USER GUIDE PRD-07745

XM Module Platform Mounting Guide

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This document provides guidance on how to install or mount the Wolfspeed® XM power modules to a cold plate and how to design and construct the mechanical system in which the module will be placed. This document does not describe how to operate the system once these steps are taken.

Contents

CAUTION

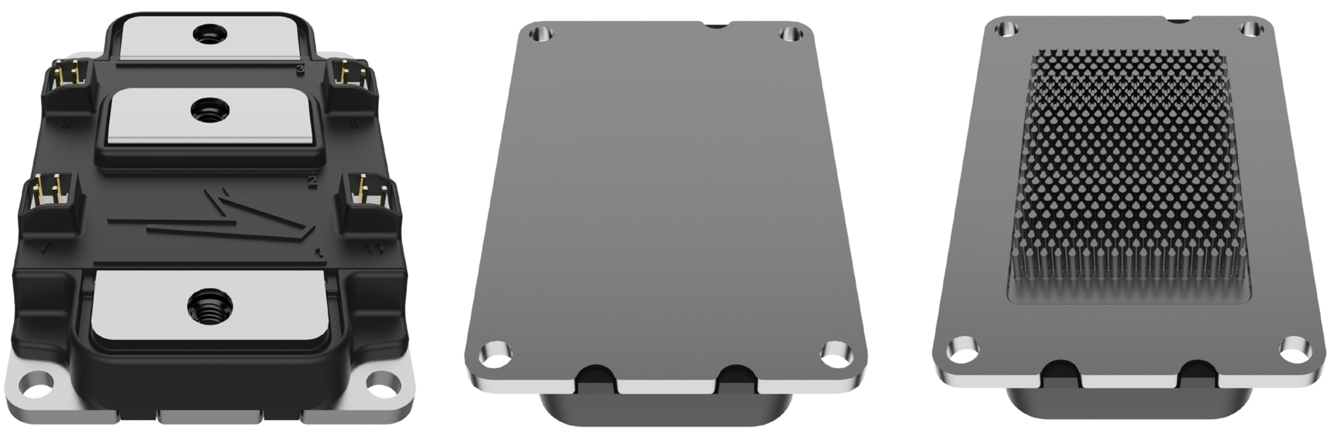
Before operating the system, please carefully review the operating limits Wolfspeed's XM Half-Bridge Modules set forth in the datasheet located at www.wolfspeed.com or available upon request, and please ensure that appropriate safety procedures are followed when working with the system. There can be very high voltages present in the system when connected to an electrical source (and thereafter until applicable capacitors are fully discharged), and some components in the system can reach very high temperatures. Serious injury, including death by electrocution or serious injury by electrical shock or electrical burns, can occur if you do not operate the module within its operating limits or follow proper safety precautions.

1. INTRODUCTION

This document provides guidance on how to properly mount Wolfspeed® XM power modules and design a system that maximizes its performance and reliability. When mounted, the power module must be securely held in place, while not exceeding the baseplate mounting hole and power terminals force ratings. Similarly, the module's gate driver should be firmly attached to a rigid surface to ensure that it remains in place, while not placing excessive force on the signal pins of the power module it is attached to. Furthermore, the bussing attached to the power module must not induce excessive stress on the module's power terminals. Following the guidance described in this document is recommended to ensure proper mechanical mounting of the XM power module.

1.1 Scope

This document applies to the XM power module platform shown in Figure 1 (a). XM power module products can be identified by the presence of 'XM' in the final 3-4 digits of the part number, such as the CAB400M12**XM**3 or EAB450M12**XM**3. The XM power module platform also has two variations, a flat baseplate model shown in Figure 1 (b) and a pin-fin baseplate shown in Figure 1 (c). The pin-fin module offers better thermal performance and does not require the use of thermal interface material (TIM) but requires more advanced cooling designs. The type of baseplate can be identified by the letter after the module current rating in the part number. An 'M' indicates that the module is a flat-baseplate module, and an 'F' indicates that the module is a pin-fin module. For example, an EAB450**M**12XM3 would be a flat baseplate model, and an EAB525**F**12XM3 would be a pin-fin baseplate model. The mounting procedure for both model variants will be discussed in this document.



(a) (b) (c)

Figure 1: XM power module platform, (a) XM module top view, (b) standard flat baseplate model, (c) pin-fin baseplate model

2. COLD PLATE MOUNTING

Cold plates are necessary to remove heat from the die during operation and maximize the module's performance. Minimizing the thermal impedance between the module baseplate and the cold plate will further improve performance by allowing operation at higher power levels and reducing the die junction temperature. In this section, the cold-plate mounting procedure for both the standard flat baseplate and pin-fin baseplate XM modules will be discussed.

