

# Keysight Technologies

## Seven Practices to Prevent Damaging Power Meters and Power Sensors



### Introduction

Year after year, a significant number of power sensors are damaged because of users' carelessness or ignorance. Knowing the proper usage and precautions for power sensors and meters would spare you inconvenience and downtime required for repair.

This paper outlines seven practices for keeping your power sensors in good shape.

### Application Note

## 1. Avoid Overpower and Overvoltage

Beyond the dynamic range, there is also the maximum power tolerable by the power sensor. Taking the U2001H USB average power sensor as an example. The label (see Figure 1) indicates an average power rating of +33 dBm (2 W). Exceeding this power limit (see Figure 2) will risk damaging its sensing element. Use an attenuator if the power to be measured could be higher than the power rating of the sensor (see Figure 3).

Another power rating, the peak power rating, is not on the label but can be found in the *Keysight U2000 Series USB Power Sensors Operating and Service Guide*. In the case of U2001H, the damaging level of peak power is specified at 50 dBm/1  $\mu$ s.

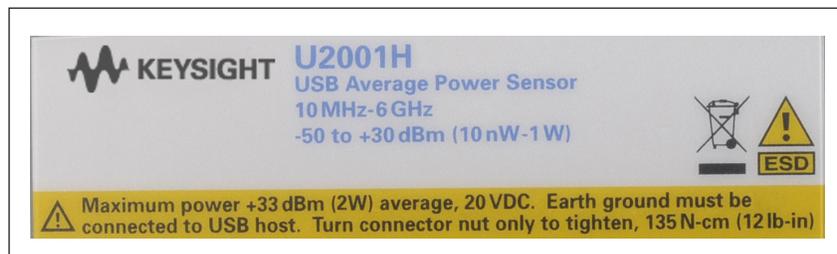


Figure 1. Front label of Keysight U2000 Series USB power sensor

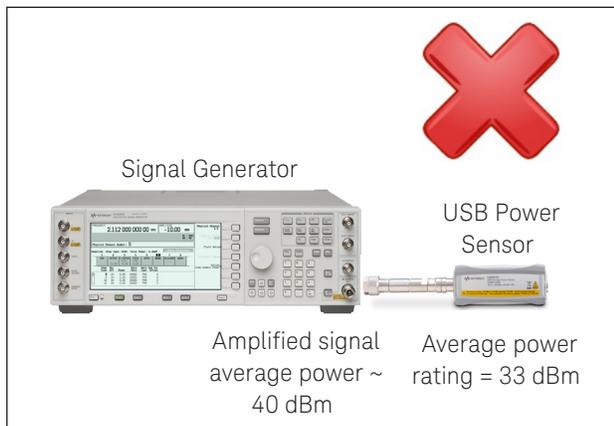


Figure 2. Measured power exceeds damage level

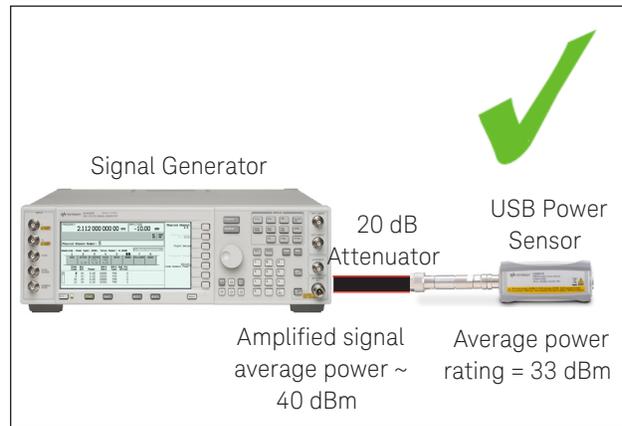


Figure 3. Measured power within dynamic range

If DC voltage is present in the signal to be measured, users are advised to use a DC block to remove the DC component. For U2001H, a presence of more than 20 VDC in the measured signal will damage the sensing element in the power sensor, as indicated on the label.

After applying the appropriate attenuator and DC block, turn on the connected equipment or device under test (DUT) at reduced power levels before slowly increasing it to the intended power level. This will prevent unexpected voltage swell from affecting the power sensor.

## 2. Adhere to Warnings and Specifications

Every power sensor has a minimum power level and a maximum power level that it is able to sense. This is known as the dynamic range and will be clearly indicated on each power sensor, as shown in Figure 4 and Figure 5.

