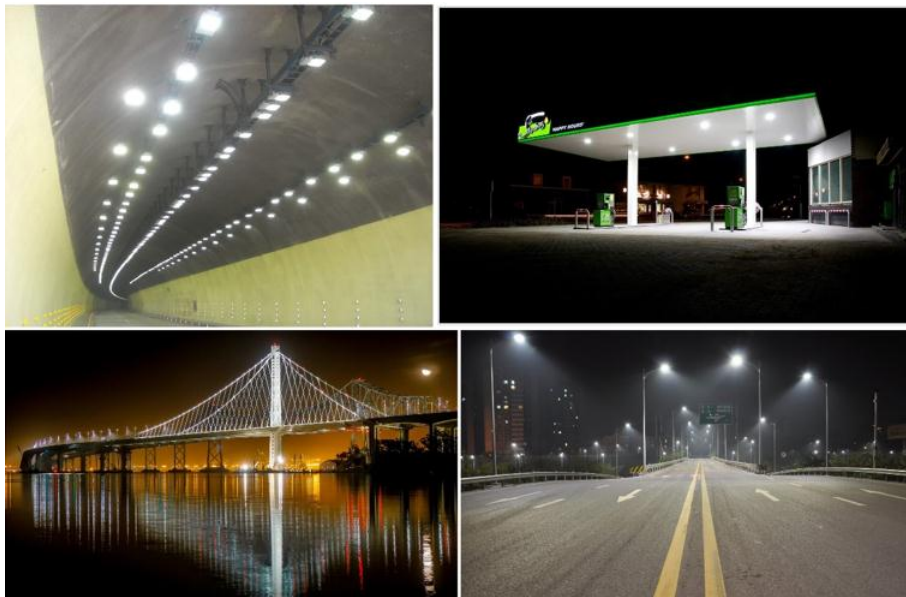


Inventronics Hipot Testing

*An Overview of High Potential Testing,
the Standards that are Involved for LED
Drivers, and Examples for Reference.*



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Introduction

The term “hipot” stands for high potential and is an electrical safety stress test. *This test is also commonly referred to as a dielectric withstand voltage test.* The primary goal of this test is to ensure that a product does not present an electrical threat to users when under normal operation.

When an electrical device is connected to the power grid, *or AC mains*, it is possible that the voltage may exceed the nominal rating. The high potential test checks that even under very severe over voltage conditions, the insulation within the product is adequate to prevent electrical shock when used in the field. When voltages are under 600V humans are able to: perceive current between 0.5mA to 1mA, feel startled or a slight shock up to 5mA, and feel pain with inability to let go of a conductive circuit when exposed to greater than 6mA.

The hipot test is performed by introducing high voltage across two portions of a device that are designed to be electrically isolated from each other, *for example, the input and case.* As the voltage is introduced, the corresponding current flow is monitored to ensure it does not exceed use for safety. All circuits have a minimal and expected, measurable leakage current due to inherent capacitance; however, the hipot test is concerned with abnormal and excessive current flowing due to the breakdown of insulation.

This breakdown can occur as a design defect if adequate insulation or spacing is not present, *for example, on a board layout or within a transformer.* It can also occur as a defect during manufacturing, *for example, a nicked cable jacket or punctured insulation between transformer windings.* These types of defects can cause shorts (or arcing points) between two

supposedly electrically isolated portions of a device, no longer making them isolated. With this, the hipot test is commonly performed both at the design phase and again on the production line in order to catch manufacturing defects. If such a defect is present and not screened out, it is possible that a user may be shocked due to unexpected current within a system.

Standards and Regulations

As hipot testing relates to safety and performance in the field, there are several organizations that define their own testing standards. These standards are available for reference, but are often adopted as requirements or even enforced as governmental regulations. Hipot testing applies across many industries and may types of devices, but this overview will focus solely on LED drivers.

The lighting industry’s two most commonly required hipot tests are defined by the International Electrotechnical Commission (*IEC*) and the Underwriters Laboratory (*UL*). The general pass/fail criteria between the two testing standards are related to the total measured leakage current and the physical appearance of the driver. During the hipot test, the driver leakage current must be limited and after the test, the driver undergoes visual inspection to ensure there are no physical defects. Though the tests are similar between the two standards, the test conditions are defined differently and will be described below.

