UL 1557

STANDARD FOR SAFETY

Electrically Isolated Semiconductor Devices

UL Standard for Safety for Electrically Isolated Semiconductor Devices, UL 1557

Seventh Edition, Dated December 6, 2022

SUMMARY OF TOPICS:

The Seventh Edition of the Standard for Electrically Isolated Semiconductor Devices, UL 1557 dated December 6, 2022, has been issued to reflect the latest ANSI approval date and to incorporate the following proposal:

- ***Temperature for determining the oven time and temperature for the LTA test***
- ***Requirements for insulating materials***
- ***Insulated case***
- ***Spacings***
- ***Compliance criteria for Limited Thermal Aging (LTA) test***
- ***Miscellaneous revisions to LTA and dielectric tests***

The new requirements are substantially in accordance with Proposal(s) on this subject dated September 30, 2022.

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UL 1557

Standard for Electrically Isolated Semiconductor Devices

First Edition – May, 1984
Second Edition – May, 1993
Third Edition – May, 1997
Fourth Edition – June, 2006
Fifth Edition – December, 2011
Sixth Edition – March, 2018

Seventh Edition

December 6, 2022

This ANSI/UL Standard for Safety consists of the Seventh Edition.

The most recent designation of ANSI/UL 1557 as an American National Standard (ANSI) occurred on December 6, 2022. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements apply to semiconductor devices of the isolated-mounting type – thyristors, transistors, diodes, and the like, and hybrid modules consisting of combinations of these devices.

1.2 The term isolation, as used in this standard, refers to the isolation of the mounting surface, or surface if there is no dedicated mounting surface, of a device to the electronic circuits within the device.

1.3 These requirements do not apply to snubber and commutation circuits associated with thyristors, transistors or other analog semiconductor devices.

1.4 These requirements cover the isolation performance of thyristors, transistors, diodes, and the like, and their combination in module packages and constructional features that are pertinent to that performance.

1.5 These requirements apply to isolated semiconductors for use as components in products. Compliance of an isolated semiconductor with these requirements does not determine that the semiconductor is acceptable for use as a component of an end product without further investigation. The acceptability of a semiconductor in any particular product depends upon its acceptability for continued use under the conditions that prevail in actual service.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this Standard shall comply with the requirements for that component.

2.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

2.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

3 Units of Measurement

3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

4 Referenced Publications

4.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

4.2 The following publications are referenced in this Standard:

ASTM D5374, *Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation*

ASTM D5423, *Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation*

IEC 60068-1, *Environmental Testing – Part 1: General And Guidance*

IEC 60664-1, *Insulation Coordination for Equipment within Low-voltage Supply Systems – Part 1: Principles, Requirements and Tests*

IEC 60664-4, *Insulation Coordination For Equipment Within Low-Voltage Systems – Part 4: Consideration Of High-Frequency Voltage Stress*

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 310, *Electrical Quick-Connect Terminals*

UL 746A, *Polymeric Materials – Short Term Property Evaluations*

UL 746B, *Polymeric Materials – Long Term Property Evaluations*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 840, *Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment*

UL 1434, *Thermistor-Type Devices*

5 Glossary

5.1 For the purposes of this Standard, the following definitions apply.

5.2 CASE – The exterior surfaces of the semiconductor device. This may consist of metal or non-metal materials.

5.3 CASE TEMPERATURE – Location on the case where temperatures are specified by the manufacturer.

5.4 ENCAPSULATED MATERIAL – a material that is completely surrounded or covered by a potting or other encapsulating material (e.g. silicone gel).

5.5 FRAME-BASED DEVICES – Semiconductor devices that use a separate material, usually polymeric, to contain the encapsulate of a semiconductor device. This material also serves as at least part of the device case.

5.6 HERMETICAL SEAL – Any material or cover employed to prevent air infiltration, that is, encapsulant.

5.7 INSULATING MATERIAL OPERATING TEMPERATURE – The temperature of the insulating material at the point of maximum electrical field stress for either the discrete semiconductor device or semiconductor power module when operating in accordance with the manufacturer's specifications. See Annex C for examples of areas of highest electrical field strength.

5.8 INSULATING MATERIALS – Any polymeric material in direct contact with live parts, closer than 0.8 mm to live parts, or providing isolation between external as well as internal live parts and the mounting surface of the semiconductor, the surface of the semiconductor not intended for mounting but declared as providing isolation, or between live parts and the surface of the semiconductor when the semiconductor is free-standing (e.g. those mounted to printed wiring board assemblies by their leads).

5.9 ISOLATION VOLTAGE – The maximum withstand potential at 60 Hz between external as well as internal live parts and metal mounting surface of the semiconductor, between live parts and the surface of the semiconductor not intended for mounting if declared, or between live parts and the surface of the semiconductor when the semiconductor is free-standing (e.g. those mounted to printed wiring board assemblies by their leads).

5.10 JUNCTION TEMPERATURE – The maximum allowable temperature of the semiconductor junction specified by the manufacturer.

5.11 MODULE PACKAGE – An assembly consisting of two or more semiconductor devices.

5.12 MOLDED DEVICES – Non-frame based semiconductor devices or modules whose semiconductor device(s) and additional insulating materials (when used) are encapsulated by being molded into a polymeric material, which also serves as the device case.

5.13 ON-STATE CURRENT – The principle current when the semiconductor is in the ON-state.

5.14 PRESSURE CONTACT SEMICONDUCTOR DEVICE – Semiconductor device where the semiconductor, current carrying metal parts, and insulating materials are stacked and primarily held together using pressure from a spring-type assembly.

5.15 SEMICONDUCTOR DEVICE – Discrete isolated-mounting type electronic device in which the characteristic distinguishing electronic conduction takes place within a semiconductor, examples include thyristors, transistors, and diodes.

5.16 STORAGE TEMPERATURE – Acceptable temperature range at which the semiconductor can be stored, without any power applied, as specified by the manufacturer.

CONSTRUCTION

6 General

6.1 A semiconductor shall be constructed in compliance with Sections 7 – 10.

6.2 See Annex A for semiconductor modules that incorporate thermistor type devices.

7 Insulating Materials

7.1 Encapsulants (e.g. silicone gel), encapsulated materials, and materials that are hermetically sealed

7.1.1 Encapsulants (e.g. silicone gel), encapsulated materials, and materials that are hermetically sealed shall be subjected to the Dielectric Voltage-Withstand Test, Section 12, and if the generic temperature index of the material is exceeded by the insulating material operating temperature, the Limited Thermal Aging Test, Section 13. The generic thermal index shall be in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

7.1.2 When the manufacturer's specified storage temperature exceeds the insulating material operating temperature of a device, the storage temperature shall be considered the insulating material operating temperature for the purpose of these requirements.

