PLEASE READ AND UNDERSTAND THE APPLICATION NOTES AND WARNINGS PRESENTED IN THIS SECTION BEFORE PROCEEDING WITH ANY NEW DESIGN, EXPERIMENT OR TEST!

Application Notes

AEB Sapphire Corp. Model XE Isolated DC-to-DC Converters

Output Fluctuations:

For virtually any regulated DC power supply, it is typical to experience decreased dynamic performance and even loop instability under certain load conditions. Placing an aluminum capacitor across the output will help alleviate this concern and improve dynamic response. The values given are strictly a guideline. Optimal values vary and will depend on the individual application and load. For dual-output units, the specified capacitance is recommended across *both* outputs.

Power Output (Model/Type)	min. recommended output capacitor (subject to test)
1-watt (#XE1000)	100 uF

Input Ripple and Noise:

Ripple current on the DC input line is often a concern for switched-mode converters. Placing an external capacitor across the input will smooth the input ripple and reduce conducted EMI. Although not necessary in many situations, capacitances of 100uF or more would be helpful to reduce ripple current, while 1000uF (or more) might be required for more sensitive applications.

Where conducted EMI is the primary concern, smaller capacitors may be used in tandem with aluminum capacitors to further reduce high-frequency noise. Ceramic types with a low ESR value are especially suited to this purpose. Where more stringent requirements are set, L-C filters can be employed on the input, as well.

Tracking (Dual-Output Devices):

Although the voltage at the positive output is precisely regulated via direct feedback to the control input, the negative output by contrast, is *indirectly* regulated. Therefore, the negative output can vary from its nominal voltage when load imbalances exist between the two outputs.

By evenly loading the two outputs *by design*, this effect is minimized. However, the simple approach is simply to guarantee that a ***10% minimum load*** is present on both outputs. A 20% minimum load will improve tracking further. Simply place a "pre-load" resistor across the lightly-loaded output to help balance the voltage across the two outputs.

No minimum load is required on single-output models. They will regulate properly even when operated open-circuit.

High Isolation Voltage and Safety:

CAUTION - Designers should always plan for fault conditions and build in redundant protection.

There always exists the slight possibility of an arc or short circuit between ***isolated high voltage circuits*** and nearby ***low voltage circuits*** (or ground). Although the "XE" converters are designed to handle a maximum of 15KVDC voltage stress from input to output, this type of short can be the result of numerous other variables.

For example, the equipment or circuitry in which the converter is used can fail, which may subject components to extreme conditions, like an overvoltage. It may be due to a design error, or simply a sporadic power surge. Even external (environmental) conditions such as humidity can compromise insulation integity.

But the most common cause of arcing is simply from point to point, across the p.c. board on which the converter is mounted. Typically, it means that two exposed connections in a circuit have not been properly spaced, or there is too much voltage present between them.

Any of these circumstances can result in insulation failure or even failure to the converter itself. But regardless of the reason, ultimately there can exist a short circuit between isolated (dangerous) HV circuits and ground.

Such scenarios can be very dangerous, as it causes high voltage and potentially high energy levels to come into contact with what is nominally a *low voltage circuit*. This is not only dangerous to personnel, but it can also result in costly damage to electronic equipment. Low voltage circuits can be destroyed beyond repair by this scenario because they may be subjected to voltages many times greater than the voltages they were designed to withstand.

Therefore, it is crucial that some type of overload protection be implemented for the high voltage source. High speed overload protection should be designed to remove power quickly enough to keep the energy deposited into the short at a minimum. This will greatly reduce system damage and increase personal safety.

Remember also, that any user interface that may exist is typically located in the low voltage section of the system, and thus danger should be immediately clear to any experienced designer.

The return paths (or grounds) for any potential fault currents should be short in length and sufficient in gauge to carry these currents safely, without fusing or opening. Transient protection must be extensively and carefully employed, and shielding should be used. Faults current should be routed away from the interface, into a safe ground return. Consider also, that the high speed overload circuitry can fail, which may result in high *sustained* fault currents.

Obviously, a complete discussion of the numerous design techniques necessary in a "hot ground" system is far beyond the scope of this app note.

In closure, it can be said that no design is 100% safe, and no one engineer or designer knows all there is to know in the scope of a very complex design. Failure modes in complex systems are also numerous, and therefore it is virtually impossible to plan for every possible failure scenario.

For this reason, high voltage design tasks should only be tackled by an experienced high voltage engineer. A thorough understanding of the many disciplines of high voltage design and its inherent dangers is absolutely crucial. Please proceed in a safe and prudent manner befitting the magnitude and complexity of the design task, and remember that the focus of such design efforts must be centered on safety.

Understanding Creepage and Corona:

Since high voltage potentials have a greater tendency to arc across a surface than through an open air space of equal distance, the term *creepage* has been created.

"Creepage" is a high voltage term used to describe the ***distance across a surface*** (in inches or mm), from one point of voltage potential to another. (In other words, a voltage present between two points on a PC board separated by 0.1" would be more likely to arc or "flash over" than the same voltage placed across two connections separated by 0.1" of air space.)

Moreover, the ionization of the air or *"corona"* created when an excessive electric field exists (due to the presence of high voltage) can cause a *breakdown* of the air, resulting in high localized temperatures. This exacerbates the situation, leading to an increased likelyhood of insulation failure and even sparking, particularly across surfaces.

