Signal Transformer

innovation in wire wound magnetic technology

Transformer Basics

January 09 Rev 1

AN05-10ST

Isolation Transformers Increase Safety of Electronic Systems

Application Note

Isolation Transformers Increase Safety of Electronic Systems
Part I: Introduction

Adequate isolation between a power source and a user of electronic equipment ensures the safety of that equipment. Given the high voltages that exist in modern electronic equipment, proper isolation protects an operator from contact with excessive electrical energy should a fault occur in the equipment. Isolation transformers have represented a traditional solution for providing high isolation in electronic circuitry. Even with the increased use of efficient, switched-mode power supplies (SMPS), isolation transformers can improve the overall isolation of an electronic design without severe penalties in added size, weight, and cost.

Isolation transformers offer an effective means of meeting the requirements of domestic and international safety standards for electronic equipment. In the United States, for example, such standards are set by the Occupational Safety and Health Administration (OSHA), with product testing performed according to appointed laboratories, such as Underwriters Laboratories (UL), Intertek Testing Services, (ITS), Factory Mutual and others. Throughout Europe, most European Normative, EN), safety standards are harmonized versions of standards published by the International Electrotechnical Commission (IEC). Testing is performed by the laboratories of individual member nations, such as the Verband Deutscher Electrotechniker (VDE) in Germany.

Isolation transformers enable a variety of electronic systems to meet safety requirements. Such systems include medical diagnostic equipment, computer systems, and telecommunications equipment. The systems may incorporate linear power supplies, SMPS, and sometimes a combination of both. A single isolation transformer can enable an electronic design to meet all of its isolation requirements. With proper system design, an isolation transformer can also help reduce the size and cost of the post secondary circuit power-electronics components.

Part II: Understanding UL

Several techniques commonly provide isolation when designing electronic equipment. Fuses or circuit breakers, for example, can protect both the equipment and its operator from overvoltage conditions or surges of high-voltage energy. Careful component placement and printed-circuit-board (PCB) layout can provide adequate room for creepage and clearance of components in close proximity of high voltages.

Creepage is defined as the shortest distance between two conductors, measured along the surface of the insulators. Clearance is the shortest path through the air between two conductors that must be isolated. An isolation transformer can reduce the impact of meeting these requirements by reducing the line voltage from hazardous to nonhazardous levels.

Avoiding considerations for creepage and clearance in an electronic design can improve a product's time to market, simplify its circuit layout, and reduce its cost. Although an effective means in screening electronic equipment from high input voltages, an isolation transformer may add cost, weight and increase cooling system requirements. However an efficient isolation transformer represents a reliable solution, even for systems employing switching power supplies.

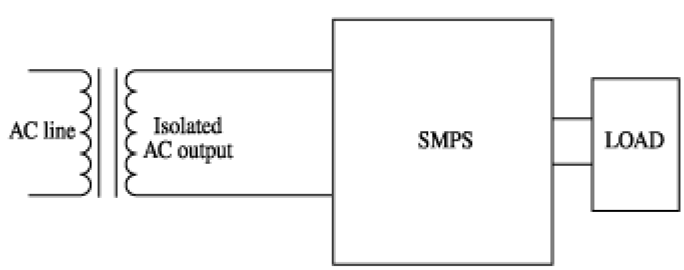
Switching power supplies convert AC voltage to DC voltage directly in an off-line rectifier followed by a capacitive filter. The converted high voltage is switched at frequencies from thousands of times per second (kilohertz rates) to millions of times per second (megahertz rates). Usually, semiconductor devices, such as silicon bipolar transistors or silicon metal-oxide-semiconductor field-effect transistors (MOSFETs) are used to switch the voltage waveforms on and off. The output voltage of a switching power supply is proportional to the pulse width of the switched or chopped waveform and the duty cycle of the pulse wavetrain. By varying the pulse width of the output waveform, the output voltage can be automatically adjusted.

