

Mounting and Handling Press-pack Semiconductor Devices

Objectives

This document outlines the minimum mounting conditions for Littelfuse high power devices along with instructions to achieve proper mounting. Press-pack devices are divided into two groups. GTOs, diodes, and thyristors share a common internal construction, while IGBTs are built using a different approach. **Figure 1** briefly highlights the differences.

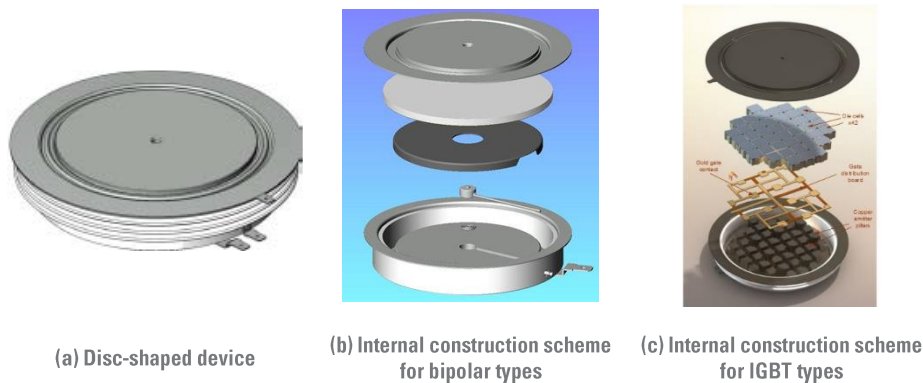


Figure 1. Differences between the Press-pack Technologies

Disc devices containing thyristors, diodes, GTOs, or IGBTs are often stacked to support dedicated demands and set up the desired topology. This mounting technology requires precise alignment and careful handling of the power semiconductors as well as sophisticated mechanical construction. The most important factor in stacked assemblies is a homogeneous distribution of mounting forces.

Applications

- High-power motor drives, Medium-Voltage drives, Soft-starters
- Welding, Induction Melting, and Electro-chemical power supplies
- Static Synchronous Compensators (STATCOM) and HVDC-based power transmission
- Rail, Marine, and Mining transportation
- Renewable energies – Wind and Solar power

Target Audience

This document is intended for potential adopters of high-power semiconductors who want to determine the appropriate mounting and handling to ensure proper electrical and thermal performance as well as achieving a reliable mechanical situation.

Contact Information

For more information on this topic, contact the Littelfuse Power Semiconductor team of product and applications experts:

- North America – NA_PowerSemi_Tech@Littelfuse.com
- Central & South America – CSA_PowerSemi_Tech@Littelfuse.com
- Europe, Middle East, & Africa – EMEA_PowerSemi_Tech@Littelfuse.com
- Asia, Australia, & Pacific Islands – APAC_PowerSemi_Tech@Littelfuse.com

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1. Introduction

High-power semiconductors appear to be robust and durable parts at first sight. Despite this robust appearance and the high forces applied to the components during mounting, care must be taken to assemble the components in a suitable manner. Major factors for a successful design include the treatment of all contact surfaces involved, the thermal management, and a mechanical construction that leads to a homogeneous pressure distribution.

2. Disc Devices

As the name implies, disc devices are of circular shape. The housing consists of cylindrical ceramic; upper and lower covers are made from metal and act as electrical contacts to the semiconductor inside. Diodes in this package only feature the power terminals while thyristors, IGBTs, or GTOs have additional terminals for control. A schematical overview is given in **Figure 2**.

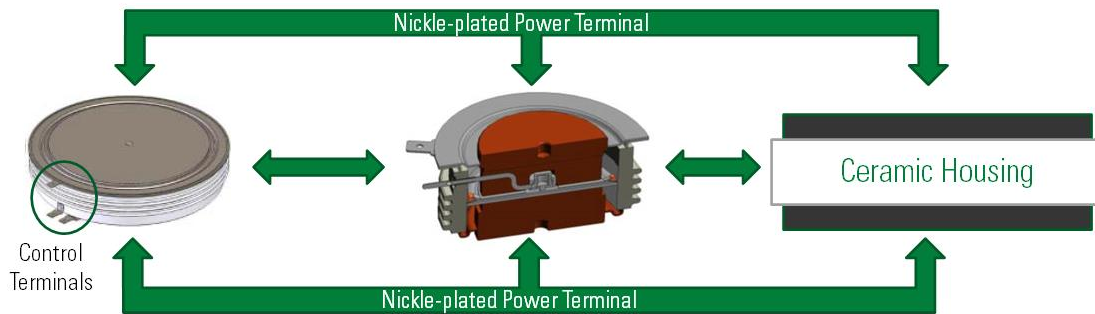


Figure 2. Schematical Overview of Disc Devices, Internal Construction, and Simplified Representation

In contrast to power modules with screw-type terminals, disc devices are contacted purely by pressure which is why they are also referred to as press-packs or capsule types.