IEC Standard

IEC is the most globally referenced (and required) standard. They define testing both for design qualification (or prototype testing) and also for manufacturing. The IEC 61347-1 hipot test definition is based upon a few driver characteristics, including whether the driver is SELV or Non-SELV and whether the driver is Class I or Class II. Each test will be performed between the input and output, between the input and case, and between the output and case if applicable. Table 1 provides more detail.

Table 1: IEC Test Conditions for Design Qualification

Types	Test Object	SELV						Non-SELV			
		Maximum Output voltage is less than 120 Vdc or 50Vrms						Maximum Output voltage is more than 120 Vdc or 50Vrms			
		Voltage between test component	<50	<=150	>150 <=300	600	1000				
Class I	INPUT-OUTPUT	Reinforced Insulation	500	2000	3000	4200	5000	Basic Insulation	2U+1000V	Reinforced Insulation	4U+2000V
	INPUT-CASE	Reinforced Insulation/Supplement Insulation	250	1000	1500	2100	2500	Basic Insulation	2U+1000V	Basic Insulation	2U+1000V
	OUTPUT-CASE	SELV	500	1000	N/A	N/A	N/A	Basic Insulation	2U+1000V	Basic Insulation	2U+1000V
Class II	INPUT-OUTPUT	Reinforced Insulation	500	2000	3000	4200	5000	Basic Insulation	2U+1000V	Reinforced Insulation	4U+2000V
	INPUT-CASE	Reinforced Insulation	500	2000	3000	4200	5000	Reinforced Insulation	4U+2000V	Reinforced Insulation	4U+2000V
	OUTPUT-CASE	SELV	500	1000	N/A	N/A	N/A	Reinforced Insulation	4U+2000V	Reinforced Insulation	4U+2000V

How the IEC Standard is Applied for Design Qualification

Asian, European, and many other regions that primarily require IEC also share a common maximum rated *nominal* voltage of 240Vac. Many Inventronics drivers are designed to operate off 90 ~ 305Vac, but it is the maximum *nominal* voltage for these regions that will be referenced when defining hipot test conditions.

EUD-200S150BD Design Qualification Test Conditions

The Inventronics EUD-200S150BD is suitable for Independent use. It is also Class II and Non-SELV, from Table 1, the portion with voltage definitions for Class II and Non-SELV drivers would be referenced. These specific definitions are shown in Table 2. Each test is to be performed for 60 seconds and requires calculations to determine the correct voltages as shown in Equation 1, Equation 2, and Equation 3. Note that “U” is equivalent to the maximum rated nominal voltage.

Table 2: Independent Class II Non-SELV Design Conditions

	INPUT-OUTPUT	Basic Insulation	2U+1000V	Reinforced Insulation	4U+2000V
Class II	INPUT-CASE	Reinforced Insulation	4U+2000V	Reinforced Insulation	4U+2000V
	OUTPUT-CASE	Reinforced Insulation	4U+2000V	Reinforced Insulation	4U+2000V

Equation 1: IEC Input to Output Calculation

$$(2 \times U) + 1000Vac = \text{required applied voltage}$$

$$(2 \times 240Vac) + 1000Vac = 1,480Vac$$

Equation 2: IEC Input to Case Calculation

$$(4 \times U) + 2000Vac = \text{required applied voltage}$$

$$(4 \times 240Vac) + 2000 = 2,960Vac$$

Equation 3: IEC Output to Case Calculation

$$(4 \times U) + 2000Vac = \text{required applied voltage}$$

$$(4 \times 240Vac) + 2000 = 2,960Vac$$

EUD-096S210DVA Design Qualification Test Conditions

The Inventronics EUD-200S210DVA is also suitable for Independent use. It is also Class I and SELV, again from Table 1, the portion with voltage definitions for Class II and Non-SELV drivers would be referenced. These specific definitions are shown in Table 3. Each test is also to be performed for 60 seconds. No calculation is required to determine the testing voltage, but driver specifications are used for reference instead.

Table 3: Independent Class I SELV Test Conditions

Types	Test Object	SELV					
		Maximum Output voltage is less than 120 Vdc or 50Vrms					
		Voltage between test component	<50	<=150	>150 <=300	600	1000
Class I	INPUT-OUTPUT	Reinforced Insulation	500	2000	3000	4200	5000
	INPUT-CASE	Reinforced Insulation/Supplement Insulation	250	1000	1500	2100	2500
	OUTPUT-CASE	SELV	500	1000	N/A	N/A	N/A

Input to Output

The test voltage is defined by the input voltage, which is a maximum rated *nominal* voltage of 240Vac. This is > 200Vac but ≤ 450Vac, so the test voltage is 3,000Vac.

