



# If Your Power Converter Is Not Safe, You May Have an Expensive Recall

Mark Batulan, Energy Management Industry Session, APEC 2020

# Product Safety Compliance Avoids Recalls

- **Laws and standard**
- **Hazard based safety engineering principles**
- **Isolation: Spacing and insulation**
- **Dielectric strength test**
- **Other safety tests**
- **Preventive requirements against hazardous sources**
- **Product safety certification**

# Global Requirements

- **Laws in U.S., EU, and globally tell us why comply**

- ▶ Protect consumers, product and surroundings
- ▶ Fines, withdrawal and jail when not in compliance

- **Standards show us how to comply**

- ▶ Design, components, and documentation
- ▶ Safety tests and compliance criteria

- **Certification is positive evidence of compliance**

- ▶ IEC and national standards are basis for certification
- ▶ Certification (marks) proves safety



# Product Safety Standards

## ■ International Electrotechnical Commission (IEC)

- ▶ Worldwide organization for standardization for electrical, electronics and related technologies
- ▶ Comprising all national level electrotechnical committees

Standard	Equivalent	Scope	Product Types
<b>Highly regulatory relevant</b>			
New: IEC 62368-1 (mandatory Dec. 2020)  Legacy: IEC 60950-1 and IEC 60065-1	UL, CSA, EN	Information and Communication Technology Equipment / Audio/Video Equipment	Computers and similar products, components intended for ITE and Audio/visual products
IEC 60601-1	UL, CSA, EN	Medical Equipment	Medical devices
<b>Others:</b> General safety standards (fire protection, working surfaces and first aid)			

# Principle of Safety Standards

- Protect the user or service personnel (and/or patients) from pain, injury or property damage caused by:

- ▶ Electric Shock
- ▶ Fire (ignition)
- ▶ Physical Injury
- ▶ Chemical Hazards
- ▶ Thermal (Heat)
- ▶ Radiation



*Electric shock occurs upon contact of (human) body with any source of electricity that causes a sufficient current through the skin, muscles, or hair*



# Hazard-Based Safety Engineering Principles

## ■ IEC 62368 is a product safety standard that

- ▶ Defines users = Body part (persons: ordinary; instructed; skilled)
- ▶ Identifies energy sources: Electrical (shock and fire), thermal, chemical, mechanical, or radiated
  - Injury occurs when energy of sufficient magnitude and duration is imparted to a Body part
- ▶ Classifies energy sources and defines its class or limits:
  - 1= detectable; 2 = pain; 3 = injury
- ▶ Describes and provides guidance for safeguards against those energy sources
  - Location, properties, parameters or construction
- ▶ Prescribed safeguards are intended to reduce the likelihood of pain, injury, and (in the case of fire) property of damage
- ▶ Advises test that qualifies the safeguards have been effective
- ▶ Help designers understand underlying principles of safety to design safe equipment

# Hazardous Energy (3 Classes)

## ■ Levels of energy sources

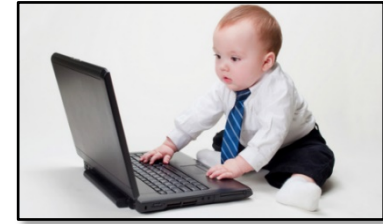
- ▶ Defined by magnitudes and durations of source parameters relative to either the body or to combustible material and responses to those energy sources

Energy Source	Effect on the Body	Effect on Combustible Materials
<b>Class 1</b>	Not painful, but may be <b>detectable</b>	Ignition not likely
<b>Class 2</b>	<b>Painful</b> , but not causing injury	Ignition possible, but limited growth and spread of fire
<b>Class 3</b>	<b>Injury</b>	Ignition likely, rapid growth and spread of fire

# Protection of Body Parts (3 Types of Persons)

## ■ Ordinary person

- ▶ Users and persons with access to, or persons in vicinity of, equipment
- ▶ Not trained to identify hazards and will not intentionally create hazard



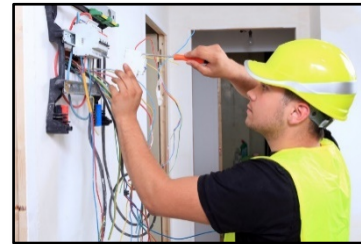
## ■ Instructed person

- ▶ Instructed and trained by skilled person, or supervised by a skilled person
- ▶ Able to identify Class 2 or greater energy hazards and take appropriate precautions
- ▶ May have access to restricted locations



## ■ Skilled person

- ▶ Trained or posses experience
- ▶ Able to identify various energy hazards, and able to take appropriate precautions