7.1.3 The insulating material operating temperature shall be the rated maximum junction temperature, or shall be the highest rated continuous operating junction temperature if the maximum junction temperature is assigned a duration or duty cycle in addition to a continuous rating, for the following devices:

a) Molded devices that are free-standing (no dedicated mounting surface), see Annex B, Figure B.1 for an example.

b) Molded devices that are intended to be mounted to a metal surface in such a way that the heat transfer is done via mold, see Annex B, Figure B.2 for an example.

c) Molded devices or frame-based devices that use an insulated metal substrate for heat transfer, where the insulating material of the insulated metal substrate is a polymeric material (may be ceramic filled or glass filled) or printed wiring board material, see Annex B, Figure B.3 and Figure B.7 (respectively) for examples.

d) Framed-based pressure contact semiconductor devices, see Annex B, Figure B.5 for an example.

7.1.4 The insulating material operating temperature shall be considered the rated case temperature for molded devices or frame-based devices that use ceramic as an insulating material, see Annex B, Figure B.4, Figure B.6 and Figure B.8 for examples.

7.1.5 The thermal index of ceramic shall be considered unlimited, therefore the insulating material operating temperature of ceramic is not considered.

7.2 Insulating materials other than encapsulants, encapsulated materials, and materials that are hermetically sealed, e.g. case material

NOTE: the following requirements are based on requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

7.2.1 Insulating materials that are in contact with or less than 0.8 mm (0.031 in) from live parts shall have a CTI in accordance with requirements in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. The CTI for each insulating material shall be specified by the manufacturer. The CTI shall be specified as a performance level category (i.e. 0, 1, 2, 3, or 4) or specified as an ASTM CTI tracking index range corresponding to the PLC (e.g. 175 – 249, which corresponds to PLC 3). See 16.5 for specification requirements.

NOTE: UL 840, the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, Section 9.2 gives ASTM CTI tracking index and PLC values.

7.2.2 Insulating materials that are in contact with or less than 0.8 mm (0.031 in) from live parts shall have high current arc resistance to ignition (HAI) in accordance with requirements for in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A and a flammability classification in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. The minimum HAI value shall be in accordance with Table 7.1 based on the material flame class rating.

Table 7.1
Insulating Material Properties

	UL 746A PLC	
UL 94 Flame Class	**HWI**	**HAI**
HB	2	1
V-2, VTM-2	2	2
V-1, VTM-1	3	2
V-0, VTM-0	4	3

7.2.3 Insulating materials that are 0.8 mm or farther from live parts shall:

a) Have a high current arc resistance to ignition (HAI) in accordance with requirements in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A and a flammability classification in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94; and the minimum HAI value shall be in accordance with Table 7.1 based on the material flame class rating; or

b) Have a high current arc resistance to ignition (HAI) in accordance with requirements in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A and a flammability classification in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94; and the manufacturer shall specify the flame class and HAI performance level category for each material. See 16.6 for specification requirements; or

c) If the material does not have a flame class or does not have an HAI PLC, the manufacturer shall indicate the material as such. See 16.6 for specification requirements.

7.2.4 Insulating materials that are in contact with or less than 0.8 mm (0.031 in) from live parts shall:

a) Have a hot wire ignition (HWI) in accordance with requirements in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A and a flammability classification in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94; and the minimum HWI value shall be in accordance with Table 7.1 based on the material flame class rating; or

b) Have a hot wire ignition (HWI) in accordance with requirements in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A and a flammability classification in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94; and the manufacturer shall specify the flame class and HWI performance level category for each material. See 16.7 for specification requirements; or

c) If the material does not have a flame class or does not have an HWI PLC, the manufacturer shall either comply with the Glow Wire End Product Test of UL 746C and specify the glow-wire temperature (see Table 12.1 of UL 746C) or indicate the material does not have an HWI value. See 16.7 and 16.8 for specification requirements.

7.2.5 Insulating materials shall have an electrical thermal index or generic thermal index in accordance with the requirements in the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B. The thermal index shall not be less than the device's specified storage temperature. For an insulating material that is also a case material, the thermal index shall not be less than the device's specified case temperature. For other parts, the higher of the electrical relative thermal index or generic thermal index shall be specified. See 16.9 for specification requirements.

7.2.6 An insulating barrier or liner employed to provide the required declared spacings between uninsulated live parts of opposite polarity and between such parts and any other uninsulated metal parts according to 10.1 shall be at least 0.71 mm (0.028 in), except that 0.33 mm (0.013 in) is acceptable where used in conjunction with an air space of at least one-half of the required clearance.

7.2.7 The case or body of a discrete semiconductor device providing isolation to its surroundings shall also comply with the requirements of insulating barrier in 7.2.6.

8 Live Parts

8.1 Metal employed for current-carrying parts shall be of stainless steel, silver, gold, copper, nickel, aluminum, an alloy of the same, or an equivalent material.

9 Wiring Terminals

9.1 A semiconductor shall be provided with a means for factory wiring for circuit wiring connections such as wire binding screws, pressure connectors, stud and nut-type connectors, solder connections, quick-connectors, wire leads, or the like.

9.2 A quick-connect terminal shall be evaluated as described in the Standard for Electrical Quick-Connect Terminals, UL 310.

10 Spacings

10.1 The following spacings through air and over surface (clearance and creepage respectively) for live parts that are not internal to an encapsulated or hermetically sealed device shall be based on the end product requirement or the device manufacturer shall declare the values. When declared, the spacings shall not be less than those declared.

a) Between uninsulated live parts of opposite polarity; and

b) Between uninsulated live parts and any other uninsulated metal parts.

NOTE: Annex C provides examples of required spacings from basic safety standards for clearance and creepage requirements.

Exception No. 1: The spacing requirements of (a) or (b), above, do not apply between terminals of discrete semiconductor devices. For example, among collector, emitter, and base of a transistor or among anode, cathode, and gate of an SCR, and the like.

10.2 If the device manufacturer declares values, see 16.4 for marking requirements.

10.3 For a discrete semiconductor device providing isolation to its surroundings, the spacings from any live part on the surface of the device, such as terminals or leads for connection to printed wiring board assemblies, to any adjacent surface shall comply with end product spacings.