2.1. Surface Requirements when Mounting Disc Devices

When using disc devices, the contact area fulfills two functions. It acts as an electrical contact to carry current and at the same time carries the thermal energy to allow proper cooling. As the contact area's partner can be both, heat sink and bus bar at the same time, it is important that these interfaces maintain a stable contact throughout the lifetime of the equipment to ensure reliable operation of the device. Both, the surface geometry, and the surface finish are important factors to be considered. For ease of understanding, heat sink or busbars are considered contact blocks throughout the remaining document. To ensure a low value of thermal resistance, the contact surface of the contact block must be flat, even, and clean. For the mounting area, the surface quality must achieve or exceed the values given in **Figure 3**.

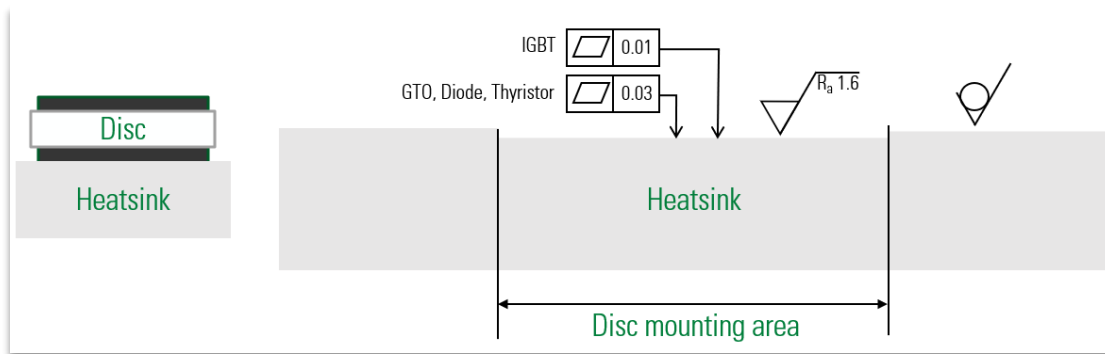


Figure 3. Contact Block Surface Requirements to Mount a Disc Device

In case the contact block is mounted between two discs, the contact surfaces on both sides must achieve parallelism as sketched in **Figure 4**.

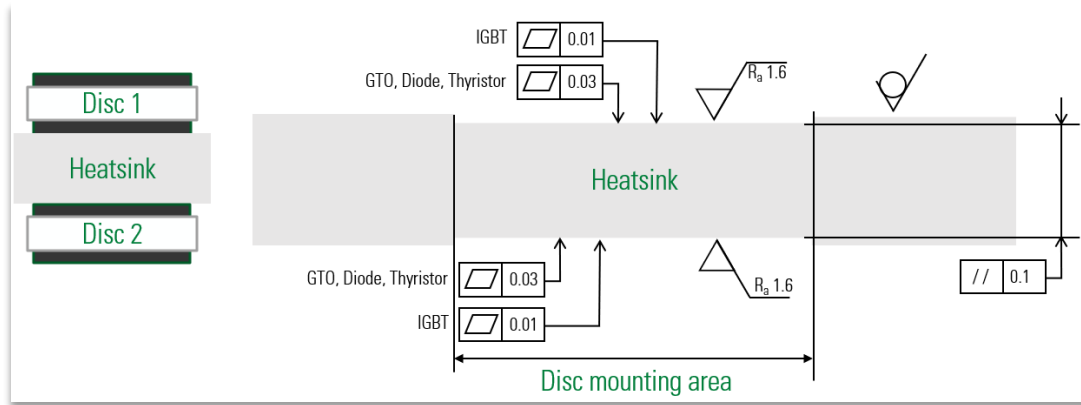


Figure 4. Contact Block Requirements When Discs are Mounted on Both Sides

Measuring the flatness of an IGBT’s surface in unmounted condition may return values that exceed those specified when being clamped. This is expected because of the component’s assembly technology and processes. In no way does this reflect or impact the device flatness once it is clamped to the nominal force.

