Chapter 2
Power Package Electrical Isolation Design

Power Electronics packaging consists of power semiconductor devices, power integrated circuits, sensors, and protection circuits for a wide range of power electronics applications [1–3], such as inverters for motor drives and converters for power processing equipment. Integration in power electronics is a rather complex process due to incompatibility of materials and processing methods used in fabrication, and due to the high electrical density levels and electrical isolation requirements these components must handle. Packaging involves the solution of electrical, mechanical, and thermal problems. Electrical isolation is one of the important factors to be considered in the power packaging design, as it relates directly to the product reliability and safety. Based on the standard of International Electrotechnical Commission (IEC) and the US Standard (UL), such as the standard IEC60950-1 [4] and UL60950-1[5], designers shall take into account not only the normal operating conditions of the equipment but also likely fault conditions, consequential faults, foreseeable misuse, and external influences such as temperature, altitude, pollution, moisture, overvoltages in a system that use the power packaging products. This chapter discusses the power package electrical isolation design considerations.

2.1 Background

Figure 2.1 is an example of a complex, high-power automotive-solenoid driver system showing the control block and power die [3]. One of the major issues that must be overcome, when combining power and control in a single package, is that the back side of the power device is normally the drain or collector of the power switch. As a result, the control die must be electrically isolated from the die-attach area on which the power die is mounted. Since the power die is typically a vertical-conducting device, a good low-resistance, high melting temperature-solder die

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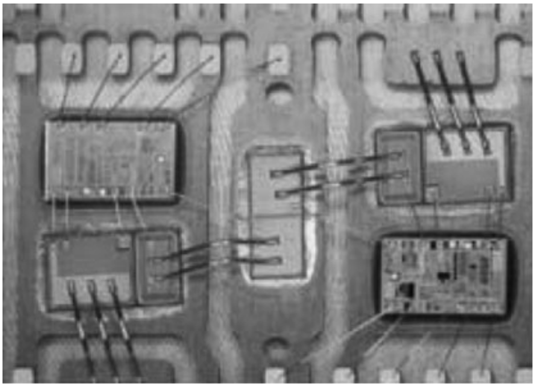

Fig. 2.1 An example of automotive power packaging

attach is normally used. There are several ways to approach the electrical isolation required between the power and control devices. One method for the electrical isolation is to separate the die-attach areas and the others are to use the nonconducting epoxy, polyimide, and the silicon back-side laminate on control die as the isolation.

Each isolation technique has its advantages and disadvantages regarding cost, reliability and manufacturability. Some packages, such as the molded leadless package (MLP) or quad flat no lead (QFN) devices (as shown in Fig. 2.1), can easily accommodate multiple die-attach areas. But traditional power packaging, such as the TO220 or TO252 (which have a thick header or tab), are not easily divided into two separated electrical areas. Use of a nonconducting epoxy die-attach is one of the easiest isolation solutions to implement, but this approach has been shown to be susceptible to reliability issues related to pin holes in the epoxy die attach. Polyimide tape is being used successfully, but the die-attach area must be larger than the attached-die area, to account for the alignment tolerance of the die to the polyimide tape. Thus, it takes up more area then the back-side laminate solution mentioned. For the back-side laminate solution, a film is attached to the entire back side of the control-die wafer, and then the die is sawn from the wafer. In this way, each die has the polyimide film attached to the back of the die, and the need for additional area to account for the alignment variability when attaching the die is eliminated. This can be particularly beneficial when the control die is being attached on top of the power die, allowing a smaller power die to still accommodate the die-on-die assembly requirements.

The electrical isolation requirement does not only apply to the power packaging for the multiple die layout, but also apply for the layout of interconnects and output pins of the packaging, especially for the median and high power application. For example, for a higher accuracy data acquisition system, it is a challenge for the designers to measure small signal variations when high common mode voltages (wanted or unwanted) are present. These high voltages exist due to the different potential in the two grounds or any sudden transient over voltages due to lightning strikes or power surges from motors or switching devices. These voltages do not only impact on the accuracy of the measurement but also damage the test systems and cause hazards to people operating the tester. Isolations are needed to physically and electrically separate two systems to protect against sudden voltage surges between two circuits or systems. They are used to provide a higher common mode voltage range; common mode voltage is the voltage that appears simultaneously between both measurement signal leads and a common ground. For example, when measuring the voltage across a specific cell in a series connected string of battery cells a high common voltage range is important. Isolations are also needed to break up ground loops, which are the unwanted currents between two points that share a common path in an electrical system. This is widely used in instrumentation probing systems that measure differential voltages. In addition, isolations can serve as a level shifter to solve incompatibility of voltage levels between systems or circuits.