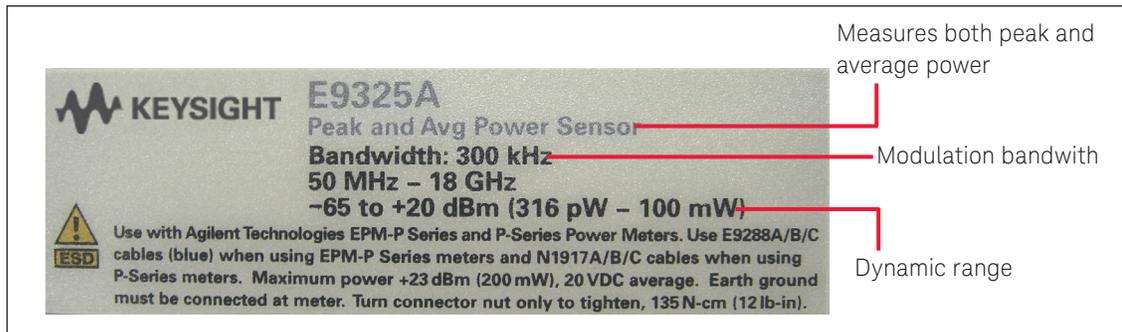


Figure 4. Front label of a diode peak-and-average power sensor

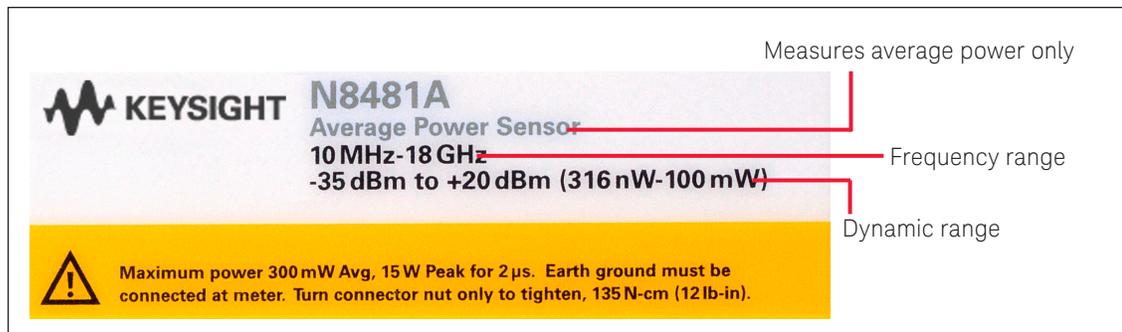


Figure 5. Front label of a thermocouple average power sensor

If the applied RF power is lower than the minimum, the measurement obtained will be unstable and probably inaccurate. However, if the measured power is higher than the maximum power limit, lying somewhere between 100 mW to 300 mW, it will be impossible to guarantee an accurate measurement.

Do not exceed the values indicated on the warning labels on the power sensor and meter. Most of the content of a typical power sensor label has been discussed in the earlier paragraphs. Grounding will be discussed in Section 5 and connectors will be covered in Section 3.

Every power sensor and meter is accompanied by a warning label that indicates the values that when exceeded may cause damage. As space on the label is limited, more details are provided in the specifications guide and/or operating manual. Refer to specification guides for conditions required to meet listed specifications. Do also take note of information regarding stabilization time, instrument settings, and calibration/alignment requirements.

### 3. Protect the RF Input Connector

Take care not to bend, bump, or flex any connected DUTs such as filters, attenuators, or cables, in order to reduce the amount of strain placed on the power sensor connector and the mounted hardware.

Make sure all connected items are properly supported. Leaving connected items freely suspended would cause their weight to exert stress on the RF connectors.

When making connections for measurements, users are advised to use a torque wrench and gauge tools. Turn the connector nut only to tighten. As shown in Figure 6 and Figure 7, turn only the connector nut and not the body of the power sensor.