Input to Case

Similarly, the maximum rated *nominal* voltage between input and ground is 240Vac, so the test voltage is 1,500Vac.

Output to Case

This driver’s no load voltage is > 50Vdc, so the test voltage is 1,000Vac.

How the IEC Standard is Applied for Manufacturing

IEC also specifies requirements for 100% hipot testing on the production line. These test conditions are described in IEC 61347-1 + A1: 2010 + A2: 2012, Appendix K.1, shown in Table 4.

Table 4: IEC Test Conditions for Manufacturing

Test	Type of control gear and compliance				
	Magnetic ballast	a.c. and d.c. electronic ballast	Step down convertor for low voltage filament lamps and LED module	Inverter and convertor for high frequency cold start lamps	Ignitor
Visual inspection ^a	applicable				
Function test/circuit continuity (with lamp or simulation lamp)	Impedance test ^b	Lamp / Operating voltage	Lamp / Operating voltage	Lamp / Operating voltage	At 90% minimum rated supply voltage: Peak voltage
Earth continuity ^c Applied between earthing terminal on control gear and accessible parts likely to become live (only for class I independent control gear)	Maximum resistance 0,50 Ω, measured by passing a minimum current of 10 A with a no-load voltage not exceeding 12 V for at least 1 s.	Maximum resistance 0,50 Ω, measured by passing a minimum current of 10 A with a no-load voltage not exceeding 12 V for at least 1 s.	Maximum resistance 0,50 Ω, measured by passing a minimum current of 10 A with a no-load voltage not exceeding 12 V for at least 1 s.	Maximum resistance 0,50 Ω, measured by passing a minimum current of 10 A with a no-load voltage not exceeding 12 V for at least 1 s.	Maximum resistance 0,50 Ω, measured by passing a minimum current of 10 A with a no-load voltage not exceeding 12 V for at least 1 s.
Electric strength ^c	Measured by applying a minimum voltage of 1,5 kV a.c. for a minimum of 1 s or 1,5 √2 kV d.c. Made between terminals short-circuited and body.	Measured by applying a minimum voltage of 1,5 kV a.c. for a minimum of 1 s or 1,5 √2 kV d.c. Made between input/output terminals short-circuited and body.	Measured by applying a minimum voltage of: -between input/output terminals short-circuited and body 1,5 kV a.c. or 1,5 √2 kV d.c. for a minimum of 1 s -between input and output terminals 3 kV a.c. or 3 √2 kV d.c. for a minimum of 1 s	Measured by applying a minimum voltage of 1,5 kV a.c. for a minimum of 1 s or 1,5 √2 kV d.c. Made between: • Input/output terminals short-circuited and body • Input and output	Measured by applying a minimum voltage of 1,5 kV a.c. for a minimum of 1 s or 1,5 √2 kV d.c. Made between terminals short-circuited and body.
^a Visual inspection:	Visual inspection should ensure that the control gear is fully assembled and free from sharp edges etc. which may cause damage or injuries. It should also ensure that any labels are legible and properly attached and any printing legible.				
^b Impedance test:	The impedance test is carried out by measuring the ballast voltage when the ballast has been loaded with its rated current; alternatively, it may be carried out at a fixed voltage (defined by the appropriate lamp data sheet) and measuring the ballast current.				
^c Class II (independent) control gear or control gear with plastic case and without earthing terminal:	the earth continuity, the electrical strength and the insulation resistance tests do not apply.				

These test conditions are more straight forward compared to the design qualification testing and simply specify that the *Input to Output* be tested to a minimum of 3000Vac and the *Input to Case* and *Output to Case* must be tested to at least 1500Vac. Each test must be performed for at least 1 second. *Note that an impedance, or resistance, test is also defined by IEC, but is not review in this application note.*

EUD-200S150BD Manufacturing Test Conditions

Table 5 shows the voltage conditions for each of the EUD-200S150DVA connection methods during production. Each test is performed for 1.5 seconds.

Table 5: EUD-200S150BD Manufacturing Test Conditions

Connection	Test Voltage
Input to Output	3000Vac
Input to Case	1500Vac
Output to Case	1500Vac

EUD-096S210DVA Manufacturing Test Conditions

Table 6 shows the voltage conditions for each of the EUD-096S210DVA connection methods during production. Each test is performed for 1.5 seconds.