2.2 Design Rule for Isolation

2.2.1 Protection with Insulation

US National Standard UL60950-1 defines five types of insulation (1) *Functional insulation* is that which is only necessary for circuit operation. It is assumed to provide no safety protection. (2) *Basic insulation* provides basic protection against electric shock with a single level; however, this category does not have a minimum thickness specification for solid insulation and is assumed to be subject to pin holes. Safety is provided by a second level of protection such as supplementary insulation or protective earth. (3) *Supplementary insulation* is normally used in conjunction with Basic insulation to provide a second level of protection in the event that the Basic level fails. A single layer of insulating material must have a minimum thickness of 0.4 mm to be considered Supplementary insulation. (4) *Double insulation* is a two-level system, usually consisting of basic insulation plus supplementary insulation. (5) *Reinforced insulation* is a single-insulation system equivalent to Double insulation. It also requires a minimum thickness of 0.4 mm for use in a single layer.

Electric circuits rely upon insulation for operator protection, but designing for safety requires the premise that anything can fail. Therefore, safety standards demand a redundant system with at least two levels of protection under the assumption that any single level may experience a failure, but the chance of two simultaneous failures in the same spot is so improbable as to represent an acceptable risk. It should be noted that while two random failures need not be considered, the possibility of a second failure as a consequence of a first failure is something that the designer must evaluate if the two together would result in a total breakdown.

With the insulation levels defined, specific requirements for the insulating medium must be considered. This medium can be either a solid material (such as plastic molding compound) or air (as in the space between components), and the requirements for both are affected by the voltage stress across the medium. Typically, a power supply is evaluated to determine the highest voltage levels possible at all points in the circuitry and under all operating conditions. The highest measured voltage between any two points then defines the working voltage for those two points. The working voltage between a primary circuit and a secondary circuit, or between the primary and ground, is taken as the upper limit of the rated voltage range for the supply. The working voltage normally stands for the highest root mean square (rms) value of the ac or dc voltage that may occur locally across any insulation at rated supply voltage transients.

2.2.2 Solid and Air Insulation

The choice and application of solid insulating material must consider, in addition to working voltage, the needs for electrical, thermal, and mechanical strength, as well as the operating environment. Only nonhygroscopic and flame resistant materials may be used. With particular respect to wiring insulation, it should be noted that some material compounds may contain plasticizers, intended to make them more flexible but with a side effect of increased flammability. Semiconductor devices and other components that are molded in solid insulating material typically are independently qualified and inspected in the manufacturing process. Solid insulation material in sheet form must also conform to the following thickness requirements (1) If a single sheet of insulation is provided, the minimum thickness is 0.4 mm. (2) With two sheets together, there is no thickness requirement but each sheet must meet the required electric strength value. (3) With three or more sheets, there is also no minimum thickness but every combination of two sheets must have adequate electric strength. (4) There is no thickness requirement for Functional or Basic insulation. The use of air as an insulation medium introduces concerns both about the "quality" of the air and the spacing between electrically conducting components. The potential for conduction through air is affected by temperature, pressure, humidity, and pollution, with "pollution" being defined according to the operating environment by the following categories: Pollution Degree 1—Components and assemblies which are sealed to exclude dust and moisture, example is the dry and clean rooms. Pollution Degree 2—General office or home environment, which normally only allows the nonconductive pollution. Pollution Degree 3—Equipment where the internal environment is subject to conductive pollution or possible moisture condensation, products used in heavy industrial, farming areas, and mechanical workshop that are typically exposed to pollution such as dust. Pollution Degree 4—Pollution generates persistent conductivity caused, for instance, by conductive dust or by rain or snow.

Table 2.1 Partial clearance distance (mm) selected from [4] IEC 61950-1 ed.2.0. Copyright 2005 IEC Geneva, Switzerland, www.iec.ch

Working voltage		AC mains < 150 V (transient to 1,500 V), pollution levels 1 and 2			AC mains < 300 V (transient to 2,500 V), pollution levels 1 and 2		
Peak dc (V)	rms (V)	F (mm)	B/S (mm)	R (mm)	F (mm)	B/S (mm)	R (mm)
71	50	0.4	1.0	2.0	1.0	2.0	4.0
210	150	0.5	1.0	2.0	1.4	2.0	4.0
420	300	1.5	2.0	4.0	1.5	2.0	4.0
840	600	3.0	3.2	6.4	3.0	3.2	6.4

Table 2.2 Partial creepage distance (mm) selected from [4] IEC 61950-1 ed.2.0. Copyright 2005 IEC Geneva, Switzerland, www.iec.ch

Working voltage	Pollution level 1 material group III			Pollution level 2 material group III			Pollution level 3 material group III		
dc or rms (V)	F (mm)	B/S (mm)	R (mm)	F (mm)	B/S (mm)	R (mm)	F (mm)	B/S (mm)	R (mm)
<50	0.4	0.7	1.4	1.2	1.2	2.4	1.9	1.9	3.8
<150	0.6	0.9	1.8	1.6	1.6	3.2	2.5	2.5	5.0
<300	1.6	1.9	3.8	3.2	3.2	6.4	5.0	5.0	5.0
<600	3.2	3.2	5.0	6.3	6.3	12.6	10	10	10

2.2.3 Design Rule of Clearance and Creepage

In the discussion that follows, the Tables 2.1 and 2.2 presented show partial quantitative values for design rule of spacing requirements, in millimeters, which are listed as a function of the voltage, material, and environment. An additional distinction is the category of insulation system of which these spaces are a part, i.e., Functional, Basic/Supplementary, or Reinforced. In other words, if the spacing between components is not needed for safety, the "F" column may be used; if only one level of safety insulation is needed because a second level is provided elsewhere, the "B/S" column is applicable; and for the equivalent of a complete two level safety insulation, the "R" column should be used. The spacing distance between components that are required to withstand a given working voltage is specified in terms of Clearance and Creepage, as shown in Fig. 2.2.

