Keysight R8486D/Q8486D Power Sensor

Operating Guide

KEYSIGHT TECHNOLOGIES

Notices

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A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

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Keysight Technologies certifies that this product met its published specifications at the time of shipment. Keysight further certifies that its calibration measurements are traceable to the United States National Institute of Standard and Technology (formerly National Bureau of Standards), to the extent allowed by that organization's calibration facility, and to the calibration facilities of other International Standards Organization members.

Warranty

This Keysight Technologies instrument product is warranted against defects in material and workmanship for a period of one year from date of shipment. During the warranty period, Keysight Technologies will at its option, either repair or replace products which prove to be defective. For warranty service or repair, this product must be returned to a service facility designated by Keysight Technologies. Buyer shall prepay shipping charges to Keysight Technologies and Keysight Technologies shall pay shipping charges, duties, and taxes for products returned to Keysight Technologies from another country. Keysight Technologies warrants that its software and firmware designated by Keysight Technologies for use with an instrument will execute its programming instructions when properly installed on that instrument. Keysight Technologies does not warrant that the operation of the instrument, or firmware will be uninterrupted or error free.

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Safety Considerations

Read the information below before using this instrument.

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards for design, manufacture, and intended use of the instrument. Keysight Technologies assumes no liability for the customer's failure to comply with these requirements.

CAUTION

- This product is designed for use in Installation Category II and Pollution Degree 2.
- This instrument has been designed and tested in accordance with IEC Publication 348, Safety Requirements for Electronic Measuring Apparatus, and has been supplied in a safe condition. The instruction documentation contains information and warnings which must be followed by the user to ensure safe operation and to maintain the instrument in a safe condition.
- "CSA" The CSA mark is a registered trademark of the Canadian Standards Association.
- Notice for Germany: Noise Declaration LpA < 70 dB am Arbeitsplatz (operator position) normaler Betrieb (normal position) nach DIN 45635 T. 19 (per ISO 7779).

Environmental Conditions

The R8486D/Q8486D is designed for indoor use and in an area with low condensation. The table below shows the general environmental requirements for this instrument.

Environmental condition	Requirement
Temperature	Operating condition – 0 °C to 55 °C Storage condition – –40 °C to 75 °C
Humidity	Operating condition – Less than 95% Storage condition – Less than 95% at 40°C
Altitude	Operating condition – Less than 4550 meters (15,000 feet) Storage condition – Less than 15,300 meters (25,000 feet)

Waste Electrical and Electronic Equipment (WEEE) Directive 2002/96/EC

This instrument complies with the WEEE Directive (2002/96/EC) marking requirement. This affixed product label indicates that you must not discard this electrical or electronic product in domestic household waste.

Product category:

With reference to the equipment types in the WEEE directive Annex 1, this instrument is classified as a “Monitoring and Control Instrument” product.

The affixed product label is as shown below.

Do not dispose in domestic household waste.

To return this unwanted instrument, contact your nearest Keysight Service Center, or visit http://about.keysight.com/en/companyinfo/environment/takeback.shtml for more information.

Sales and Technical Support

To contact Keysight for sales and technical support, refer to the support links on the following Keysight websites:

- www.keysight.com/find/powersensors
  (product-specific information and support, software and documentation updates)
- www.keysight.com/find/assist
  (worldwide contact information for repair and service)

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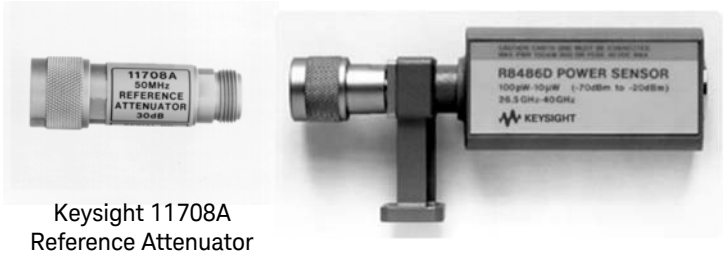
1 General Information

