Introduction

There are many national and international standards which deal with the safety aspects of electrical and electronic products. These standards aim to ensure that products are designed, manufactured and tested to eliminate hazards, so that users get equipment which can be installed and used with complete safety. They are intended to prevent injury and damage to persons and property from such hazards as electric shock, fire, dangerous temperatures and mechanical instability. The standards are of particular importance to designers and users of power conversion products. Power converters, especially mains operated power supplies often contain the only barrier separating secondary circuits and accessible metal parts from dangerous AC mains voltages. Furthermore they contain components intentionally designed to dissipate heat which may give rise to high temperature risks.

Applicable Safety Standards

Most industrialised countries published their own safety standards for electrical and electronic equipment. Many of these were based upon IEC recommended standards, but national modifications and variations dependent on end use caused almost insurmountable problems to organisations designing and distributing standard catalogue products in international markets. However, most of these standards were only recommended guidelines and did not have the backing of legislation. In recent years, safety issues have become important politically, and in many countries laws have been enacted to empower enforcement of recognised standards. The reluctance of National Standards Authorities and designated test laboratories to recognise the validity of standards and tests carried out elsewhere has resulted in expensive and time consuming approval programmes. Often six or more separate, but very similar comprehensive safety test programmes have to be carried out on the same product or equipment to obtain safety marking for the main world markets for information technology equipment (ITE) and telecoms equipment (TE). This unsatisfactory situation is gradually being improved, but by no means resolved, by international harmonisation of standards and mutual recognition of test laboratories.

Harmonisation and IEC950

Considerable progress towards an internationally harmonised approach to safety has now been achieved largely due to efforts within the member states of the EU to comply with the Low Voltage Directive (LVD) backed up by work carried out by IEC and CENELEC in the production and promotion of unified standards. The current position is that a single standard, IEC950 is now the predominant safety standard for many electrical and electronic products, including component power supplies.

IEC 950 was first published in 1986, entitled “Safety of Information Technology Equipment” including Electrical Business Equipment. In effect it brought IEC380 (office machines) and IEC435 (data processing) into a single standard. CENELEC adopted IEC 950 and with minimal changes to the text published it with the same title as the IEC document as EN60950.

Brussels based CENELEC comprises the electrotechnical committees of each country within the EU, plus Norway, Switzerland and Iceland, and is responsible for issuing European Norms (EN’s). With regard to EN60950, by the 1st March 1991 CENELEC member countries were bound to withdraw conflicting existing standards and publish new harmonised national standards. For instance, in the UK, BS5850 and BS6204 were withdrawn and a new unified standard BS7002 (EN60950) published to replace them. CENELEC has also sponsored moves for mutual recognition of test data produced by officially recognised authorities within member states. CECC marked components are now well established with reciprocal recognition within Austria (OVE), Belgium (CEBEC), Denmark (DEMKO), Finland (SETI), France (UTE), Germany (VDE), Ireland (IIRS), Italy (IMQ), Netherlands (KEMA), Norway (NEMKO), Spain (IRANOR), Sweden (SEMKO), United Kingdom (BS). With respect to component power supplies, the mark of a national test organisation from any one of these countries showing compliance with EN60950, should be sufficient proof of compliance in any other country.

The IEC (International Electrotechnical Commission) is a voluntary body with worldwide recognition. It is Geneva based and now has more than 40 countries worldwide as participating members, including the USA and Canada. It has been setting recommended standards for electrical equipment for worldwide use for many years.

IECEE CB scheme is an international system based on international IEC standards and national differencies of member countries. CB test reports issued by certification organizations are accepted by member countries and no additional testing is required.

Relevant EC Directive

Directive 72/23/EEC, the Low Voltage Directive (LVD) was published to provide a common set of basic rules for the safety of electrical equipment throughout the EU, and to thereby promote freedom of trade for such goods within the EU. It covers with minor exceptions all equipment operating over 50V to 1000VAC and 75V to 1500VDC.

To demonstrate compliance with the directive, testing to the relevant EN is required and then: either

a) a recognised mark affixed
or b) a certificate of conformity supplied
or c) a manufacturer’s statement of conformity supplied

a) and b) are obtainable from recognised national test authorities such as SEMKO, VDE, BS etc.

