearance will also need to be achieved at the winding leadouts.

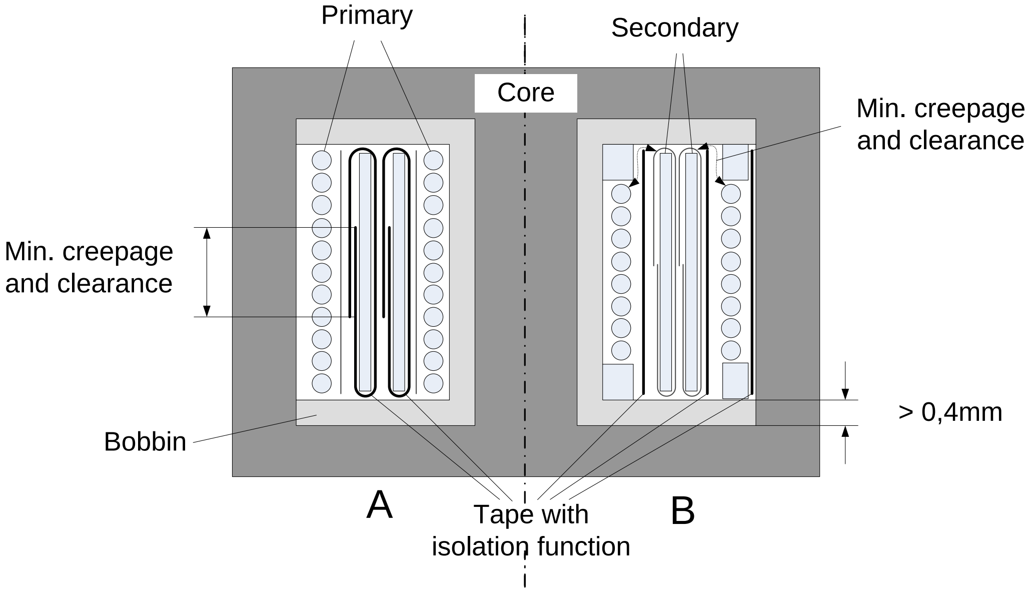

Figure 8: Cross section of an isolation transformer with double/reinforced insulation

3.9.2.1. Electrical Insulation system

An Electrical Insulation System (EIS) comprises of a set of materials used within component for electrical isolation purposes, i.e. a transformer. By the right choice of materials chemical reactions are avoided.
Insulation systems are classified in temperatures classes from 130 (class B) ~ 180 (class H) and above. According to the standards the maximum allowed operating temperatures depend on the measurement method and are lower than the temperature class. For example class 130 (B) is allowed to be max. 120°C, and if thermocouples are used for measurement, another 10°C shall be deducted to permit a maximum of 110°C, unless the thermocouple is embedded in which case no deduction is required.
EISs are recognized under Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) standards UL 1446 and IEC 60085.

3.9.3. X-capacitor

This component is rated and approved to be connected between two mains lines, either between the phases or between line and neutral. The rated voltage has to be matched with the maximum supply voltage.
If the power supply becomes disconnected from the mains, the capacitor has to be discharged.

3.9.4. Y-capacitor

A component that is allowed to be used across an insulation barrier. It can be connected from the input lines to PE (usually basic insulation) as well as to connect primary with secondary (usually double or reinforced insulation).
As an example up to 300Vac input voltage, over voltage category III, Y1 capacitors can be used between primary and secondary, and Y2 between primary and PE.

3.9.5. Cables, wires, copper foils

The characteristics of insulation materials used for electrical interconnections and within transformers and inductors include the following:

- Reinforced insulation on wires/foils are required to have either a minimum thickness of 0,4mm or three layers of overlapping spirally wrapped tape or extrusion material (triple insulated wire). When used for reinforced insulation, triple insulated wires have to comply with annex U of the standards.
- Wires usually have temperature ratings, often printed directly on the insulation.
- Cables without ratings are assumed to be 75°C rated.

3.9.6. Insulating tape, insulation foil

These comprise of a thin material with no minimum thickness requirement that is rated for a certain voltage, usually used for insulation purpose in transformers and inductors.

- Functional/basic insulation: 1 layer
- Supplementary/reinforced insulation: 2 layers
- Reinforced insulation: 3 layers

3.9.7. Bobbin

This component is part of a transformer or inductor insulation system. Minimum thickness of 0,4mm is required, if used within a component for insulation purposes. Materials are required to have appropriate temperature and flammability ratings.

3.9.8. Fuse

Marking shall be located adjacent to each fuse, giving the fuse current, voltage and time delay rating. The fuse with the appropriate current breaking capability has to be chosen or another breaking means, fuse or circuit breaker, with sufficient rating has to be put in series at the mains connection. Fuses are usually used for protection against catastrophic failures, such as fire and explosion.