PERFORMANCE

11 General

11.1 Samples of semiconductors shall be tested as described in the Dielectric Voltage-Withstand Test, Section 12, and the Limited Thermal Aging Test, Section 13.

11.2 All testing shall be carried out under ambient laboratory conditions that fall within the ranges noted in the table below:

Temperature °C (°F)	Relative Humidity[a] (%)	Air Pressure[a] kPa (mbar)	Altitude[a] m (ft)
15 – 35 (59 – 95)	25 to 75	86 to 106 (860 to 1060)	0 to 2,000 (0 to 6562)
a These values are inclusive.			
NOTE: The values are consistent with those of IEC 60068-1			

12 Dielectric Voltage-Withstand Test

12.1 Following each of the conditionings indicated in 12.4 – 12.6, a semiconductor device shall be capable of withstanding without breakdown for 60 seconds a 48 – 62 Hz essentially sinusoidal potential equal to the rated isolation rms voltage applied between metal mounting surface and all of the device terminals. For this test, all of the terminals are to be connected together.

12.2 The test potential is to be obtained from any convenient source having either a capacity of at least 500 VA or a lower capacity source with the meter connected in the output circuit. The voltage is to be gradually increased until the required test level is reached and is to be held at that value for one minute. The increase in the applied potential is to be at a uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter.

12.3 The test shall be done as soon as practicable, but within 10 minutes or in a time such that the temperature of the module is no less than the insulating material operating temperature, after the oven conditioning of 12.5. If alternate heating means, such as a heating plate, are used after the modules are removed from the oven to maintain the module temperate at or above the insulating material operating temperature, the tests may be conducted in any convenient time. The test shall be done as soon as practicable following the conditioning in 12.4 and 12.6.

12.4 Six samples are to be subjected to the dielectric test procedure in the as-received condition.

12.5 Six samples are to be exposed to the maximum rated junction temperature for 7 hours.

NOTE: The number of fresh air exchanges per hour for the oven is not specified.

12.6 Six samples are to be exposed to 0.0 ±2.0 °C (32.0 ±3.6 °F) for 7 hours.

12.7 For a discrete semiconductor device providing isolation to its surroundings, all surfaces that do not have dead metal intended for mounting of live parts such as terminals and leads for connection to printed wiring board assemblies shall be tightly wrapped in a conductive foil. The dielectric test shall be conducted between the terminals and conductive foil.

13 Limited Thermal Aging Test

13.1 Three samples of the material described in 7.1.1 shall be aged in a full-draft circulating-air oven at a temperature and time chosen from Table 13.1 or Table 13.2, using the index line that corresponds to the maximum operating temperature of the insulating material or the maximum storage temperature of the device, whichever is greater. Linear interpolation of Table 13.1 and Table 13.2 is permitted.

13.2 As soon as practicable, but within 10 minutes or in a time such that the temperature of the module is no less than the insulating material operating temperature, after this oven conditioning, all three samples of the device shall be capable of withstanding the rated isolation rms voltage when tested as described in 12.1 and 12.2. If alternate heating means, such as a heating plate, are used after the modules are removed from the oven to maintain the module temperate at or above (but within 10 °C [18 °F] of) the

insulating material operating temperature throughout the test, the tests of 12.1 and 12.2 may be conducted in any convenient time.

13.3 The air oven is to be essentially as indicated in the Standard Specification for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ANSI/ASTM D5423 (Type I ovens) and the Standard Test Methods for Forced-Convection Laboratory Ovens for Evaluation of Electrical Insulation, ANSI/ASTM D5374. A portion of the air may be recirculated, but a substantial amount of fresh air is to be admitted continuously to maintain an essentially normal air content surrounding the samples. The oven is to be adjusted to achieve 5 – 20 complete fresh-air changes per hour.

Table 13.1
Conditioning Time Versus Oven Temperature for Required Temperature Ratings 105 °C to 155 °C (221 °F to 311 °F) Applicable to Encapsulating Material[a]

Aging hours	Required temperature rating °C (°F)							
	105 (221)	**110 (230)**	**115 (239)**	**125 (257)**	**130 (266)**	**140 (284)**	**150 (302)**	**155 (311)**
	Oven temperature °C (°F)							
300	176 (349)	181 (358)	186 (367)	195 (383)	200 (392)	209 (408)	219 (426)	223 (433)
400	171 (340)	176 (349)	181 (358)	190 (374)	195 (383)	205 (401)	214 (417)	219 (426)
500	168 (334)	172 (342)	177 (351)	187 (369)	191 (376)	201 (394)	210 (410)	215 (419)
600	165 (329)	169 (336)	174 (345)	184 (363)	188 (370)	198 (388)	208 (406)	212 (414)
700	162 (324)	167 (333)	172 (342)	181 (358)	186 (367)	196 (385)	205 (401)	210 (410)
750	161 (322)	166 (331)	171 (340)	180 (356)	185 (365)	195 (383)	204 (399)	209 (408)
800	160 (320)	165 (329)	170 (338)	179 (354)	184 (363)	194 (381)	203 (397)	208 (406)
900	158 (316)	163 (325)	168 (334)	177 (351)	182 (360)	192 (378)	201 (394)	206 (403)
1000	156 (313)	161 (322)	166 (331)	176 (349)	180 (356)	190 (374)	200 (392)	205 (401)
1250	152 (306)	158 (316)	163 (325)	172 (342)	177 (351)	187 (369)	196 (385)	201 (394)
1500	150 (302)	155 (311)	160 (320)	169 (336)	174 (345)	184 (363)	194 (381)	199 (390)
1750	148 (298)	153 (307)	157 (315)	167 (333)	172 (342)	182 (360)	192 (378)	196 (385)
2000	146 (295)	151 (304)	155 (311)	165 (329)	170 (338)	180 (356)	190 (374)	194 (381)
2500	142 (288)	147 (297)	152 (306)	162 (324)	167 (333)	177 (351)	186 (367)	191 (376)
3000	140 (284)	145 (293)	149 (300)	159 (318)	164 (327)	174 (345)	184 (363)	189 (372)
3500	137 (279)	142 (288)	147 (297)	157 (315)	162 (324)	172 (342)	182 (360)	187 (369)

Table 13.1 Continued on Next Page

Table 13.1 Continued

Aging hours	Required temperature rating °C (°F)							
	105 (221)	110 (230)	115 (239)	125 (257)	130 (266)	140 (284)	150 (302)	155 (311)
	Oven temperature °C (°F)							
4000	136 (277)	140 (284)	145 (293)	155 (311)	160 (320)	170 (338)	180 (356)	185 (365)
4500	134 (273)	139 (282)	144 (291)	154 (309)	158 (316)	168 (334)	178 (352)	183 (361)
5000	132 (270)	137 (279)	142 (288)	152 (306)	157 (315)	167 (333)	177 (351)	182 (360)
7500	127 (261)	132 (270)	137 (279)	147 (297)	151 (304)	161 (322)	171 (340)	176 (349)
10000	123 (253)	128 (262)	133 (271)	143 (289)	148 (298)	158 (316)	167 (333)	172(342)

[a] Linear interpolation of this table is allowed.