2.1 Flat Baseplate XM Module with TIM

The XM module with a flat baseplate should be adhered to a cold plate using a thermal interface material. Before applying the TIM, it is important to make certain that the contact surfaces—the cold plate mounting surface and module baseplate—are clean and free from any type of debris. This can be achieved by using an alcohol based cleaner and a lint free cloth. Another important parameter to consider when selecting a proper cold plate is the roughness of its surface. Any cold plate surface will have imperfections in the surface finish that will cause void regions to develop in the contact region between the module and the cold plate. Thermally conductive material should be used to fill these void regions. To ensure the filling of these voids and to minimize the thermal impedance, it is recommended to select a cold plate that meets the requirements listed below and in Figure 2. It is recommended to apply the TIM using a stencil with 0.006" thickness and stencil fixture, as described in the TIM material application user guide, Document PRD-07933, located at www.wolfspeed.com or available upon request. Following the application of the TIM, the module baseplate should be attached to the cold plate using the procedure described in section 2.3.

1. Surface flatness ≤ 25.4 µm per 25.4 mm (DIN EN ISO 1101)
2. Surface roughness R_z ≤ 10 µm (DIN EN ISO 4287)
3. No steps > 10 µm (DIN EN ISO 4287)

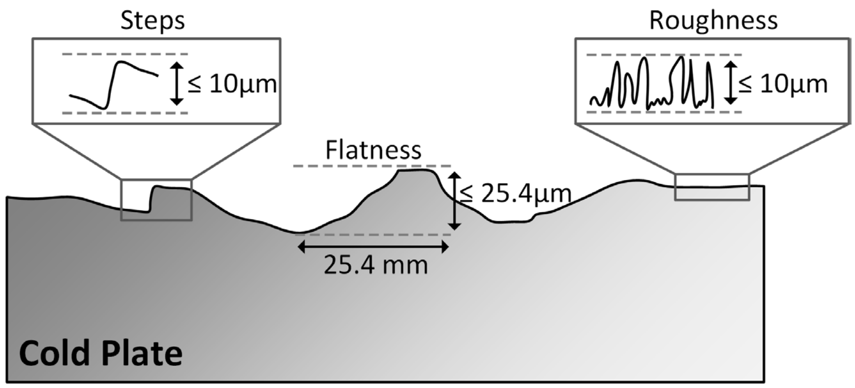


Figure 2: Required cold plate surface tolerances

A recommended cold plate for flat-baseplate XM modules is the CP 4012 aluminum friction stir welded cold plate shown in Figure 3. This cold plate has been optimized for XM power modules and uses micro deformation technology to allow for very low thermal resistance. Refer to the Wieland CP4012 datasheet for more information [1].

Figure 3: Assembly of direct-cooled XM modules mounted on a CP4012 cold plate

2.2 Pin-Fin Module

Wolfspeed® XM pin-fin power modules offer excellent ampacity due to its advanced thermal interface and dense packaging. The pin-fin baseplate XM module shown in Figure 4 is compatible with direct-cooled thermal solutions that offer better thermal performance over a TIM approach. The reduced thermal impedance allows for operation at higher power levels and better reliability. The pin-to-pin spacing has a minimum distance of 0.65 mm edge to edge and are designed to be in direct contact with the coolant. The pin shapes are designed to balance pressure drop and have anti-clogging characteristics to improve performance.

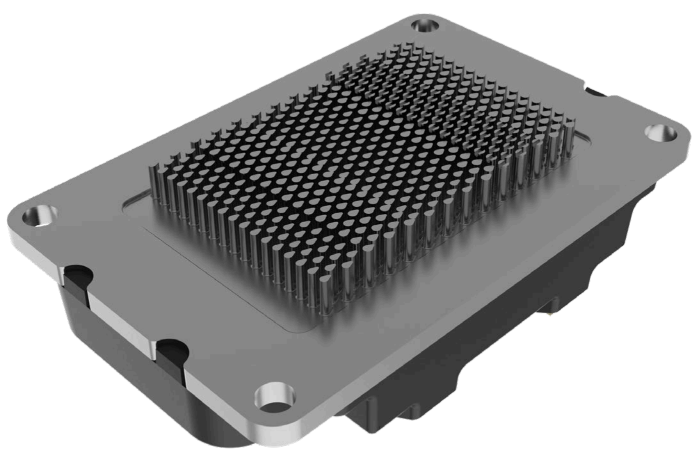


Figure 4: Bottom view of a direct-cooled XM module showing its pin-fin structure

The XM pin-fin power module is compatible with a Wieland MicroCool CP 4012 Oring Tub cold plate, shown in Figure 5. The CP4012 cold plate uses micro-deformation technology, which is a manufacturing method for creating pin surfaces for use in heat transfer applications. The micro-deformation pins are designed to create turbulence so the cooling water supply can only flow in one direction to allow very low thermal resistance, low pressure drop and balanced parallel flow.

The cold plate has interior coolant channels and machined cavities that the baseplate sits inside, allowing the coolant to pass through the pins and has an O-ring seal to prevent leaks. The cooling water supply goes in the mid terminal passing directly through the pins and comes out from the V+ terminal of the module. Refer to the Wieland CP4012 datasheet for more information [2].