3.9.9. Switches, AC connectors EMI filters, Relays

These components have certain voltage and current ratings and are generally components which are already separately safety approved. If they are operated within their ratings, they can be easily used without the need for extra tests.

3.9.10. Potting compounds

Potting compounds are frequently used for these reasons:

- Heat transfer to heat sink surfaces
- Solid insulation
- Encapsulation to provide a pollution degree 1 environment

Provided the potting compound meets the test requirements it can be used for basic supplementary or reinforced insulation. Where potting is used as a method encapsulation of the circuit and provided it meets the test criteria, pollution degree 1 and the associated reduced creepage and clearance will be applicable.

3.9.11. Surge suppressors

All types of surge suppressors are permitted in secondary circuits. For use in primary circuits, special restrictions apply as listed in the standards appendix Q. Requirements and testing methods are listed in IEC 61643-21.

3.9.11.1. VDR (MOV), ABD

Voltage depending resistors VDRs and avalanche breakdown diodes ABDs are permitted to bridge functional insulation. If used across basic insulation, one side of the component has to be connected to PE. Bridging of supplementary, double or reinforced insulation is prohibited. A VDR used in the primary has to have a continuous voltage rating of >120% of the rated voltage of the equipment.

3.9.11.2. GDT

Gas discharge tubes are allowed to be used across functional and basic insulation.

3.9.12. PCB

Printed circuit board, a component used to interconnect electronic circuits. Minimum flammability requirement is V1, but V0 is recommended. For FR4 PCBs, the glass temperature Tg, when the PCB starts to lose its original shape is recommended to be >130°C. Ceramic substrate based boards do not have such limitations. Creepage and clearance details are explained in 3.7.3.

3.10. Safety area diagram

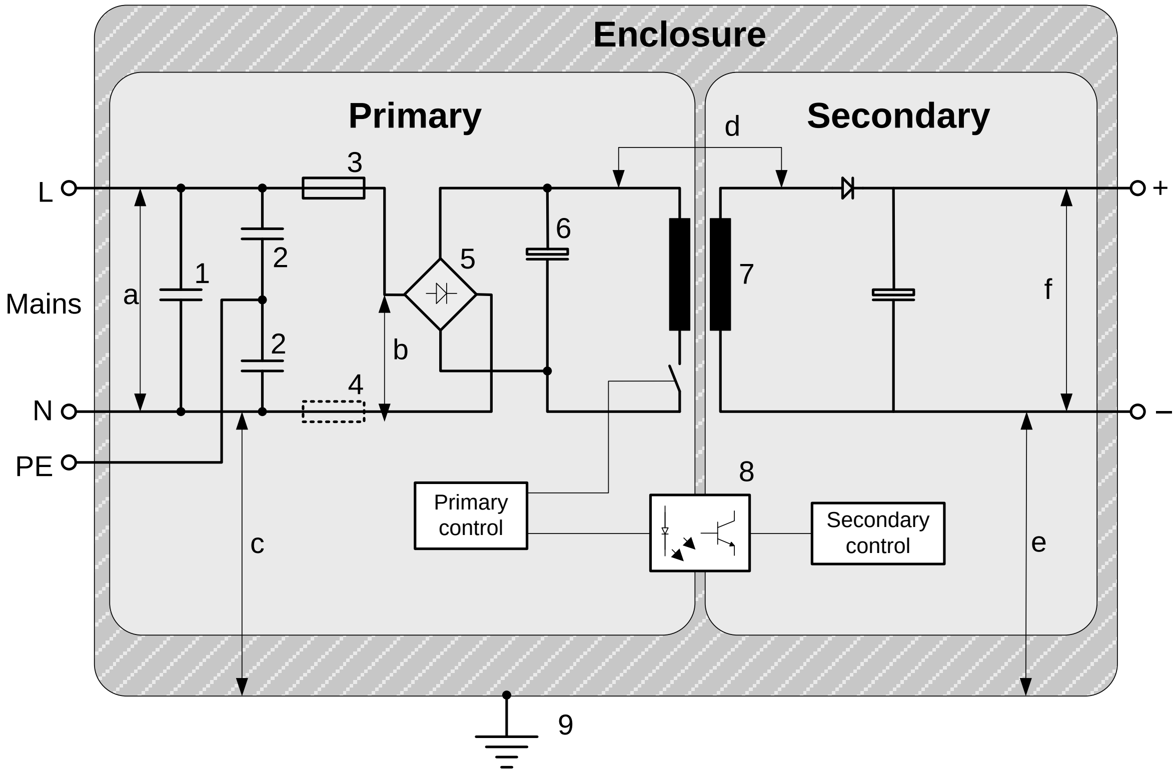

Figure 9: Safety area diagram

Above diagram showing the following parts and voltages:

1. X-capacitor
2. Y-capacitor
3. Input fuse, single fuse sufficient for line-neutral connection
4. Optional input fuse, required if input voltage is line-line
5. Bridge rectifier
6. Storage capacitor
7. Isolation transformer, transfers energy from primary to secondary, requires double or reinforced insulation
8. Opto coupler, between primary and secondary, requires respective safety ratings for creepage and clearance distance
9. Protective earth (PE) potential, connected to chassis if made of conductive (metal) material.

a. Primary-Primary, requires basic insulation
b. Primary-Primary, requires functional insulation, if after the input fuse
c. Primary-PE, requires basic insulation*
d. Primary-Secondary, requires double or reinforced insulation
e. Secondary-PE, requires functional insulation, special case is PoE (Power over Ethernet), requires 1500Vac test to PE

*) If basic insulation is used between primary and earth potential (functional earthing) the connection quality has to be PE (protective earth). This means the PE connection has to withstand the required earth continuity test, see § 2.6.3, particularly 2.6.3.4

3.11. Calculation of safety relevant voltages

3.11.1. The working voltage

Highest voltage (excluding external overvoltages) to which the insulation or the component under consideration is, or can be, subjected when the equipment is operating under conditions of normal use.

- RMS working voltage:
  root mean square value of a working voltage, including any d.c. component
- Peak working voltage:
  peak value of a working voltage, including any d.c. component and any repetitive peak impulses generated in the equipment, like spikes and ringing

3.11.2. Determining the working voltage

For isolation determination the highest voltage between any two points in two parts has to be taken. External voltages have to be varied as such that measured voltage difference gets maximized. The maximum peak (positive or negative, whatever is higher) and the RMS has to be measured. . The RMS voltage is relevant for calculation of the required creepage and the peak voltage for clearance distances in the product.

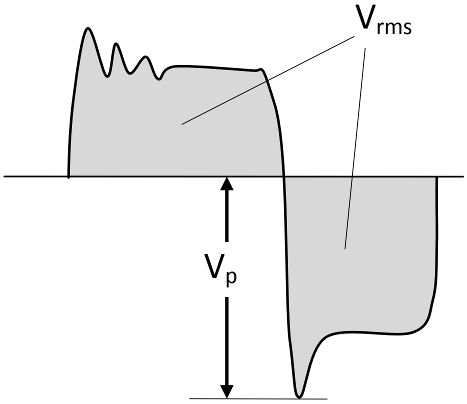

Figure 10: Example of working voltage measured between two points across an insulation

3.12. Creepage distance

The creepage distance is the shortest path between two conductive parts along an insulation surface. Below a minimum groove width X, which is specific to the pollution degree, the groove is assumed bridged for distance determination.
RMS working voltage is used in the calculation of the creepage distance.

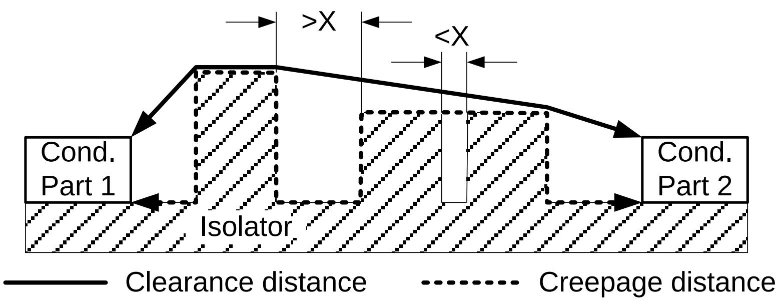

Figure 11: Determination of creepage and clearance distance

Conditions influencing the creepage distance:

- Material class – I, II, IIIa & b (chapter 3.7.4)
- Pollution degree (chapter 4)

RMS Working Voltage	Creepage Distances [mm]						
	Pollution degree						
	1	2			3		
	Material group						
	I, II, IIIa+b	I	II	IIIa+b	I	II	IIIa+b
10	0,080	0,400	0,400	0,400	1,000	1,000	1,000
12,5	0,090	0,420	0,420	0,420	1,050	1,050	1,050
16	0,100	0,450	0,450	0,450	1,100	1,100	1,100
20	0,110	0,480	0,480	0,480	1,200	1,200	1,200
25	0,125	0,500	0,500	0,500	1,250	1,250	1,250
32	0,140	0,530	0,530	0,530	1,300	1,300	1,300
40	0,160	0,560	0,800	1,100	1,400	1,600	1,800
50	0,180	0,600	0,850	1,200	1,500	1,700	1,900
63	0,200	0,630	0,900	1,250	1,600	1,800	2,000
80	0,220	0,670	0,900	1,300	1,700	1,900	2,100
100	0,250	0,710	1,000	1,400	1,800	2,000	2,200
125	0,280	0,750	1,050	1,500	1,900	2,100	2,400
160	0,320	0,800	1,100	1,600	2,000	2,200	2,500
200	0,420	1,000	1,400	2,000	2,500	2,800	3,200
250	0,560	1,250	1,800	2,500	3,200	3,600	4,000
320	0,750	1,600	2,200	3,200	4,000	4,500	5,000
400	1,000	2,000	2,800	4,000	5,000	5,600	6,300
500	1,300	2,500	3,600	5,000	6,300	7,100	8,000
630	1,800	3,200	4,500	6,300	8,000	9,000	10,000
800	2,400	4,000	5,600	8,000	10,000	11,000	12,500