Table 13.2
Conditioning Time Versus Oven Temperature for Required Temperature Ratings 160 °C to 220 °C Applicable to Encapsulating Material[a]

Aging hours	Required temperature rating								
	160 (320)	170 (338)	175 (347)	180 (356)	190 (374)	195 (383)	200 (392)	210 (410)	220 (428)
	Oven temperature								
300	228 (442)	238 (460)	242 (468)	247 (477)	261 (502)	268 (514)	275 (527)	285 (545)	295 (563)
400	224 (435)	233 (451)	238 (460)	243 (469)	256 (493)	263 (505)	270 (518)	280 (536)	290 (554)
500	220 (428)	230 (446)	234 (453)	239 (462)	253 (487)	259 (498)	266 (511)	276 (529)	286 (547)
600	217 (423)	227 (441)	232 (450)	236 (457)	250 (482)	256 (493)	263 (505)	273 (523)	283 (541)
700	215 (419)	224 (435)	229 (444)	234 (453)	247 (477)	254 (489)	260 (500)	271 (520)	281 (538)
750	214 (417)	223 (433)	228 (442)	233 (451)	246 (475)	253 (487)	259 (498)	269 (516)	280 (536)
800	213 (415)	222 (432)	227 (441)	232 (450)	245 (473)	252 (486)	258 (496)	268 (514)	278 (532)
900	211 (412)	221 (430)	225 (437)	230 (446)	243 (469)	250 (482)	256 (493)	266 (511)	276 (529)
1000	209 (408)	219 (426)	224 (435)	229 (444)	242 (468)	248 (478)	255 (491)	265 (509)	275 (527)
1250	206 (403)	216 (421)	221 (430)	226 (439)	238 (460)	245 (473)	251 (484)	261 (502)	271 (520)
1500	203 (397)	213 (415)	218 (424)	223 (433)	235 (455)	242 (468)	248 (478)	258 (496)	268 (514)
1750	201 (394)	211 (412)	216 (421)	221 (430)	233 (451)	239 (462)	245 (473)	256 (493)	266 (511)

Table 13.2 Continued on Next Page

Table 13.2 Continued

Aging hours	Required temperature rating								
	160 (320)	170 (338)	175 (347)	180 (356)	190 (374)	195 (383)	200 (392)	210 (410)	220 (428)
	Oven temperature								
2000	199 (390)	209 (408)	214 (417)	219 (426)	231 (448)	237 (459)	243 (469)	253 (487)	264 (507)
2500	196 (385)	206 (403)	211 (412)	216 (421)	228 (442)	234 (453)	240 (464)	250 (482)	260 (500)
3000	194 (381)	203 (397)	208 (406)	213 (415)	225 (437)	231 (448)	237 (459)	247 (477)	257 (495)
3500	191 (376)	201 (394)	206 (403)	211 (412)	223 (433)	229 (444)	235 (455)	245 (473)	255 (491)
4000	190 (374)	199 (390)	204 (399)	209 (408)	221 (430)	227 (441)	233 (451)	243 (469)	253 (487)
4500	188 (370)	198 (388)	203 (397)	208 (406)	219 (426)	225 (437)	231 (448)	241 (466)	251 (484)
5000	187 (369)	196 (385)	201 (394)	206 (403)	218 t(424)	224 (435)	229 (444)	239 (462)	249 (480)
7500	181 (358)	191 (376)	196 (385)	201 (394)	212 (414)	218 (424)	223 (433)	233 (451)	243 (469)
10000	177 (351)	187 (369)	192 (378)	197 (387)	208 (406)	214 (417)	219 (426)	229 (444)	239 (462)

[a] Linear interpolation of this table is allowed.

MANUFACTURING AND PRODUCTION-LINE TEST

14 Dielectric Voltage-Withstand Test

14.1 Each product shall withstand without electrical breakdown, as a routine production-line test, the application of a potential at a frequency within the range of 40 – 70 Hz between live parts and accessible dead metal parts.

Exception: A dc potential equal to 1.414 times the specified 40 – 70 Hz potential may be used.

14.2 The production-line test potential shall be the rated isolation rms voltage for 60 seconds or 120 % of the rated isolation rms voltage for one second.

Exception: For a dc test potential:

a) 1.414 times the rated isolation rms voltage for one minute, or

b) 1.414 X 1.2 times the rated isolation rms voltage for one second.

14.3 The product may be in a heated or unheated condition for the test.

14.4 For an ac test, the test equipment shall include a transformer having an essentially sinusoidal output, a means of indicating the test potential, an audible or visual indicator of electrical breakdown, and either a manually reset device to restore the equipment after electrical breakdown or an automatic feature that rejects any unacceptable unit.

14.5 If the output of the test-equipment transformer is less than 500 VA, the equipment shall include a voltmeter in the output circuit to indicate the test potential directly.

14.6 If the output of the test-equipment transformer is 500 VA or more, the test potential may be indicated:

a) By a voltmeter in the primary circuit;

b) By a selector switch marked to indicate the test potential; or

c) In the case of test equipment that has a single output potential, by a marking in a readily visible location to indicate the test potential.

When marking is used without an indicating voltmeter, the equipment shall include a positive means, such as an indicator lamp, to indicate that the manually reset switch has been reset following a dielectric breakdown.

14.7 Test equipment other than that described in 14.4 – 14.6, may be used if found acceptable to accomplish the intended factory control.

14.8 During the test, the terminals are to be connected together and to one terminal of the equipment, and the second test-equipment terminal is to be connected to accessible dead metal.

RATING

15 General

15.1 Each device shall be rated in maximum ON-state current.

15.2 Each device shall have either:

a) A curve of ON-state or forward current versus case temperature; or

b) A maximum case temperature.

15.3 Each device shall be provided with an rms isolation-voltage rating according to 12.1. This rating shall state clearly if the isolation-voltage rating applies to a mounting surface or to the device surroundings, or both. If the isolation is provided to the device surroundings, this may be stated as a case insulation-voltage rating or similar.

