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Vibration Damage Mitigation in Electronics is Key to Optimum Performance

Vibrations and intermittent shocks can disable and even destroy electronic systems unless proper measures are taken.

One of the realities of the explosive growth in the Cloud and Internet of Things (IoT) is the need for more and more advanced devices to address consumer needs, and a larger and more complex infrastructure to support those devices. This means that more electronic systems are being deployed in places and situations that are incredibly hostile to normal operation.

The automotive and military/aerospace markets have long been used to the fact that their solutions are deployed and used in environments that are very hard on any complex machine. These market spaces are full of regulations on sealing, ruggedness, and resistance to water and the environment. However, more and more products serving application spaces from medical to entertainment are finding themselves in harsh environments.

The nature of a harsh environment may not even be readily apparent. It's easy to spot a place that is muddy, wet, dusty, or otherwise visibly challenging, but not all environmental hazards show themselves readily. One of the most pernicious environmental dangers to electronics can even be found in a shirtsleeve environment, and that is vibration and intermittent shock.

Vibration damages in a variety of ways, which can be boiled down into three basic categories: wear, integrity, and connectivity. Even a device kept in a managed temperature and humidity environment can fail due to vibration-related artifacts, as they are often difficult to pinpoint, especially if it occurs on an irregular basis due to external factors. Unless addressed at every level, from the initial design to maintenance in the field, vibration issues can cause not only a loss of functionality but can even cause catastrophic failure in the system involved.

Wearing Out

Vibration is such a powerful mechanism for wear it is used in ablating devices like sanders, drills, and jackhammers. Any motion, intended or not, can create vibration and resonances that can generate extreme loads in unexpected places. These loads can create points of accelerated wear and aging in a system, from the circuit board to the packaging. This can be manifested in a variety of ways, from damage or deformation of a structural component, or even the circuit board itself, leading to catastrophic failure in some cases.

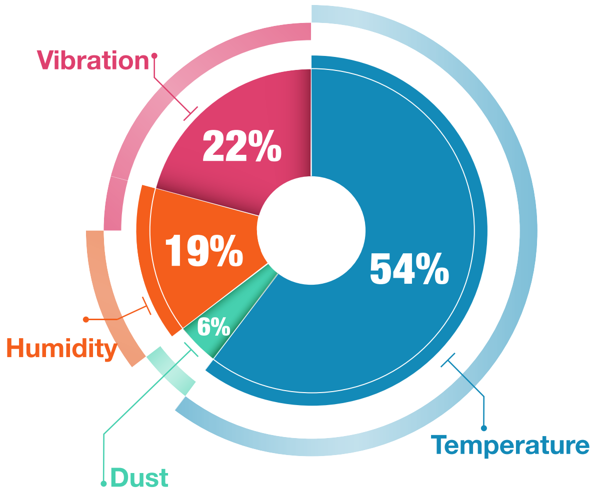


Figure 1: Vibration and shock among the most pernicious environmental dangers to electronics.

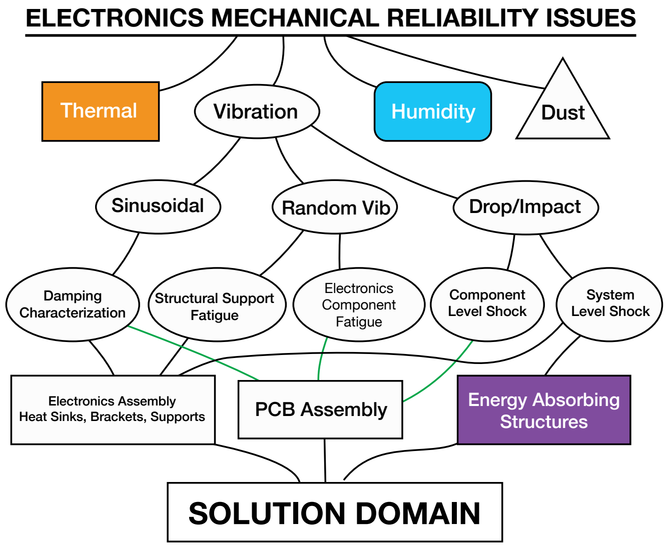


Figure 2: Vibration damage can be manifested in a variety of ways.

Figure 3: Secure fasteners ensure vibration-resistant connections.

Proper mitigation for such vibrational damage isn't an isolated fix, but rather a part of a general approach to system hardening. Some of the actions that can be taken against vibration at the board level, like thermal potting of components for example, can also address vibration absorption if semi-elastic materials are used, and the solution is spread in all appropriate areas, not just those needing it for thermal management.