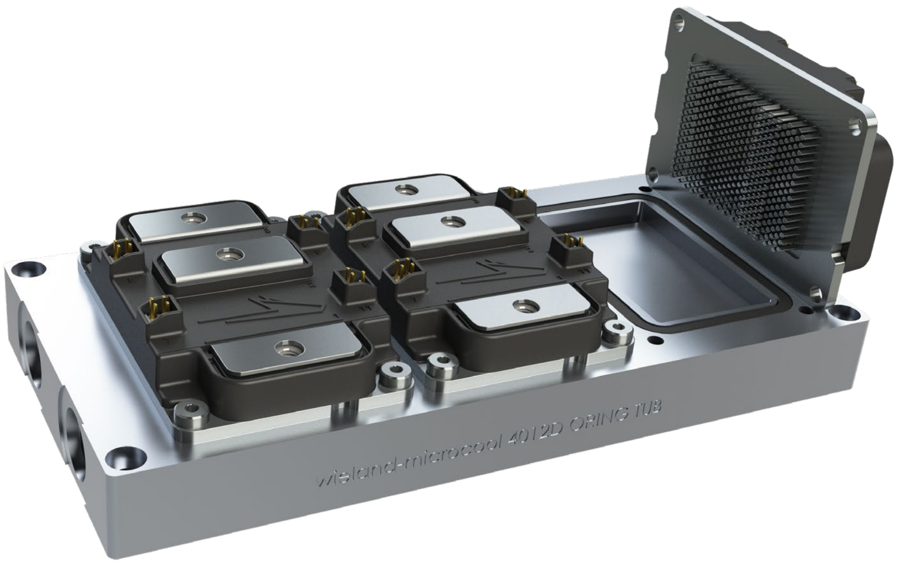


Figure 5: Assembly of direct-cooled pin-fin XM modules mounted on a CP4012 O-ring tub cold plate with chamber and gasket exposed

The O-ring used in the direct-cooled cold plate is the Oil-Resistance Buna-N O-Ring available from McMaster-Carr with part number 9262K314 with 3 mm wide and 63 mm ID (internal diameter) and Buna-N Rubber material. Refer to Figure 6 for a dimensional diagram of the O-Ring.

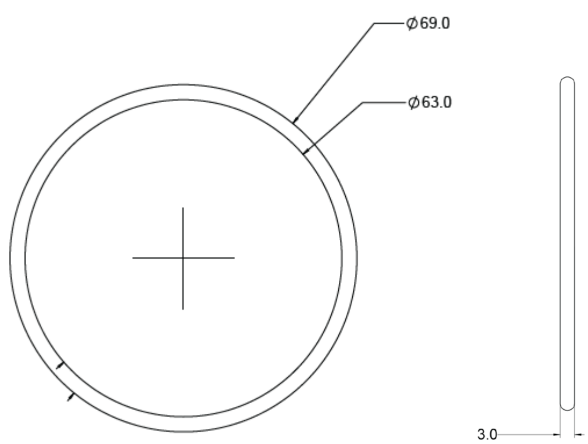


Figure 6: Oil-resistance Buna-N-O-ring (units in mm)

To install the O-ring seal, first carefully place the O-ring seals into the groove of the cold plate. Then, align the XM module with the machined cavity and mounting holes. Install the washers and fasten the M5 bolts until finger tight. Then, slightly tighten each of the four bolts evenly until a torque value of 3 Nm is reached.

2.3 Bolt Tightening Procedure

Carefully align the mounting holes and place the module onto the cold plate taking care not to slide the module around. Install the washers and thread in the M4 bolts until seated finger tight. Following Figure 7 and using a torque wrench, tighten the bolts in the sequence described below until the desired torque is reached. The recommended torque for the XM is 3 N-m.

1. Torque bolt number: 1 – 2 – 3– 4 to 1/3 final torque
2. Torque bolt number: 3 – 4 – 2 – 1 to 2/3 final torque
3. Torque bolt number: 2 – 1 – 3 – 4 to final torque

Figure 7: XM bolt pattern reference

3. POWER TERMINAL MOUNTING

The power terminals of the XM are designed for DIN M5 bolts (class 6.8 minimum) tightened to 4 N-m. The engagement depth of the screw into the power terminals must not exceed the maximum penetration depth of 5.50 mm, which is found in the XM Module datasheet located at www.wolfspeed.com or available upon request and depicted in Figure 8. Exceeding the rated torque may result in significant damage to the power module.