Figure 12: Minimum creepage distances

The values in above table are applicable to functional insulation (F), basic insulation (B) and supplementary insulation (S). Abbreviations in brackets are related to figures 13 and 14. For reinforced insulation the values are twice those in the table.
Linear interpolation is permitted between the nearest two points, the calculated minimum creepage distance being rounded to the next higher 0,1 mm increment.

3.13. Clearance distance

The clearance distance is the shortest line of sight, direct connection between two conductive parts. For details see Figure 11 at 3.12 creepage distance.

Conditions influencing the clearance distance:

- Pollution degree
- Over voltage category – I, II, III, IV
- Altitude

Method of clearance distance calculation for Primary Circuits and Primary to Secondary Circuits:

- If peak working voltage is below peak supply voltage, use minimum clearances (Figure 13)
- If peak working voltage is above peak supply voltage, but peak supply voltage is >210V and below 420V (equivalent to < 300Vac), use 420V line and add additional clearance according to peak working voltage. (Figure 13 and Figure 14)

- If supply voltage is above 420V peak, linear interpolate in minimum clearance table (Figure 13)

Peak working voltage [V]	Clearance distance [mm]														
	Mains transient voltage [V]														
	1500						2500						4000		
	Pollution degree														
	1 and 2			3			1 and 2			3			1, 2 and 3		
	Insulation type Functional F Supplementary S Reinforced R														
	F	B/S	R	F	B/S	R	F	B/S	R	F	B/S	R	F	B/S	R
71	0,4	1,0 (0,5)	2,0 (1,0)	0,8	1,3 (0,8)	2,6 (1,6)	1,0	2,0 (1,5)	4,0 (3,0)	1,3	2,0 (1,5)	4,0 (3,0)	2,0	3,2 (3,0)	6,4 (6,0)
210	0,5	1,0 (0,5)	2,0 (1,0)	0,8	1,3 (0,8)	2,6 (1,6)	1,4	2,0 (1,5)	4,0 (3,0)	1,5	2,0 (1,5)	4,0 (3,0)	2,0	3,2 (3,0)	6,4 (6,0)
420	F 1,5 B/S 2,0 (1,5) R 4,0 (3,0)												2,5	3,2 (3,0)	6,4 (6,0)
840	F 3,0 B/S 3,2 (3,0) R 6,4 (6,0)														
1400	F/B/S 4,2 R 6,4														

Figure 13: Min. clearances for insulation in primary circuits and between primary and secondary Values in bracket are for special manufacturing quality control, double/reinforced require individual tests

Clearance distance [mm]						
Mains transient voltage [V]						
1500				2500		
Pollution degree		F/B/S insulation	Reinforced Insulation	Pollution degree	F/B/S insulation	Reinforced Insulation
1 and 2	3			1, 2 and 3		
Peak working voltage				Peak working voltage		
210 (210)	210 (210)	0,0	0,0	420 (420)	0,0	0,0
298 (288)	294 (293)	0,1	0,2	493 (497)	0,1	0,2
386 (366)	379 (376)	0,2	0,4	567 (575)	0,2	0,4
474 (444)	463 (459)	0,3	0,6	640 (652)	0,3	0,6
562 (522)	547 (541)	0,4	0,8	713 (729)	0,4	0,8
650 (600)	632 (624)	0,5	1,0	787 (807)	0,5	1,0
738 (678)	715 (707)	0,6	1,2	860 (884)	0,6	1,2
826 (756)	800 (790)	0,7	1,4	933 (961)	0,7	1,4
914 (839)		0,8	1,6	1006 (1039)	0,8	1,6
1002 (912)		0,9	1,8	1080 (1116)	0,9	1,8
1090 (990)		1,0	2,0	1153 (1193)	1,0	2,0
		1,1	2,2	1226 (1271)	1,1	2,2
		1,2	2,4	1300 (1348)	1,2	2,4
		1,3	2,6	(1425)	1,3	2,6

