What creepage does my isolated gate driver need?

Document Version : 19
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2 What is Creepage?

Creepage is defined as the shortest distance between two conductive leads, across the isolation barrier, measured across the surface of insulation.

Clearance, on the other hand, is measured through air from lead to lead, as shown in Figure 1.

For more details on creepage and clearance, see TI Precision Labs' Isolation Series training.

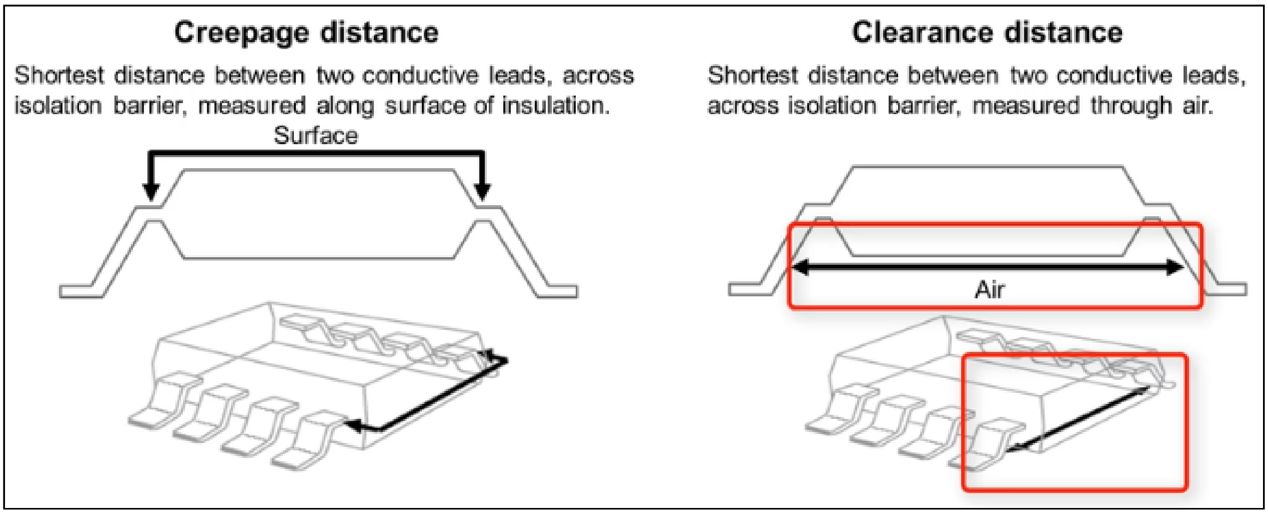

Figure 1: Creepage vs. Clearance

3 What affects the creepage requirement?

There are three things we need to know to determine our minimum creepage requirement for our isolated gate driver:

- What is the highest peak Voltage we will see across the isolator? → (V_{RMS})
- How "dirty" is the environment our gate driver will operate in? → (Pollution degree)
- How good is our insulating material/mold compound → (Material group)

We will define these parameters in the later sections.

3.1 What is Pollution Degree?

Not all gate drivers are exposed to in the same environmental conditions, so *Pollution degree* is used to classify these conditions which have the potential to reduce the effectiveness of isolation and modify the creepage requirement accordingly.

The pollution degree depends, for example, on whether system is sealed and the nature of the particle fallout. For example, an environment where there is a lot of conductive dust or non-conductive dust that *becomes* conductive with condensation would fall under *Pollution degree* 3. It is potentially possible to improve a system's pollution using potting/conformal coating.

The definitions are specified in Table 4.6.2 of the IEC60664-1 standards, shown below in Figure 2.

4.6.2 Degrees of pollution in the micro-environment

For the purpose of evaluating creepage distances and clearances, the following four degrees of pollution in the micro-environment are established:

– *Pollution degree 1*

No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.

– *Pollution degree 2*

Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

– *Pollution degree 3*

Conductive pollution occurs or dry non-conductive pollution occurs which becomes conductive due to condensation which is to be expected.

– *Pollution degree 4*

Continuous conductivity occurs due to conductive dust, rain or other wet conditions.

Figure 2: Explanation of Pollution degree from IEC60664-1 Standard

3.2 What is Material group?

Some materials experience electrical breakdown earlier than others. A gate driver's package molding compound can breakdown and creative a semi-conductive path along the outside surface of the package.