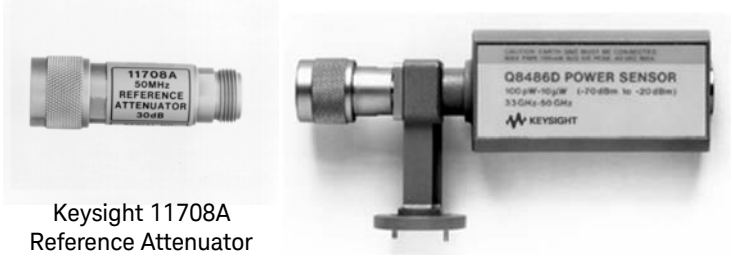
General Information

This operating manual contains information about initial inspection and operation of the Keysight R8486D and Keysight Q8486D power sensors.



Keysight 11708A
Reference Attenuator
(11708-60001)

Figure 1-1 Keysight R8486D power sensor and reference attenuator



Keysight 11708A
Reference Attenuator
(11708-60001)

Figure 1-2 Keysight Q8486D power sensor and reference attenuator

Table 1-1 Accessories included with the Keysight R8486D/Q8486D power sensor

Power sensor	Accessories part number	Description
R8486D	11708-60001	Keysight 11708A reference attenuator
	2260-0002	Flange nut
	3030-0209	Flange screw
	5040-0359	Flange cover
	8710-1539	Hex ball driver
Q8486D	11708-60001	Keysight 11708A reference attenuator
	1390-0671	Flange screw
	1401-0211	Flange cover
	8710-1539	Hex ball driver

Warranty

The power sensors are warranted and certified as indicated on the last page of this manual. Do not open the power sensors. Any attempt to disassemble the power sensors will void warranty.

Description

The Keysight R8486D and Keysight Q8486D are diode power sensors. They measure power levels in a range from –70 dBm to –20 dBm (0.1 nW to 10 μW). The Keysight R8486D measures at frequencies from 33 GHz to 50 GHz (Specifications for power sensors are in Table 3-1)

The power sensors measure the power dissipated in a 50 Ω load place on the microwave source. The power is determined from the AC voltage developed across the 50 Ω load. The diodes convert this AC voltage to DC. The DC voltage produced is the square of the AC voltage. This low-level DC voltage requires amplification before it can be transferred on standard cables to the power meter.

The amplification is provided by an input amplifier assembly which consists of a chopper (sampling gate) and an input amplifier. The DC voltage is routed to the

chopper circuit which converts the low-level DC voltage to an AC voltage. The chopper is driven by a 220 Hz square wave generated by the power meter. The result is an AC output signal proportional to the DC input. The AC signal is then amplified by the input amplifier. The relatively high-level AC signal output can now be routed by standard cables.

NOTE The Keysight R8486D/Q8486D power sensors are compatible with the Keysight 435B, Keysight 436A, Keysight 437B and Keysight 438A power meters. The Keysight R8486D/Q8486D power sensors cannot be used with Keysight 435A power meters.

In application, the power sensors are connected between a microwave source and a compatible power meter. The power sensors provide a matched load to the microwave source for very low SWR. The power meter indicates the power dissipated in the load in μW, nW or in dBm.

CAUTION Do not disassemble the power sensors. The power sensors are extremely static sensitive and can be easily damaged.

Accessories

Included with each power sensor is the Keysight 11708A 30 dB reference attenuator (Figure 1-1). To calibrate the power sensors, the reference attenuator must be used to reduce the 1 mW calibration signal provided by the power meter to 1 μW. Also included is a hex ball driver plus the waveguide mounting screws. Refer to Table 1-1 to check what should be included with your power sensor.

CAUTION Do not use Keysight 11708A 30 dB reference attenuator for any purpose other than calibrating the power meter and power sensor. It is intended for use only at the 50 MHz 1 mW reference signal port on the power meter front panel. Its usefulness as a calibration reference may be compromised if used for other purposes.