Figure 14: Additional distances for insulation in primary and between primary and secondary Values in bracket correspond to bracket values of Figure 13 and any functional isolation

3.14. Creepage and clearance distances on a printed circuit board (PCB)

3.14.1. Isolation between conducting traces on the same layer

I. All traces on the same layer, even if they are not at the surface of the PCB (inner layer) have to be treated exactly the same as if they are outer (surface) layers. This means that the full creapage and clearance distances apply according to the standards. No reduction of any means is allowed as it was possible according to the first edition of the standards

II. Ways to reduce creepage distance on inner layers by applying pollution degree I

   a. PCB temperature at this respective location is ≤ 90°C

   b. If local temperature is > 90°C, temperature cycle tests on at least one or many samples is required, duration ≥ 1 month. Tests to be done acc. to § 2.10.10 / 2.10.11

3.14.2. Isolation between conducting traces on different layers

I. According to 60950-1 second ed. § 2.10.6.3 (PCB trace on the same layer in inner layers) the isolation between traces on different layers has to be a cemented joint, see § 2.10.5.5ts).

II. Traces on different layers have to be separated by minimum 2 layers of impregnated glass fibermaterial, so called “prepreg”, which are in sum ≥ 0,4mm can be handled as usual, which is DTI (distance through insulation)

3.15. Operating altitude

Operating altitude is generally from sea level up to 2000m. If the specified operating altitude is higher, the standard DIN VDE 0110 part 1 section 3.1 table A2 has to be looked up, where increases in clearance distances are defined.

3.16. Electric strength test

EST (Hipot) is dependent on peak working voltage. The tests are either to be done with sinusoidal 50/60Hz voltage or peak equivalent DC voltage.
There shall be no insulation breakdown during the test, however, Corona discharge or a single momentary flashover is not regarded as insulation breakdown.
For levels up to 1,41kV and double/reinforced insulation the type test level is 3kVrms.
For functional, basic and supplementary insulation see standards Table 5B and 5C.

3.17. Touch current

- Touch current from a floating circuit, generated by capacitive coupling to primary
- Touch current from an earthed circuit, has to be of type SELV or TNV

Maximum tolerable touch current is dependent on the connection to the supply voltage.

- Class II equipment: <0,25mA
- Hand held equipment: <0,75mA
- Class I pluggable equipment type A or B: <3,5mA.
- For fixed connection to mains the possible r.m.s. protective conductor current may be up to 5% of the input current.

3.18. Ground continuity

- For current protection levels up to 16A:
  To test the reliability twice the branch fuse current is supplied into the PE connection and the chassis for 2 minutes. The maximum resistance measured has to be <0,1Ω.
- For higher current levels the testing time goes up to 10 minutes and circuit voltage has to stay below 2,5V.
- For DC supply, the tests are done with 150% of the fuse current for 2 minutes.

3.19. Type label

Mandatory content: Input voltage, current and frequency (if applicable), manufacturer's name or trademark, type/model reference. UL approved units need also factory ID, if produced in multiple locations.
Optional content: Output ratings (voltage, current, power, frequency), maximum permitted ambient temperature,
Approvals (UL, TUV…)
CE mark (including efficiency class)

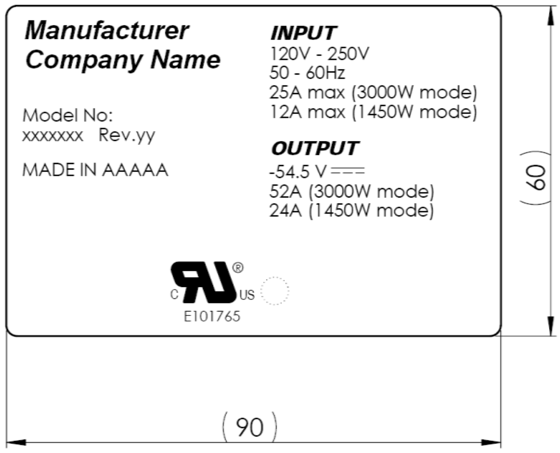

Figure 15: Sample of a type label

A durability test has to ensure that the printing is permanent.

3.20. Thermal measurements

- Thermocouple measurement
  Temperature measured using thermocouples is a very common method, however, it requires adding 10°C to the measured value according to the standards. (not if it is embedded in e.g. a transformer or potting compound)
- Resistive method
  The resistance of the component such as a transformer is measured at room temperature (20°C) as well as at the temperature of interest. Actual elevated temperature is calculated from the following formula, where α is the temperature coefficient of the material. The value shown applies to copper.

  $R_t = R_{20}[1+\alpha(t-20)]$ with α = 3930ppm

- Thermal imaging
  Not an approved method to determine absolute temperature, but recognized to identify hot spots to be measured with other methods.

