The Hazards of Hipot Testing

Hipot testing is an abbreviation for “high potential” testing - a category of electrical tests used to verify the effectiveness of electrical insulation in transformers, motors, printed circuit boards, electrical sub-assemblies (such as power supplies) and finished equipment. It’s also known as “dielectric withstand” testing. This article considers the requirements for testing and provides broad guidelines on what is required of an equipment manufacturer in the type test procedure. It primarily refers to Class I equipment, the differences for Class II equipment are detailed separately. **Kent Smith, Applications Engineer, XP Power, Pangbourne, UK**

Electrical equipment that is connected to the AC mains supply must pass a ‘type’ test requirement by the relevant safety agency. The commonly applicable specifications are IEC60950-1 for ITE & industrial equipment and IEC60601-1 for medical equipment. Before sending equipment for type testing, the manufacturer, or the power supply manufacturer, will usually want to ensure that it meets the requirements by carrying out their own tests. However, test specifications can be misinterpreted, leading to damage to power supplies and delays in gaining the relevant approvals for a product to be brought to market. The safety regulations refer to the following types of insulation:

* Between primary (AC input) and secondary (DC output) reinforced insulation is required
* Between primary and earth basic insulation is required
* Between secondary and earth operational insulation is required

Class I equipment utilizes an insulation system where a protective earth is employed to ensure safe operation. Class II equipment utilizes double or reinforced insulation to ensure safe operation with no provision for protective earth. Figure 1 represents a typical Class I power supply insulation system.

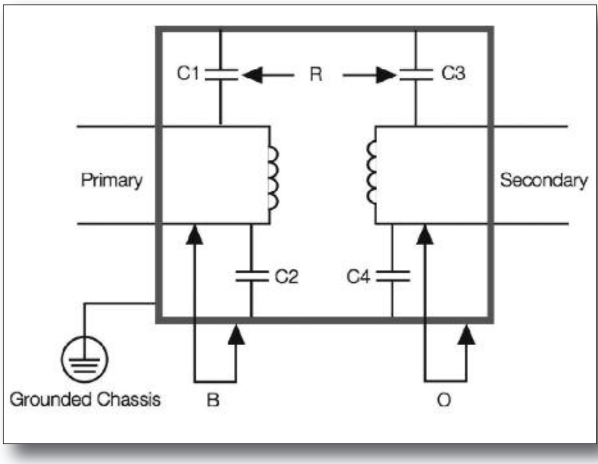

Figure 1: **Typical power supply insulation (R - location of typical reinforced insulation; B - location of typical basic insulation; O - location of typical operational insulation)**

Safety agency testing

Hipot testing requirements are categorized as either type testing (design verification) or production testing.

Hipot type testing is performed by the safety agency, and tests are intended to prove that the construction of the power supply meets the requirements dictated by the relevant safety standard. For IEC60950-1 (ITE) and IEC60601-1 (Medical) the requirements are shown in Table 1.

Hipot production testing is performed during the manufacturing process and is intended to ensure integrity of safety critical insulation. Production line testing is conducted on basic insulation and on reinforced insulation during the manufacturing process of the subassembly and barrier components.

Reinforced insulation cannot be tested without over-stressing basic insulation on the end product. (Note: see UL60950-1, C5.2.2 or UL60601-1 2nd Edition Section 20.4 or IEC60601-1 3rd Edition Section 8.8.3 for more information).

Because of this, manufacturers are permitted to test reinforced insulation separately, meaning that they are permitted to test transformers and other primary to secondary isolation barriers separately before other components are incorporated into the product. Only basic insulation or primary to earth insulation is tested on the final assembly prior to shipping the product.

Because only basic insulation exists between primary and chassis ground and only operational insulation exists between secondary and chassis ground, applying 3000VAC directly from primary to secondary on the finished product will over-stress the primary to chassis ground and secondary to chassis insulation resulting in a potential failure.

60950-1	Primary to Secondary	3000 VAC, or the equivalent DC voltage
	Primary to Grounded chassis	1500 VAC, or the equivalent DC voltage
	Secondary to Grounded chassis	No requirement provided the secondary voltage is less than 42.4 VAC or 60 VDC
60601-1	Primary to Secondary	4000 VAC, or the equivalent DC voltage
	Primary to Grounded chassis	1500 VAC, or the equivalent DC voltage
	Secondary to Grounded chassis	No requirement provided the secondary voltage is less than 42.4 VAC or 60 VDC

Table 1: **Insulation type testing levels**

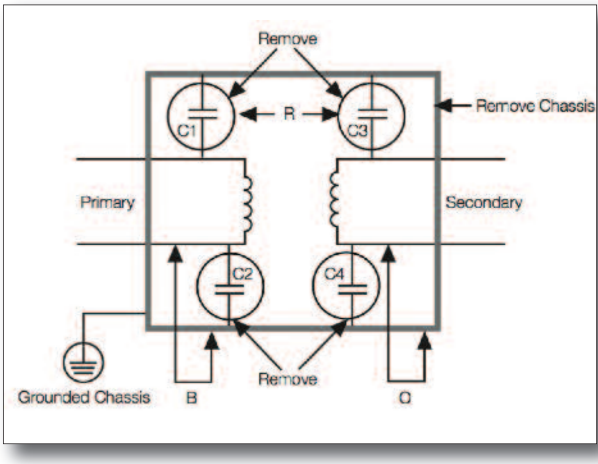

Figure 2: Power supply disassembly may be required for type testing

To properly test reinforced insulation the power supply needs to be removed from the chassis. In addition, all paths to chassis ground, as far as practical, need to be removed so as not to over-stress basic and operational insulation during the test.