Figure 6. Do not turn the power sensor body

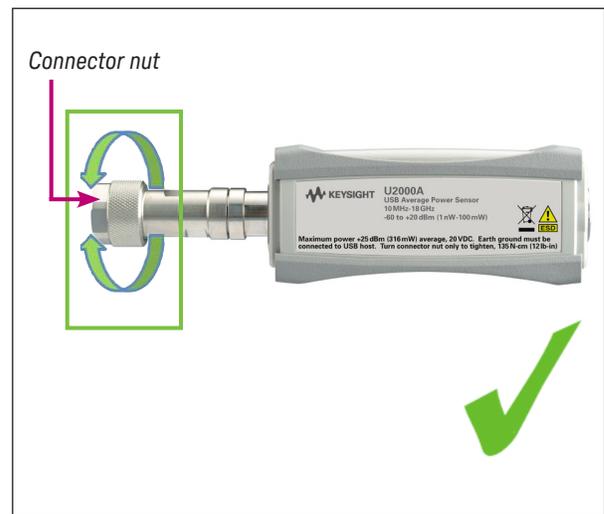


Figure 7. Turn only the connector nut

The rotating force applied must not exceed 135 N-cm. A torque wrench will ensure that the rotating force is not too strong. Figure 8 depicts a straightened torque wrench that will remain straight as you tighten the power sensor RF connector to a DUT. However, in case any excessive force is applied to a sufficiently tightened connection, the torque wrench will bend as illustrated in Figure 9, preventing damage to the RF connector.



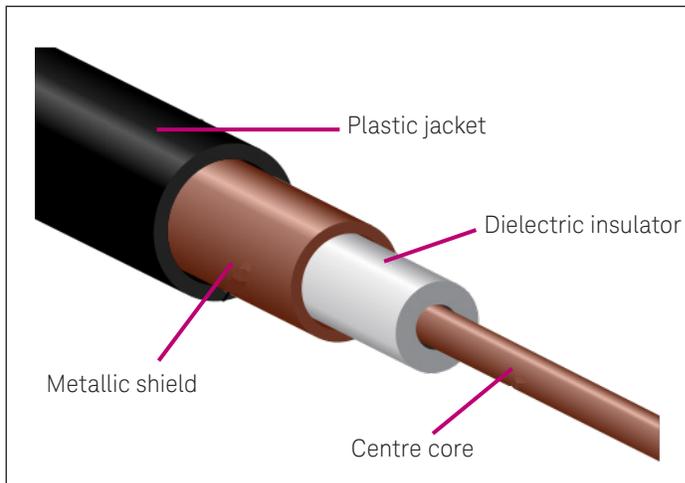
Figure 8. Straightened torque wrench



Figure 9. Bent torque wrench

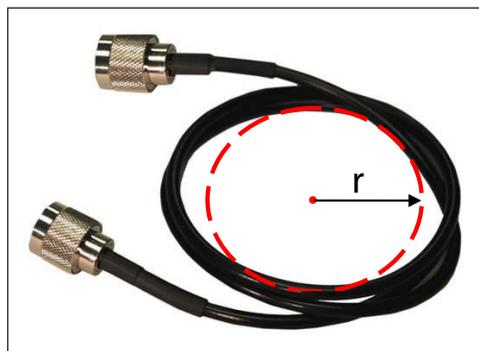
## 4. Follow Proper RF Cable and Connector Care

Designed to conduct RF power, the coaxial cable is constructed to prevent power loss. The spacing between the center conductor and shield has to be uniform. Any abrupt change in the spacing of the two conductors along the cable tends to reflect RF power back towards the source. To hold the shield at a uniform distance from the central conductor, the space between the two is filled with a semi-rigid plastic dielectric.



**Figure 10.** Coaxial cable cross section

For this reason, the manufacturers specify minimum bend radius,  $r$ , to prevent kinks that will cause reflections. Bending the cable in a smaller bend radius than the specified minimum will collapse the dielectric and ruin the necessary spacing between the center conductor and shield. As a general rule, let the cable take its natural turn when the cable is in use or put away in storage.



**Figure 11.** Do not bend to less than a radius  $r$

A damaged or out-of-specification connector can ruin a good connector attached to it even on the first connection. Even though connectors are designed and manufactured to the highest standards, every connector has a limited service life. This means that connectors can become defective due to wear and tear. For best results, all connectors should be inspected and maintained to maximize service life.

## 4. Follow Proper RF Cable and Connector Care (cont'd)

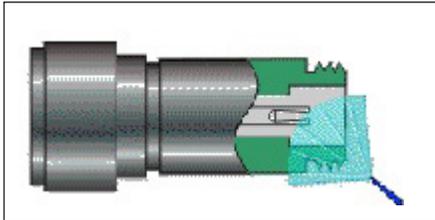
### Inspect Connectors

Inspect connectors with a magnifying glass (>10X) prior to use. Look for badly worn plating, deep scratches, deformed threads, metal particles on thread, and bent, broken, or misaligned center conductors.