4. Fire Protection

4.1. Fire enclosure

Part of the equipment that is provided to ensure that in the event of materials igniting the spread is reduced to a minimum.
The respective tests apply only if the component is part to the fire enclosure (outer shell).

4.2. Materials to be used

For fire enclosures most kinds of metals, ceramics and other non flammable materials are used. Special plastics and potting (molding) materials may also be used provided they are rated above V0 in the actual component construction.

5. Mechanical Safety

Equipment shall have adequate mechanical strength and shall be so constructed that no hazard is created in the meaning of the standard when subjected to handling as may be expected. Parts internal to the enclosure are not to be tested.
The mechanical enclosure has to be adequate to contain or deflect parts, which because of failure or for other reasons might become loose, separated or thrown from a moving part. (e.g. loose screws and parts of fans)

- **Mechanical hazard**
  - Loss of mechanical stability
  - Sharp edges
  - Moving parts, e.g. fans
  - Hazardous liquids, from exploded capacitors

5.1. Impact test

For tests of a horizontal surface a solid smooth steel ball, approximately 50 mm in diameter and with a mass of 500 g ± 25 g, is permitted to fall freely from a vertical distance of H =1,3 m onto the largest unreinforced area of a product sample in its normal position.
For tests of a vertical surface the steel ball is swung as a pendulum from a height of 1,3m.

The test is required for all products, where creepage and clearance distances may become reduced due to mechanical deformation caused by the test. For determination of resulting safety hazards, measured (reduced) distances after impact have to be considered.

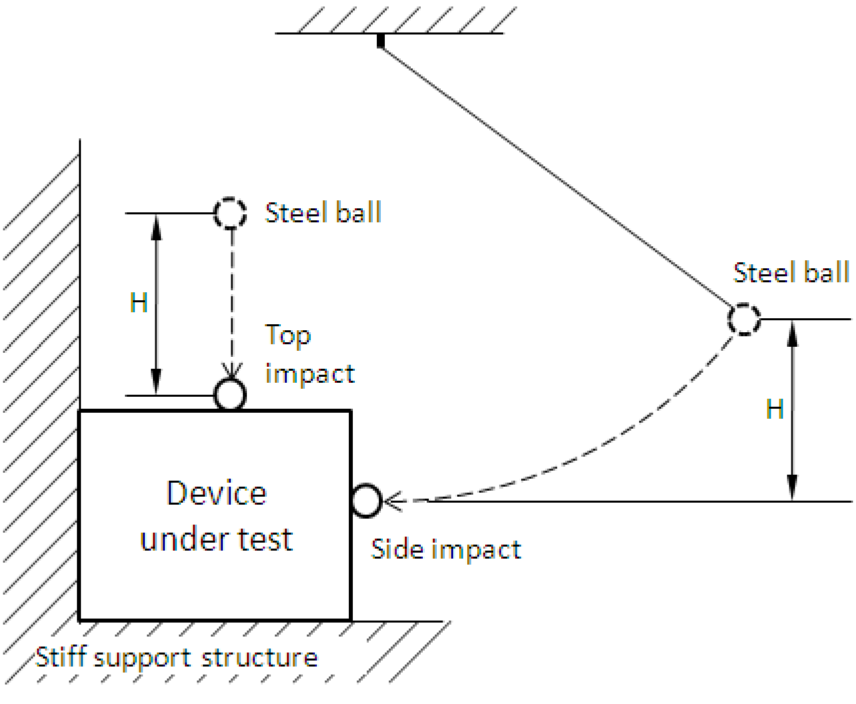

Figure 16: Steel ball test

5.2. Steady force test

- **Steady force test**
  Components and parts, other than parts serving as an enclosure, are subjected to a steady force of 10 N ± 1 N.

- **Finger test / 30N**
  Parts of an enclosure located in an operator access area, which are protected by a cover or door, are subjected to a steady force of 30 N ±3 N for a period of 5 s, applied by means of a straight unjointed version of the test finger.

- **30mm diameter / 250N**
  External enclosures are subjected to a steady force of 250 N ± 10 N for a period of 5 s, applied in turn to the top, bottom and sides of the enclosure fitted to the equipment, by means of a suitable test tool providing contact over a circular plane surface 30 mm in diameter.

5.3. Drop test

The following equipment is subjected to a drop test onto a wooden floor:

- Hand held equipment (e.g. mobile phone) – 1m drop height
- Direct plug in equipment (e.g. phone charger) – 1m drop height
- Transportable equipment (e.g. cord connected telephone handset) – 0,75m drop height
- Movable equipment that requires lifting or handling as part of its intended use – 0,75m drop height

5.4. Touch protection

In order to avoid electrical shock all conductive surfaces have to be insulated by appropriate means or enclosed as such that there is limited access through possible openings. To prove the access limitation standardized tools are available, the test finger and the test pin.

