

High-Voltage Discrete Silicon MOSFETs (≥ 2 kV) and their Applications

The role of high-voltage (HV) discrete power semiconductor devices has become increasingly important in the world of power electronics today. Littelfuse addresses this development with an extensive portfolio of discrete HV Silicon (Si) MOSFETs featuring improved overall device performance, reduced losses, increased avalanche robustness, and reliable operation. This article focuses on the Littelfuse offering of HV discrete Si MOSFETs ≥ 2 kV.

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Market Comparison of Discrete HV Si MOSFET Portfolios

Figure 1 represents Littelfuse's leadership in the HV discrete Si MOSFET market, notably above 1700 V. Being the only manufacturer developing the industry's highest voltage blocking capability of up to 4700 V, Littelfuse is the one and only supplier and thus the market leader of HV discrete Si MOSFETs above 1700 V. No other manufacturer provides discrete Si MOSFETs at this HV level. A portfolio with rugged and reliable devices, competitive product performance, patented packaging technology, and leading technical expertise have enabled Littelfuse to successfully support customers in developing demanding applications.

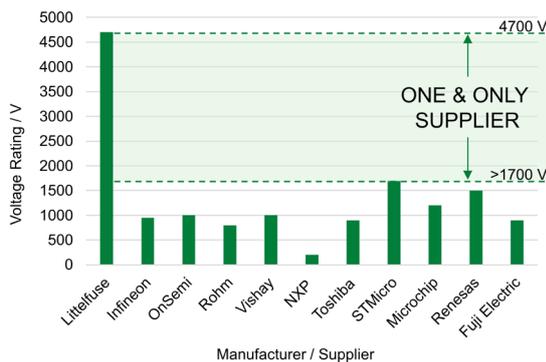
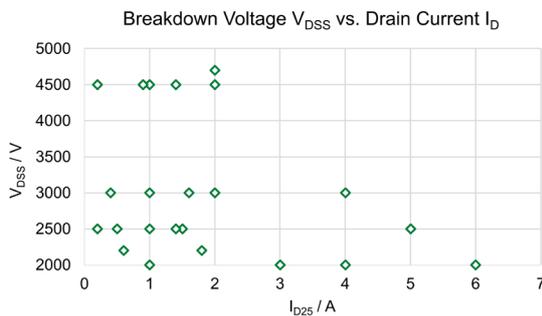


Figure 1: Market comparison of discrete HV Silicon MOSFET portfolios



V_{DSS} / kV	I_{D25} / A	$R_{DS(ON)}$ / Ω	P_D / W
2, 2.2, 2.5, 3, 4.5, 4.7	0.2 - 6	4 - 625	78 - 960

Figure 2: Littelfuse portfolio of discrete HV Silicon MOSFETs

Littelfuse Portfolio of Discrete HV Si MOSFET

The distinct and broad portfolio of discrete HV Si MOSFETs by Littelfuse from 2000 to 4700 V is depicted in Figure 2. A key highlight is the availability of these n-channel discrete HV MOSFETs in both, standard and unique packages with current ratings ranging from 200 mA to 6 A and power dissipation capability ranging from 78 to 960 W. These HV MOSFETs are capable of withstanding high avalanche energies and are specifically designed to address de-

manding, fast-switching power conversion applications requiring very high blocking voltages. The HV MOSFETs represent an optimal solution in applications such as laser and X-ray generation systems, HV power supplies, pulsed power applications, and are particularly of interest for auxiliary power supplies in medium voltage motor drives, photovoltaic (PV) inverters, high-voltage direct-current (HVDC) grid converters, traction, and uninterruptable power supplies (UPS).

Moreover, the HV discrete Si MOSFETs are suitable for parallel device operation due to the positive temperature coefficient of their on-state resistance. These HV discrete devices provide a more reliable and cost-efficient solution than employing series-connected, lower-voltage MOSFETs. Figure 3 enumerates the main advantages of implementing a HV design with Littelfuse's HV discrete Si MOSFETs in comparison to a series-connection of low-voltage (LV) MOSFETs.