It is also important to ensure that all components in a stack deform only elastically. A flatness exceeding the maximum specified may result if plastic deformation of the contact surfaces occurs under loading. One example where such effects can potentially be observed is a local collapse of heat sinks. Loss of reliability or lifetime can be a consequence of such an effect.

2.2. Surface Treatment

All contact surfaces should be clean and dry prior to assembly. If necessary, non-plated contact surfaces like these from extruded aluminum heat sinks should be lightly abraded to remove oxide films. A proper tool to do so is a rotary wire brush equipped with a suitable contact grease like Jet-Lube SCX13 to form a slurry. Note that the slurry produced by the abrasion should be left on the contact surface until the device is ready to be mounted. This helps to prevent oxidation of the surfaces. Alternatively, polishing the surfaces using 3M Scotch-Brite™ or a similar product can be considered. Right before conflatting, the contact surfaces should be cleaned using ethanol or a similar solvent and a lint free cloth. The different steps of this procedure are depicted in **Figure 5**.



(a) Contact grease is applied to the surface sparingly

(b) Abrasion of the heatsink using contact grease and rotating wire brush

(c) Cleaning the surface right before mounting the disc

(d) Mounting surface, lightly abraded

Figure 5. Surface Preparation Sequence

Regarding the power semiconductor or heat sinks with plated surfaces, no further mechanical preparation is required. Cleaning with a suitable cleaning agent prior to mounting is advised to make sure that no particles remain on the surface.

In order to maintain a good electrical connection and avoid corrosion over time, Littelfuse recommends that all non-aluminum contact surfaces be nickel-plated. Chemical plating is preferable to electroplating in high reliability applications. Plating thickness should be 4-6 µm in accordance with that applied to the device or module.

Prior to mounting, a tiny amount of contact grease is applied to the power terminals of the press-pack homogeneously. In contrast to modules with isolated base plates, this grease must enhance the transfer of thermal energy but may not hinder electric current to flow. Therefore, materials like Jet-Lube SCX13 with metallic particles are used. With some experience, the application can be done with a rubber-roller, as depicted in **Figure 6**.



(a) Applying a very small amount of contact grease with a roller



(b) The result is a very thin, homogeneous layer

Figure 6. Applying Contact Grease by Roller and Inspection of the Result

Once the mounting force is applied, only the material necessary to fill microscopic gaps between the contact surfaces remains. Excess material is pressed out and forms a small bead around the semiconductor's perimeter. To get familiar with the process and gather experience, unmounting the disc can be done to inspect the result.

The mounting area should appear almost clean and a small bead with a line width of about 0.1 mm should remain, as seen in **Figure 7**.

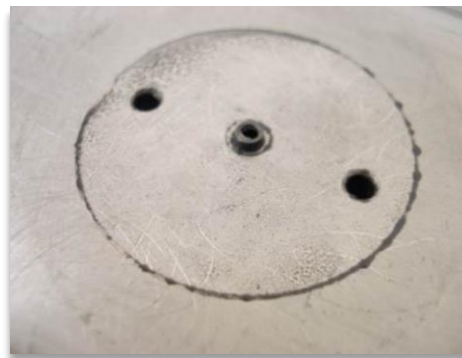


Figure 7. View After Unmounting the Device. A Bead Remains While Mounting Area Appears Almost Clean

Important: This inspection is just to get familiar with the process. Once the device was removed from the heat sink, thorough cleaning of the contact surfaces is mandatory and new contact grease needs to be applied. Putting the device back in place after unmounting is not recommended!

2.3. Applying the Assembly Force

It is mandatory, yet not trivial, to set up a mechanical fixture that applies the necessary mounting force and achieves a homogeneous distribution at the same time. Littelfuse offers a variety of proven clamp systems to support the construction of high-power semiconductor applications. Size and shape depend on the individual requirements of the application, the size of the component in use, and how many components need to be combined. Common ground for all the designs is the target of applying a proper force and spreading it to the semiconductors in a suitable manner.

The force must be applied perpendicular to the semiconductor’s surface. In theory, an even distribution is achieved by applying the force to a single point aligned with the center line of the semiconductor and using suitable mechanical means to spread the force to the available contact area. A schematical overview is seen in **Figure 8**.