Table 6: EUD-096S210DVA Manufacturing Test Conditions

Connection	Test Voltage
Input to Output	3000Vac
Input to Case	1500Vac
Output to Case	1500Vac

UL Standard

Underwriter’s Laboratory is predominantly used in the United States and Canada. With this, the North American line voltages are used for testing and the hipot definition is described in UL 8750. UL also has a hipot testing definition for design qualification and this test is modified to define testing on a production line.

How the UL Standard is Applied for Design Qualification

Table 7 is used when qualifying a design and obtaining UL certification. This test incorporates the same test connections as IEC, but also includes additional component level testing. The test is typically performed with an AC voltage, but it can also be performed with the equivalent DC voltage (*multiply the required AC voltage by 1.414*).

Table 7: UL Test Conditions for Design Qualification

Applied potential	Circuit location
2V + 1000	Between primary circuits or secondary circuits operating at greater than 70 V peak and accessible dead conductive parts
	Between the primary and secondary of a transformer
	Between PWB traces or other parts operating at different potentials
500 V	Between a secondary circuit operating at no more than 70 V peak and accessible dead conductive parts

Universal Input Drivers (90~305Vac)

As previously stated, many Inventronics product families are specified to operate between 90Vac ~ 305Vac. The maximum rated *nominal* voltage for this type of driver when certified for North American use is 277Vac. Each test is to be performed for 60 seconds and requires calculations to determine the correct voltages as shown in Equation 4 and Equation 5. *Note that “V” is equivalent to the maximum rated nominal voltage and the Output to Case test is always 500Vac.*

Equation 4: UL Input to Output Calculation (90 ~ 305Vac)

$$1000 + (2 \times V) = \text{required applied voltage}$$

$$1000 + (2 \times 277Vac) = 1,554Vac$$

Equation 5: UL Input to Case Calculation (90~305Vac)

$$1000 + 2 \times V = \text{required applied voltage}$$

$$1000 + (2 \times 277Vac) = 1,554Vac$$

Output to Case
500Vac

High Input Drivers (249~528Vac)

Inventronics also offers product families targeting high input applications and are specified to operate between 249 ~ 528Vac. The maximum rated *nominal* voltage for this type of driver when certified for North American use is 480Vac when operated in North America and is what will be required by UL. Each test is to be performed for 60 seconds and requires calculations to determine the correct voltages as shown in Equation 6 and Equation 7. *Note that “V” is equivalent to the maximum rated nominal voltage and the Output to Case test is always 500Vac.*

Equation 6: UL Input to Output Calculation (249 ~ 528Vac)

$$1000 + (2 \times V) = \text{required applied voltage}$$

$$1000 + (2 \times 480Vac) = 1,960Vac$$

Equation 7: UL Input to Case Calculation (249~528Vac)

$$1000 + 2 \times V = \text{required applied voltage}$$

$$1000 + (2 \times 480Vac) = 1,960Vac$$

Output to Case
500Vac

How the UL Standard is Applied for Manufacturing

Like IEC, UL also requires 100% hipot testing on the production line. These test conditions are based off the design qualification standards, but are also altered slightly to decrease the total amount of time required for each driver. The test definition is summarized in the Table 8 below.

Table 8: UL Test Conditions for Manufacturing

Test Voltage Condition ^a	Application time, seconds ^a	Applied potential, AC ^a	Applied potential, DC ^a
A ^a	60 ^a	1000 + 2 times V ^a	1400 + 2.8 times V ^a
B ^a	1 ^a	1200 + 2.4 times V ^a	1700 + 3.4 times V ^a
C ^a	1 ^a	500 ^a	500 times 1.4 ^a

^a "V" is the maximum marked input voltage, the voltage to ground, or the output voltage, whichever is higher.^a

All tests are decreased to 1 second; however, the voltage is increased to help compensate for the shortened test duration. The new calculations to determine the correct applied voltages for universal input and high input drivers are shown in Equation 8 and Equation 9 respectively.