15.4 Each device shall have a rated maximum junction temperature. Modules containing multiple semiconductor devices shall have a rated maximum junction temperature for each type of semiconductor.

15.5 Each device shall have a maximum storage temperature.

MARKING

16 General

16.1 Each device shall be marked with the manufacturer's name or trademark and model number. This marking shall appear on the device itself or on the smallest shipping carton in which the devices are shipped.

16.2 The terminals shall be identified to indicate their function. This marking shall appear on the device or the marking shall be provided as part of the manufacturer's specifications.

16.3 Ratings according to Section 15 and the installation instructions shall be provided in the manufacturer's specifications.

16.4 If the manufacturer declares the spacing value in accordance with 10.2, the installation instructions or specification/data sheet shall specify between which parts or circuits the spacings apply and the minimum spacing, either as through air or over surface, or clearance or creepage respectively.

16.5 The CTI shall be provided as part of the manufacturer’s specifications. Where the CTI for more than one part is required and the CTI values are different, the manufacturer shall specify each CTI by part or shall specify the lowest CTI (in reference to performance).

NOTE: For example, if the manufacturer has an upper and lower part to the case made of different materials, one with a CTI PLC of 3 and another with a CTI PLC of 4, they must specify the CTI for the upper case and the CTI for the lower case, or specify a single CTI of 4.

16.6 When required by 7.2.3(b), the manufacturer shall specify the flame class and HAI PLC for the material. Where the HAI for more than one part is required and the HAI values are different, the manufacturer shall specify each HAI by part or shall specify the lowest HAI (in reference to performance). When a material does not have a flame class or does not have an HAI PLC in reference to 7.2.3(c), the manufacturer shall specify “HAI: –“ or similar for that material.

16.7 When required by 7.2.4(b), the manufacturer shall specify the flame class and HWI PLC for the material. Where the HWI for more than one part is required and the HWI values are different, the manufacturer shall specify each HWI by part or shall specify the lowest HWI (in reference to performance). When a material does not have a flame class or does not have an HWI PLC in accordance with 7.2.5(c), the manufacturer shall specify “HWI: –“ or similar for that material.

16.8 When the manufacturer conducts the glow-wire end product test in accordance with 7.2.5(c), the manufacturer shall specify the glow-wire temperature used for the test.

16.9 In accordance with 7.2.5, for parts other than the case, the manufacturer shall specify the insulating material thermal index.

ANNEX A (normative) – SEMICONDUCTOR DEVICES INCORPORATING THERMISTOR TYPE DEVICES

A1 Scope

A1.1 These requirements cover semiconductor devices that incorporate sensing type thermistor devices and include the optional marking as in A5.1. The semiconductor device shall comply with the requirements in Sections 6 – 16, inclusive supplemented by and in some cases amended by the requirements in this Annex.

A2 Glossary

A2.1 For semiconductor devices incorporating thermistor type devices and marked as in A5.1, the following definitions apply.

A2.2 CIRCUIT, SAFETY – A primary or secondary circuit that contains a control relied upon to reduce a risk of fire, electric shock, or injury to persons. Examples include a circuit that limits the wattage to a limited-energy level or a circuit designed to limit temperatures.

A2.3 RESISTANCE (R_{min}) – For a ceramic PTC thermistor, the point of minimum resistance on the R/T curve.

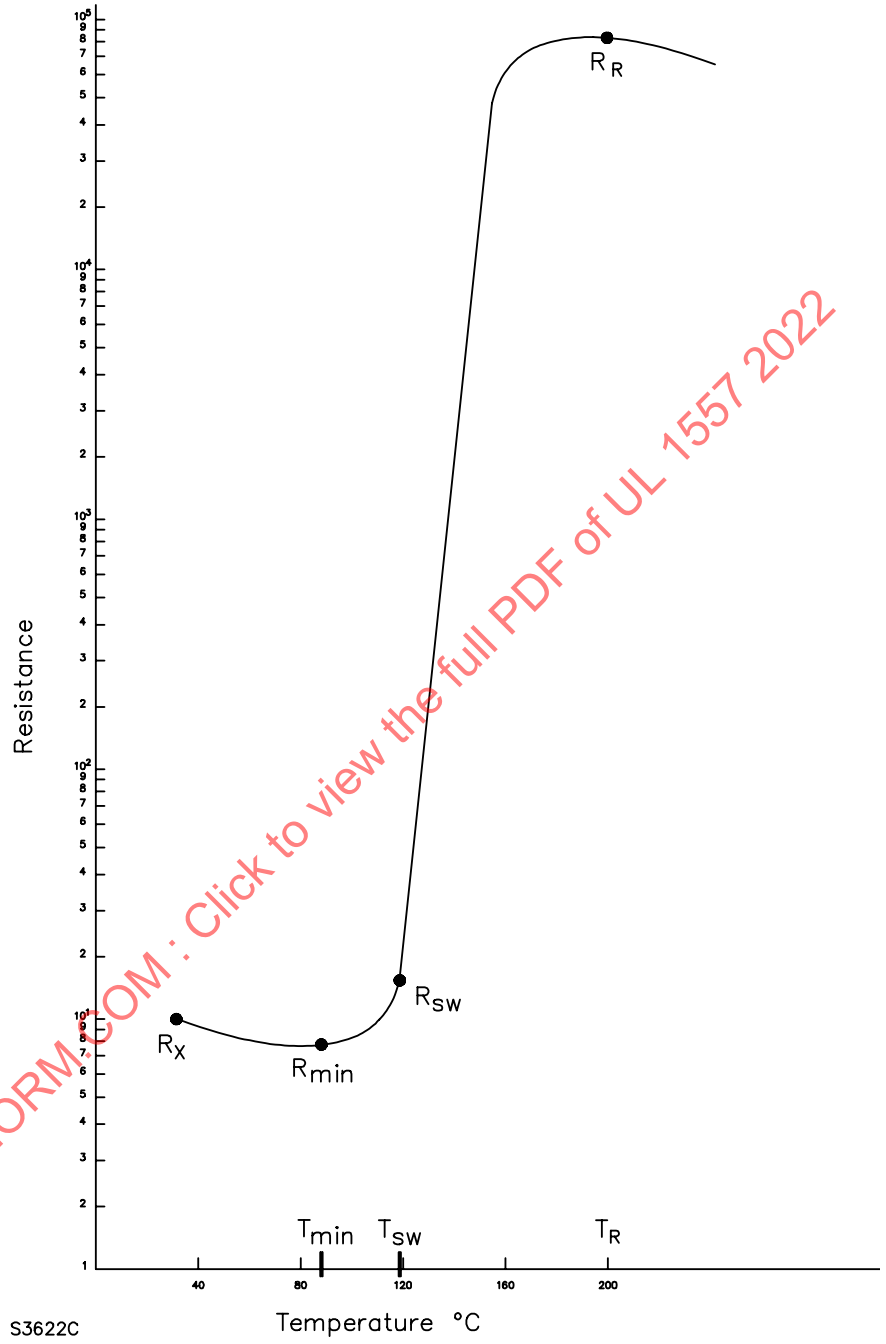
A2.4 RESISTANCE, R_X (R_{25}) – The rated resistance at a temperature specified by the manufacturer for R_X or at 25 ±2 °C (77 ±3.6 °F) for R_{25}.