5.4.1. Test finger

The test finger is an artificial finger that represents the human equivalent to be used for checking the access to hazardous part inside the device under test.

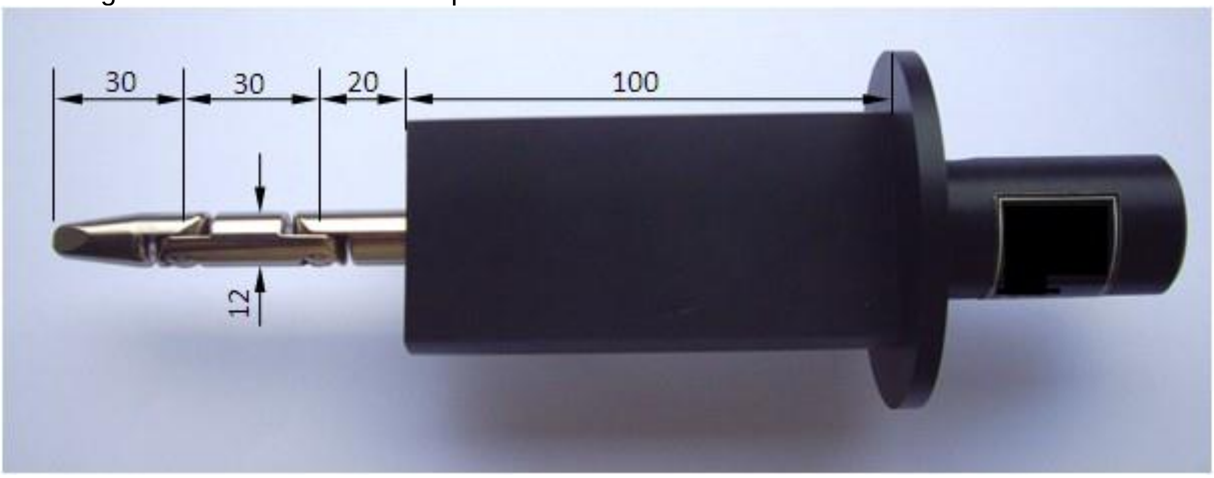

Figure 17: Test finger and dimensions

5.4.2. Test pin

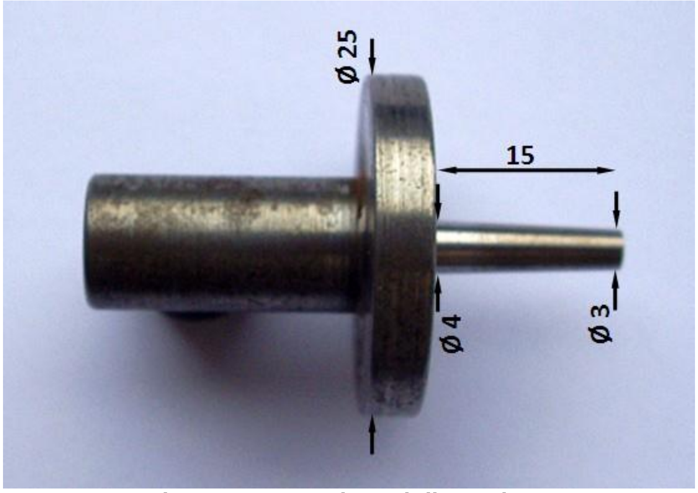

Figure 18: Test pin and dimensions

Both test finger and test pin are used to simulate access to surfaces and into openings of the device under test. It is neither allowed to touch any live part inside the equipment that has higher voltage than SELV nor to bridge two potentials that would cause an energy hazard. Also it should not be possible to touch the insulation protecting some voltage types.

6. Other Safety Hazards

6.1. Heat related hazards

High temperatures under normal operating conditions may:

- cause injuries such as burns while touching hot surfaces
- degradation of insulation performance of safety relevant components
- ignition of inflammable liquids

Risk can be mitigated by

- reduce and avoid high temperature on accessible parts
- avoid temperatures above ignition point of liquids
- marking of hot parts

6.2. Chemical hazards

There is risk of injury that results from contact with some chemicals or from inhalation of their vapors and fumes. Risk can be reduced by:

- avoid the use of hazardous substances
- prevent that liquids and vapors leak out of their encapsulation
- marking hazardous components and part

6.3. Radiation

Some forms of radiation emitted by equipment such as sonic (acoustic), radio frequency, infra-red, ultra violet, ionizing radiation and high energy visible light like LASER.
Risk reduction can be done by:

- limiting the energy level of potential radiation sources;
- screening radiation sources
- provision of safety interlocks
- provision of markings to warn users where exposure to the radiation hazard is unavoidable.