2 Installation

Installation

Initial inspection

Inspect the shipping container for damage. If the shipping container or packaging material is damaged, it should be kept until the contents of the shipment have been checked mechanically and electrically. If there is mechanical damage or if the instrument does not pass the performance tests, notify the nearest Keysight Technologies office. Keep the damaged shipping materials (if any) for inspection by the carrier and a Keysight Technologies representative.

Interconnections

The Keysight R8486D and Keysight Q8486D power sensors have two inputs: a Type-N connector and a waveguide flange. During calibration, the Type-N connector is used to connect to the Keysight 11708A reference attenuator which is connected to the calibration port of the power meter. The waveguide flange is connected to the device under test.

The Keysight Q8486D waveguide flange holes are threaded to allow screws to be inserted from either side of the connection.

Use the plastic flange cover to protect the waveguide connector from dirt and mechanical damage whenever it is not in use. Any burn, dents or dirt on the flange or waveguide surface will increase the SWR and change the Cal Factor.

Refer to the power meter operating and service manual for interconnecting instructions.

CAUTION **Connect the power sensor by turning only the nut on the Type-N connector. Damage can occur if torque is applied to the power sensor body.**

The waveguide flanges can be damaged if the flange screws are over-tightened. Do not fully tighten one flange screw without tightening the one opposite. First insert screws and tighten until finger tight. If you are using the hex ball driver, hold the driver between thumb and forefinger while incrementally tightening screws opposite each other. If you are using a torque driver, incrementally tighten screws opposite each other until reaching a maximum torque of 60 inch-ounces (0.42 N x m).

Storage and Shipment

Original packaging

Containers and materials identical to those used in factory packaging are available through Keysight Technologies offices. If the instrument is being returned to Keysight Technologies for servicing, attach a tag indicating the type of service required, return address, model number, and serial number. Also, mark the container FRAGILE to assure careful handling. In any correspondence, refer to the instrument by model number and serial number.

Operation

WARNING BEFORE CONNECTING THE POWER SENSOR TO OTHER INSTRUMENTS ensure that all instruments are connected to the protective (earth) ground. Any interruption of the protective earth grounding will cause a potential shock hazard that could result in personal injury.

Operating precautions

If the following energy and power levels are exceeded, the power meter system may be damaged:

- Maximum average power: 100 mW
- Maximum peak power: 100 mW

Connect the power sensors by turning only the nut on the Type-N connector.

Damage can occur if torque is applied to the power sensor body.

The waveguide flanges can be damaged if the flange screws are over-tightened. Do not fully tighten one flange screw without tightening the one opposite. First insert screws and tighten until finger tight. If you are using the hex ball driver, hold the driver between thumb and forefinger while incrementally tightening screws opposite each other. If you are using a torque driver, incrementally tighten screws opposite each other until reaching a maximum torque of 60 inch-ounces (0.42 N x m).

Use the plastic flange cover to protect the waveguide connector from dirt and mechanical damage whenever it is not in use. Any burns, dents or dirt on the flange or waveguide surface will increase the SWR and change the Cal Factor.

The Type-N connector plastic bead deteriorates when contacted by any chlorinated or aromatic hydrocarbons such as acetone, trichlorethylene, carbon tetrachloride, benzene, etc. Clean the connector face with a cotton swab saturated in isopropyl alcohol.

Power meter calibrations

The procedure for calibrating one power meter may be different for another power meter. Follow the calibration directions given in your power meter manual.

NOTE **Terminate the waveguide flange with a waveguide short (Keysight R921A or Q921A) when calibrating. Due to the sensitivity of these sensors, stray millimeter waves can be sensed.**

Power measurements

To correct for varying responses at different frequencies, a cal factor chart is included on the power sensors. To use the cal factor at the frequency of interest, adjust the power meter's CAL FACTOR control according to the instructions in the power meter's operating and service manual.