The official publishing and implementation within the EU of the CE marking Directive 93/68/EEC makes clear that the provisions of this directive, originally intended to apply to “New Approach Directives” have been extended to one “Old Approach Directive”, the LVD. All products and equipment which are covered by the LVD must then be CE marked to be legally sold within the EU. CE marking implies compliance with all relevant directives. Many component power supplies are open frame units with no user protection against contact with live parts. They can only be regarded as fully satisfying the LVD when assessed in situ within the final host equipment. They should be supplied together with a warning notice which could be worded as follows: “Although CE marked in accordance with the LVD, these units are intended for use only within other equipment. The final equipment manufacturer is responsible for protection against contact with hazardous live parts”.

EN60950

Latest edition of this standard is EN60950-1 and equivalent UL standards is UL60950-1.

Because a very large proportion of power converters have their end use in information technology equipment and electrical business machines, and because the standard must attain the status of a regulation in member countries, it has become accepted as the most important safety standard for power conversion equipment.

Hazards

EN60950 introduces the principles of safety and defines the hazards with which it is concerned, these being

- Electric shock
- Energy hazard
- Fire
- Mechanical and heat hazards
- Radiation hazards
- Chemical hazards

Application

Application of the standard is wide. It is applicable to information technology equipment, including electrical business equipment and associated equipment with a rated voltage not exceeding 600V. It is intended to ensure the safety of operators, members of the public and service personnel.

Classes of Equipment

Classes I, II and III are defined:

Class I equipment
Electric shock protection is achieved by
a) basic insulation
and b) protective earth

All conductive parts which could assume hazardous voltages in the event of failure of basic insulation must be connected to a valid protective earth conductor.

Class II equipment
There is no provision for protective earthing and electric shock protection is by double insulation or reinforced insulation.

Class III equipment
Protection against electric shock relies on supply from SELV circuits and it is impossible for hazardous voltages to be generated within the equipment.

Definitions

There are many definitions contained in the standard, some of these with great relevance to power converter designers and users are:

i) *Hazardous voltage*
A voltage exceeding 42.2V peak or 60VDC in a circuit which does not meet the requirements for a limited current circuit.

ii) *Extra-low voltage (ELV)*
A voltage in a secondary circuit not exceeding 42.4 V peak or 60VDC, the circuit being separated from hazardous voltage by at least basic insulation.

iii) *Safety extra-low voltage (SELV) circuit*
A secondary circuit that under normal operation or a single fault condition cannot reach a hazardous voltage between any two accessible parts or an accessible part and protective earth. In the event of a single fault condition (insulation or component failure) the voltage in accessible parts of SELV circuits shall not exceed 42.4V peak or 60VDC for longer than 0.2 s. Also an absolute limit of 71V peak or 120VDC must not be exceeded.
SELV circuits must be separated from hazardous voltages (e.g. primary circuits) by two levels of protection which may be double insulation, or basic insulation combined with an earthed conductive barrier. The importance of power supply SELV secondaries is that they are considered safe for operator access. Also circuits fed by SELV power supply outputs do not require extensive safety testing or creepage and clearance evaluations in approval test programmes.

iv) *Limited current circuits*
These circuits may be accessible even though voltages are in excess of SELV requirements. A limited current circuit is designed and protected so that under a likely fault condition, the current which can be drawn is not hazardous. Limits are detailed as follows:

a) For frequencies not in excess of 1 kHz the steady state current drawn through a 2000Ω non-inductive resistor connected between an accessible part of the circuit and either pole of that circuit or earth shall not exceed 0.7 mA peak AC or 2 mA DC. For frequencies above 1 kHz the limit of 0.7 mA is multiplied by the frequency in kHz but shall not exceed 70 mA.
b) For accessible parts not exceeding 450 V peak or DC, the maximum circuit capacitance allowed is 0.1 µF.
c) For accessible parts not exceeding 15000V peak or DC the maximum stored charge allowed is 45µC and the available energy shall not be above 350 mJ.

To qualify for limited current status the circuit must also have the same segregation rules as SELV circuits.