A large transformer is not needed in a SMPS to achieve the same levels of isolation and voltage step-down functions compared to a lower-frequency 50/60-Hz linear power supply with the same power rating. As a result, switching power supplies are smaller, lighter, and dissipate less power than equivalent linear regulated power supplies. Because of this, SMPS have long been used in airborne, military, and space applications where weight and size were key design requirements.

When used with a switching power supply, an isolation transformer can prevent higher-order harmonic signals from degrading the performance of adjoining circuitry. This is especially important in computers or other equipment incorporating microprocessors, which rely on harmonically rich, high-frequency clock signals for their timing. Improperly isolated, these harmonic signals can appear as interference to other functions in the system, even resulting in excessive output-voltage ripple in the power supply.

Isolation transformers are specified in terms of dielectric isolation that they provide, voltage rating and total power, in volts-amperes (VA). Additional specifications include efficiency (in percent) and the tolerance of the voltage regulation (in percent).

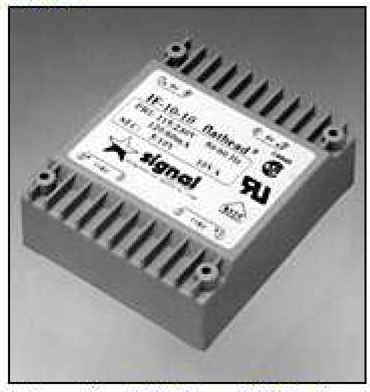
Fig.1 - Schematic of an isolation transformer in a SMPS circuit



An isolation transformer placed before linear power supplies or SMPS circuitry can provide safe operation in accordance with a variety of standards.

Switching power supplies can be designed with either internal or external isolation transformers, although greater isolation is achieved by means of the latter approach. When an external isolation transformer is placed within an electronic design in series with a switching power supply, the output voltage from the transformer can be reduced to a level that is no longer hazardous to the operator, (Fig. 1). The Extra Low Voltage, (ELV) or Safety Extra Low Voltages, (SELV) produced by the transformer establishes the subsequent circuitry below the voltage threshold (30.0 V RMS or 42.4 VDC peak open circuit for Class 2 circuits) required for circuits to meet creepage and clearance electronic safety requirements. Because the transformer provides adequate isolation within a single component, there is no longer a need to achieve distributed isolation throughout the circuitry of a product. Because the voltage following the transformer is low, smaller components (such as inductors and capacitors) can be used throughout the remaining circuitry. In many cases, standard off-the-shelf switching power supplies can be used in the design because of the relaxed creepage and clearance requirements of lower-voltage circuitry. Isolation transformers that meet international safety standards can be specified for use with both linear and switching power supplies, with a variety of power ratings. For example, low-profile isolation transformers in Signal Transformer's International Flathead series meet a wide range of North American and international standards, including UL 5085, CSA 22.2 #66.1, IEC60950 and IEC61558.

Fig.2 - International Flathead Series

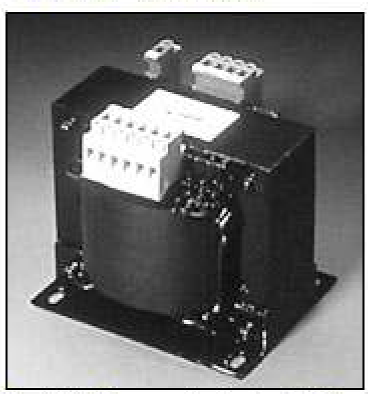


International Flathead (IF) Series isolation transformers meet UL, IEC, VDE, and CSA safety standards.

The IF series having heights as low as 0.69 in., offer isolation of 4000 V RMS and can be supplied with ratings from 2 to 30 VA. They offer standard dual primaries, 115/230-V, 50/60-Hz operation (Fig. 2). These compact transformers are ideal for applications on densely packed PCBs.