Equation 8: UL Calculation for Manufacturing (90~305Vac)

$$1200 + 2.4 \times V = \text{required applied voltage}$$

$$1200 + (2 \times 277Vac) = 1,865Vac$$

Equation 9: UL Calculation for Manufacturing (249~528Vac)

$$1200 + 2.4 \times V = \text{required applied voltage}$$

$$1200 + (2 \times 480Vac) = 2,352$$

Table 9 provides a direct comparison between the hipot test used for the design qualification and the test used on the production line. *Note that Inventronics also certifies UL drivers to IEC standards, so these product families have both certifications. The hipot test conditions will be defined by comparing the two certifications and using whichever test has the highest voltage.*

Table 9: UL Test Condition Comparison Between Design Qualification and Manufacturing

	Universal Input (90 ~ 305Vac)				High Input (249 ~ 528Vac)			
	Test Duration		Test Voltage		Test Duration		Test Voltage	
	Design Qual.	Production Line	Design Qual.	Production Line	Design Qual.	Production Line	Design Qual.	Production Line
Input to Output	60s	1s	1,554Vac	1,865Vac	60s	1s	1,960Vac	2,352Vac
Input to Case	60s	1s	1,554Vac	1,865Vac	60s	1s	1,960Vac	2,352Vac
Output to Case	60s	1s	500Vac	500Vac	60s	1s	500Vac	500Vac

Gas Discharge Tube and How it Affects Hipot Testing

Due to the relatively sensitive nature of electrical devices, Inventronics focuses on providing robust designs and application driven feature sets. With this, a common feature added to outdoor drivers is high internal surge protection that is able to withstand up to 6kV between line to line and 10kV between line to earth. In order to achieve such high surge protection, a gas discharge tube (GDT) is added to the design which remains *open* under normal operation. In the event of a very large overvoltage or surge event, the GDT will be triggered, *or short*, and will shunt the excess power to ground only for the duration of the event. Figure 1 provides a simplified view of the path for excess power to ground. When the driver is under normal operation, the power will bypass the surge protection components and flow to the isolated transformer to then provide a regulated output.

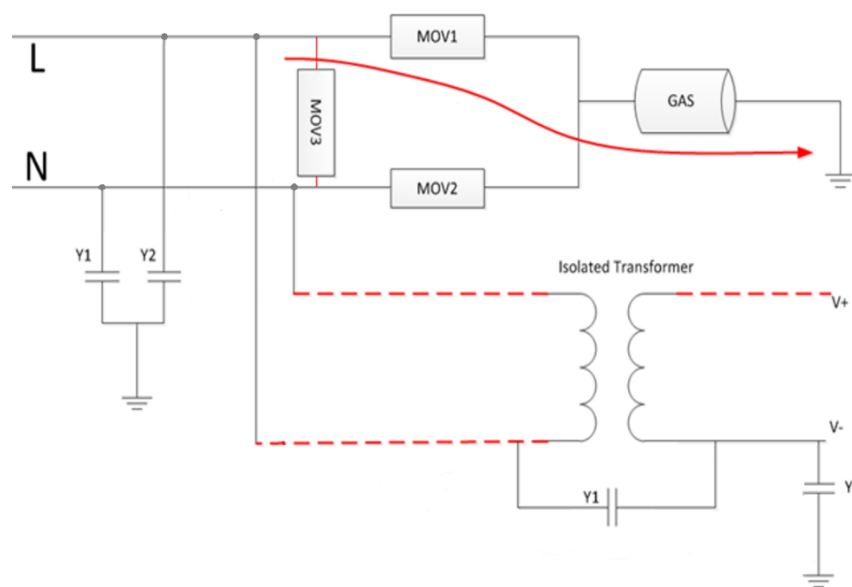


Figure 1: Path of Current Flow Through GDT to Ground During Over Voltage Event

When the driver is withstanding a large over voltage event, the input and ground, *or case*, will no longer be isolated. If the hipot test were performed while the GDT is connected within the circuit, the GDT would trigger and the test would fail as expected due to the excess current being shunted through the case. The test would not fail due to insufficient insulation or a manufacturing defect as the test is intended detect, but would only fail due to the surge protection circuitry working as intended.

Rather than limit the protection within the design to pass hipot testing, a method to momentarily disconnect the GDT has been added to the mechanical design for a majority of the outdoor portfolio. *Note that drivers that do not include a way to disconnect the GDT undergo hipot testing on the assembly line when the GDT is not connected and the driver is not fully assembled. (Rare exceptions utilize a GDT with a much higher trigger voltage, allowing the drivers to pass testing even without a method to remove the GDT.)* After final assembly, an additional hipot test is performed relative to the GDT trigger voltage. The applied voltage will be low enough that it will not trigger the GDT, but it will also be high enough to simulate an over voltage condition (typically 500Vac or 800Vac).