IEC60664-1 sets the *Material group* of the device package based on the "Comparative Tracking Index" of the insulating material, which in the case of gate driver IC is the molding compound. The comparative tracking index, in brief, measures how well the material resists electrical breakdown/tracking. *Material group* is defined in Section 4.8.1.3 of IEC60664-1

Material group I:	600 V < CTI
Material group II:	400 V < CTI < 600 V
Material group IIIa:	175 V < CTI < 400 V
Material group IIIb:	100 V < CTI < 175 V

Figure 3: Material Group Classifications

Material group is specified in the isolated gate driver's datasheet in Insulation Specifications, as shown in the excerpt from UCC21732-Q1's datasheet in Figure 4. TI's isolated gate drivers are all Material Group I, the highest classification.

	Material group	According to IEC 60664–1	I	
	Overvoltage Category per IEC 60664–1	Rated mains voltage ≤ 300 V_{RMS}	I-IV	
		Rated mains voltage ≤ 600 V_{RMS}	I-IV	
		Rated mains voltage ≤ 1000 V_{RMS}	I-III	
DIN V VDE V 0884-11 (VDE V 0884-11):2017-01 [2]				
V_{IORM}	Maximum repetitive peak isolation voltage	AC voltage (bipolar)	2121	V_{PK}
V_{IOWM}	Maximum isolation working voltage	AC voltage (sine wave) Time dependent dielectric breakdown (TDDB) test	1500	V_{RMS}
		DC voltage	2121	V_{DC}
V_{IOTM}	Maximum transient isolation voltage	V_{TEST}=V_{IOTM}, t = 60 s (qualification test)	8000	V_{PK}
		V_{TEST}=1.2 x V_{IOTM}, t = 1 s (100% production test)	9600	
V_{IOSM}	Maximum surge isolation voltage [3]	Test method per IEC 62368-1, 1.2/50 µs waveform, V_{TEST} = 1.6 × V_{IOSM} = 12800 V_{PK} (qualification)	8000	V_{PK}
q_{pd}	Apparent charge [4]	Method a: After I/O safety test subgroup 2/3, V_{ini} = V_{IOTM}, t_{ini} = 60 s; $V_{pd(m)}$ = 1.2 × V_{IORM} = 2545 V_{PK}, t_m = 10 s	≤ 5	pC
		Method a: After environmental tests subgroup 1, V_{ini} = V_{IOTM}, t_{ini} = 60 s; $V_{pd(m)}$ = 1.6 × V_{IORM} = 3394 V_{PK}, t_m = 10 s	≤ 5	
		Method b1: At routine test (100% production) and preconditioning (type test) V_{ini} = V_{IOTM}, t_{ini} = 1 s; $V_{pd(m)}$ = 1.875 × V_{IORM} = 3977 V_{PK}, t_m = 1 s	≤ 5	
C_{IO}	Barrier capacitance, input to output [5]	V_{IO} = 0.5 sin (2πft), f = 1 MHz	~ 1	pF
R_{IO}	Insulation resistance, input to output [5]	V_{IO} = 500 V, T_A = 25°C	≥ 10^{12}	Ω
		V_{IO} = 500 V, 100°C ≤ T_A ≤ 125°C	≥ 10^{11}	
		V_{IO} = 500 V at T_S = 150°C	≥ 10^9	
	Pollution degree		2	
	Climatic category		40/125/21	

Figure 4: UCC21732 Material Group

4 How do we determine minimum creepage?

Once we know Material group, peak voltage, and pollution degree, we can use IEC60664-1 Standard Table F4to see the minimum creepage requirement. This table copied below in Figure 5.

To find the minimum requirement, we first need to know the *material group* and *pollution degree* for our driver/ system. In UCC217xx, the *Material Group* is I, and a *pollution degree* of 2 is assumed, as shown in the Figure 4, which is copied from UCC21732's insulation specifications.

Note that the first two columns in Figure 5, labeled "Printed Wiring Material," are not used for determining the gate driver's creepage requirement; these first two columns cover PCB traces and copper.

