

Ground Resistance Measurement with Smart Ohm

Application Note



Today's integrated circuits (ICs) are designed with increasingly smaller geometries and higher processing speeds. These design features cause semiconductors to become increasingly vulnerable to electrostatic discharge (ESD) damage. ESD can be triggered by human touch, machine handling, testing by automated testers, or by pre-charge events such as friction produced by the handlers. ESD poses a serious threat to every IC design facility and fabrication process house. ESD-related failures are estimated to cost millions of dollars in lost revenue for IC manufacturers every year.

In battling ESD, factories are equipped with conductive flooring materials to conduct the electric charges from the work area. Operators handling ICs are required to wear special coats with conductive filaments, and/or heel-straps. At the work bench, operators are required to wear wrist straps to ensure that they are grounded. However, based on investigations by ESD experts, less than 0.10% of all the documented damage actually comes from ungrounded personnel touching ESD-sensitive products. In other words, 99.9% of ESD damage is attributed to charging/discharging events that occur in production equipment and processes. Consequently, maintaining ground integrity for equipment plays a vital role in the reduction of ESD.

This application note shows how you can get an accurate ground resistance measurement in the presence of offset voltage using the Agilent Technologies U1272A/U173A handheld digital multimeter with Smart Ohm.



Agilent Technologies

Ground Resistance

In the IC manufacturing industry, electrical circuits are connected to ground for several reasons. The equipment's exposed metal parts are connected to ground to prevent contact with a dangerously high voltage if the electrical insulation fails. Grounding also serves to drain off static electricity charges on the metal part before a spark-over potential is reached.

For a brand-new installation, grounding connections on the tester may be good; but after some time, the wires may bend, stretch, and break. Ground resistance will then tend to increase. If proper grounding checks are not performed consistently, semiconductors may be damaged due to ESD.

So what is a good ground resistance value? Ideally, its value should be zero ohms. In the IC testing environment, any reading below < 1 ohm is considered good.

Measuring Resistance

When you perform a ground resistance measurement, you should take into consideration the residual voltage induced by ground current. Even a small offset voltage of 7 mV can cause deviation in measurements. With a regular handheld multimeter, you would have to perform multiple voltage measurements and use an external current excitation source to get the exact measurement result. Now, the Agilent U1272A/U1273A handheld multimeter with the new Smart Ohm feature simplifies the whole process. A circuit designer can also measure leakage current using the Smart Ω function—instead of having to use a high-precision multimeter with 1 nA, 0.1 nA, or a precision shunt.

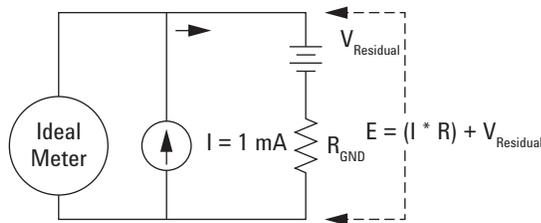
Smart Ohm is an offset compensation function that removes the effect of any voltage in the circuit being measured. Once the Smart Ohm function is enabled, Agilent U1272A/U1273A performs the two resistance measurements, one with the current source turned on, and one with the current source turned off. The difference is then used to compute ground resistance. The result is displayed on the screen while the amount of leakage current or offset voltage is shown on the handheld's secondary display.

How Does the Smart Ohm Work?

In every resistance measurement, the digital multimeter supplies a test current of 1 mA and then measures the voltage drop across the unit under test. The measured voltage drop is then used in the calculation for resistance. However, this technique is not able to generate an accurate resistance measurement with the presence of residual voltage. The offset has to be removed first.

Smart Ohm - Offset Compensation Technique

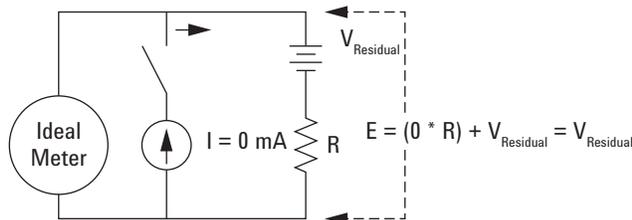
Step 1: The offset compensation technique makes a voltage measurement with 1 mA supply to the device under test. This measurement measures the residual voltage, plus the voltage drop across the R_{GND} , ground resistance due to the 1 mA test current.



$$\begin{aligned} E &= V_{Residual} + (I * R) \\ &= 7.0 \text{ mV} + (1 \text{ mA} * R_{GND}) \\ &= 7.2 \text{ mV (measured)} \end{aligned}$$

Note: Residual voltage is induced by the ground current.

Step 2: During the second measurement, the current source is switched off to measure the residual voltage due to the ground current.



$$V_{Residual} = 7 \text{ mV (measured)}$$

$$\begin{aligned} V_{Different} &= E - V_{Residual} \\ &= 7.2 \text{ mV} - 7.0 \text{ mV} \\ &= 0.2 \text{ mV} \end{aligned}$$

$$\begin{aligned} R_{GND} &= V_{Different} / 1 \text{ mA test current} \\ &= 0.2 \text{ mV} / 1 \text{ mA} \\ &= 0.2 \Omega \end{aligned}$$

Only using Step 1 for resistance measurement, produces a resistance measurement with offset error.

$$\begin{aligned} R_{GND \text{ Error}} &= E / 1 \text{ mA test current} \\ &= 7.2 \text{ mV} / 1 \text{ mA} \\ &= 7.2 \Omega \end{aligned}$$

$$\begin{aligned} \text{Ratio} &= R_{GND \text{ Error}} / R_{GND} \\ &= 7.2 \Omega / 0.2 \Omega \\ &= 36 \text{ times} \end{aligned}$$

Sometimes the measurement value can be up to 100 times higher than the original value.



Note: The maximum correctable offset/bias voltage is +50 mV / -30 mV for the 30 Ω range and +1.0 V / -0.2 V for the 300 Ω, 3 kΩ, 30 kΩ, and 300 kΩ ranges. If the dc voltage on the resistor is over the maximum correctable offset/bias voltage, the OL sign is shown on the secondary display.

Conclusion

Proper grounding is the most fundamental element of ESD management in manufacturing and service. A broken ground connection may result in personnel exposure to dangerous voltage, equipment lock-up or malfunction, and damage to sensitive components. Only continuous ground monitoring can assure proper grounding at all times. Agilent U1272A/U1273A with its Smart Ohm function is the ideal tool for maintenance technicians or engineers to ensure their equipment is properly grounded.



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