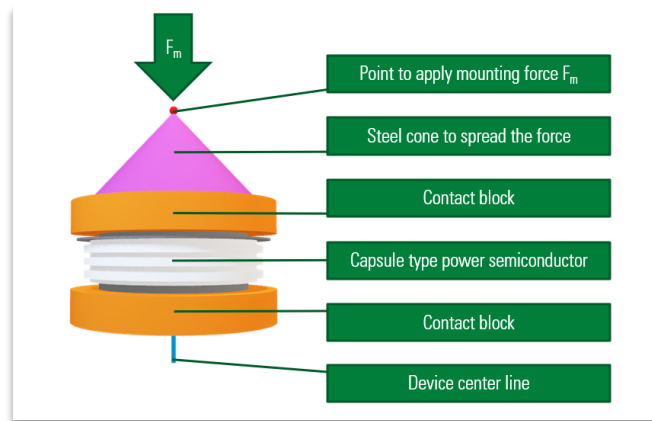


Figure 8. Spreading the Mounting Force to Uniform Distribution

To properly spread the applied force, the cone’s diameter must match the semiconductor’s diameter and the point angle must not exceed 90°.

2.3.1. Side-by-side Mounting

Depending on the topology to be built, either parallel or anti-parallel connection of power semiconductors may be necessary. Slight variations in the components’ dimensions due to tolerances might lead to unnecessary mechanical stress if two devices are clamped using a single bracket. When combining devices with different height dimensions, spacers would be needed to achieve parallel arrangements which would make the design unnecessarily complex. **Figure 9(a)** holds an example where tilting angles due to different dimensions can lead to high mechanical stress to the disc’s rims. **Figure 9(b)** displays an illustration with the preferred setup that inherently decouples the mounting forces and is also well-suited to combine devices with different geometries.

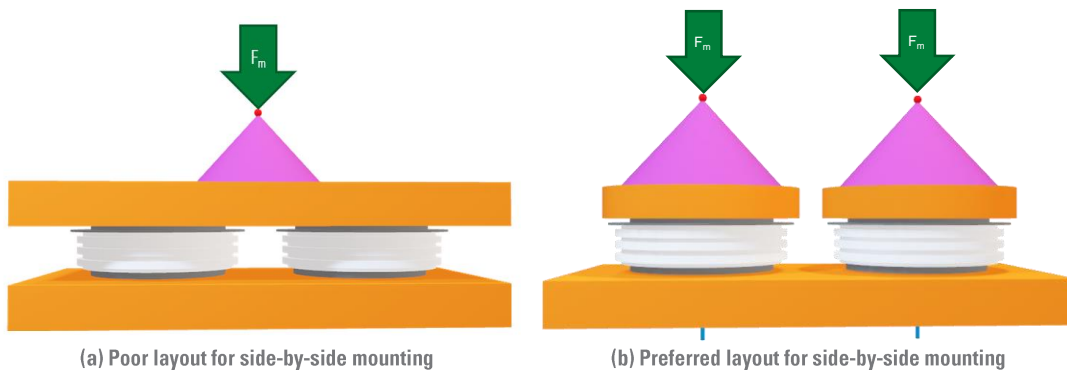


Figure 9. Mounting Two Devices Side-by-side on a Common Carrier

2.3.2. Stacking Disc Devices

In high-power applications, it is very common to stack devices either to form the desired topology or to achieve higher blocking voltages. As an example, the image in **Figure 10** represents a diode arrangement, capable of blocking 90 kV. Due to specific application requirements, no heat sinks are needed in this design.

