APPLICATION NOTE

EXCELSYS COOLX SERIES AN10440 – Hipot

Description

Many 60601-1 certified class I power supplies cannot undergo a 4 kVAC input to output hipot test when fully assembled without test failure and damaging the power supply. This paper explains why this is the case, suggests alternative testing procedures and explains why the 4 kVAC option of the CoolX range of configurable power supplies can undergo 4 kVAC input to output hipot tests without issue.

Products

- CX06M Series
- CX10M Series
- CX18M Series

What is an Isolation Barrier for?

The fundamental rule of electrical safety states that the voltage or current between any accessible surface and any other accessible surface (or potential earth) must be low enough to not present a hazard, both in normal operating conditions and in single fault conditions. The only scenario in which this rule can be violated is when the voltage or current in question is performing a medical function in the application.

An isolation barrier is a physical separation between electrical circuits and prevents the transmission of DC or AC energy between the two circuits. Their role in safety is to prevent hazardous voltages or currents appearing on accessible parts in violation of the fundamental rule of safety detailed above.

What is a Means of Protection?

60601-1 sets certain minimum requirements of isolation barriers before they are recognized as a barrier between hazardous voltages and accessible parts. When the isolation barrier meets these requirements (Creepage, Clearance and Dielectric Strength), it is considered a Means of Protection (MOP).

During safety compliance testing, it is considered Normal Operation to breach any barrier not considered a Means of Protection (MOP). It is considered a Single Fault Condition (SFC) when any single MOP is breached.

There are two types of MOP defined in 60601-1:

- Means of Operator Protection (MOOP) are designed to protect the operator from hazardous voltages.
- Means of Patient Protection (MOPP) are designed to protect the patient from hazardous voltages. The requirements of a MOPP are stricter than the requirements of a MOOP as the patient is considered weaker and so is at greater risk.

For medical power supplies, isolation barriers are usually designed to comply with the requirements of MOPP so that both the operator and patient are protected.

Referring back to the fundamental rule of safety, since the system must be safe both in normal condition and single fault condition (the breaching of a single MOP), the system should have 2 MOP between any hazardous voltages and any accessible part so that there is always a backup.

These MOPs can be implemented as two separate MOP, or a single isolation barrier can be sized so that it is the equivalent of two MOP.

What is Hipot Testing?

A hipot test (otherwise known as a Dielectric Withstand Test) is a means of testing the isolation barriers of electrical systems. By applying a high voltage across an isolation barrier and monitoring the current flowing through it, any inadequacies in physical separation distances are highlighted.

Hipot testing carried out as a part of the medical safety certification process ensures that the isolation barriers performing a safety function in a system design meet the minimum dielectric strength requirement to be considered a means of protection.

Production level testing ensures that there have not been any errors in the manufacturing process that have resulted in a breach of the isolation barrier. It is not testing the system design (this has been done in safety testing), it is a test of the manufacturing process.

How to Size an Isolation Barrier

For an isolation barrier to meet the requirements of a MOPP, it must meet three specifications:

- Creepage Distance – separation across a surface (see Table 12 of 60601-1)
- Clearance Distance – separation across open space (see Table 12 of 60601-1)
- Hipot or Dielectric Withstand Voltage (see Table 6 of 60601-1)

These tables use the working voltage measured across the barrier to determine the barriers required creepage and clearance distances, and the dielectric withstand voltage. Working voltage is the highest voltage to which the isolation barrier under consideration is or can be subjected under the conditions of normal use.

Usually, for mains connected devices, a 1 MOPP isolation barrier between the input and an accessible part requires at least 1.5 kVAC hipot test, and 2 MOPP requires at least 4 kVAC hipot test.

Does a MOP Have to be an Isolation Barrier?

An isolation barrier is not the only way to implement a MOP. For example, see the insulation coordination implemented by the Ultimod / Xgen range of configurable power supplies in Figure 1 below.