7. Accessibility

- **Operator access area**
  Part of the equipment to which, under normal operating conditions, the operator has direct and deliberate access to.
- **Service access area**
  Part of the equipment to which service people have access to, even if the equipment is switched on
- **Restricted access location**
  Location for the equipment to which access by a tool or key and lock is controlled by the authority responsible for the location. Users or service personal has been instructed about the reasons of restrictions and which precautions have to be taken.

8. Conditions of Acceptability

A small example of conditions of acceptability for UL is given in below table. The CB report uses a different format.

CF1.0	**Engineering Conditions of Acceptability**
CF1.1	For use only in or with complete equipment where the acceptability of the combination is determined by Underwriters Laboratories Inc. When installed in an end-product, consideration must be given to the following:
CF1.5	The following secondary output circuits are SELV: All
CF1.7	The following secondary output circuits are at non-hazardous energy levels: All
CF1.11	The power supply terminals and/or connectors are: Suitable for factory wiring only
CF1.13	The investigated Pollution Degree is: 2
CF1.19	The following end-product enclosures are required: Mechanical, Fire
CF2.0	The case temperature, measured on the face opposite the pins, shall not exceed 130°C in the end-use application.

9. Alternative approval methods

In January 2010, “IEC 62368-1 Ed 1.0: Audio/Video, Information and Communication Technology Equipment — Safety Requirements” was published as an international standard.

IEC-62368 covers both IEC-60950-1 (IT equipment) and IEC- 60065 (Video and Audio), which will become mandatory from ~2015 for IT and A/V equipment.
The standard IEC-62368 is based on a new form of safety evaluation called “Hazard Based Safety Engineering” (HBSE). The HBSE approach aims to prevent injury by applying engineering fundamentals to the design and analysis of provably safe products.

9.1. IEC-62368 evolution

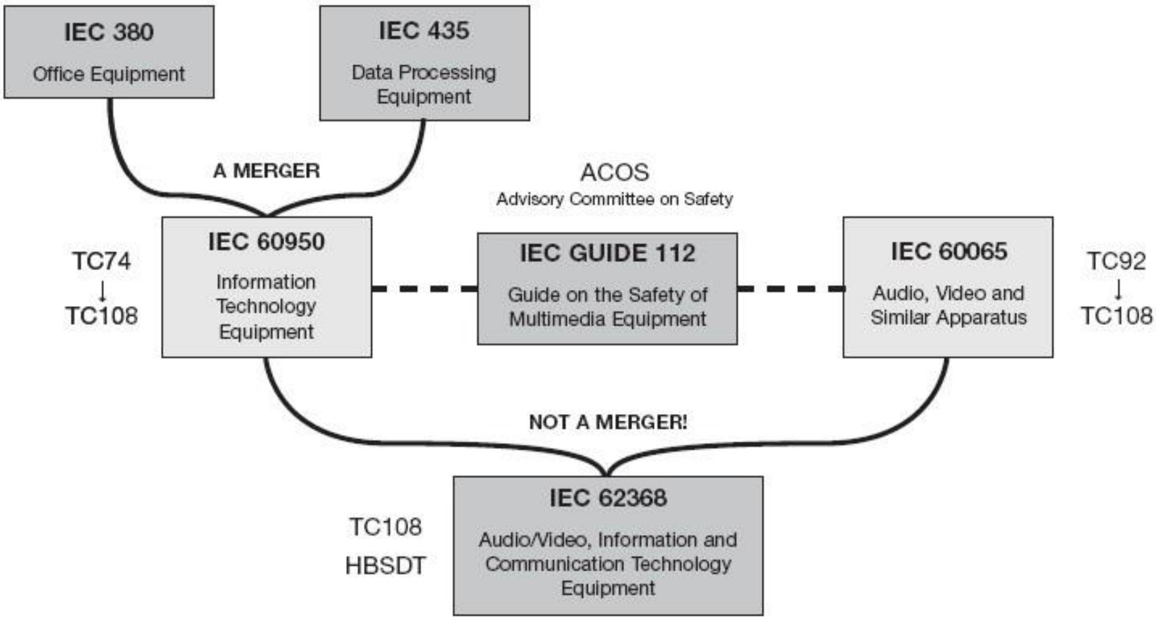

Figure 19: IEC-62368 and its predecessors

10. References

UL Standard for Safety for Information Technology Equipment – Safety – Part 1: General Requirements,
UL 60950-1
Second Edition, Dated March 27, 2007

Einrichtungen der Informationstechnik –Sicherheit –Teil 1: Allgemeine Anforderungen
(IEC 60950-1:2005, modifiziert);
Deutsche Fassung EN 60950-1:2006