A big risk from vibration and intermittent shock damage is the scalable aspect of failure. A wire bond can fail from vibration, and then the loose wire can be caused by those same vibrations to move about, creating a significant short-circuit risk with potential for catastrophic thermal runaway resulting in an electrical fire. Even if protection circuitry prevents such extreme damage, the resulting shut-off prevents the device from operating further until repaired.

Although this damage is usually thought of in the context of solder bonds, overlooked places where wear can occur inadvertently and without warning prior to failure can also be found in the cables and connectors not soldered to the board. Twisted wire, pushed-on connectors, and other non-solder means of attaching a connector or component to the circuit board can pull off and move about dangerously. Even screwed-down connectors can vibrate loose and come free.

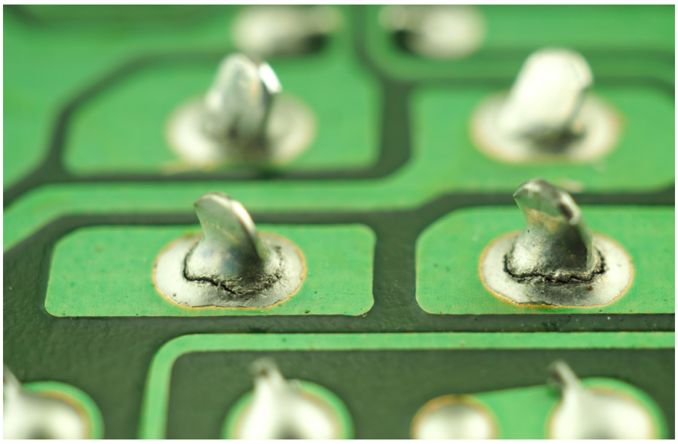


Figure 4: Vibration failure modes include solder cracks, pad lifts, and pin cracks.

At the package level, any point where flex can occur is a problem, as that is a location where excessive wear can occur. Common wear points are around joins, mounting hardware, and doors. Other locations are vias into the package, be it vents for thermal management, package openings for pass-though, and cable connection points. Any place where two or more surfaces could rub together eventually will and should be gasketed and/or padded to address this.

The areas where cables and other lines enter the package are especially vulnerable, as they can be impacted by external vibrations from the source of those wires, cables, and/or pipes. In the case of cable vias, gasketing and padding can only go so far as it can be worn through. The best solution is to have secure fasteners to ensure vibration-resistant connections. This is another solution with extended benefits, as it also aids in harsh-environment protection from dust and moisture.

Losing Contact

This leads us to how vibration can directly impact (no pun intended) a device's operational performance. Vibrational stress in cables and their vias can not only result in excessive wear conditions in the device but can also result in a loss of signal and/or power. If a cable is worn through by vibration, the results are never positive. At the very least there is a discontinuity of whatever that cable was conducting, and at worst there will be a short-circuit event that may even find ground through the device itself and create an uncontrollable thermal runaway.

Such power and signal discontinuities don't just occur at the macro level in wires, they also occur at the board level in the solder bonds. There are multiple fail modes possible when it comes to components at the point they are soldered to the board. These failure modes include solder cracks, pad lifts, and pin cracks (Figure 4). These will not necessarily cause any potential catastrophic failure (unless in concert with other issues like moisture ingress) but will result in a loss of performance at a minimum, and failure to operate at worst.

Again, mitigation efforts like potting can not only benefit the system through vibration resistance, but such methods can also address issues like thermal management and moisture rejection. Rub-throughs, cracks, and pad disconnections aren't the only discontinuity problems that can occur at that level, as inter-board connections, especially those for things like microwaves, can be easily disrupted by any gapping or shearing caused by vibration. Any terminations should be reviewed for the most rugged connection capability that can be cost-effectively applied.