### Cleaning Connectors

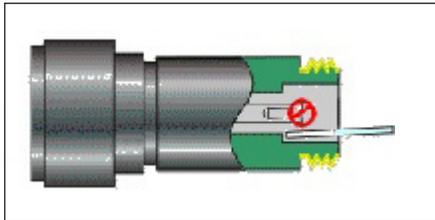
Cleaning the dirt and contamination from the connector mating plane surfaces and threads can extend the service life of the connector and improve the quality of calibration and measurements.

Use clean low air pressure to remove loose particles from mating plane surfaces and threads. Inspect the connector thoroughly.



**Figure 12.** Clean mating plane surfaces and threads using low air pressure

If, after using low air pressure, additional cleaning is required, moisten – do not saturate – a lint-free swab with isopropyl alcohol. When cleaning interior surfaces, avoid exerting pressure on the center conductor and keep swab fibers from getting trapped in the female center conductor.



**Figure 13.** When additional cleaning is required, do not apply pressure on the center conductor and keep swab fibers from getting trapped in the female center conductor

Then, let the alcohol evaporate before blowing surfaces clean with compressed air to make sure no particles or residue remain.

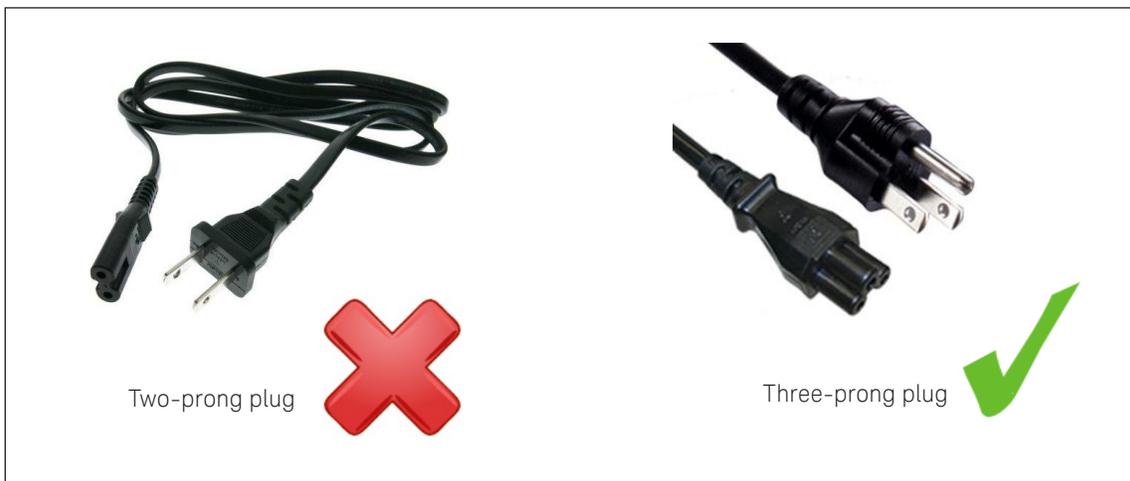
If defects are still visible at this stage of cleaning, the connector itself may be damaged and should not be used. Determine the cause of damage before making further connections.

For more connector-cleaning and cable-care tips, refer to Application Note 326 at [www.keysight.com/find/cable\\_care](http://www.keysight.com/find/cable_care)

## 5. Ensure Proper Grounding

The impact of incorrect or absent grounding ranges from noise interference, resonance, or humming during use of electrical equipment. In the worst case, it can lead to electrical leakage through the chassis, causing personal injury or damage to instrument components.

Proper grounding of the instrument will prevent a build-up of electrostatic charge that may be harmful to the instrument and the operator. Always use the three-prong AC power cord supplied with the power meter. The third prong in three-prong plugs connects exposed metal in the equipment to ground. When the instrument is working properly, there will be no current in the equipment ground. If a malfunction occurs, the equipment ground provides a path for the current to flow to ground. Make sure the polarity of the hotline and neutral line are correct. The voltage between the neutral and ground lines should be less than 1 V. At the socket end, the impedance between neutral and the ground lines should be lower than 1  $\Omega$ .



**Figure 14.** Use three-prong plug for the safety of yourself and your equipment

Check the stability of the AC power and whether there are unpredictable impulses that may cause measurement to fail or even damage the instrument. Generally, the transient voltage should not exceed  $\pm 15\%$  within 120 V, and the voltage should be restored to 120 V within 0.5 second. The total harmonic component should be less than 5%. Install uninterruptible power supply (UPS) if necessary.