Protective Earth

Class I equipment must have a protective earthing conductor which may be bare wire or insulated. If insulated it must be green/yellow or transparent covering. No switch or fuse is allowed. Resistance between earthed parts and the earthing termination must not exceed 0.1Ω. This is tested by a current 1.5 times the current capacity of any hazardous voltage circuit at the point where failure of basic insulation would make the earthed part live. Test voltage maximum is 12V. Test current may be AC or DC but must not exceed 25 A.

Clearances required for insulation

Clearances between primary and secondary circuits and for isolation in primary circuits depend on working voltages and the degree of pollution of the operating environment. Power converters which are intended for general application should be designed for worst case conditions (pollution degree 3 and mains voltages to 264 AC).

From the table published in the standard it can be deduced that the minimum clearances are as follows:

4.00 mm for reinforced or double insulation
2.00 mm for basic and supplementary insulation
(table is valid for installation class II)

Where a formal manufacturing quality control programme is in place relaxation to 3.4 mm and 1.7 mm is allowed, but reinforced insulation is then subjected to 100% electric strength testing. If an air gap serves as reinforced insulation between a hazardous voltage and an accessible conductive part of the enclosure of floor standing equipment or the non-vertical surface of desk top equipment the required clearance is 10 mm.

Creepage distances

Tables of creepage distances for basic insulation are given for various pollution conditions and materials, the distances depending on working voltages. These distances are doubled for reinforced insulation.

Power cords and connectors

Mechanical strength and electrical requirements are dealt with in depth. An important table for power converters which are connected to mains power via studs or screw terminals is the table of terminal sizes reproduced below

Rated current A	Minimum nominal thread dia mm	
	Pillar or stud type	Screw type
≤10	3.0	3.5
10-16	3.5	4.0
16-25	4.0	5.0
25-32	4.0	5.0
32-40	5.0	5.0
40-63	6.0	6.0

Flammability

The standard requires that the equipment design

a) avoids high temperatures, or shields and separates flammable materials from high temperature parts
b) uses materials of low flammability both internally and for enclosures
c) uses fire enclosures to limit the spread of fire

Compliance can be achieved by using V-2 or better rated, insulating and printed board materials throughout and ensuring adequate spacing between high temperature components and plastic and painted parts. Even better, use UL listed materials and the necessity for exhaustive and messy flammability testing is removed.

Earth Leakage Current

For Class II equipment this shall not exceed 0.25 mA, for hand held Class I equipment 0.75 mA, and other Class I equipment 3.5 mA.

The test for Class II equipment requires conductive metal foil to be attached to an area not exceeding 10 x 20 cm on accessible non-conductive parts and the test is made between this and conductive parts.

Tests are carried out at the most unfavourable (highest possible) supply voltage.

Electric strength test voltages

Insulation between circuits is tested using a sinewave voltage at 50/60 Hz or a DC voltage equal to the peak voltage of the prescribed AC test voltage, applied for 1 (one) minute without breakdown.

For common peak working voltages (maximum of input voltage + internal generated peak voltages) the rms AC test voltages for primary to body, primary to secondary and between parts in primary circuits are as follows:

Insulation	<184V peak working	184V <354V peak working
Basic	1000Vrms	1500Vrms
Reinforced	2000Vrma	3000Vrms

No test is required from secondary to body if the secondary voltage is less than or equal to 60VDC or 42.4V peak. For higher voltages a table of test values is given in the standard.

User Instructions and Labelling of Equipment

Labelling of equipment is covered in detail including the correct display of rating data and any important safety warnings. Where symbols are used these must conform to ISO standard 7001 and IEC publication 417.

Installation and operating instructions must be made available as should any special safety instructions needed to avoid hazards when operating, installing, maintaining, transporting or storing equipment.

Stability and Mechnical Hazards

Equipment should be able to safely survive a tilt of 10° in any direction and return to an upright position. Floorstanding equipment (e.g. UPS) should withstand forces equal to 20% of total weight (to a maximum of 250 Newtons) applied in any direction except vertically, at any height up to 2m. Equipment should operate safely when tilted continuously up to 5° from the normal position.

Telecommunications Safety Standards

Providers of telecommunication services have particular safety concerns:

a) Safety of service personnel working on the network ensuring that the network cannot become energised by hazardous voltages emanating from equipment connected to the network.

b) Conversley ensuring that users of equipment connected to the network are properly isolated from voltages on the network.