A2.5 RESISTANCE, SWITCHING (R_{SW}) – For a ceramic PTC thermistor, the resistance value at which the resistance begins to increase sharply with temperature increase. For this Standard, R_{SW} is the value where the resistance is twice R_{min}; unless the manufacturer specifies R_{SW} with reference to R_{min} with a multiplying factor other than two, or with reference to R_X.

A2.6 RESISTANCE/TEMPERATURE (R/T) CURVE – The graphical representation of the characteristics of resistance versus temperature. See Figure A2.1 and Figure A2.2 for typical curves. The significant portion of the curve for a PTC thermistor, as illustrated in Figure A2.1, is usually that portion of the curve representing the range of temperature over which the product is used. The R/T curve of some PTC thermistors has a negative slope from R_X (R_{25}) to R_{min} before the resistance begins to increase.

Figure A2.1

Typical R/T Curve for a Ceramic PTC Thermistor



NOTES –

R_{min} – The point of minimum resistance.

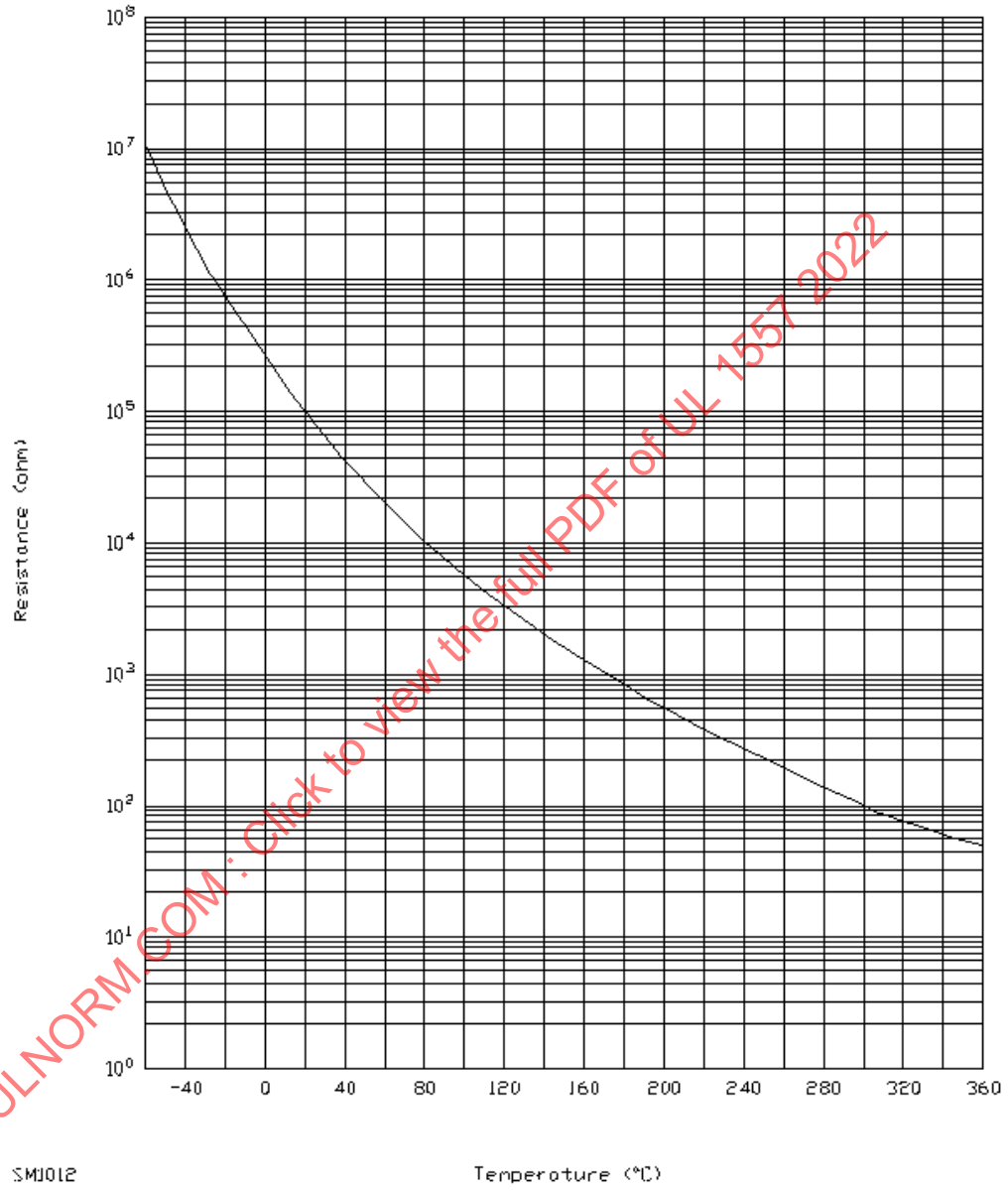
R_X (R_{25}) – Resistance at a temperature specified by the manufacturer for R_X or at 25 ±2 °C (77 ±3.6 °F) for R_{25}.

T_{SW} – Switching temperature at which the resistance R_{SW} begins to increase sharply with temperature increases.

T_R – Thermal runaway temperature where resistance R_R starts to decrease.

Figure A2.2

Typical R/T Curve for a NTC Thermistor



A2.7 TEMPERATURE, SWITCHING (T_{SW}) – For a ceramic PTC thermistor, the temperature at which the resistance is at R_{SW}.

A2.8 TEMPERATURE, THERMAL RUNAWAY (T_R) – The high temperature point on the R/T curve at which a PTC thermistor's resistance no longer increases with increasing temperature.