2.2.3.1 Clearance Distance

Clearance is defined as the shortest distance through air between two conductive parts, as shown in Fig. 2.3. Breakdown along a Clearance path is a fast phenomenon where damage can be caused by a very short duration impulse. Therefore, it is the maximum peak voltage, including transients, that is used to determine the required Clearance spacing according to charts given in the standard. A sample of one of

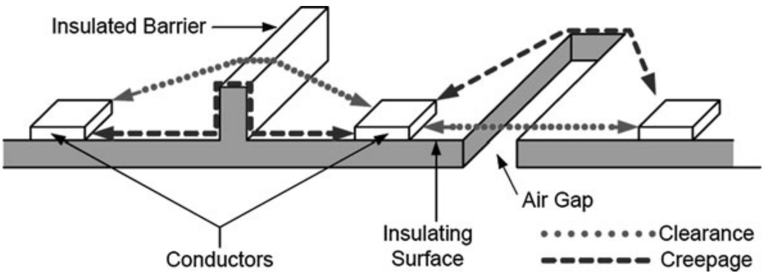

Fig. 2.2 The clearance and creepage in a system

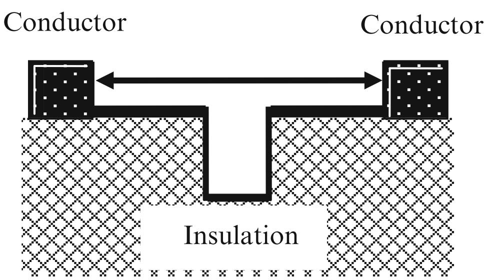

Fig. 2.3 The definition of clearance

these design rules is shown in Table 2.1 [4] where the spacing in millimeters required for different levels of insulation is given as a function of working voltage. Additional variables of ac mains voltage and the quality of the air within the space are indicated in this illustration but are applied more quantitatively in additional charts given in the complete standard.

2.2.3.2 Creepage Distance

Creepage is defined as the shortest distance between two conductive parts along the surface of any insulating material common to both parts as shown in Fig. 2.4. While the path is in the air, it is heavily influenced by the surface condition of the insulating material. Breakdown of the Creepage distance is a slow phenomenon, determined by dc or rms voltage levels rather than peak events. Inadequate Creepage spacing may last for days, weeks, or months before it fails. A sample of a table of Creepage requirements for design rule is given as Table 2.2 [4] with different pollution levels and material group III, where the spaces are given as a function of the steady-state working voltage with additional variables of insulation type, material composition, and content of the air.

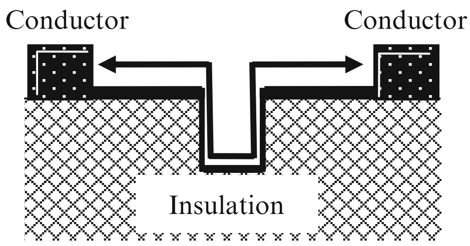

Fig. 2.4 The definition of creepage

Table 2.3 Design rule *X* [4] (IEC 61950-1 ed.2.0. Copyright 2005 IEC Geneva, Switzerland, www.iec.ch)

Pollution degree	Design rule *X* (mm)
1	0.25
2	1.0
3	1.5

2.2.3.3 The Measurement of Clearances and Creepage Distances

The methods of measuing clearance and creepage distances which are specified in IEC/UL60950-1 in the following figures are used in interpreting the design rule of the clearance and creepage for power package. In Table 2.3, *X* is the design rule. Where the distance in design is less than *X*, the depth of the gap or groove is disregarded when measuring a creepage distance.

Figure 2.5 shows six cases of the clearance/creepage distances with the design variable less or larger than the design rule *X* (mm) in Table 2.3. In Fig. 2.5, the solid line stands for clearance distance and the dot line stands for the creepage. Figure 2.5 (1) shows that the path under consideration includes a parallel or converging-sided groove of any depth with width less than *X* mm, the design rule is to measure the clearance and creepage distances across the groove. Figure 2.5(2) that the path under consideration includes a parallel or converging-sided groove of any depth with width equal or more than *X* mm, the design rule for clearance is the “line of sight” to measure the clearance distances across the groove, while the creepage distance path follows the contour of the groove. Figure 2.5(3) shows that the path under consideration includes a V-shaped groove with internal angle of less than 80° and a width greater than *X* mm. The clearance is the “line of sight” distance across the V-shaped groove. The creepage distance is the path follows the contour of the groove but “short circuits” the bottom of the groove by a link *X* mm long. Figure 2.5 (4) shows the path is a rib-like shape. The design rule requires that the clearance is the shortest direct air path over the top of the rib and the creepage distance path follows the contour of the rib. Figure 2.5(5) shows the creepage path as the gap between the head of screw and wall of recess is too narrow to be taken into account. This induces the short cut of the creepage distance. Figure 2.5(6) shows the creepage path as the gap between head of screw and wall of recess is wide.