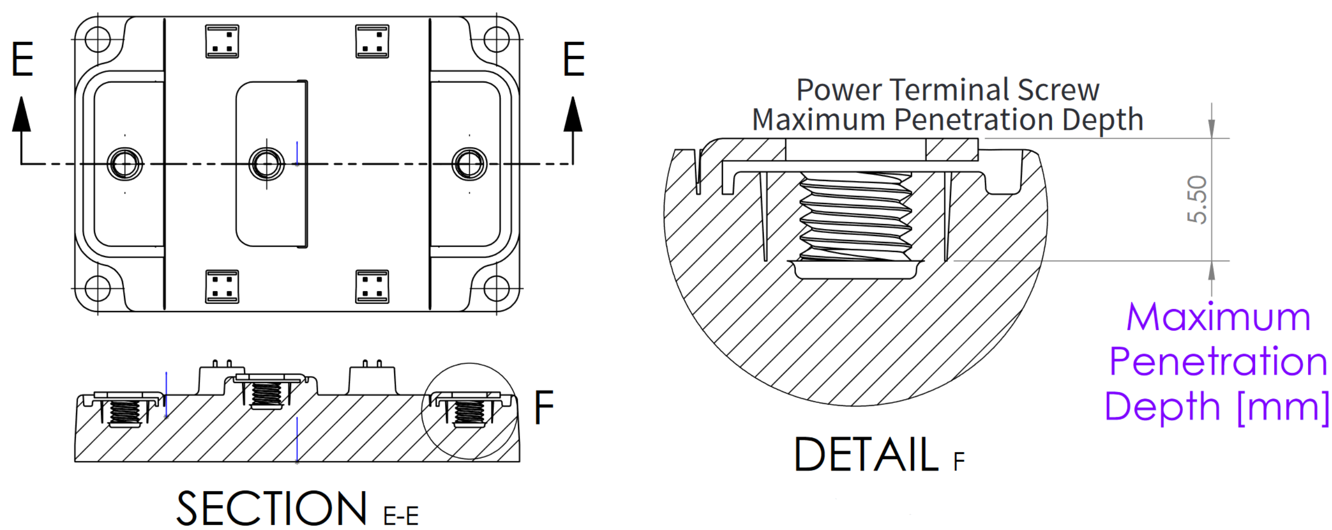


Figure 8: Power terminal maximum penetration depth

The power terminals of the XM module are threaded for M5 bolts. As such, the mounting hole in the bussing that is attached to the module should be as close to the standard M5 clearance hole of 4.5 mm as possible, given the tolerances in your system. Exceeding the standard M5 clearance hole size may result in damage to the power terminals of the module. An example of power terminal damage caused by improper bussing hole size is shown in Figure 9.

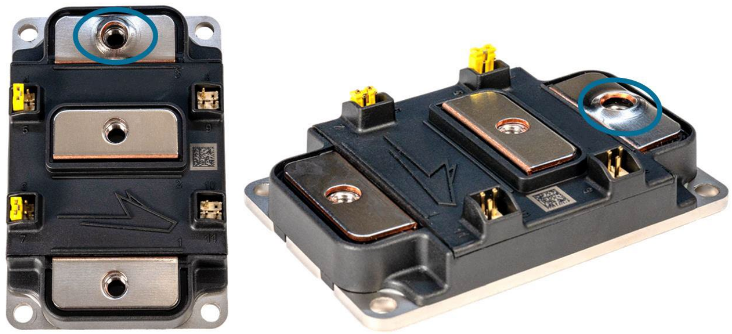


Figure 9: Damage resulting from improper bussing hole size

3.1 Example Mounting Design

When mounting the XM power modules into an application, the mechanical structure of the system should be scrutinized to ensure that the bussing connecting to the power terminals 1) does not place excessive shear force on the power terminals and 2) limits the possibility of forces pulling the terminals away from the module. This is particularly important for systems that may be subject to shock and vibration conditions. For additional information on provisions for vibration, refer to section 5.

An example of a properly designed system using XM power modules are the Wolfspeed® XM3 Inverter Reference Design Kits. A render of the XM3 inverter reference design is provided in Figure 10. The design of the bus bars ensures that no shear force is exerted on the terminals, and the rigid vertical structure of the system between the bussing, capacitors, cold plate, and module ensures that the power terminals will always remain in tension (pushing down on the module).