Table F.4 – Creepage distances to avoid failure due to tracking

Voltage r.m.s. [1]	Minimum creepage distances								
	Printed wiring material								
	Pollution degree								
	1	2	1	2			3		
	All material groups	All material groups, except IIIb	All material groups	Material group I	Material group II	Material group III	Material group I	Material group II	Material group III [2]
V	mm	mm	mm	mm	mm	mm	mm	mm	mm
10	0,025	0,040	0,080	0,400	0,400	0,400	1,000	1,000	1,000
12,5	0,025	0,040	0,090	0,420	0,420	0,420	1,050	1,050	1,050
16	0,025	0,040	0,100	0,450	0,450	0,450	1,100	1,100	1,100
20	0,025	0,040	0,110	0,480	0,480	0,480	1,200	1,200	1,200
25	0,025	0,040	0,125	0,500	0,500	0,500	1,250	1,250	1,250
32	0,025	0,040	0,14	0,53	0,53	0,53	1,30	1,30	1,30
40	0,025	0,040	0,16	0,56	0,80	1,10	1,40	1,60	1,80
50	0,025	0,040	0,18	0,60	0,85	1,20	1,50	1,70	1,90
63	0,040	0,063	0,20	0,63	0,90	1,25	1,60	1,80	2,00
80	0,063	0,100	0,22	0,67	0,95	1,30	1,70	1,90	2,10
100	0,100	0,160	0,25	0,71	1,00	1,40	1,80	2,00	2,20
125	0,160	0,250	0,28	0,75	1,05	1,50	1,90	2,10	2,40
160	0,250	0,400	0,32	0,80	1,10	1,60	2,00	2,20	2,50
200	0,400	0,630	0,42	1,00	1,40	2,00	2,50	2,80	3,20
250	0,560	1,000	0,56	1,25	1,80	2,50	3,20	3,60	4,00
320	0,75	1,60	0,75	1,60	2,20	3,20	4,00	4,50	5,00
400	1,0	2,0	1,0	2,0	2,8	4,0	5,0	5,6	6,3
500	1,3	2,5	1,3	2,5	3,6	5,0	6,3	7,1	8,0 (7,9) [4]
630	1,8	3,2	1,8	3,2	4,5	6,3	8,0 (7,9) [4]	9,0 (8,4) [4]	10,0 (9,0) [4]
800	2,4	4,0	2,4	4,0	5,6	8,0	10,0 (9,0) [4]	11,0 (9,6) [4]	12,5 (10,2) [4]
1 000	3,2	5,0	3,2	5,0	7,1	10,0	12,5 (10,2) [4]	14,0 (11,2) [4]	16,0 (12,8) [4]
1 250			4,2	6,3	9,0	12,5	16,0 (12,8) [4]	18,0 (14,4) [4]	20,0 (16,0) [4]
1 600			5,6	8,0	11,0	16,0	20,0 (16,0) [4]	22,0 (17,6) [4]	25,0 (20 0) [4]
2 000			7,5	10,0	14,0	20,0	25,0 (20,0) [4]	28,0 (22,4) [4]	32,0 (25,6) [4]
2 500			10,0	12,5	18,0	25,0	32,0 (25,6) [4]	36,0 (28,8) [4]	40,0 (32 0) [4]
3 200			12,5	16,0	22,0	32,0	40,0 (32,0) [4]	45,0 (36,0) [4]	50,0 (40,0) [4]

Figure 5: Creepage Table taken from IEC60664

5 Example: determining creepage requirement for UCC21732-Q1

In our case, if we consider Pollution Degree 2, we look at the highlighted column in Figure 5 and match to the peak transient RMS Voltage that the driver could experience. We can go between RMS and Peak voltage using the following relationship: $V_{pk} = V_{RMS} \cdot \sqrt{2}$.

As an example, we choose an RMS voltage of 1000V.

For basic Isolation: using the table, we find the creepage requirement is 5.0mm.

For reinforced Isolation: The requirement is 2x of the requirement listed in the table, so 10.0mm in this case.

UCC21732-Q1 for example, whose SOIC DW-16 package has 8mm creepage, will meet the requirement for basic isolation but not for reinforced isolation.

6 Additional Resources

- IEC60664-1 2007 Standard
- **(TI)** High-Voltage Reinforced Isolation: Definitions and Test Methodologies
- **(TI)** Isolated Gate Driver 101: From Insulation Spec to End Equipment Requirements
- **(TI)** TI Precision Labs Isolation Series: What are creepage and clearance?