Corona is another concern. It turns the oxygen in the air to ozone (O_2 becomes O_3), which is extremely reactive and corrosive. This gas will cause the equivalent of years of corrosion and rust on metal parts, in just a matter of days. It will also break down and destroy many other materials quickly, such as plastics.

Even worse is that corona itself is a plasma that is conductive, which requires that even greater creepage distances be held than would be necessary, were there no corona.

Therefore, designers need to be experienced with the subtleties of creepage and corona, and their vast implications.

The external creepage distance of "XE" isolated converters is roughly 1.7 inches. Using the "10 KV per inch" safety rule, the devices can be operated safely with 15 KVDC between the input and output pins.

Inasmuch as the PC board itself onto which the converter is mounted, also creates a "creepage" path from the input to the output pins, it is crucial that good engineering practices be exercised when designing the PC layout.

- Consult with a high voltage expert for reliable PC board layout recommendations.
- Use the recommended PC Board Layout illustrated on this datasheet.
- Remove (from the PCB layout design) any and ALL copper between the input and output pins.

- Remove any "grounded" copper within (min) 1.8 inches from the output pins and related high voltage circuits.
- Use the 10KV per inch rule for air-insulated systems.
- Create wide slots in the PCB layout design that will increase the surface path distance (creepage) between input and output circuits.
- Flush clip through-hole p.c. board leads to reduce the sharp points often associated with problems.
- Use "smoothing" hardware (small solderable metal discs, rings, spheres or beads) to cover exposed points, protrusions and sharp edges on PC boards that might otherwise cause corona or sparking.
- Build up solder beads onto circuit board pads and traces for additional smoothing, to reduce corona.
- With HV systems in particular, always assume fault conditions will be present. In other words, ask the question, "What happens if... ?"
- Use proper and suitable grounding practices to protect against dangerous fault conditions, and ensure that return paths are safe and sufficient to handle the magnitude and duration of the fault current.
- Include safe measures in the design to handle fault currents and keep high voltage away from the user interface.

AEB isolated converters are intended for PCB mounting only - If the device will not be PC board mounted, all mounting hardware as well as the mounting surface must be non-conductive/non-metallic. Use a non-metallic mounting plate or insulator, plastic screws and brackets (Nylon, PVC, CPVC, Polypropylene, Delrin, ABS, TFE, Phenolic, Rubber, etc.).

Coating and Encapsulation:

In stringent applications in which high-level reliability, near-rated voltages and/or tight clearances are required, consider the use of an encapsulant or coating product. Environmental ratings often mandate the use of a coating or encapsulant, as well. Vibration and shock resistance is also superior when assemblies are "potted" or coated.

- Where possible, encapsulate the finished PC board in a suitable potting material such as epoxy or silicone.
- If operating in air, consider coating all or part of the PC board surface with a specially-designed voltage-grading product. (Special voltage-grading "paints" or coatings are highly-insulating materials with a volume resistivity on the order of 10^{+12} ohm-cm.) Their insulative but slightly-conductive nature helps distribute the voltage stress evenly across surfaces. This minimizes "hot spots" and corona, and promotes uniform voltage distribution.
- Consider using a conformal coating before the encapsulation phase. This creates a homogeneous surface on which to encapsulate, and removes the concern of having a complex substrate consisting of many different materials. It also promotes adhesion.
- All encapsulants and coatings require surface adhesion to the substrate, and should be voidless (free of trapped air). Surface adhesion is itself another subject which requires a detailed knowledge of the product(s) to be applied. Immaculately-clean surfaces, vacuum (airless) processing, as well as *additional* coatings or primers will or may be required to achieve satisfactory surface adhesion. The material compatibilities of any and all materials involved in the coating and encapsulation processes should also be considered. Consult with the product manufacturer or an expert, and perform surface adhesion and cure tests before committing to a design.
- When employing coatings or encapsulants, scrape the I.D. tag off of the converter and clean off the adhesive, as well. This will promote adhesion and remove unnecessary materials from further chemical/electrical consideration.
- Always consult a specialist before proceeding with any encapsulating or coating process.

Final Caution:

Although AEB Sapphire Corp isolated converters do not generate dangerous voltages, they are intended for applications in which dangerous voltages will be present, due to their special insulating characteristics.

Do not proceed with any high voltage design or experiment without a thorough understanding of the high voltage discipline and its many obscure dangers. An extensive knowledge of electrical safety, grounding practices, insulation, and potential failure modes are necessary, to name just a few.

! Important note to the graduate student, technician or engineer's assistant attempting a new design, project or experiment: DO NOT APPLY POWER TO ANY CIRCUIT WITHOUT FIRST CONSULTING AN EXPERT. ADDITIONALLY, ALL CIRCUIT TESTING SHOULD BE DONE UNDER DIRECT SUPERVISION OF AN EXPERIENCED TEACHER, ENGINEER OR EXPERT.

PLEASE PROCEED IN A PRUDENT AND SAFE MANNER!

AEB Sapphire Corp. makes no guarantee, either written or implied, for consequential damages resulting from the use of our isolated DC converters. A thorough knowledge of the electrical disciplines and high voltage is the best defense against property damage and personal injury.