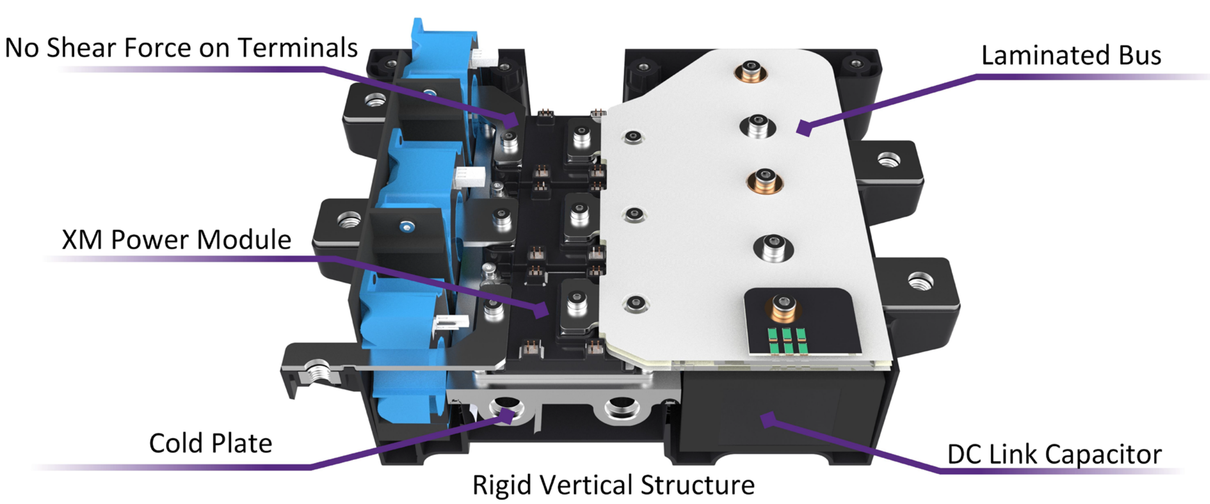


Figure 10: Wolfspeed XM3 inverter reference design: XM module mounting

4. SIGNAL TERMINAL MOUNTING

The XM power module signal terminals are interfaced with a 2x2 stacking header with 0.100" pitch. A top-down view of the XM power module and the 2x2 header pin dimensions are provided in Figure 11. A compatible female header must be used to attach the gate driver (or PCB) to the signal pins. For each 2x2 connector, it is important to interface with all four pins. Failure to do so may result in damage to the module or reduced performance. This section will provide guidance on selecting and mounting an appropriate header to interface with the XM power module signal pins.

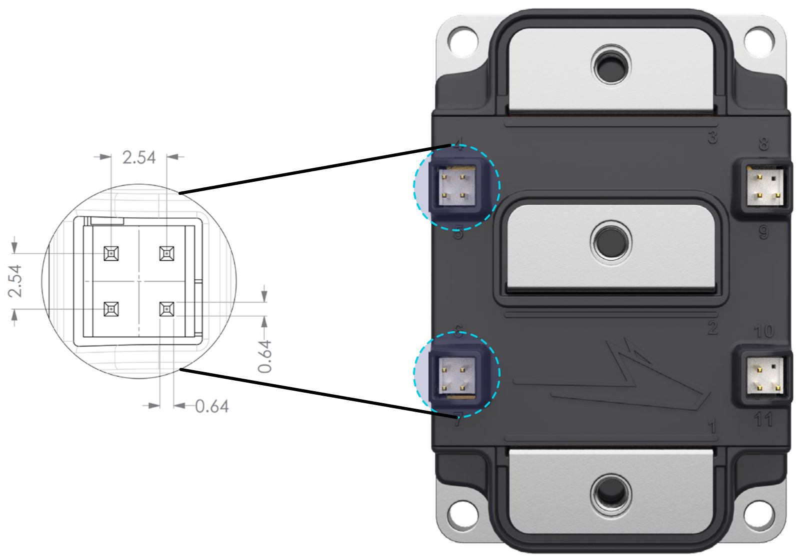


Figure 11: XM signal terminal locations and dimensions (all units in mm)

4.1 Signal Terminal Header Requirements

A dimensional 3D render of the 2x2 signal pin header used in the XM power module is shown in Figure 12 (a). The recommended receptacle for interfacing with this connector is the Samtec® ESQ-102-33-L-D-LL header shown in Figure 12 (b). If an alternative receptacle must be used, ensure that its minimum rated engagement is less than 5.46 mm. The widths of the receptacle (see d1 and d2 in Figure 12 (b)) must be less than 5.8 mm to ensure that it can press into the signal pins without interfering with the XM module housing.

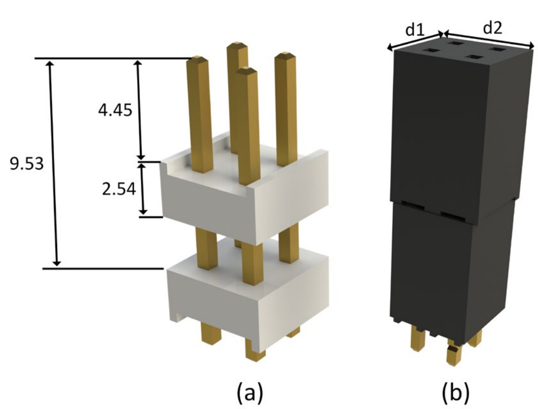


Figure 12: XM signal headers, (a) XM signal pin header embedded within XM power module, (b) recommended Samtec ESQ-102-33-L-D-LL header for attaching to the XM signal pins. Not to scale. All units are in mm.

4.2 Signal Terminal Maximum Engagement and Vertical Tolerances

It may be necessary to consider the vertical dimensions and tolerances of the XM module to ensure that the module, gate driver, and bussing assembly will work in production processes. A side cut out view of the XM module with pin engagement specifications for the signal terminals is provided in Figure 13. On the left, the 18.26 mm ±0.30 mm dimension is critical because it defines the minimum and maximum height of the XM module from the bottom of the baseplate to the top of the signal pins. In addition, the 12.5 mm MAX specification limits the engagement of the XM signal pins with the gate driver receptacle. Figure 14 demonstrates the meaning of and reason for the 12.5 mm specification. In Figure 14 (a), the XM signal pin header is embedded within the XM power module, and has a plastic piece that can freely slide up and down the signal pins. Normally, this plastic piece can slide down and lie flush with the bottom plastic piece. However, the encapsulant material may prevent the top plastic piece from sliding to that position, as demonstrated in Figure 14 (b). When slid down to its minimum position, the distance between the top face of the top plastic piece will never be greater than 12.5 mm. When designing an assembly process for a system, ensure that the specified pin engagement does not require the plastic piece to slide down beyond this position. Failure to do so may cause the assembly to fail or the module to become damaged if excessive force is placed on the signal pins. Given this, a maximum pin engagement of 5.46 mm (18.26 mm – 0.3 mm – 12.5 mm) can be consistently achieved when considering the tolerances of the XM module.