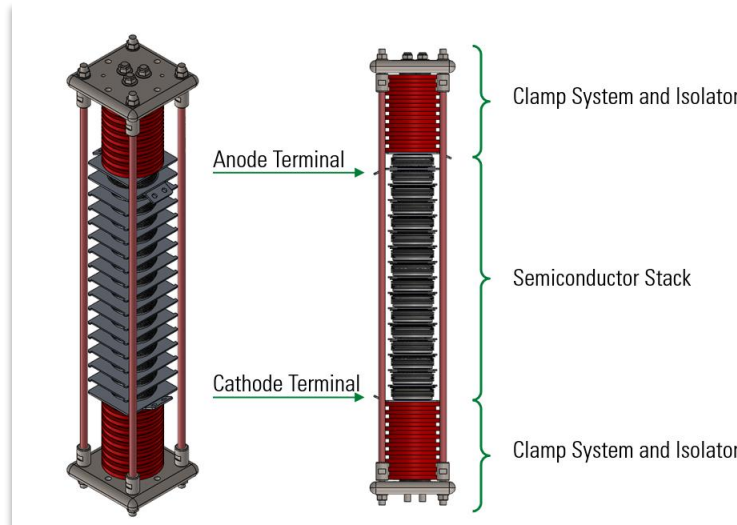


Figure 10. Stacked Diode Arrangement Using Littelfuse Clamping System

Stacks formed from more than just two devices required special attention during construction and assembly. Stacking several identical devices as in the given example is the most basic approach. When combining different devices, their mounting forces must be compatible. This prevents single devices from being overstressed or receiving an unsuitable low pressure. It is also favorable if the diameters of all press-packs involved are in a similar range. During assembly, the mounting direction of the discs is defined by the topology to be built. Attention needs to be paid to mount the discs with the correct orientation.

To facilitate the center alignment, press-packs feature centering holes on both the power terminals. In combination with a corresponding pin, this can be used to precisely align the devices to their central axes. Mechanical holders that align the discs during assembly can also be considered.

As the exploded view in **Figure 11** demonstrates, Littelfuse can supply kits, parts, and complete assemblies to speed up development of stacks.

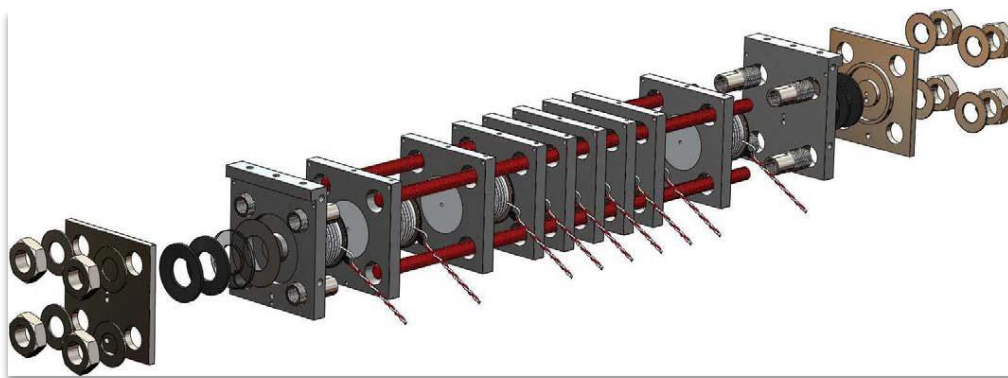


Figure 11. Clamps, Rods, Heatsinks, and other Mechanical Components for Stack-Assemblies

2.3.3. Design Verification

A homogeneous pressure distribution is a mandatory prerequisite when mounting disc devices as uneven distribution leads to accelerated aging of the components with a risk of premature failure. The pressure distribution is a consequence of properly designing and assembling the stack. As it cannot be measured or monitored in every stack, the mounting procedure and the stack’s clamp system need to be defined in a way that ensures a suitable result by design.

A verification of the design needs to be done by monitoring the pressure in a fully assembled system. There are two potential methods of achieving a robust statement regarding pressure distribution.

Littelfuse recommends the use of Fuji Prescale film or a similar film product to confirm the pressure uniformity. These films are available in several different pressure ranges and should be inserted between the semiconductor device and the corresponding contact block. Once pressure is applied to an area of the film, the material irreversibly changes color to indicate the local pressure.

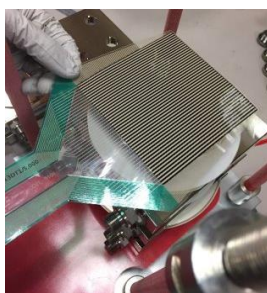
The pressure distribution achieved with a given setup can be judged by disassembling the stack and inspecting the film. Uniform color change signals uniform pressure. A suitable pressure distribution and a non-uniform result are summarized in **Figure 12(a)** and **Figure 12(b)** respectively.



