QuadTech

Application Note

Ground Bond Testing per UL 60950

UL 60950, “Safety of Information Technology Equipment”, defines numerous safety tests for IT equipment including electrical shock, radiation hazards, chemical hazards, wiring, physical construction, connection to telecommunication networks and flammability. Per UL 60950, this standard is “applicable to mains-powered or battery powered information technology equipment with a rated voltage ≤ 600V and designed for installation in accordance with NFPA 70 and CSA C22.1, CSA C22.2 No. 0”[1]. Examples of applicable equipment include: cash registers, copy machines, modems, ATMs, personal computers, photo-printing machines, postage machines and typewriters.

If you have read (and re-read) paragraph 2.6.3 of UL 60950 and are still confused as to which current to use in the ground bond test, you are not alone. The intention of this particular application note is to investigate, define and clarify the protective earthing and bonding requirements in paragraph 2.6.3.3. Let’s first define the terms used in ground bond testing and those found in UL 60950.

Definitions:

Earth:	same as Ground.
Ground:	base reference from which all voltages are measured, nominally the same potential as the physical Earth. To ‘ground a circuit’ is to make a path for the energy (voltage/current) to drain (disperse) to zero (0).
Ground Bond Test:	a high current (25-30A) is applied to the product under test to verify that all conductive parts of said product (exposed to the user) are connected to power line ground.
Power Line Ground:	connection to Earth through 3rd prong of power cord and 3rd wire of AC outlet (of building installation).
Protective Bonding Conductor:	“a conductor in the equipment or (combination of conductive parts in the equipment) connecting a main protective earthing terminal to a part of the equipment required for safety.” [2] [Equipment ⇔ PE of Equipment]
Protective Earthing Conductor:	“a conductor in the building installation wiring (or in the power supply cord) connecting a main protective earthing terminal in the equipment to an earth point in the building installation.” [2] [PE Equipment ⇔ PE of Building (Earth)]

[1]: UL 60950 ¶1.1.1 Equipment covered by this standard.
[2]: UL 60950 ¶1.2.13.11 and ¶1.2.13.10, respectively

Definitions (continued)

Protective Earth (PE): terminal/conductor connected to Earth through power line ground. Also known as Chassis Ground.

Functional Earth (FE): terminal/conductor directly connected to a circuit that is intended to be earthed for functional (not protective) purposes. The ground point in a circuit that is necessary for the function of the circuit but not for safety.

Over-Current Protective Devices: Electrical or electro-mechanical device in a circuit that will detect and interrupt the over-current flowing in any possible fault current path: line to line; line to neutral, line to PE conductor or line to PB conductor. Example: fuse

Telecommunications Network: (TN): Metallically terminated transmission medium intended for communication between equipment that may be located in separate buildings excluding:

- Mains system for supply, transmission and distribution of electrical power (if used as a telecommunication transmission medium)
- Television distribution systems using cable
- SELV circuits connecting units of data processing equipment

UL 60950 Circuit Definitions[3]:

Primary: Circuit directly connected to AC Mains Supply

Secondary: No direct connection to primary circuit. Derives its power from a transformer, converter or equivalent isolation device or from a battery.

ELV: Secondary circuit with voltage ≤ 42.4V peak or 60V DC separated from hazardous voltage by basic insulation.

SELV: Secondary circuit designed/protected so that under normal operating conditions or single fault conditions its voltages do not exceed a safe value.
Normal Operating condition: Safe Value: ≤42.4V peak or 60V DC
Single Fault condition: Safe Value: ≤ 71V peak or 120V DC

TNV: Secondary circuit in the equipment and to which the accessible area of contact is limited and that is so designed/protected that under normal operating conditions or single fault conditions its voltages do not exceed a safe value.