# Electrical Source (ES) Classification Related to Electric Shock (Applies to Voltage and Current)

- **ES1 voltage = 60 VDC, 30 V RMS, 42.4 V PK**
- **ES1 current = 2 mA DC, 0.5 mA RMS, 0.707 mA PK**
  - ▶ **ES1** is a Class 1 electrical energy source with levels not exceeding ES1 limits under normal operating conditions, and abnormal operating conditions that do not lead to a single fault condition, and not exceeding ES2 limits under single-fault conditions
- **ES2 voltage = 120 VDC, 50 V RMS, 70.7 V PK**
- **ES2 current = 25 mA DC, 5 mA RMS, 7.07 mA PK**
  - ▶ **ES2** is a Class 2 electrical energy source with levels not exceeding ES2 limits under normal operating conditions, abnormal operating conditions, and single-fault conditions
- **ES3 are levels exceeding ES2**
  - ▶ **ES3** is a Class 3 electrical energy source with levels exceeding ES2 limits under normal operating conditions, abnormal operating conditions, or single-fault conditions

# Safeguard Types

## ■ Basic safeguard

- ▶ Provides protection in normal condition and under abnormal conditions when a hazardous energy source is present in the equipment (e.g., creepage and clearance)

## ■ Supplementary safeguard

- ▶ Applied in addition to the basic safeguard that is (or becomes) operational in the event of failure of the basic safeguard (e.g., earth connection required or additional insulator)

## ■ Reinforced safeguard

- ▶ Single safeguard that is operational under normal operating conditions, abnormal operating conditions, and single-fault conditions (e.g., reinforced insulation or electrical insulated glove)

## ■ Double safeguard

- ▶ Safeguard comprising both a basic safeguard and supplementary safeguard
- ▶ Equivalent to reinforced

# Isolation

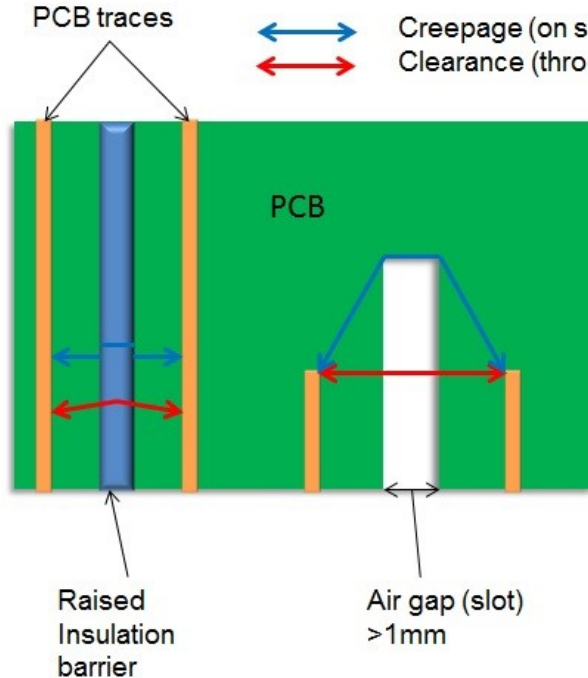
## ■ Isolation

- ▶ Means there is no direct electrical connection between two or more circuits or between circuits and accessible metal parts
- ▶ It's purpose is to isolate transient **overvoltages** and **hazardous voltage** circuits, which if connected together could allow the flow of harmful current, voltage, energy or charge

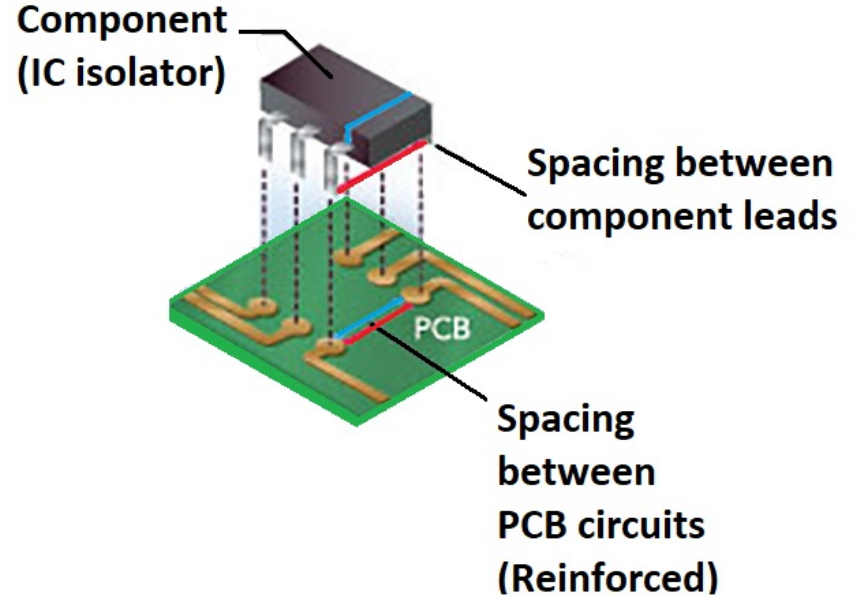


# Spacing

## ■ Creepage and Clearance



*Note:*  
Creepage distance on a PCB between two adjacent traces can be increased by putting a slot in between. The minimum slot width is 1mm