These particular concerns have been addressed in the UK by safety standard BS6301, which has been used as the basis for obtaining BABT approval (British Approvals Board for Telecommunications).

The EU has adopted EN60950 as the core safety standard for telecommunications equipment. This is supplemented with EN41003 “Particular Safety Requirements for Equipment to be connected to Telecommunications Networks”. Following the publication of edition 2 of IEC950 the EU has issued an updated version of EN60950 which incorporates EN41003 as clause 6.

This introduces the concept of a TNV (Telecommunications Network Voltage) circuit which is defined as “A circuit which under normal operating conditions carries telecommunications signals”. TNV circuits are treated as additional secondary circuits that must be isolated from “Excessive Voltages” by one of

i) double or reinforced insulation

ii) basic insulation with protective earthed screen

iii) basic insulation with protective circuitry (e.g. fuses and MOVs).

Excessive voltages are defined as voltages not normally found on telecommunication networks and where:

Vac/70.7 + Vdc/120 >1, Vac and Vdc being maximum voltage deviations under worst case conditions (EN 60950 section 1.4). TNV circuits require only basic insulation for isolation from SELV circuits. Where SELV circuits are earthed TNV circuits may be directly connected.

Medical

In the EU, technical safety problems of Electromedical Equipment are addressed by the EN60601 series of standards which follow IEC 60601. In the USA, UL544 covers medical and dental equipment, but in 1994 UL2601-1 came into effect. This standard is harmonised with IEC 60601-1.

A power supply approved to IEC 60950 (EN60950) would need to pass additional tests to meet the requirements of EN60601-1 for separation, leakage, dielectric strength and isolation transformer construction to enable its use in medical equipment. The “Y” capacitors required in the input filter of a standard ITE switched mode power supply would almost certainly cause the power unit to fail on the grounds of excessive leakage current. Briefly, the more stringent requirements which are of particular relevance to power supplies are:

a) Mains to secondary creepage and clearance distances for double or reinforced insulation for equipment operating up to 250VAC (over the isolation barrier) maximum must be 8mm and 4mm respectively.

b) Primary to secondary dielectric withstand test must be 4000VAC.

c) Earth leakage current maximum is 0.5mA (0.3mA for UL60601-1) for normal operation and 1mA maximum for a single fault condition. These values are for type B, type BF and type CF equipment categories.

type B (Body)	*Non-patient equipment, or equipment with grounded patient connection.*
type BF (Body Floating)	*Equipment with a floating patient connection*
type CF (Cardiac Floating)	*Equipment with a floating connection for direct cardiac application*

d) Patient leakage current for the above categories is 0.1mA (0.5mA single fault) for type B and BF and 0.01mA AC (0.05mA @ single fault) for type B and BF and 0.01mA AC (0.05mA @ single fault) for type CF. For DC leakage current the values are 0.01mA DC (0.05mA DC) for all protection.

Safety Testing

Power converters supplied by Powerbox have been tested by the manufacturers to the relevant standards.

Customers need not, and should not carry out safety testing on units supplied by Powerbox, especially where a properly designed safety test fixture is not available. Such a test fixture should have an operator’s shield with a high voltage disable safety interlock to protect personnel from danger.

Manufacturers Test

For AC operated power supplies, 100% of converter transformers, and other devices coupling primary and secondary circuits, such as feedback transformers and opto couplers, are subjected to safety testing. This is normally 3750V RMS primary to all secondaries for 1 minute without breakdown or flashover.

Complete power units are usually type tested to the same level but with the “Y” capacitors removed from the input line filter.

The test voltage normally used as a final high voltage flash test to prove the safety integrity of fully assembled power supplies is 1500V RMS. This is applied between AC inputs and all outputs connected together and to ground. A functional test follows to check that no circuit components have been damaged.

Warnings

Removal of the “Y” capacitors by customers to carry out high voltage safety tests invalidates the warranty.

Input/output isolation tests carried out on switched mode power supplies without grounding the outputs are usually disastrous! Division of the test voltage by capacitances to ground applies almost all of the test voltage between output and ground so damaging secondary components. Isolation (high pot) tests on complete systems with power units in place can cause similar damage. Therefore such tests should be carried out with the power units removed or with all power unit outputs strapped to earth. Units which have been damaged in this way are not covered by the warranty.