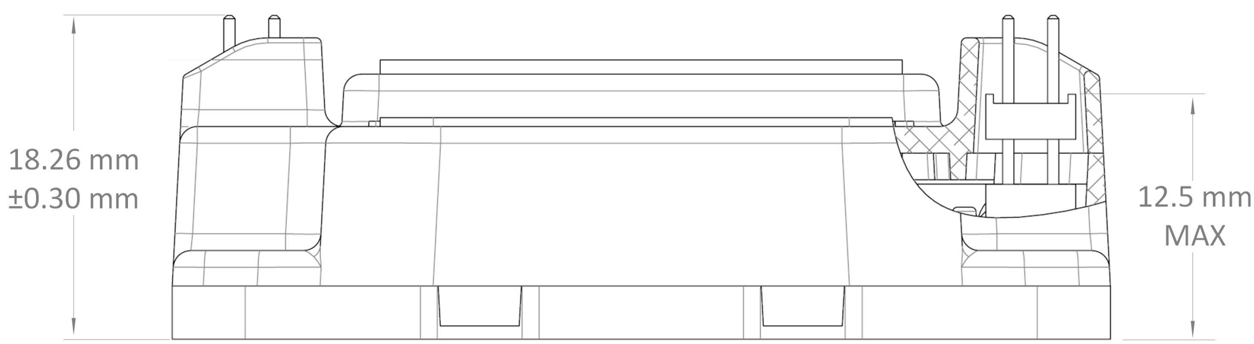


Figure 13: XM cut out view with pin engagement specifications. All units are in mm.

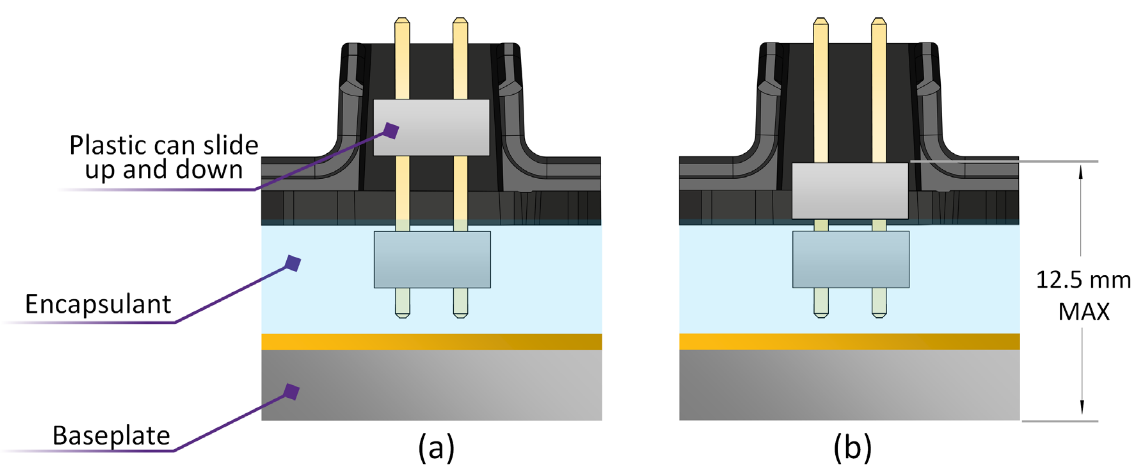


Figure 14: XM signal header engagement tolerances, cutaway of signal terminal stack-up with (a) plastic slider in its typical position, (b) plastic slider in its slid-down position

4.3 Example Signal Terminal Mounting

Similar to the power terminals, the gate driver must be mounted to the module without stressing the signal terminals. This mechanical requirement also must be balanced with the condition that the gate driver signal connector remains electrically connected to the signal pins of the power module. The best way to protect the power module signal terminals from excessive force while maintaining a reliable electrical connection is by mounting the gate driver with mechanical supports in place to provide mechanical stress relief. Just as with the bussing mechanical relief, the gate driver mechanical relief should lock the position of the gate driver relative to the power module.

A simplified cross section of the Wolfspeed® XM Inverter Reference Design Kits with the gate drivers mounted is shown in Figure 15. This example demonstrates how to use mechanical relief to support the gate driver. In the figures, the gate driver is bolted to the top piece of the enclosure, which is then rigidly attached to the modules through the link between the enclosure, cold plate, and module baseplate.