- **TNV1:** Normal Operating Voltage ≤ SELV circuit Limits
AND
Over-voltages from TN are possible

- **TNV2:** Normal Operating Voltage > SELV circuit Limits
AND
NOT subjected to over-voltages from TN

- **TNV3:** Normal Operating Voltage > SELV circuit Limits
AND
Over-voltages from TN are possible

[1]: UL 60950 ¶1.1.1 Equipment covered by this standard.
[2]: UL 60950 ¶1.2.13.11 and ¶1.2.13.10, respectively
[3]: UL 60950 ¶1.2.8.2, 1.2.8.3, 1.2.8.5, 1.2.8.6, and ¶1.2.8.9-12, respectively

UL 60950 Ground Bond Specifics

UL 60950, paragraph 2.6.3.3, "Resistance of earthing conductors and their terminations" states:
1: Protective Earthing (PE) Conductors comply without test.
2: Protective Bonding (PB) Conductors are divided into two groups.

2a: Protective Bonding (PB) conductors that comply with the minimum conductor sizes specified in Table 3B and are terminated as specified in Table 3E, comply without test.

2b: Those PB conductors that do not, are subjected to the following resistance test:

If the current rating of the circuit under test is ≤16A, these test conditions apply:

Test Current = 2x current rating of circuit under test (AC or DC)
Test Voltage ≤12V
Test Time = 120 seconds

The resistance of the PB conductor shall not exceed 0.1Ω.

If the current rating of the circuit under test is >16A, these test conditions apply:

Test Current = 2x current rating of circuit under test (AC or DC)
Voltage drop across DUT ≤ 2.5V
Test Time = Refer to Table 1.

Table 1: Test Time for Current Rating > 16A

Current Rating of Circuit under Test (A)	Test Time (minutes)
≤30	2
30 ≤ 60	4
60 ≤ 100	6
100 ≤ 200	8
>200	10

The resistance of the PB conductor shall not exceed 0.1Ω.

Before calculating an example, investigate what the requirements for protective earthing really entail for the device under test (DUT). Over-current protection, circuit classification, test current and current rating are defined in the following paragraphs to further clarify the PE test and DUT.

Figure 1 illustrates over-current protection between the person touching the device under test and the possible fault current in the device. There is over-current protection between the AC mains supply coming into the facility and the electrical device under test. The DUT has two levels of protection in the form of fuses and electrical insulation between the live circuit and the operator. So that, in the case of a fault current, the resistance between the operator and DUT is ≤ 0.1Ω.

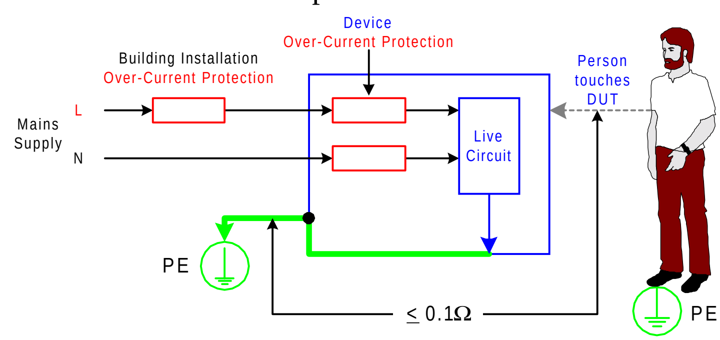


Figure 1: Over-Current Protection

Classify the Equipment

Classification:

The equipment under test, specifically the part of the equipment to be tested (circuit requiring PE) must first be classified in accordance with paragraph 2.6.1 of UL 60950. Paragraph 2.6.1 discusses what types of current the earthed part is likely to carry, the use of over-current protection and the use of protective earthing for different purposes in SELV and TNV circuits and other parts. All parts likely to carry fault currents intended to operate over-current protective devices are specified in subparagraphs a, b, c or d. Earthed parts that carry other currents, NOT intended to operate an over-current protective device but are required to be earthed, are specified in subparagraphs e, f and g.

Parts likely to carry fault currents:

¶ 2.6.1.a	All conductive parts that might assume hazardous voltage in the event of a single fault condition. Example of single fault condition: failure of basic insulation between the primary circuit (mains) and the conductive parts.
¶ 2.6.1.b, c, d	SELV, and TNV circuits in which basic insulation combined with protective earthed (PE) parts or an earthed screen are used in lieu of double or reinforced insulation and the power source is not a TN. Special circumstances exist for pluggable equipment Type A & B and should be reviewed in ¶ 2.3.2 of UL 60950.