At higher power levels, the company's Multi-Purpose Isolation (MPI) and High Power International (HPI) isolation transformers operate at line frequencies of 50/60 Hz with a power range of 200 to 3500 VA (Fig. 3). Designed for use with UPS and linear power supplies, these transformers are certified to UL, CSA, VDE, and IEC safety specifications. A typical 1-kVA unit features 3-percent voltage regulation and 96-percent efficiency.

Fig.3 - MPI Transformer



The MultiPurpose Isolation (MPI) and High Power International (HPI) line of isolation transformers meet a wide range of safety standards with power ratings from 200 to 3500 VA.

Isolation transformers represent an effective means of achieving high isolation in distributed-power systems, such as computers and telecommunications systems. In a typical distributed power system, multiple DC-to-DC converters, rather than a single, centralized power source, provide voltage and current to the system's subsystems and circuits. Small, efficient converters can typically generate 200 W or more at a specific location, helping to overcome voltage drops common when power is transmitted over a distance within a system. By locating converters on each of the system's circuit boards, the system can be assembled in a modular fashion, speeding and simplifying manufacturing and testing processes.

Even though isolated DC-to-DC converters can be used to achieve high isolation in modular, distributed-power architecture, they are expensive compared to non-isolated converters. A better approach is the use of non-isolated DC-to-DC converters where necessary in a distributed-power system, with a single isolation transformer providing the necessary high-voltage isolation. In this way, the DC-to-DC converter need not meet the high-voltage isolation, creepage, and clearance requirements demanded by safety standards. The isolation transformer provids the isolation and the low-voltage transformation to simplify the safety requirements of subsequent circuitry.

Isolation transformers are commonly used with linear power supplies to improve the amount of isolation in the overall circuit. But such transformers can also pay huge dividends when incorporated into high-frequency switching power supplies. They can improve the isolation of a design, as well as enable the overall power-supply circuitry to be made smaller, lighter, less complicated, and less expensive.

In Europe, the IEC either directly or indirectly sets the electrical safety standards for a great many individual nations. The IEC's chief standard for Safety Isolation and Safety Isolating Transformers is the IEC61558-1 and relevant part twos.

The IEC 60601-1, is generally accepted throughout Europe as the standard by which medical electronic equipment must comply (such as UL 544 in the United States and C22.2 No. 125 in Canada).

As with the UL requirements, IEC 950 specifies the amount of leakage current that can be allowed while still gaining certification. Per IEC 950, leakage current should not exceed 3.5 mA for Class I machines and 0.25 mA for Class II machines. Class I electronic products that are designed for hand-held use must be limited to 0.75 mA or less leakage current.

In order to simplify the design and manufacture of electronic products in Europe, a great deal of harmonization has taken place in the European Community. The EN standards are an example of this trend. These harmonization efforts are designed to provide an umbrella standard that safety agencies in various countries can use either as is or with national deivations.

The expected end result is a set of electrical safety standards which is uniformly adopted and recognized throughout all Europe.

Worst-case conditions should always be considered when trying to comply with one or more international standards. The following recommendations can be applied to the selection of a transformer for working voltages of 250 V or less. For example, a transformer should be specified with high dielectric strength of 4 kV or more. This ensures that the level of isolation will meet general as well as specific medical standards. Transformers should also meet minimum requirements for creepage and clearance, with a worst case for 250V and pollution degree 3 at 12 mm. The transformer's temperature class should be at least +130 ºC, and the primary-to-secondary current leakage should be no more than 30 μA.

By meeting these minimum provisions, and evaluating related requirements, such as the type of operating environment (indoors, outdoors, surrounded by hazardous materials, etc.) product designers can ensure compliance with a large number of international standards for operating voltages of 250 V or less. Strategies can be applied similarly to higher or lower operating voltages. Meeting minimum requirements may add some expense to a design however; failure to achieve minimum standard requirements can result in costly redesign and extend design to market cycles.