# Minimum Creepage Based on IEC 62368

- **Use Table 19**

- ▶ Distance in mm

- **Need to know**

- ▶ Working voltage (input rating or isolating component)
- ▶ Pollution Degree 2 (offices/labs)
- ▶ Basic or reinforced insulation
- ▶ Material group

- **To find spacings and Hi-pot values**

- ▶ PCB spacings (traces)
- ▶ Other spacings (components)
- ▶ Withstand test voltage (AC or DC)

RMS Working Voltage or DC up to and including V	Functional, Basic, and Supplementary Insulation		
	Pollution Degree 1 <sup>1)</sup>	Pollution Degree 2	Pollution Degree 3
	Material Group I, II, IIIa, or IIIb	Material Group IIIa, or IIIb	Material Group IIIa, or IIIb
50	0.18	1.2	1.9
63	0.2	1.25	2.0
80	0.22	1.3	2.1
100	0.25	1.4	2.2
125	0.28	1.5	2.4
160	0.32	1.6	2.5
200	0.42	2.0	3.2
250	0.56	2.5	4.0
320	0.75	3.2	5.0
400	1.0	4.0	6.3
500	1.3	5.0	8.0
630	1.8	6.3	10.0
800	2.4	8.0	12.5
1 000	3.2	10	16

# Minimum Clearance Based on IEC 62368 (Using Temporary Overvoltage Value)

- Use Table 11

- ▶ Distance in mm

Voltage up to and including <i>peak</i>	Basic Insulation or Supplementary Insulation	Reinforced Insulation
	Pollution Degree 1, 2 and 3	Pollution Degree 1, 2 and 3
2000	1.27	2.54
2500	1.80	3.60
3000	2.40	4.80
4000	3.80	7.60
5000	5.70	11.0
6000	7.90	15.8

- 1) Temporary Overvoltage value is **2000 Vpeak** if nominal AC mains system voltage does not exceed 250 V; and value will be **2500 Vpeak** if nominal AC mains system voltage exceeds 250 V but does not exceed 600 V.
- 2) The contents of this Table is not totally the same as the Table 10 in the IEC62368-1 standard. The portions that are irrelevant were deleted to avoid confusion.