Parts likely to carry other currents:

¶ 2.6.1.e	SELV, and TNV circuits in which basic insulation combined with protective earthed (PE) parts or an earthed screen are used in lieu of double or reinforced insulation AND the power source is a Telecommunications Network (TN). Special circumstances exist for pluggable equipment Type A & B and should be reviewed in ¶ 2.3.2 of UL 60950.
¶ 2.6.1.f, g	Components and circuits NOT assuming a hazardous voltage in the event of a single fault but are earthed to reduce transients that might affect insulation or to reduce touch currents. Example: A SELV or TNV circuit that uses double or reinforced insulation that is earthed to reduce touch currents.

Okay, the equipment, specifically the circuit requiring PE, can be put into a test category. Based on what current the circuit is likely to carry, the test current for the ground bond test can now be selected.

Current Rating of Device under Test

Test Current for devices Specified in:

¶ 2.6.1.e — Test current is 1.5 times the maximum current from the telecommunication network (if known) or 2 A, which ever is the larger.

¶ 2.6.1.f, g — No test current requirements except that the conductors shall be adequate for the actual current under normal operating conditions.

¶ 2.6.1.a, b, c, d — Test current depends upon current rating of the circuit or equipment being tested and is 2 times the current rating.

The circuit is classified and the test current is selected, now determine the current rating for the circuit under test.

Current Rating:

Current rating of the circuit under test can also be confusing especially when the circuit is just one part of an electrical device. The current rating of the circuit depends upon the location of the over-current protective device(s) and the current rating shall be taken as the **smallest** of the following conditions:

1. Rated current of the equipment.
2. Rating of an over-current protective device specified in the equipment installation instructions. (Generally a 20Ampere circuit is assumed)
3. Rating of the over-current protective device in the equipment that protects the circuit or part to be earthed.

In some cases it might be acceptable to assume worst case value for current rating, which would be condition #2, and this would give a test current of 40Amperes. The standard however specifically states the **smallest of the following** not the largest or worst case. In most conditions #3 or #1 would be chosen as the current rating, assuming that over-current protective device, such as a fuse, is located in such a way that current from the primary circuit, i.e. mains, does not have an alternate path around the fuse. A device where the use of condition #2 would be applicable is a rack cabinet that has no over-current protection.

Device under Test

The device under test can take on many forms: an electronic instrument, a circuit within the electrical equipment or plug-in electrical devices. It's determining the protective earthing of circuits within electrical equipment and measuring their respective ground resistance that can be tricky. Let's look at three device examples and how a ground bond test would be performed to check for protective earthing of said devices. Take a computer hard drive tower. It has a 3-prong power cord, the 3rd wire being the ground plane, protective earth connection, for the tower itself. Inside the tower there are a many plug-in components (power supply, memory card, nic card, sound card, video card) but they are grounded by connection to the tower case. Figure 2 illustrates the most straightforward ground bond test, measuring the resistance through the power cord.

Basic Ground Bond Test

The ground bond test in Figure 2 verifies the ground connection of the case of the DUT (here a computer monitor) through the power cord, also known as the chassis ground connection. Earthing and bonding refer to the grounding of any exposed metal on the device under test (DUT) to the main Protective Earthing (PE) terminal. Before a high voltage (hipot) stress test is done, a ground bond test is typically done to verify that the DUT is indeed grounded before the high voltage is applied. A 4-terminal Kelvin connection to the DUT is illustrated in Figure 2.