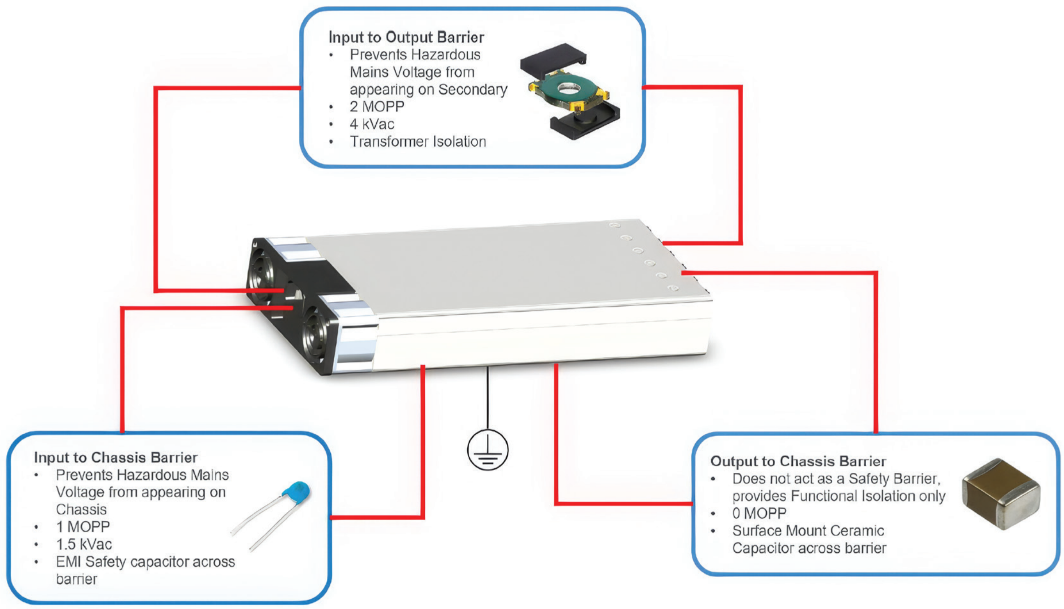

Figure 1. Ultimod / Xgen Insulation Coordination

For the Ultimod / Xgen design, both the chassis and output terminals are considered accessible. We therefore need to implement MOPs between the input and output, as well as between the input and the chassis.

The input to output MOP is implemented by the main isolation transformer (located on the output module of the supply), which is sized for 2 MOPP. The separation between the input and the chassis is sized for one MOPP, with the other MOPP being provided by the connection of the chassis to the potential earth.

For single fault condition testing, when the input is shorted to the chassis, the earth connection keeps the chassis at a safe voltage, and when the earth connection is broken, the isolation barrier ensures that the chassis remains safe.

In this way, the earth connection acts as a means of protection and ensures that the fundamental rule of electrical safety (safe in normal conditions and safe in single fault conditions) is maintained.

Hipot Testing on an Assembled Power Supply

The fact that the chassis being tied to potential earth is used as a MOP is the reason why it is often not possible to carry out input to output hipot tests on fully assembled power supplies to the same hipot voltage as is carried out during safety testing. We must remember that there are two paths from input to output, one across the main isolation transformer (which we are trying to test), but another from input to chassis to output.

The input to chassis to output path is bridged by EMI capacitors. These act as a potential divider for the AC hipot voltage. Often (as is the case with the Ultimod), the input to chassis capacitance is much smaller than the output to chassis capacitance. Through potential division, the voltage across the input to chassis barrier is greater than the voltage across the output to chassis barrier.