# Additional Clearance with Altitude of More than 2000 Meters

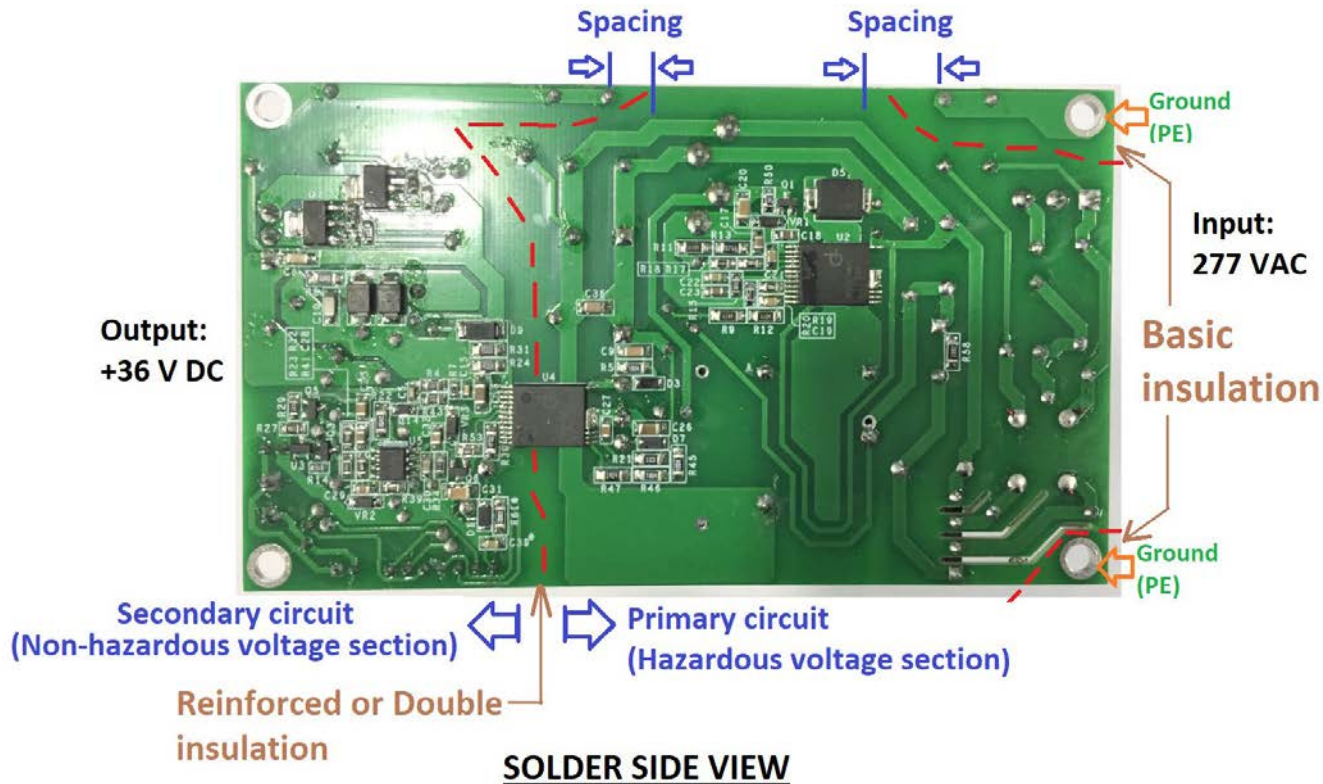
- Use Table A.2 (Altitude Correction Factors of IEC60664-1)
- If the power supply will be operated at more than 2000 meters above sea level, the minimum clearances obtained in shall be multiplied by the factor given in Table A.2 of IEC60664-1
- The calculated minimum clearance using this multiplication factor shall be rounded up to the next higher 0.1 mm increment

Altitude (m)	Barometric Pressure (kPa)	Multiplication Factors for Clearances
2 000	80.0	1.00
3 000	70.0	1.14
4 000	62.0	1.29
5 000	54.0	1.48
6 000	47.0	1.70
7 000	41.0	1.95
8 000	35.5	2.25
9 000	30.5	2.62
10 000	26.5	3.02
15 000	12.0	6.67
20 000	5.5	14.50

Note:

- 1) Linear Interpolation is permitted for in between values of altitudes
- 2) The contents of this Table is not totally the same as the Table in the IEC60664-1 standard. The portions that are irrelevant were deleted to avoid confusion.

# Basic and Double or Reinforced Insulation on PCB Layout





# Safety Test Examples

Test	Purpose
<b>Dielectric Withstand (Hipot)</b>	Dielectric withstand or High potential (Hi-pot) stresses insulation to verify high voltage (overvoltage) withstand
<b>Ground Continuity</b>	Ground continuity checks bond strength of metal parts and enclosures to ensure proper grounding
<b>Abnormal Condition</b>	Simulates clogged air filters, blocked vent openings and fan malfunction
<b>Single Fault Condition</b>	Simulates likely fault conditions that are liable to result in hazards such as, hazardous voltage, current, temperature, fire
<b>Mechanical Strength</b>	Product enclosures are subjected to various force, drop, and impact tests.
<b>Temperature</b>	Temperature shall not cause a hazard in normal or abnormal condition, nor shall it cause spread of fire
<b>Permissible Limits</b>	Accessible parts shall not be hazardous live in normal or single fault condition
<b>Others</b>	Additional tests may be required depending on product design

# Hi-Pot Test

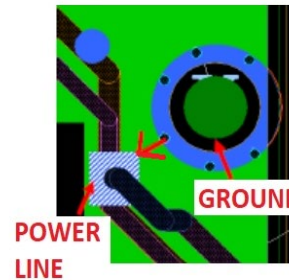
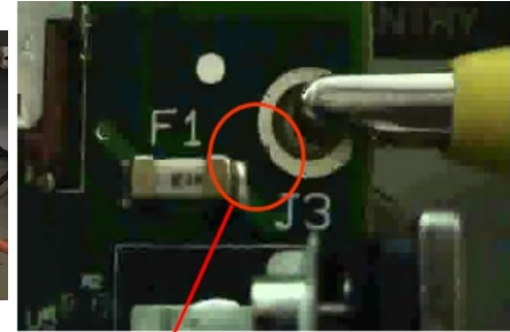
## ■ High Potential (Hi-pot) or Dielectric Withstand test