A2.9 THERMISTOR – A thermally sensitive semiconductor resistor that has, over at least part of its R/T curve, a significant nonlinear change in its electrical resistance with a change in temperature. Typically, a change in temperature occurs due to the flow of current through the thermistor, as a result of a change in the ambient temperature, or a combination of both.

A2.10 THERMISTOR, NTC – A thermistor that exhibits a negative temperature coefficient (NTC) as indicated by a decrease in resistance with increasing temperature over the significant portion of the R/T curve. See Figure A2.2.

A2.11 THERMISTOR, PACKAGE – A thermistor pellet with leads, terminals, heatsink, housing, or any other additions.

A2.12 THERMISTOR, PELLET – A thermistor without any leads, terminals, heatsink, housing, or other additions.

A2.13 THERMISTOR, PTC – A thermistor that exhibits a positive temperature coefficient (PTC) as indicated by an increase in resistance with increasing temperature over the significant portion of the R/T curve. See Figure A2.1.

A2.14 THERMISTOR, SENSING – An NTC or PTC thermistor used as a sensor. A sensing thermistor does not carry a load current.

A2.15 VALUE – A NTC thermistor's index, which expresses the degree of resistance change when calculated from any two points specified by the manufacturer on the resistance/temperature (R/T) curve.

A3 Termistor Type Devices

A3.1 When marked as in A5.1 the electrically isolated semiconductor device shall incorporate a sensing thermistor type device that complies with the Standard for Thermistor Type Devices, UL 1434. The thermistor shall be suitable for use in safety circuits and have a calibration class of C4 or better.

A4 Rating

A4.1 When marked as in A5.1, each electrically isolated semiconductor device shall be provided with the complete electrical rating of the thermistor type device contained in the device per Table A4.1.

Table A4.1
Thermistor Electrical Rating

	Thermistor type[a]	
Characteristic	**PTC[b]**	**NTC[b]**
Beta value (β)	–	X[c]
Calibration class number	R	R
Resistance – R_{25} and tolerance	R	R
Temperature – maximum operating ambient	R	R
Temperature – switching (T_{SW}) or trip (T_{tr})	R	–
Voltage – insulation rating	R[d]	R[d]

Notes:

1 The "R" designation indicates ratings for the device that are required to be provided by the manufacturer.

2 The "X" designation indicates characteristics of the device that the manufacturer shall declare and is verified by testing.

[a] These apply to sensing type thermistors only. The range of ambient temperature shall be specified.

[b] The range of ambient temperature shall be specified.

[c] A beta value (ß) is not required.

[d] For devices declared by the manufacturer as insulated.

A5 Marking

A5.1 When employing a thermistor type device evaluated to the Standard for Thermistor Type Devices, UL 1434, the electrically isolated semiconductor may be marked "Provided with a UL 1434 Thermistor Type Device". This marking shall appear on the electrically isolated semiconductor itself or on the smallest shipping carton in which the devices are shipped.

A5.2 When marked as in A5.1, the electrically isolated semiconductor device shall be marked with the complete electrical ratings of the thermistor type device per Rating, Section A4. This marking shall appear on the electrically isolated semiconductor or the marking shall be provided as part of the manufacturer's specifications.

ANNEX B (informative) – EXAMPLES OF SEMICONDUCTOR DEVICE CONSTRUCTIONS

The figures in this Annex are intended to provide reference for specific device construction requirements used in the body of this standard.