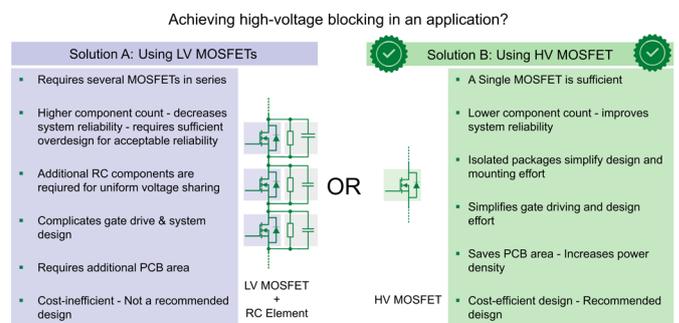


Figure 3: Key advantages of building a HV design utilizing Littelfuse's HV Si MOSFET in comparison to LV MOSFETs

Packaging - Unique HV and Proprietary Isolated Packages

Littelfuse offers unique high-voltage and patented isolated packages with several benefits resulting in value addition for the customer. At high voltage and power levels, the heat dissipated in the power device becomes critical. Packaging significantly influences the thermal behavior of the power device and could become a limiting factor. The unique high-voltage and proprietary ISOPLUS™ packages developed by IXYS-Littelfuse support to deal with critical concerns of isolation and thermal management in HV applications. Figure 4 highlights some differences between Littelfuse HV packages and standard packages.

The high-voltage versions of the standard packages offer increased creepage distances as an essential benefit. The HV discrete Si MOSFETs from Littelfuse ≥ 2 kV are available in unique HV packages such as:

- TO-263HV and TO-268HV for surface-mount-device (SMD), and
- TO-247HV and PLUS247HV for through-hole-technology (THT) PCB assembly.

The removal of the middle drain pin in TO-263HV and TO-268HV packages, as well as the larger distance between the drain and source pins of the TO-247HV package result in increased creepage distances. This supports customers to ease the prevention of possible arcing conditions in their HV applications. For instance, the lead-to-lead creepage distance of the TO-263HV and TO-268HV has approximately doubled to 4.2 mm and 9.5 mm, respectively, compared to the standard packages. Another critical concern in HV applications is the electrical isolation itself. Littelfuse proprietary isolated discrete ISOPLUS™ packages are an excellent choice for implementing HV designs. As illustrated in Figure 5, the design incorporates a direct-copper-bond (DCB) substrate instead of the usual copper lead frame onto which the Si chip is soldered.

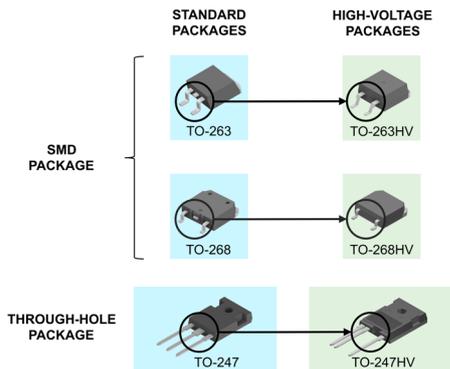


Figure 4: Increased creepage distances (lead-to-lead) offered by Littelfuse HV packages in comparison to standard packages

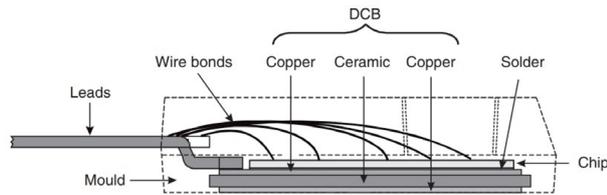


Figure 5: Cross section of Littelfuse isolated discrete package showing the direct-copper-bond (DCB) substrate

The electrically isolated tab is provided for heat sinking. DCBs provide a high isolation capability, of 2500 V_{RMS} for up to 60 s. This potentially eliminates the need for external tab isolation and additional insulator-mounting steps in the final assembly, depending on the isolation and grounding concept of the heatsink. This in turn results in cost savings for the customer in the system assembly stage.

Littelfuse isolated packages offer an overall lower thermal resistance of the junction-to-heat sink path, R_{thjH} , compared to non-isolated packages with external insulation pads. This significantly improves the thermal performance of the device. Furthermore, the lower coupling capacitance between the die and heat sink in these isolated packages helps the customer to improve the EMI shielding. The HV discrete Si MOSFETs available in the ISOPLUS i4-PAC™ and ISOPLUS i5-PAC™ (ISOPLUS264™) packages display the aforementioned qualities. Figure 6 depicts the various standard, HV and proprietary isolated packages offered by Littelfuse for HV discrete Si MOSFETs.