Loss of Integrity

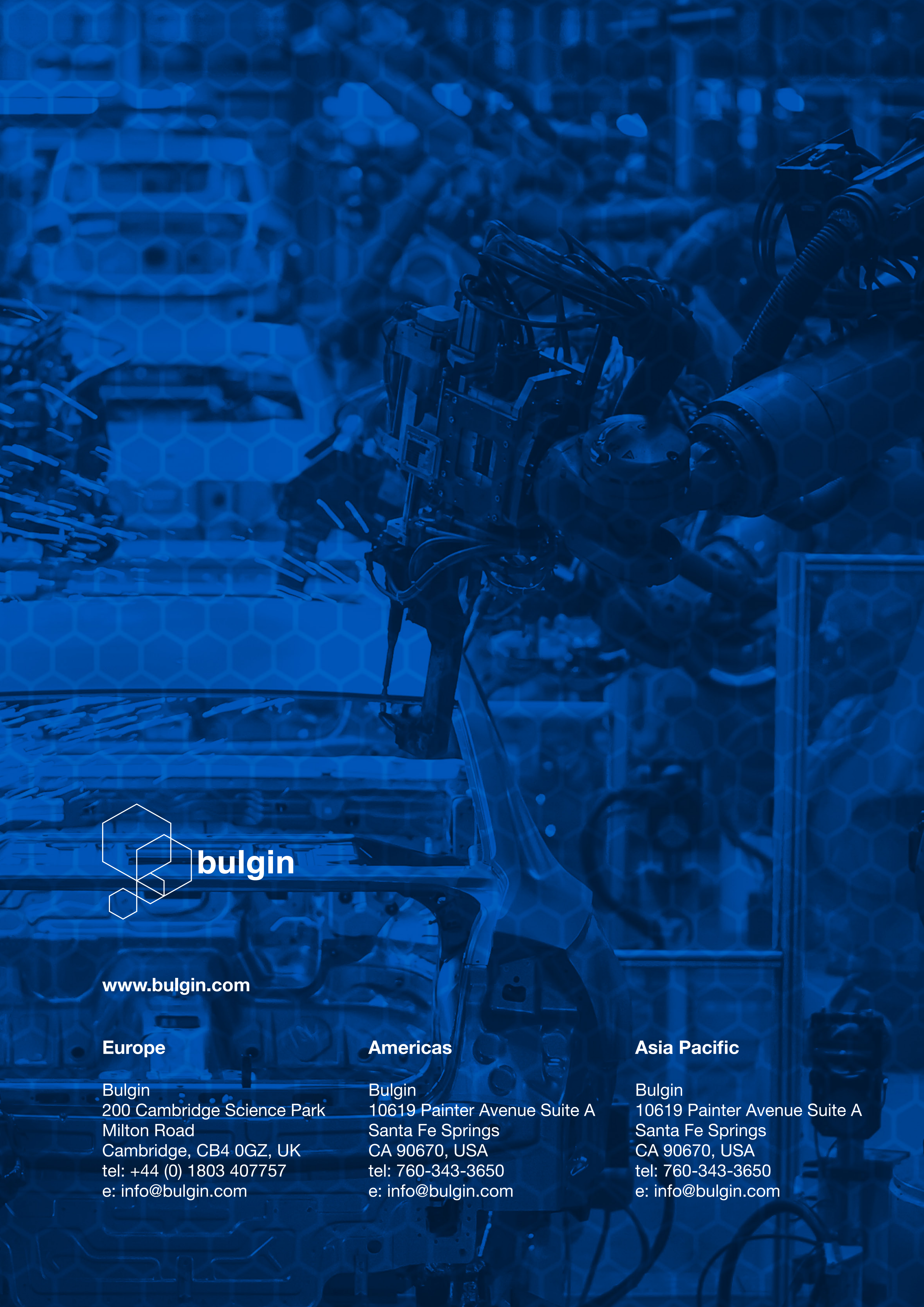
The issue of package integrity differs from the issue of package wear in that wear does not need to exist for vibration to negate a package's ability to resist the weather. Vibration and intermittent shock can create gaps in sealing between joins, cause misalignment in doors and openings, and cause delamination of surfaces. Any or all of these can lead to package permeability to water, moisture, dust, and vermin.

These issues can be addressed by increasing packaging stiffness, or reflexively, increasing package flexibility, allowing it to “ride” the vibration events with less damage to integrity. Reducing the number and kinds of openings can also help by minimizing pain points. Another mitigation approach includes hardening all cable access points, which will also simultaneously address continuity issues in said cables.

Using rugged screw-down panel connectors at all points of cable entry significantly hardens an electronic package. Again, the various mitigation efforts can be creatively deployed to leverage one another to gain maximum advantage of all benefits available. Rugged cable connections protect both the cable and the device it is serving, as well as the devices it is connected to.

Forging Ahead

Vibration is a serious, and often overlooked, risk to the proper operation of electronic systems. Potting and gasketing, using screw-down connectors, ensuring package stiffness and integrity, and other ruggedization methodologies are all complimentary when deployed properly. A layered defense works for electronics as well as for a military position. In fact, considering an electronic package as a fortress to protect may help you develop better defense methodology.



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