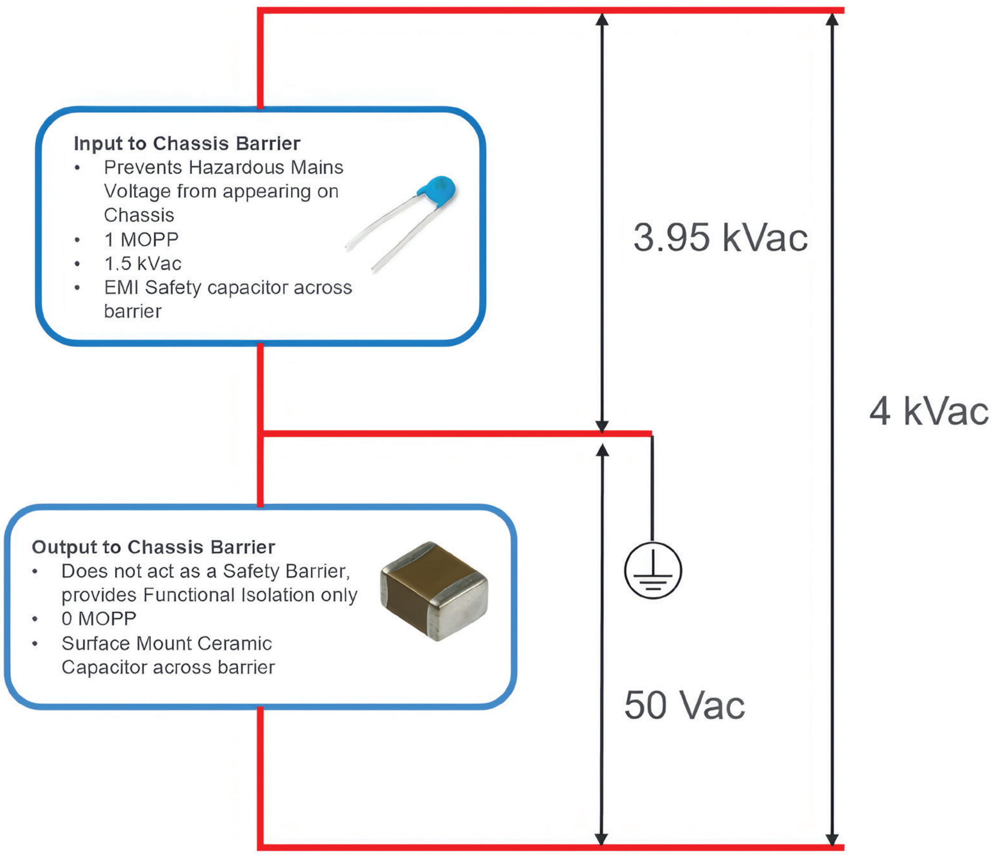

Figure 2. EMI Capacitor Potential Divider

This greatly exceeds the input to chassis isolation rating (it is sized for one MOPP; the other being provided by potential earth connection). This will invariably lead to arcing across the input to chassis barrier, and possible damage.

By applying an input to output hipot voltage on a fully assembled class I power supply, we test (and overstress) one of the parallel isolation barriers as opposed to the input to output barrier.

This is well recognized in the 60601-1 safety standard, where subclause 8.8.1 states that “if there are multiple paths between the same points, these might need to be tested separately. There could, for example, be one path from the mains part to a patient connection that has basic insulation plus a protective earth connection” and advises that “parts might need to be disconnected to allow the reinforced insulation to be tested without overstressing the separate insulation of the mains part or the patient connections.”

This indicates a method of showing compliance. By removing the Xgen / Ultimod supply from the chassis, the parallel path of input to chassis to output is broken, and the input to chassis barrier can be safely tested.

This is the method used during the manufacture of the Xgen / Ultimod where 100% of units are tested to 4 kVAC.

Another method of showing compliance is described in 8.8.3 which describes the hipot test conditions, and states “a DC test voltage equal to the peak value of the AC test voltage may be used”.

This means a DC test voltage of 5.6 kVDC (equivalent of 4 kVAC) can be used for the input to output test.

Using a DC voltage means that the voltage share across the barriers is not set by the EMI capacitors and is shared more equally. However, this test method is not guaranteed to work for all configurations (we rely on trace impedances from input to chassis and from output to chassis), and any debris in the chassis could also lead to a breakover.

What is Different about the CoolX?

The isolation barriers implemented by the CoolX are shown in Figure 3 below.