This usually entails removal of all Y-capacitors. Figure 2 shows the components that need to be removed.

On many products not all potential paths can be removed. Printed circuit boards may utilize earth traces between primary and secondary while complying with creepage and clearance requirements. In some instances, when applying the primary to secondary hipot voltage, a breakdown or arcing may be observed which can lead to component failure, rendering the power supply inoperable. This is a breakdown of operational insulation (secondary to chassis ground) only. It does not indicate a failure of primary to secondary insulation that is the focus of the test. Provided this 'fails' in a safe manner, the test is considered successful for safety purposes.

Class II power supplies

The previous sections of this document deal with Class I power supplies, which employ a safety earth. In the case of Class II power supplies there is no safety ground and so there is no need, nor ability, to test from primary to earth. Because of the lack of any grounding we also do not have to worry about over stressing any components from the primary to ground, or from the output to ground. The user is able to simply test from the input to the output on the power supply at 3000VAC (or 4121VDC) for ITE devices or 4000VAC (5656VDC) for medical devices to verify the insulation in the supply.

Trends in Medical Power Supplies

Medical electronic equipment is getting smaller. Of course, this could be said of all electronic equipment but it is in the medical area that pressure for size and weight reduction is greatest. Not only is the hospital bedside environment very space-constrained but there is a trend for more equipment to be used in the home, in doctors' offices, and even in cars and on planes. This is creating particular pressure on power supply manufacturers to reduce the size of their products.

In the last 10 years a typical convection-cooled, 100W AC/DC power supply has shrunk from a 4 x 7 inch (10.16cm x 17.78cm) footprint in 1998 to just 2 x 4 inches (5.08cm x 10,16cm) today, a reduction of over 70%. This size reduction has had to be managed carefully. Smaller packages mean less area for heat dissipation, which in turn requires higher efficiency. For example, taking an industry standard footprint of 3 x 5 inches (7.62cm x 12.7cm), convection cooling can effectively remove about 18W of waste heat. Extrapolating from the 20W power loss curve in Figure 1, a 120W power supply needs to be at least 86% efficient for convection cooling to be sufficient.

Figure 1 also shows the dramatic effect that a relatively small improvement in efficiency can have on the available power from a power supply for a given heat dissipation. Taking the 20W power loss curve, an efficiency gain from 88% to 93% would enable an power supply to deliver over 250W rather than around 150W, within a given footprint.

For the power supply designer, size and efficiency are usually the most important trade-offs. Increasing the switching frequency means that smaller components can be used - notably capacitors and inductors. However, switching losses rise and a power supply that may be 92% efficient at 30kHz will be only 83% efficient at 200kHz. Reliability is always of paramount importance in medical applications, so keeping the power system running well within its maximum ratings is always desirable.

The main converter topology is critical to efficiency. For power supplies in the 100W to 200W range, a resonant topology is often chosen. This can virtually eliminate switching losses, enabling smaller heatsinks to be used - so contributing to the dual goals of smaller size and higher efficiency.

In many power supplies, it has become economical to use Silicon Carbide (SiC) diodes in power factor correction circuits. These need no snubber circuits, reducing component count and saving space while giving a typical 1% boost to efficiency.

The falling price of power MOSFETS means that they are now becoming common as the main rectifier of switching power supplies. Efficiency improvements of more than 40% in this part of the circuit are possible. For example, a 20A diode with 0.5V forward voltage dissipates 10W, whereas a MOSFET with an 'ON' resistance of, say, 14mΩ at 100°C dissipates just 5.6W.

Lastly, control circuits have been greatly simplified in recent years, largely through higher integration of semiconductor functions. Application specific chips are now available that can provide the main converter voltage and a host of automatic protection features. Comprehensive monitoring and control signals are also more easily implemented thanks to more highly integrated power management devices.

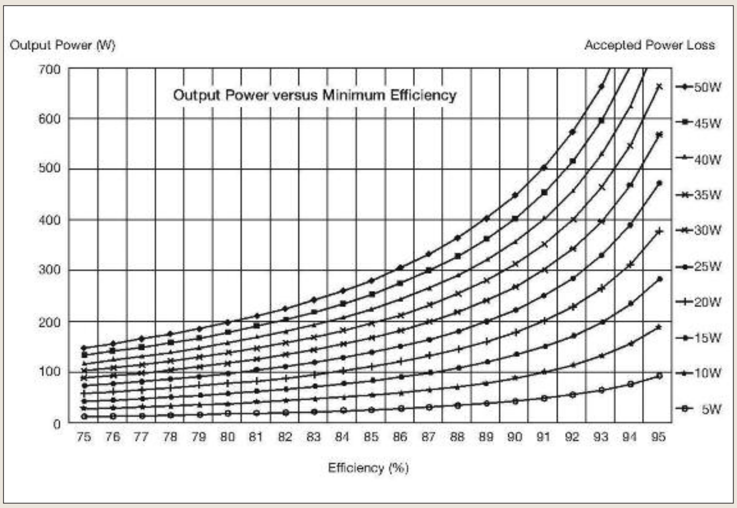

Figure 1: Minimum efficiency required for a given power supply output to ensure compliance with safety standards