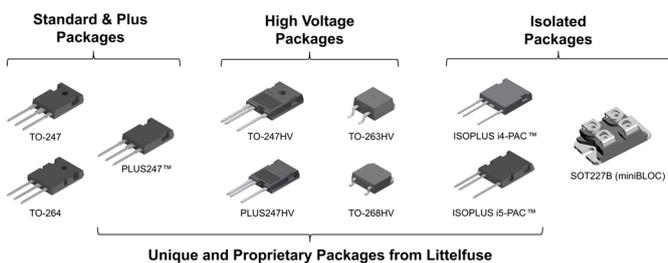


Figure 6: Standard, HV and proprietary isolated packages offered by Littelfuse for HV discrete Si MOSFETs

Applications

Figure 7 a) illustrates an example, where a HV auxiliary (AUX) power supply is used. It is a sub-component of a larger system to power gate-driver units, measurement and monitoring systems, as well as other safety-critical functions. Typically, less than 100 W of output power and output voltages between 5 and 48 V are required. Therefore, the flyback circuit, as depicted in Figure 7 b), is widely utilized.

The input to the AUX power is usually the HV DC link voltage of the power converter. An inherent requirement of the HV flyback is a power device with a very high blocking voltage rating to withstand the reflected voltage from the transformer's secondary side. Littelfuse HV discrete Si MOSFETs are a perfect fit for HV AUX power supplies in HVDC grids, electric vehicle (EV) chargers, solar inverters, medium voltage drives, UPS, and HV battery applications.

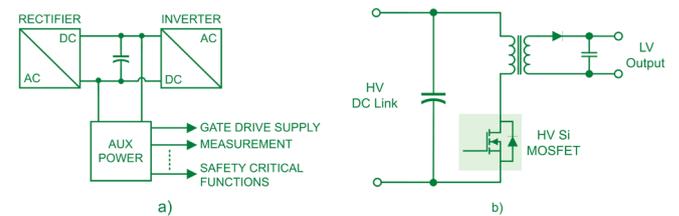


Figure 7: a) Block diagram of an inverter with the auxiliary power supply b) Flyback topology typically used for HV AUX power supplies

Pulsed power is another potential application for Littelfuse HV discrete Si MOSFETs. Pulsed power consists of releasing stored energy quickly, in a fraction of a second to apply a well-defined amount of power. Figure 8 a) depicts the simplified schematic of a pulsed power application utilizing a HV MOSFET to transfer the energy from the HV DC input capacitor to the load within a short period of time. Pulsed power is utilized in different applications such as high energy density plasma generators, intense electron beam radiography, high power microwave, medical equipment, food pasteurization, water treatment, and ozone generation, to name a few. An example of a pulsed power application illustrated in Figure 8 b) is an ultrasound-based diagnostic imaging used in medical diagnosis and treatment of patients.

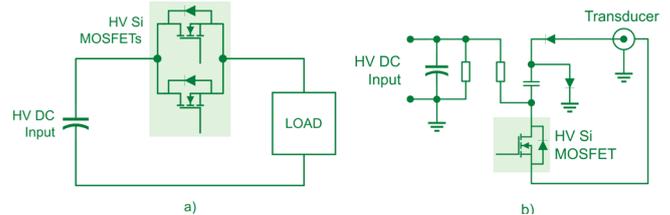


Figure 8: a) Simplified schematic of pulsed power application b) Ultrasound-generation as an example of pulsed power application

Summary

Littelfuse portfolio of unique HV discrete power devices is supporting the development of modern HV applications which have witnessed an unprecedented demand in recent times. With a broad portfolio of HV discrete Si MOSFETs in innovative, distinct packages such as the high-voltage and ISOPLUS™ types, these MOSFETs from Littelfuse have become the choice for design engineers developing novel high-voltage applications. With its uniquely positioned portfolio, Littelfuse discrete HV Si MOSFETs are particularly well-suited for AUX power solutions across a wide range of applications.

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