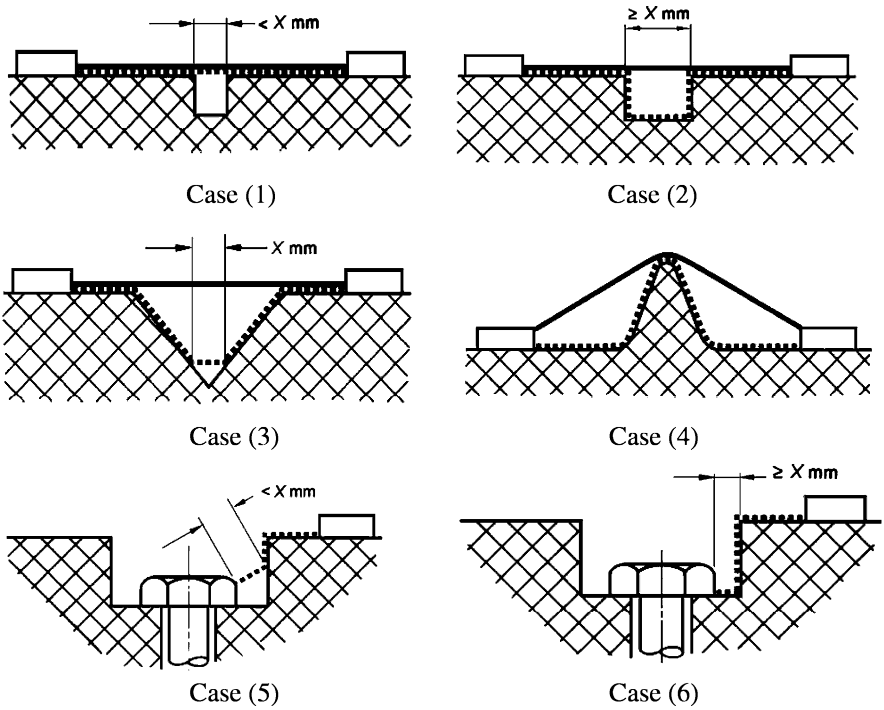

Fig. 2.5 The clearance and creepage distances in different cases when the design variable less or larger than *X* (mm) (IEC 61950-1 ed.2.0. Copyright 2005 IEC Geneva, Switzerland www.iec.ch)

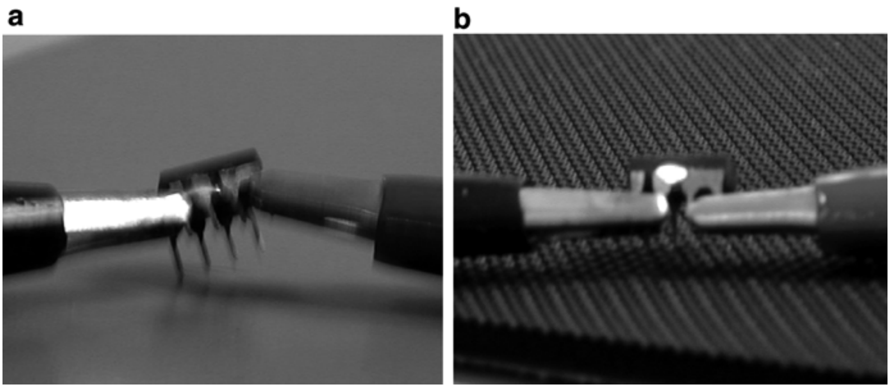

Fig. 2.6 The dielectric breakdown modes of clearance and creepage. (**a**) Clearance, (**b**) creepage

The dielectric breakdown modes are different between clearance and the creepage. The dielectric breakdown of clearance is through air between the leads while the dielectric breakdown of creepage happens on the surface of insulation material such as epoxy mold compound in power packaging. Figure 2.6 shows the two dielectric breakdown modes.

2.3 Estimation of the Clearance and Creepage Distances

2.3.1 Required Major Functions

There are four major functions that can be used to judge the clearance and creepage distances. These functions are pollution degree, comparative tracking index (CTI) value, insulation type, and the working voltage. In Sect. 2.2, the concepts and defintions of pollution degree, insulation type, and the working voltage are introduced, while the CTI value is defined the measurement of the breakdown voltage on surface tracking that a materials exhibits under specific test conditions. Figure 2.7 shows the schmetic diagram of the CTI test. The breakdown voltage is measured by 50 drops 0.1% ammonium chlorde on a 3-mm thick insulating material. Based on the measured result, the insulating materials may be divided into different groups, which normally are three groups: Material Group I, II, and III (see IEC60664-1 [6]). Some standard like UL 746 [7] perfers to divide the CTI results with performance level categories (PLC), which normally have categories: level 0–6. Table 2.4 lists the material groups and the PLC levels with related CTI values based on IEC60664-1 and UL746 standards. If the CTI value of a metrail is not known, apply the material group III for it.