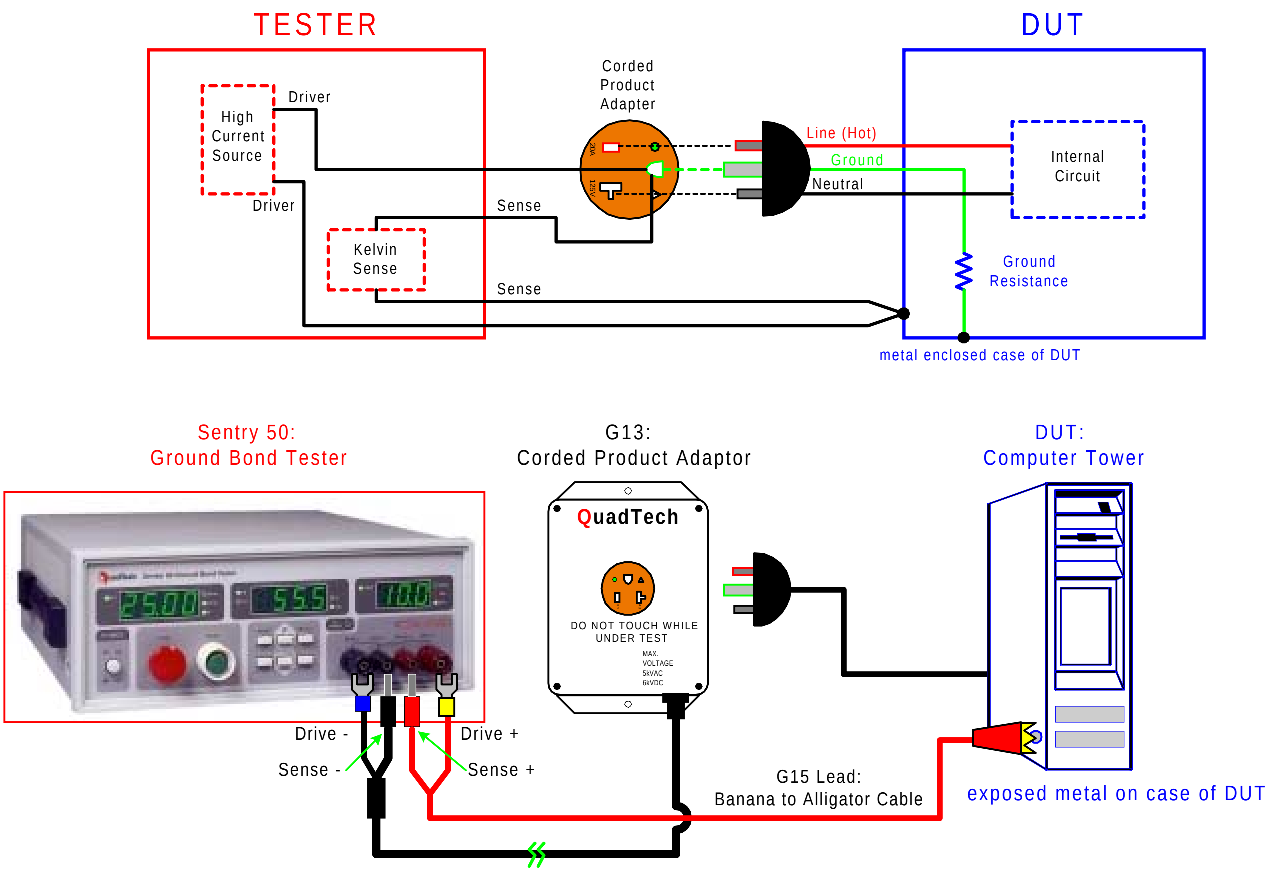


Figure 2: Ground Bond Test Setup

A ground bond test consists of three steps:
1: Apply High AC (or DC) current to the DUT with low voltage for a period of time.
2: Measure the Voltage drop between the PE terminal and the part to be earthed.
3: Calculate the Resistance = Voltage drop divided by the Applied Current.

For devices without power cords, those that plug into a rack or system, the ground bond test is not so straightforward. Investigate two such examples next and calculate their respective test currents.

Plug-In Devices

The two examples of devices (circuits) under test that we'll determine the PE test current for are a computer power supply and a telecomm carrier card.

Computer Hard Drive Power Supply

The power supply would fall under the "¶ 2.6.1.b, c, d with PE and Basic Insulation" definition of parts likely to carry fault currents and therefore it's test current would depend on the current rating of the circuit under test, which is 2 times the current rating.