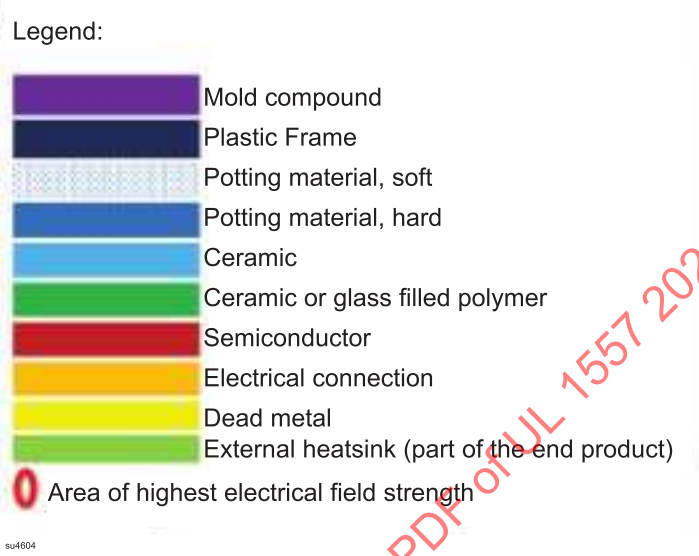


Figure B.1

Molded device, free standing

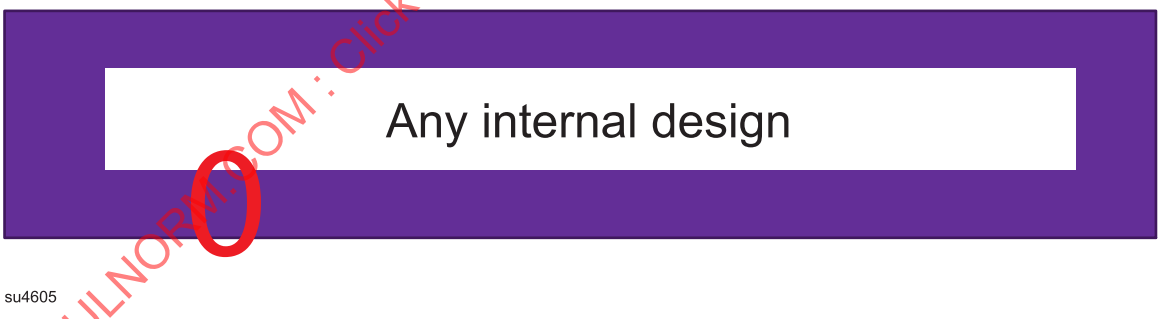


Figure B.2

Molded device with dedicated non-metallic mounting surface

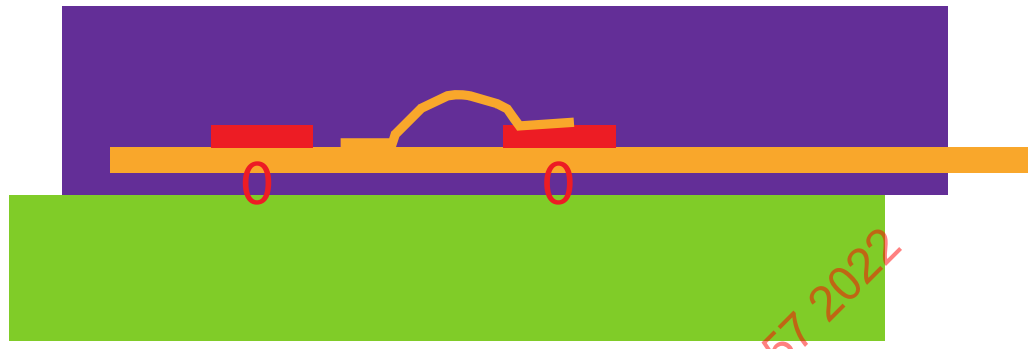


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Figure B.3

Molded device with insulated metal substrate

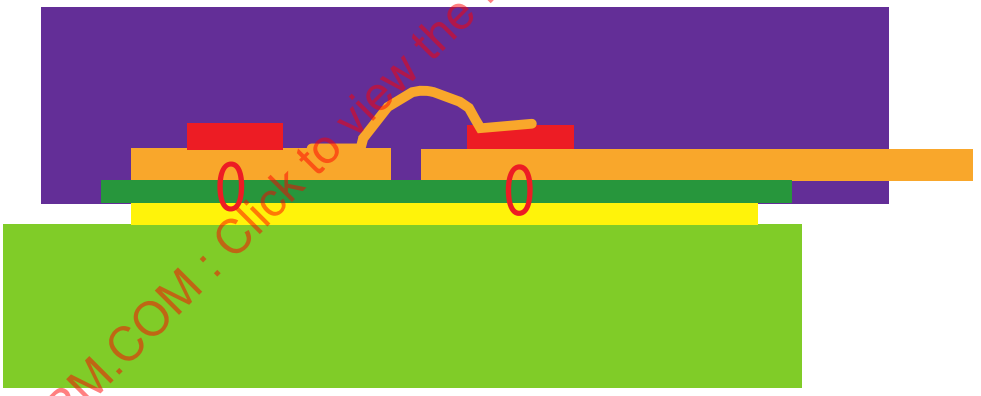

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Figure B.4

Molded device with ceramic insulation

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Figure B.5

Pressure contact device

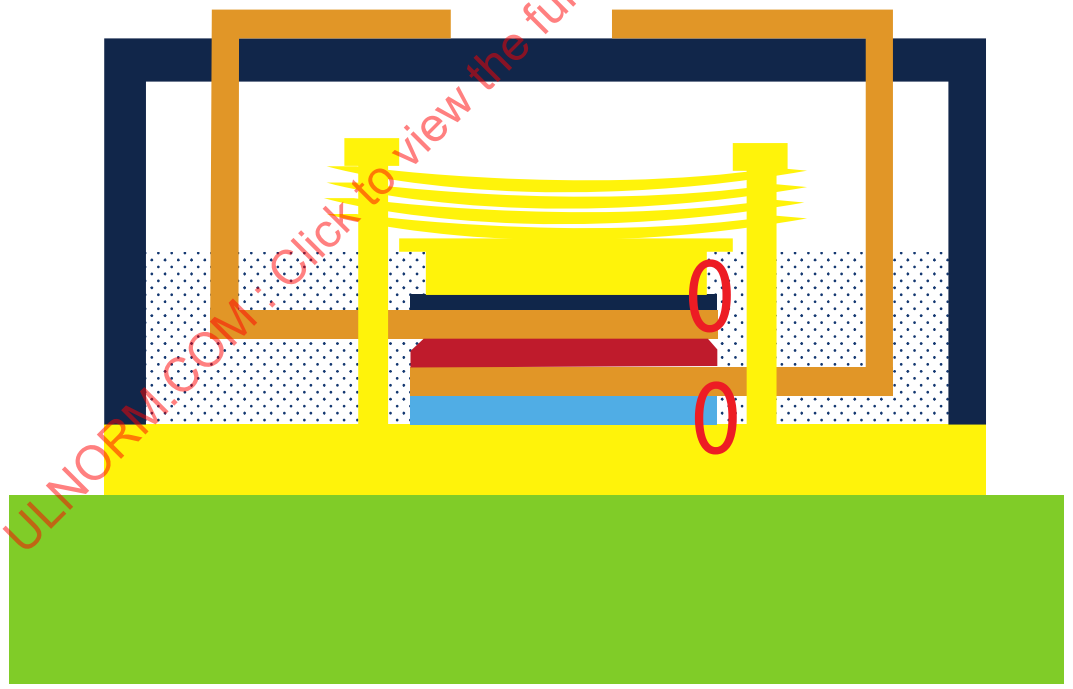

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Figure B.6

Potted device

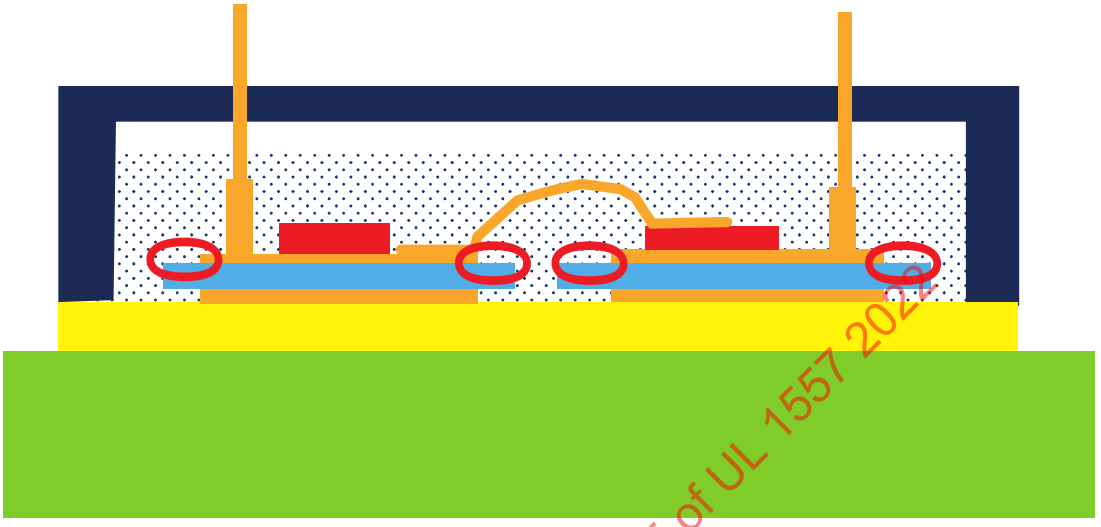

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Figure B.7

Potted device with insulated metal substrate

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