As an example, let’s examine the effect of humidity and corrosive chemicals on the breakdown voltage of a 8 lead DIP package. The distance between leads is 1.01 mm as shown in Fig. 2.8. Two group test samples are investigated. One is in the normal operation environment and the other is the samples after autoclave (ACLV) with 96 h.

The test result is shown in Table 2.5. From the Table 2.5, it can be seen that the sample with normal operation, its average breakdown voltage is 3.46 kV with

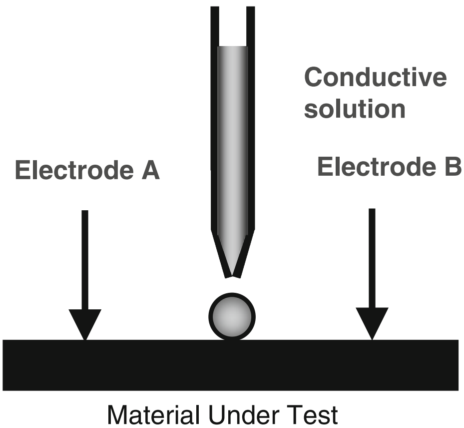

Fig. 2.7 The schemetic CTI test diagram

Table 2.4 Insulating material group and PLC levels

Performance level categories (PLC) UL746	Insulating material group IEC60664-1	CTI (V)
0	I	600 and above
1	II	400–599
2	III_a	250–399
3		175–249
4	III_b	100–175
5		Less than 100

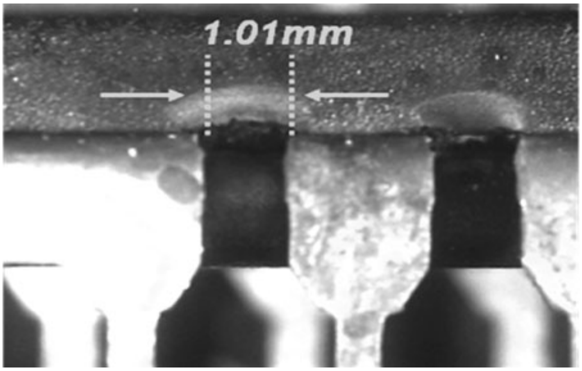

Fig. 2.8 The leads layout of the 8 lead DIP with 1.01 mm distance between leads

Table 2.5 The comparison of the dielectric breakdown voltage CTI value

Breakdown voltage	Minimum (kV)	Maximum (kV)	Average (kV)	Remark
Normal	3.02	3.97	3.46	Clearance
ACLV	1.27	3.75	2.76	Creepage

1.01 mm clearance distance. While the sample after 96 hours ACLV, its average breakdown voltage is 2.76 kV even with creepage distance (greater than 1.01 mm). Therefore, the sample after ACLV has reduced the breakdown voltage about 700 V. This is because the sample after 96 hours ACLV, it has been in a humid and corrosive environment. The humid and corrosive conditions will reduce the breakdown voltage which will be easy to damage the power device.

Figure 2.9 shows two PCB FR4s, one is coated with solder resist and the other does not coat with solder resist. The dielectric breakdown voltages are measured for the two cases in Fig. 2.9. In each case, the clearance and creepage distances

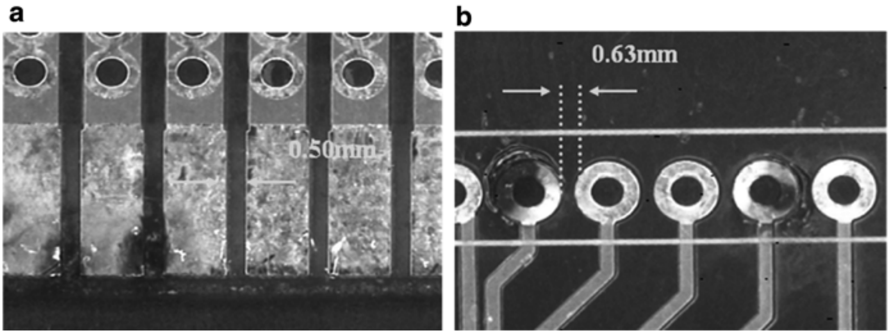

Fig. 2.9 The PCB FR4 with and without the solder resist. (**a**) FR4 coated with solder resist, (**b**) FR4 not coated with solder resist

Table 2.6 The breakdown voltage CTI for the FR4 with and without the solder resist

Test cases	Clearance/creepage distance (mm)	Minimum breakdown voltage (kV)	Maximum breakdown voltage (kV)	Average breakdown voltage (kV)
FR4 without solder resist	0.63	1.37	2.20	1.75
FR4 with solder resist	0.50	2.20	2.65	2.46

are selected the same distance. The results are listed in Table 2.6. From the Table 2.6, it shows that the FR4 with solder resist has larger breakdown voltage (CTI value) than the FR4 without the solder resist which has even larger clearance/creepage distance.