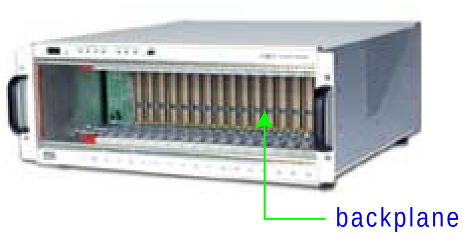
This particular power supply for a computer hard drive can provide 20A @ +5V. This current (20A) is > 16A, therefore the ground bond test conditions would be: current equal 2 X (20A) = 40A with the test voltage equal to 5V for a duration of 2 minutes. The measured resistance should be < 0.1Ω. **Hold On!** If the power supply hot/neutral connections are fused, then the current rating of the 'circuit under test' becomes the current rating of the fuse. Said power supply has a fuse rating of 5A/250V. Therefore the ground bond test condition becomes: 2 X (5A) = 10A at 5V for a duration of 120 seconds.

Telecomm Carrier Card

The telecom carrier card, plugged into a slot of a multi-port telecommunications network, would fall under the "¶ 2.6.1.e" definition of parts likely to carry other currents whose power source is a telecommunications network. The test current would then be 1.5 times the maximum current from the telecommunications network (if known) or 2A, which ever is larger. A telecom carrier card is not fused but has a laminated ground connection. It is inserted into a multi-port network against a backplane.

Not knowing the maximum current of the TN, calculate the test current using the current rating of the telecom card. The telecom card itself provides 2A @ 5V. This current rating is < 16A, so the ground bond test conditions would be: current equal 2 X (2A) = 4A with the test voltage equal to 5V for a duration of 120 seconds. The measured resistance should be < 0.1Ω.

Telecom carrier card



Multi-port TN

UL 60950 Conductor Specifications

Paragraph 2.6.3 of UL 60950 calls out specific current values, wire sizes, and conductor sizes for protective earthing and bonding conductors. They are included in this application note for reference.

UL 60950 Table 3B – Conductor Sizes

Rated Current of Equipment	Minimum Conductor Size		
	Nominal Cross Sectional Area (mm^2)	AWG or kcmil [ ] = c-s area in mm^2	
≤ 6	0.75 [1]	18	[0.8 mm^2]
6 ≤ 10	1.00 (0.75)[2]	16	[1.3 mm^2]
10 ≤ 13	1.25 (1.0)[3]	16	[1.3 mm^2]
13 ≤ 16	1.5 (1.0)[3]	14	[2 mm^2]
16 ≤ 25	2.5	12	[3 mm^2]
25 ≤ 32	4	10	[5 mm^2]
32 ≤ 40	6	8	[8 mm^2]
40 ≤ 63	10	6	[13 mm^2]
63 ≤ 80	16	4	[21 mm^2]
80 ≤ 100	25	2	[33 mm^2]
100 ≤ 125	35	1	[42 mm^2]
125 ≤ 160	50	0	[53 mm^2]
160 ≤ 190	70	000	[85 mm^2]
190 ≤ 230	95	0000	[107 mm^2]
230 ≤ 260	120	250 kcmil	[125 mm^2]
260 ≤ 300	150	300 kcmil	[152 mm^2]
300 ≤ 340	185	400 kcmil	[202 mm^2]
340 ≤ 400	240	500 kcmil	[253 mm^2]
400 ≤ 460	300	600 kcmil	[304 mm^2]
[1] For RATED Current up to 3A, a nominal cross-sectional area of 0.5mm^2 is permitted in some countries provided the power cord is ≤2m.			
[2] The value in parenthesis applies to DETACHABLE POWER SUPPLY CORDS fitted with the connectors rated 10A in accordance with IEC 60320 (types C13, C15, C15A and C17) provided that the length is ≤2m.			
[3] The value in parenthesis applies to DETACHABLE POWER SUPPLY CORDS fitted with connectors rated 16A in accordance with IEC 60320 (types C19, C21 and C23) provided that the length is ≤2m.			

UL60950 Table 3E:
Terminal Sizes for ac mains supply conductors and protective earthing conductors

Rated Current of Equipment A	Minimum Nominal Thread Diameter (mm)	
	Pillar or Stud Type	Screw Type[1]
≤ 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
[1] "Screw Type" refers to a terminal that clamps the conductor under the head of a screw, with or without a washer.		

For complete product specifications on the Sentry 50 Ground Bond Tester, or any of QuadTech's products, visit us at http://www.quadtech.com/products. Call us at 1-800-253-1230 or email your questions to info@quadtech.com.