Verify the grounding of the equipment or DUT. If voltage differences exist between the equipment or devices, connecting them may cause conflicting situations. The sudden pulses generated when equipment is powered on may damage vulnerable modules. If this happens, the links between the equipment and DUT should be disconnected before the AC power is tuned on. Each piece of equipment and DUT should be reconnected only after all equipment and devices have stabilized.

Use an extension cable, power cable, or autotransformer with a protective ground conductor. This is to prevent damaging the earth-grounding protection.

## 6. Follow Electrostatic Discharge Precautions

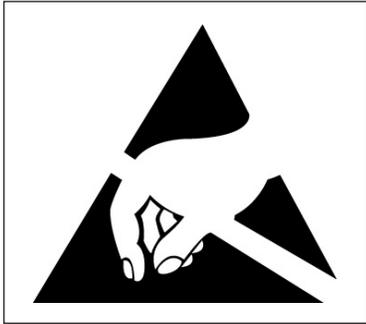


Figure 15. ESD symbol

Power sensors are static-sensitive devices.

Somewhere on the power sensors, there will be a ESD Susceptibility Symbol (see Figure 15). The triangle indicates “caution,” and the slash through the hand means “Do not touch.” Due to its broad usage, the hand in the triangle has become associated with electrostatic discharge (ESD) and indicates that handling or use of this item may result in damage from ESD if proper precautions are not taken.

Electrostatic discharge can damage or destroy electronic components. Do not, under any circumstances, open the power sensor unless the power sensor and you are in a static-free environment.

Clean the connector only at a static-free workstation. Electrostatic discharge to the center pin of the connector will render the power sensor inoperative.

Before connecting any coaxial cable to the instrument, momentarily short the center and the outer conductors of the cable together to ground.

Whenever possible, conduct testing at a static-free workstation.

Keep electrostatic-generating materials at least 1 meter away from all components.

When not in use, always put connector cap on the power sensor to prevent ESD.

For more information about ESD, contact the Electrostatic Discharge Association (<http://www.esda.org>)



Figure 16. Power sensor with connector cap

## 7. Check for Proper Temperature and Humidity



Figure 17. Typical indoor climate monitor

Keep power sensors and meters in a clean and dry environment. Fans and cooling vents should be inspected and cleaned frequently. Ensure proper ventilation among racks. The optimal operating temperature is  $23^{\circ}\text{C} \pm 5^{\circ}\text{C}$ . Always keep the instrument ambient temperature at  $< 30^{\circ}\text{C}$ . The temperature for typical storage condition is between  $-40^{\circ}\text{C}$  and  $75^{\circ}\text{C}$  with humidity of  $< 95\%$  RH.

Relative humidity is the ratio of the amount of water vapor currently in the air to the maximum amount of water vapor possible at a given temperature and pressure. Often overlooked, it is actually a significant environmental factor in ESD. Dry air causes electrostatic build-up when air flows, over an insulated surface. Moisture content in the air reduces the resistance of floors, carpets, table, mats, and other insulating surfaces by creating a conductive film over the surface. Substantial electrostatic voltage can accumulate with a decrease in relative humidity.

If humidity is too high, condensation can build up, causing erosion or short-circuiting in components. This will impact the lifespan of your equipment.

## CONCLUSION

Most damages to the power meters and sensors can be avoided by following a few precautions. One of the main things to remember is to ensure that measured power and DC voltage are always below the maximum limit indicated on the power sensor. RF connectors of both the equipment and connecting cables should be cleaned and protected when not in use. Take precautions to prevent ESD, and make sure the equipment is properly grounded and that the ambient temperature is  $< 30^{\circ}\text{C}$ .

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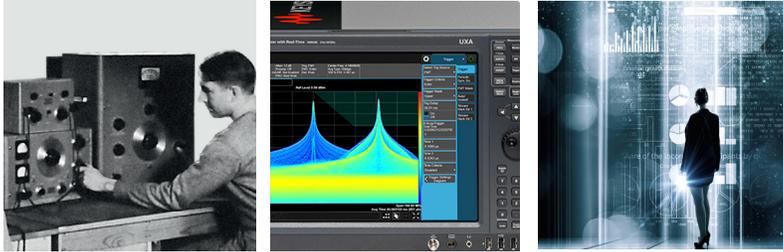
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