2.3.2 Determine the Clearance and Creepage for Power Package

The package TO-220 for high voltage application like TV is investigated. The working voltage (rms) is 400 V, and the peak working voltage is 1,100 V. The pollutiion degree is 2 for office and home environment. The insulation type is the basic insulation. The material group is III_a or III_b. Based on the standard IEC60950-1 [4] (refer to Tables 2.7 and 2.8), the required minimum creepage distance between the leads of the TO-220 is 4.0 mm, and the required minimum clearance distance between the leads of the TO-220 is 4.2 mm. Therefore, when we design the leadframe for the TO-220 in TV application, the minimum distance between the leads should be 4.2 mm for a reliable product.

Table 2.7 The creepage distance (IEC60950-1, Section 2.10.4, Table 2L) in millimeters (IEC 61950-1 ed.2.0. Copyright 2005 IEC Geneva, Switzerland, www.iec.ch)

WORKING VOLTAGE V r.m.s.or d.c.	FUNCTIONAL.BASIC and SUPPLEMENTARY INSULATION						
	Pollution Degree 1	Pollution degree 2			Pollution Degree 3		
	Material Group	Material Group			Material Group		
	I, II,IIIa or IIIb	I	II	IIIa or IIIb	I	II	IIIa or IIIb
50	See(1)	0.6	0.9	1.2	1.5	1.7	1.9
100		0.7	1.0	1.4	1.8	2.0	2.2
125		0.8	1.1	1.5	1.9	2.1	2.4
150		0.8	1.1	1.6	2.0	2.2	2.5
200		1.0	1.4	2.0	2.5	2.8	3.2
250		1.3	1.8	2.5	3.2	3.6	4.0
300		1.6	2.2	3.2	4.0	4.5	5.0
400		2.0	2.8	4.0	5.0	5.6	6.3
600		3.2	4.5	6.0	8.0	9.6	10.0
800		4.0	5.6	8.0	10.0	11.0	12.5
1000		5.0	7.1	10.0	12.5	14.0	16.0

1) No minimum CREEPAGE DISTANCE is specified for insulation in Pollution Degree 1. However, the minimum CLEARANGE, as previously determined in 2.10.3 or annex G, still applies.
2) Linear interpolation is permitted between the nearest two points, the calculated spacing Being rounded to the next higher 0.1mm increment

Table 2.8 The clearance distance (IEC60950-1, Section 2.10.3, Table 2H) in millimeters (IEC 61950-1 ed.2.0. Copyright 2005 IEC Geneva, Switzerland, www.iec.ch)

WORKING VOLTAGE up to and including		MAINS TRANSIENT VOLTAGE 1 500 v (Nominal AC MAINS SUPPLY voltage ≤150 v)						MAINS TRANSIENT VOLTAGE 2 500 v (Nominal AC MAINS SUPPLY voltage >150 V≤300 v)						MAINS TRANSIENT VOLTAGE 4000 V (Nominal AC MAINS SUPPLY voltage >300 v≤600 v)		
Voltage Peak or d.c.	Voltage r.m.s. (Sinu-soidal)	Pollution Degree 1 and 2			Pollution Degree 3			Pollution Degree 1 and 2			Pollution Degree 3			Pollution Degree 1,2, and 3		
V	V	F	B/S	R	F	B/S	R	F	B/S	R	F	B/S	R	F	B/S	R
71	50	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	150	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	300	F 1.5 B/S 2.0(1.5) R4.0(3.0)												2.5	3.2 (3.0)	6.4 (6.0)
840	600	F3.0 B/S3.2(3.0 R6.4(6.0)														
1400	1000	F/B/S4.2 R6.4														
2800	2000	F/B/S/R 8.4														
7000	5000	F/B/S/R 17.5														
9800	7000	F/B/S/R 25														
14 000	10 000	F/B/S/R 37														
28 000	20 000	F/B/S/R 80														
42 000	30 000	F/B/S/R 130														

2.4 Packaging Design Layout Consideration

The power package design layout may impact the creepage distance and breakdown voltage of the device. Good package design can sugnificantly increase the creepage and breakdown voltage without changing the dimention and outline of the package. Figure 2.10 shows that there are two designs for TO-220 package. One is the regular TO-220 package and one is TO-220 package for the high voltage application. In the design layout of TO-220 for high voltage application, there are two design grooves as shown in the arrow indication in Fig. 2.10. The comparison of the clearance and the creepage distances are listed in Table 2.9. The design of TO-220 for high voltage application with grooves has significantly increased the creepage distance while it keeps the same clearance as the regular TO-220 package.

Figure 2.11 shows the design consideration for the layout of a Fairchild smart power module (SPM®) to check the effect of the inserting grooves and how the dielectric voltage changes with and without the grooves. The size of the groove is 0.5 mm width and 0.8 mm depth in one layout. The other design layout does not have groove. The dielectric breakdown voltages are measured in the two design layouts with and without the grooves.