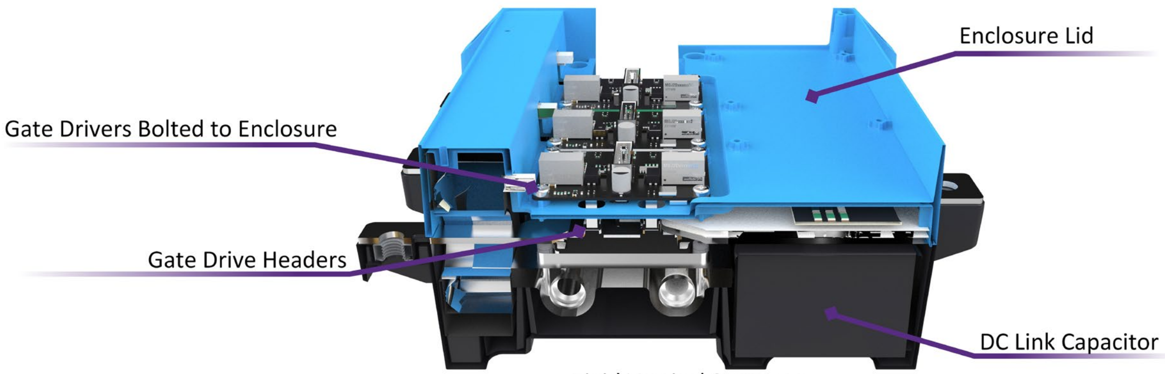


Figure 15: Wolfspeed XM3 inverter reference design: gate drive mounting

5. PROVISIONS FOR SYSTEM VIBRATION

Vibrations over time have the potential to cause a failure in any inverter. For applications where vibrations are expected, such as in vehicles, it is important to minimize the amount of force that vibrations will induce at the interfaces. The module itself is a stiff object and is subject to vibrations as part of the qualification process. However, in applications, the entire system will be subject to vibrations. This will include not only the module, but also the interfaces between the module and the system. Thus, it is crucial to understand how the vibration environment will affect the module and all its interfaces. The following sections provide guidance to maximize device lifetime in environments where vibrations are a concern.

5.1 Cold Plate Vibrations

A core point is that the power terminal and cold plate interfaces depend on bolted elements. Bolts are, in effect, stiff springs; the torque on the bolt induces a force on the threads to create friction that keeps the part fixed, as shown in Figure 16 below. A key design element is ensuring that vibration does not induce a counter force in the interface that will overcome the torque induced force, which can cause the bolt to loosen. Under all circumstances, this bolted interface must be under tension. While solutions such as lock washers, fixing compounds or bolts with inserts can be used to assist the frictional resistance, they should not be used in lieu of the above recommendation.

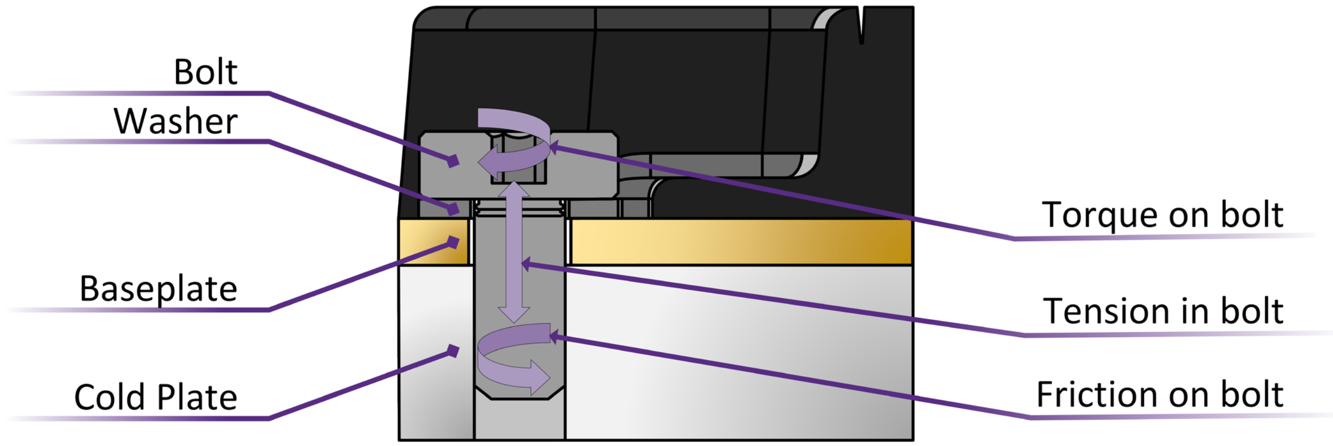


Figure 16: Side cutaway of a baseplate bolt interface.

5.2 Power Terminal Vibrations

The power terminals are made of a copper conductor with a bolted interface. The module terminal is bent down to trap a threaded nut that allows the bus to be bolted firmly to the terminal. This external power connection can be a lug on the end of a cable but in most cases will be some form of laminated copper sheets or even thick copper printed wiring board. This trapped nut and the bolt form a bolted interface requiring sufficient torque to prevent an induced vibration from causing the interface to come apart.

When the bussing is bolted to the terminal, it should not impart tension on the module terminal part that connects into the module. Instead, it should impart some compression, as shown in Figure 17, and be designed so that vibration in the system does not ever impart tension on the interface. Vibrations that cause the interface between the bussing and the module terminals to oscillate between compression and tension and is likely to lead to fatigue failure. The power interface structure needs to be analyzed across the vibration environment to ensure that they will not overcome the compressive force on the terminal.