- ▶ High voltage test that checks a product's insulation to ensure there's no electrical breakdown
- ▶ Type Test
  - One minute test for product designs after 48 hour humidity preconditioning to verify design meets safety spacing and insulation (Reinforced or Basic)
- ▶ Routine Test
  - Two second test in production without humidity preconditioning to check for manufacturing safety defects such as wire, screw and others

## ■ Hi-pot Arching Example



HIPOT TESTER



**Problem:** 1.2 mm creepage between Power Line and Ground. **Failed** at 2400 VDC.

**Solution:** Meet 2.5 mm required creepage. PCB redesign to **Pass**.

# Single Fault Condition Test (Safeguard for fire)

## ■ Reducing the likelihood of ignition by testing single fault conditions

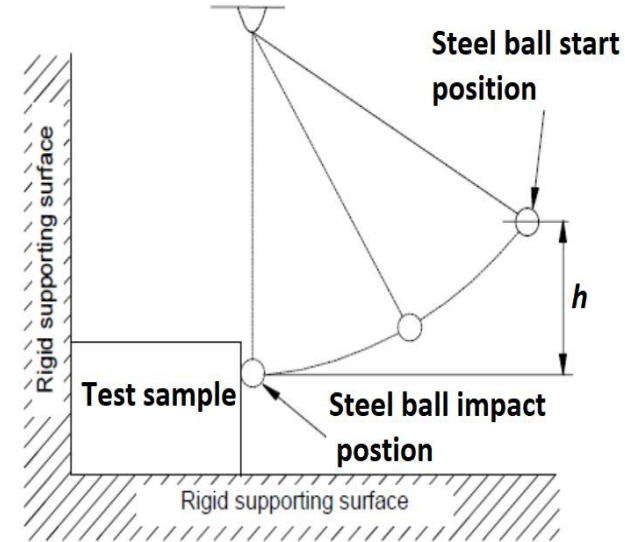
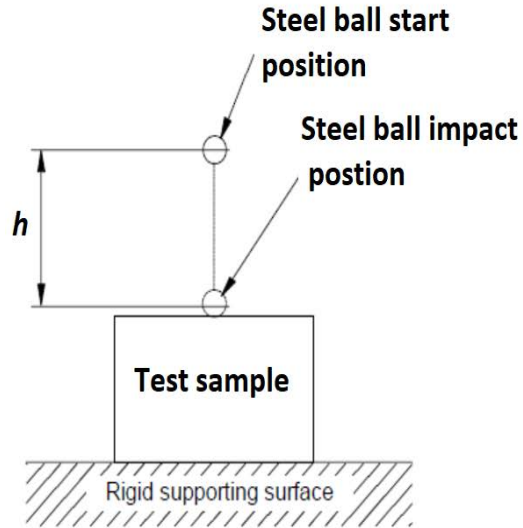
- ▶ Short and or open components one at a time
- ▶ No fire
- ▶ Components and parts within its applicable temperature limit
- ▶ Pass Hi-pot test after single fault test
- ▶ Protective devices acting as a safeguard (thermal links, fuses, varistors and others) shall comply with relevant IEC certified component standards

## ■ Preventive requirements

- ▶ Use of plastic material having appropriate flammability rating
- ▶ Provide fire enclosure
- ▶ Provide thermal controls to avoid occurrence of overheating and fire

# Enclosure Impact Test

- Accessible parts of enclosure
- After Ball Impact test
  - ▶ No access to hazardous voltage
  - ▶ Pass in Hi-pot test
- Preventive requirements
  - ▶ Guard all movable parts
  - ▶ Provide good mechanical stability
  - ▶ Strong enclosure to withstand abuses like drop, deflections and impacts



Steel ball (50 mm diameter, 500 grams mass) to fall from distance ( $h$ ) of 1.3 meters

# Enclosure Protection

## ■ Electrical

- ▶ Prevents contact with hazardous voltage
- ▶ Ensures isolation from overvoltages



## ■ Fire

- ▶ Minimizes ignition risk within
- ▶ Prevents flame propagation outside



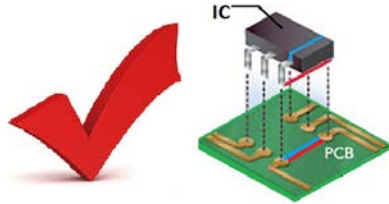
## ■ Mechanical

- ▶ No sharp edges, corners or burrs
- ▶ Stops access to moving parts
- ▶ Stability, rigidity and limits burn



# Checks for Product Safety

- Design



- Testing



- Certification



- Marks or Logos Prove Compliance



# power integrations™

power.com