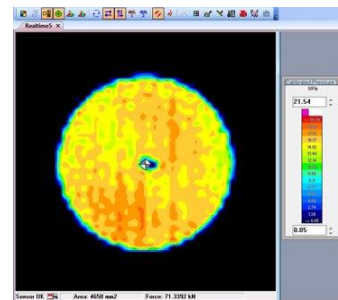
(a) Exemplary results showing uniform pressure distribution (b) Poor results, revealing highly non-uniform pressure distribution

Figure 12. Results from Inspecting Pressure Distribution Using Color-Changing Film

The second option is to use pressure sensitive electrical sensor arrays. These consist of a matrix of pressure-sensitive resistors that can be measured by dedicated equipment. The result is displayed as a color-map. In contrast to the irreversible color change of the film, these sensors allow monitoring in real-time and can be reused. A common sensor and a typical result from such a measurement are included in **Figure 13**.



(a) Sensor Matrix gets inserted between devices



(b) Dedicated software enables visualizing the captured data

Figure 13. Piezo-electric, Tactile Pressure Sensor, and Captured Results

Both the sensor types need to be removed from the stack as they would prevent proper electric function. As this comes with releasing the pressure in the assembly, re-applying the force after removing the sensor is necessary. The result demonstrated by the measurement can substantiate that the chosen assembly technique reproducibly leads to the correct magnitude of force and to homogeneous pressure distribution.

2.4. Isolation Coordination

High-power applications typically come with high voltages, making isolation coordination an important issue in protecting hardware and people. Clearance and creepage distances for high voltages need to be considered. Correlating information can be derived from the relevant standards, particularly IEC 60664-1 and UL840.

2.5. Thermal Management Details

The power sections built by disc devices typically reach outstanding efficiency values. Given the amount of energy handled, the absolute value of losses that appear require proper considerations. In general, three types of use-cases can be identified:

- Pulse power applications where energy is handled in a time frame well below a single second. In these cases, the thermal capacity of the material involved may be large enough to absorb the thermal energy without exceeding the technological limits. If so, additional heat sinks turn out to be obsolete.
- Assemblies that need to dissipate a moderate amount of heat which can be done by forced air cooling using extruded aluminum heat sinks.
- Challenging applications with restrictive power-density requirements that can only dissipate the heat with advanced liquid cooling systems.

With press-packs, the cooling systems inevitably makes galvanic contact with electrically life parts. To prevent malfunction or even catastrophic failure, it is important to ensure galvanic connectivity is only present where device terminals share a common voltage node within the intended circuit. Particularly in liquid cooling, cold plates are mounted between the electronic devices. Electrically, each cold plate has a different voltage level while all of them are connected by sharing the same cooling liquid, as sketched in **Figure 14**.

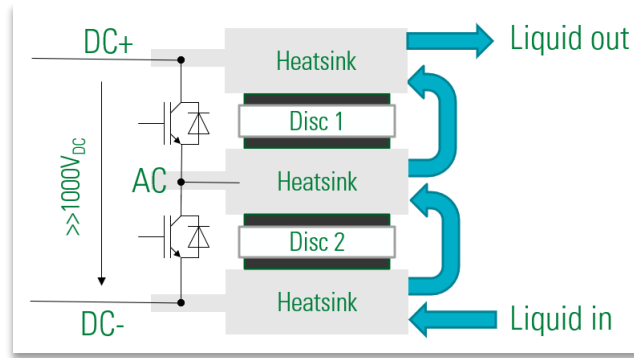


Figure 14. Basic Two-Level Phase Leg with Liquid Cooling

The use of a common cooling liquid requires that neither the cooling liquid itself nor the tubes in use may be electrically conductive. A suitable setup can be achieved using plastic tubes instead of metal parts and a mixture of 80% de-ionized water and 20% glycol ethylene as a cooling liquid. For the same reason, grounding the heat sinks is not an option!

3. Conclusion

Disc-, capsule- or press-pack-devices are key components in high-power electronics in a broad spectrum of applications and use cases. Despite their robust appearance, these components are challenging in terms of handling and mounting. Building and verifying a power section based on disc devices can best be done by applying proven mechanical concepts and components. Mastering the mechanical, thermal, and electrical challenges is a prerequisite to achieving long-lasting, reliable, and efficient designs. As there are plenty of standardized solutions for different applications that potentially can be customized to particular needs, a primary evaluation should consider whether acquiring a ready-made system solution could be the better option.

For additional information please visit www.Littelfuse.com/powersemi

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