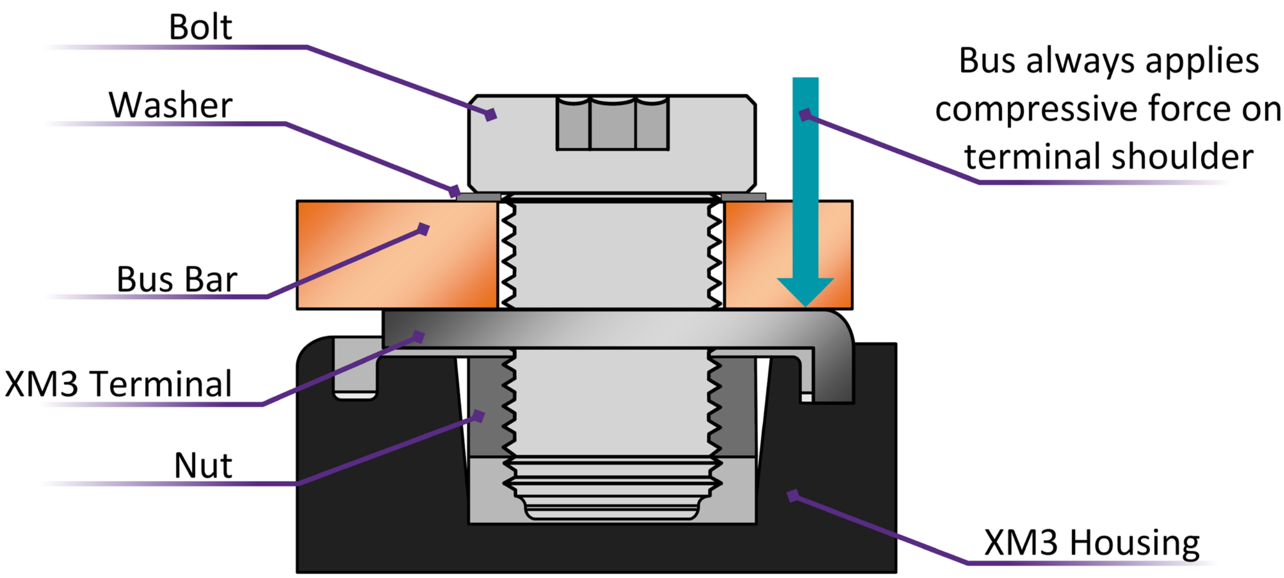


Figure 17: Side cutaway of the bolted interface between the power terminal and bus

5.3 Signal Terminal Vibrations

Like the power terminals, the signal pins are susceptible to long-term damage from vibrations. A cross sectional view of the signal pin connection interface is provided in Figure 18. The male XM gate signal pins press into the female gate drive connector pins. However, because the male XM signal pins and the female header are not locked together, vibrations in the vertical axis (along the length of the pins) can cause the pins to rub together. Over time, this will erode the metal surfaces, which can cause the connection to fail and allow corrosion. To avoid this issue, the gate driver and XM module must be fixed relative to each other such that vibrations in the system (particularly on the gate driver PCB) do not cause the pins to repeatedly slide against each other. Do not place excessive compressive force on the XM signal pins, as this may cause damage to the XM module.

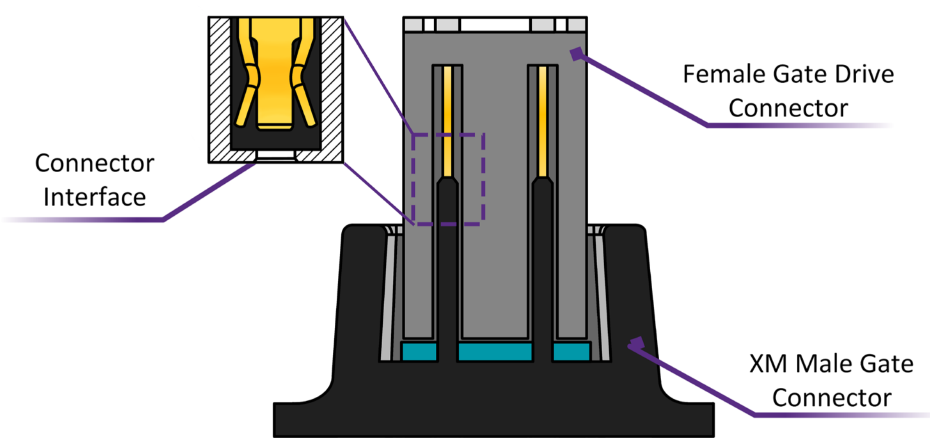


Figure 18: Side cutaway a gate connector mated to the gate pins of the XM module.

Revision History

Date	Revision	Changes
November 2019	1	Initial release
October 2023	2	Added pin-fin module mounting. Added vertical stack tolerance and provisions for vibrations.

References

[1] Wieland Microcool, "CP 4012 aluminum friction stir welded cold plate," [Online]. Available: https://www.microcooling.com/our-products/cold-plate-products/4000-series-standard-cold-plates/cp-4012/.

[2] Wieland Microcool, "CP 4012 Oring Tub," [Online]. Available: https://www.microcooling.com/our-products/cold-plate-products/4000-series-standard-cold-plates/cp-4012-oring-tub/.