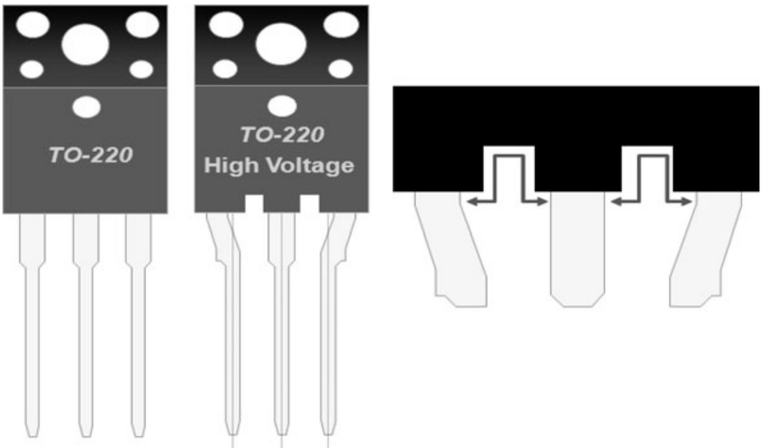

Fig. 2.10 The design layout for high voltage TO-220 package with groove

Table 2.9 The comparison of creepage and clearance distances

Design layout	Creepage distance (mm)	Clearance distance (mm)
TO-220	1.07	1.07
TO-220 HV	5.09	1.07

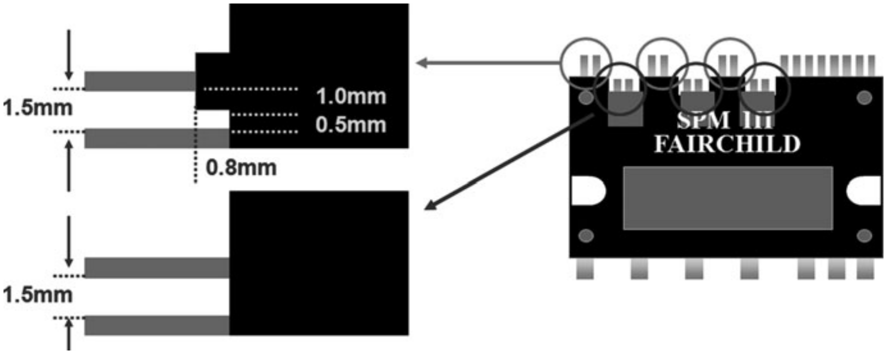

Fig. 2.11 The design layout between pins for a Fairchild SPM package

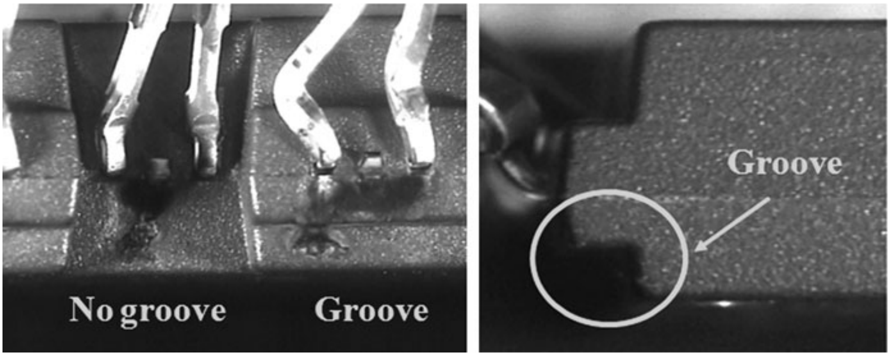

Fig. 2.12 The comparison of designs with and without grooves after the breakdown voltage

Table 2.10 The breakdown voltage measurement for the the two design layouts

Design layout	Minimum breakdown voltage (kV)	Maximum breakdown voltage (kV)	Average breakdown voltage (kV)
With groove	4.32	5.99	5.36
No groove	3.46	5.07	4.20

Figure 2.12 shows the SEM photos of the SPM package with and without the groove after the breakdown voltage. The result of design without consideration of the groove is clearly worse than the case with groove from the surface of the EMC. Table 2.10 gives the measurement result of the breakdown voltage for the SPM package with and without the groove design. The average voltage of the breakdown voltage with the groove design has increased 1.16 kV as compared with the design without consideration of the goove.

Besides the design and layout considerations, materials and mechanical design are two important factors that should not be neglected. Pick components and materials which have prior safety certification. With certified components, the safety engineer looks only to see that they have been applied correctly and physical testing is done only as a complete system. Without certified components, additional component-level testing or excessively conservative design techniques could be required. As an example, the Y capacitor in an input EMI noise filter would be accepted as a certified device, but otherwise might require two capacitors in series to allow a safety test to short one of them, plus the additional testing of the capacitors themselves. For mechanical design, the safety engineer looks for rigid construction with all components securely attached and no sharp edges or corners. All areas containing hazardous voltages have been protected from access by the user, including through any openings in the enclosure. Openings in the enclosure are examined to ensure that there is no user access to hazardous voltage, sharp edges, hot components, fan blades, or any other item that might cause injury.