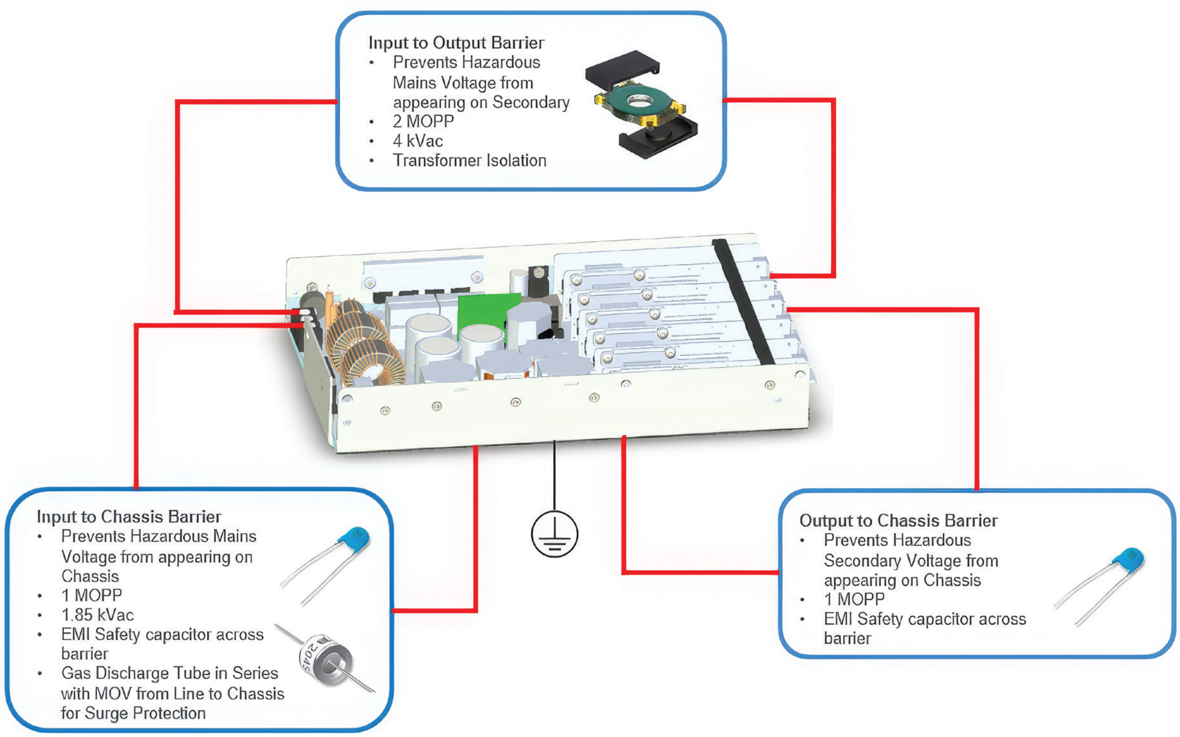

Figure 3. CoolX Insulation Coordination

There are a number of differences evident between the CoolX design and the Ultimod / Xgen design.

- The CoolX has a smaller output to chassis capacitance, which results in a more even distribution of hipot voltage from input to chassis to output during AC hipot tests.
- There is increased output to chassis isolation in the CoolX range, making the output to chassis barrier able to withstand higher voltages without breakdown.

But there is one more critical difference, the CoolX has been designed with a network of MOVs and GDTs on the input, which makes it able to withstand Level 4 surges (4 kV Line to Earth, 2 kV Line to line). However, when an input to output hipot voltage is applied, if the input to chassis barrier sees 2 kV or more the gas discharge tube from input to chassis will breakover. This will result in all the hipot voltage being applied from output to chassis which may result in an arc, and a hipot test fail.

The 4 kVAC option of the CoolX has no GDT from input to chassis, which means that as long as the correct hipot procedure is followed (all outputs, including the auxiliary output, are tied together), a 4 kVAC hipot can be carried out on a fully assembled CoolX without risk of damage. With no GDT the CoolX surge rating drops from Level 4 to Level 3 (2 kV Line to Earth and 1 kV Line to Earth) which is industry standard.

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