Disable GDT with External Screw Solution

Most Inventronics outdoor drivers will include the external screw solution. With this added screw, the GDT can be removed from the circuit by removing the nut and metal lock sheet from the end cap. After the hipot test is performed, the screw must be added again to the end cap to provide line-to-earth surge protection in the field. *Note for automated testing, the nut's required twisting force is 6.5 ± 0.5 kgf.cm.* Inventronics uses this solution and removes the GDT for hipot testing on the production line. Once the hipot test has passed and the nut is secured back on the end cap, an additional lower voltage hipot test (typically 500Vac or 800Vac) is performed for final assembly.

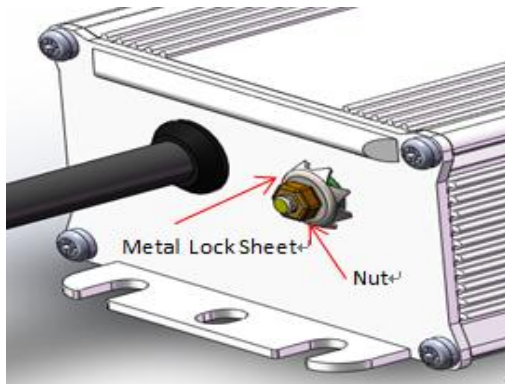


Figure 2: External Screw Solution with GDT Enabled

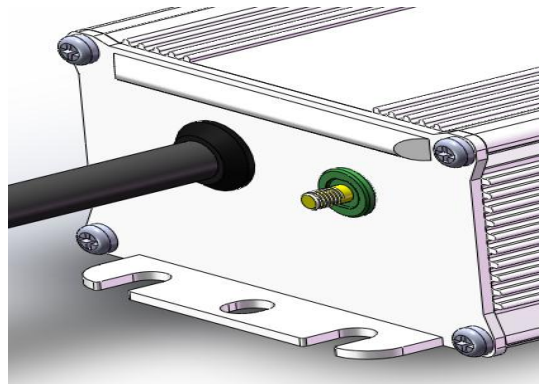


Figure 3: External Screw Solution with GDT Disabled

Disable GDT for External Ground Wire Solution

The EBD series includes an external ground wire solution that is fixed to the case with an end cap screw. After the test is performed, the external wire and end cap screw should be added again to provide line-to-earth protection in the field. *Note for automated testing, the screw's required twisting force is also 6.5 ± 0.5 kgf.cm.* Inventronics uses this solution and removes the GDT for hipot testing on the production line. Once the hipot test has passed and the screw is secured back on the end cap, an additional lower voltage hipot test (typically 500Vac or 800Vac) is performed for final assembly.

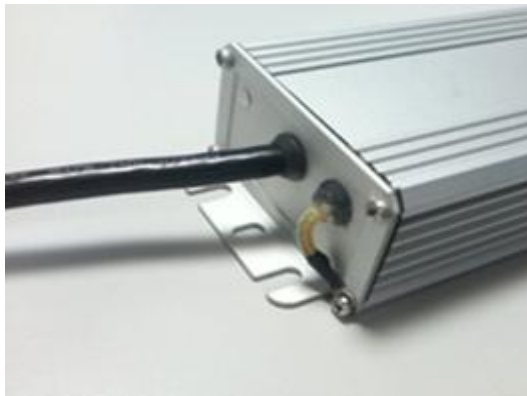


Figure 4: External Ground Wire Solution with GDT Enabled



Figure 5: External Ground Wire Solution with GDT Disable

* The removal of the GDT is only meant for hipot testing and should always be re-secured once testing is complete. *

Summary

Hipot testing is important for electrical safety and is typically required both at the design level and on the manufacturing line. Inventronics complies with the IEC and UL standards and hipot tests 100% of LED drivers that are manufactured. Some standards require additional testing for the luminaire and this may be performed by disabling the gas discharge tube (when applicable). *Note that some testing certification bodies or testing laboratories may allow simple impedance testing on the luminaire or they may even allow the luminaire hipot test to be skipped since the LED driver already underwent testing at the factory.* If there are questions about luminaire hipot testing requirements, it is recommended to contact your local certification body for more information as standards are constantly being updated.

Disclaimer

The application note is for reference only. It is the responsibility of the customer to thoroughly analyze all aspects of the customers' proposed application for the products. The customer is solely responsible for making the final selection of the product(s) to be used and to assure that all performance and safety requirements of the application are satisfied. Inventronics makes no representation or warranty as to the completeness or accuracy of the information contained herein. The products and specifications set forth in this document are subject to change without notice and Inventronics disclaims any and all liability for such changes.

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