2.5 Safety Standards and Categories of Application [8–18]

The first international standard for safety, IEC950, was prepared by the International Electrotechnical Commission (IEC) primarily for information technology industry. Later, the IEC had generated a harmonized standard, IEC60950 (third edition), to cover products from the most industries. Upon its release in 1999, it was quickly adopted by most countries and is today the primary standard for safety for most users of power supplies (IEC60950-1 first edition, 2003 and second edition, 2005). In addition to IEC, designations of this standard can be found as EN (European Union), UL (United States), and CSA (Canada). In the USA, the plan is to withdraw approvals to all earlier standards by July, 2006. The US Standard, as of this writing, is UL60950-1, first edition, published in 2003, second edition published in 2007. While UL60950-1 is the most widely applied standard for power supplies, it is also intended for use with information technology, business, and telecom equipment. Other standards exist for other industries, such as IEC 60065 for audio and video, IEC 60335-1 and 2 for household and similar electrical appliances, like air conditioner, refrigerator, vacuum cleaner etc, IEC 60664-1 for equipment within low voltage systems, IEC 60598-1 and 2 for general requirements and tests, IEC 60601 for medical, IEC 61010 for laboratory supplies, and others. The first version of standard, IEC 61204-7, which is intended for use with power supplies sold into multiple industries, was proposed by IEC in 2006. One of the first tasks for power electronic package designers in any new design should be to identify the standards, including recent revisions, which applies to the intended end use. As an example, Table 2.11 lists the basic categories of home applications and the related IEC standards. Figure 2.13 shows the list of other standards that may be used for the power electronic packaging design.

Table 2.11 The basic categories of home applications and related IEC standards

Item	Products of home application	IEC standards
1	Cooking range	IEC-60335-2-6
2	Hair dryer	IEC-60335-2-23
3	Iron	IEC-60335-2-3
4	Microwave oven	IEC-60335-2-25
5	Room air conditioner	IEC-60335-2-40
6	Rice cooker	IEC-60335-2-15
7	Refrigerator	IEC-60335-2-24
8	Vacuum cleaner	IEC-60335-2-2
9	Kettle	IEC-60335-2-15
10	Washing machine	IEC-60335-2-7
11	Home computer system	IEC-60950
12	Coffee maker, slow cooker	IEC-60335-2-15
13	Table, standing lamp	IEC-60598-2-4
14	Toaster, grill, roaster	IEC-60335-2-9
15	Decorative lighting fixture	IEC-60598-2-20
16	TV set, monitor	IEC-60950

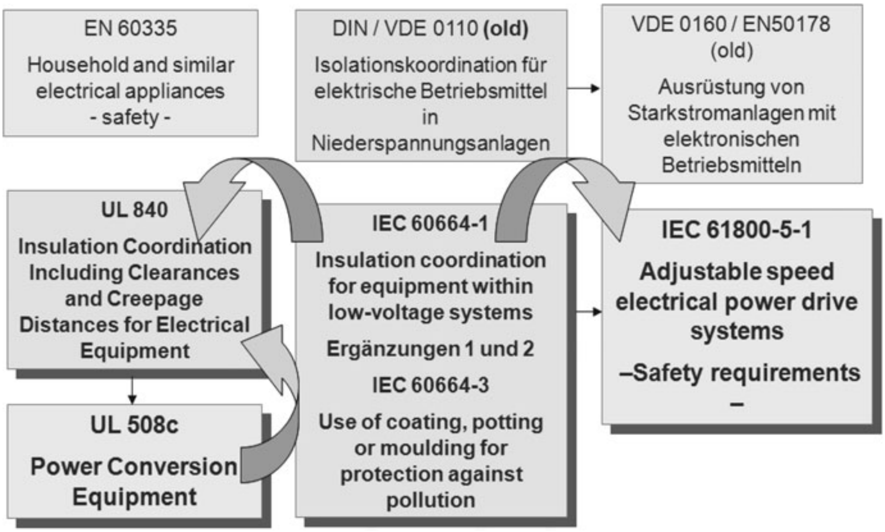

Fig. 2.13 The diagram of other standards for power electronic packaging design

2.6 Summary

This chapter introduces the isolation design for the power electronic packaging. There are many decisions in the design process where a knowledge of safety requirements and the application of their principles can go a long way toward easing the time and cost of the safety certification process. Particularly if a failure in safety testing requires a redesign effort late in the program. Anticipating the testing which may be required and designing accordingly certainly pays off at the end of the day. While definitely not all inclusive, a summary of some of the design considerations for power packaging is given below: (1) The spacing between the power devices and pins is essential in the design of power packaging that needs to meet the requirements of the IEC or UL product safety standards. (2) Increasing the creepage distance in package layout can help to present the arcing and the current leakage across the package surface caused by high voltage or by humidity. (3) In design of the power packaging for isolation, four major functions need to be considered and identified: Pollution degree, CTI value of insulated material, insulating type, and the working voltage. Besides the above isolation design and layout considerations, material selection and mechanical design are two important factors that should not be neglected. It is always necessary to pick components and materials which have prior safety certification and to avoid the sharp edges or corners in mechanical design.

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