LEAKAGE CURRENT	AN-113

Leakage Current

WHAT IS LEAKAGE CURRENT?

Leakage current is the current that flows through the protective ground conductor to ground. In the absence of a grounding connection, it is the current that could flow from any conductive part or the surface of non-conductive parts to ground if a conductive path was available (such as a human body). There are always extraneous currents flowing in the safety ground conductor.

WHY IS IT IMPORTANT?

Electrical equipment commonly includes a grounding system to provide protection against a shock hazard if there is an insulation failure. The grounding system usually consists of a grounding conductor that bonds the equipment to the service ground (earth). If there is a catastrophic failure of the insulation between the hot (power) line and touchable conductive parts, the voltage is shunted to ground. The resulting current flow will cause a fuse to blow or open a circuit breaker; preventing a shock hazard. Obviously, a possible shock hazard exists if the grounding connection is interrupted, either intentionally or accidentally. The shock hazard may be greater than supposed because of the leakage currents. Even if there is no insulation failure, interruption of the leakage currents flowing through the ground conductor could pose a shock hazard to someone touching the ungrounded equipment and ground (or other grounded equipment) at the same time. This possibility is of much more concern in medical applications, where a patient may be the recipient of the shock. A fatal shock could result if the patient is in a weakened condition or unconscious, or if the leakage current is applied to internal organs through patient contacts. The double insulation provided in non-grounded equipment provides protection by using two separate layers of insulation. The protection in this case is ensured because both layers of insulation are unlikely to fail. However, the conditions that produce leakage currents are still present, and must be considered.

WHAT CAUSES LEAKAGE CURRENT?

There are two types of leakage current: ac leakage and dc leakage. Dc leakage current usually applies only to end-product equipment, not to power supplies. Ac leakage current is caused by a parallel combination of capacitance and dc resistance between a voltage source (ac line) and the grounded conductive parts of the equipment. The leakage caused by the dc resistance usually is insignificant compared to the ac impedance of various parallel capacitances. The capacitance may be intentional (such as in EMI filter capacitors) or unintentional. Some examples of unintentional capacitances are spacings on printed wiring boards, insulations between semiconductors and grounded heatsinks, and the primary-to-secondary capacitance of isolating transformers within the power supply.

HOW IS IT MEASURED?

A meter specially designed for measuring leakage currents is used. The current flowing in the ground conductor is measured by connecting the meter in series with the grounding connection. For information processing equipment, the ground connection is opened and the current flowing to the neutral side of the power line is measured. For medical equipment, the current flowing to ground is measured. The meter may also be connected between the outputs of the power supply and ground. The test conditions include swapping the ac line and neutral connections, and turning power switches off and on while monitoring the current. The test is performed after the equipment has warmed to normal operating temperature and, in some cases, following certain tests that cause abnormally high temperatures within the equipment. The intent is to identify and measure the worst-case leakage current.

For very low leakage currents, the meter is replaced with a network consisting of either a resistor or a resistor and capacitor combination. The voltage drop across the network is then measured using a sensitive ac voltmeter. Ungrounded or double-insulated equipment is checked by connecting the meter between any touchable conductive part and ground. In the case of non-conductive housings, a copper foil of a specific size is placed on the housing, and the current flowing from it to ground is measured.

WHAT IS A SAFE LEVEL?

For non-medical equipment, the safe levels have been determined by an international organization and documented in the IEC 950 safety standard. Most countries around the world have adopted this standard. The limits are defined in Table 1.

Table 1. IEC 950 Safety Standards

Equipment	Type	Max. Leakage Current
Double Insulated	All	0.25 mA
Grounded	Hand Held	0.75 mA
	Movable (other than hand-held)	3.5 mA
	Stationary (Permanently connected)	3.5 mA (Note 1)

1. Leakage currents greater than 3.5 mA are allowed under certain conditions.

Medical equipment leakage current limits are much lower. The requirements are summarized in Table 2. Because of the lower values of allowable leakage current in medical power supplies, it is important to substantially reduce the capacitances that cause leakage currents. This poses a special design problem for the power supply and especially EMI filters. For example, line-to-ground capacitors are an important part of the EMI filter's ability to perform properly. Reducing their value can severely reduce the filter's effectiveness. Condor's medical designs and patented EMI filtering techniques have overcome these problems.

Table 2. IEC601-1, UL2601-1 Safety Standards

Medical Device Category	**Type B**		**Type BF**		**Type CF**	
Conditions	**N.C.**	**S.F.C.**	**N.C.**	**S.F.C.**	**N.C.**	**S.F.C.**
Earth Leakage Current, Portable	0.5[1]	1.0	0.5[1]	1.0	0.5[1]	1.0
Earth Leakage Current, Fixed	2.5	5.0	2.5	5.0	2.5	5.0
Enclosure Leakage Current	0.1	0.5	0.1	0.5	0.1	0.5
Patient Leakage Current	0.1	0.5	0.1	0.5	0.01	0.05

Notes:
All leakage currents are in mA
N.C. = Normal Condition
S.F.C. = Single Fault Condition
(1) 0.3 mA for UL 2601-1.