If you are using a Keysight 435B or Keysight 436A, the minimum cal factor setting is 85% and the maximum is 100%. If the cal factor setting for your frequency of interest is below the meter's minimum or above the meter's maximum, set the cal factor control to 100%, and divide the reading , in watts units, by the decimal equivalent of the cal factor. For example, if the cal factor is 75%, divide the reading by 0.75. (This will result in a larger value of power than that displayed by the meter) If the cal factor is 104% divide the reading by 1.04. (This will result in a smaller value of power than that displayed by the meter).

If reading in dBm, use the chart in Table 2-1 to convert the cal factor to dB and add this value to the reading. Interpolate for values between those shown. Set the cal factor control to 100%. If the cal factor is 75%, *add* 1.25 dB to the displayed value. On the other hand, if the cal factor is 104%, *subtract* 0.170 from the displayed reading.

NOTE **The above procedure has eliminated some mathematical steps, the following formula may be of some use:**

Correction dB = Reading dBm – 10 x Log_{10} Cal factor (decimal)

Table 2-1 Cal factor to dB conversion chart

Cal factor	dB	Cal factor	dB
70%	1.55	101%	–0.43
71%	1.49	102%	–0.86
72%	1.43	103%	–0.128
73%	1.37	104%	–0.170
74%	1.31	105%	–0.212
75%	1.25	106%	–0.253
76%	1.19	107%	–0.294
77%	1.14	108%	–0.334
78%	1.08	109%	–0.374
79%	1.02	110%	–0.414
80%	0.97		
81%	0.92		
82%	0.86		
83%	0.81		
84%	0.76		
85%	0.71		

The sensitivity of the power sensors is influenced by ambient temperature. The sensors should be recalibrated at each change in temperature to obtain the most accurate results. Typical temperature sensitivity variations are shown in Figure 2-1.

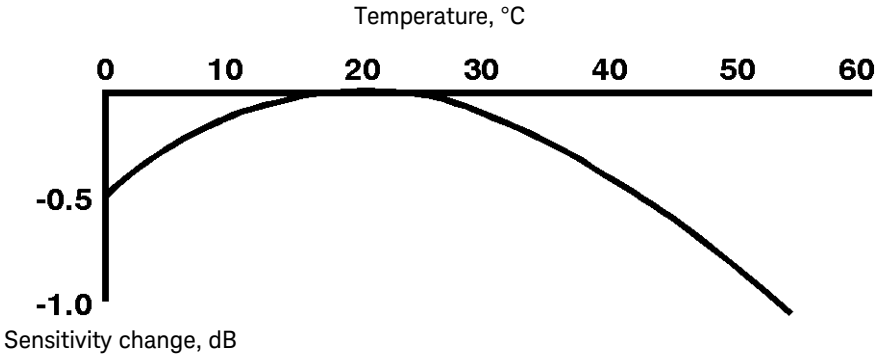


Figure 2-1 Typical influence of temperature on sensitivity

Operating instructions

To operate the power sensor, refer to the operating instructions in Section III of the power meter operating and service manual.

NOTE **If having an open RF connection on your system is a concern, terminate the sensor Type N calibration port with a 50 Ω load.**

Modulation effects

When measuring microwave sources that are modulated at the chopper frequency (nominally 220 Hz), or at the first or second harmonic or submultiples of the chopper frequency, beat notes will occur. Unless these beat notes are exactly the chopper frequency, they can usually be eliminated by averaging since the amplitudes are plus and minus the actual power. These frequencies may also be avoided by changing the modulation frequency slightly, if possible.

If you are using a Keysight 437B power meter, select a manual filter setting of at least 128 (as displayed on power meter) to minimize beat note interference. To minimize beat note interference using a Keysight 438A power meter, select a filter number of at least 7.

Performance tests

This section does not establish SWR test procedures since there are several test methods and different equipment available for testing the SWR or reflection coefficient. Therefore, the actual accuracy of the test equipment, all source match corrections, and all harmonics must be accounted for when measuring against instrument specifications to determine a pass or fail condition.

To measure the SWR across the waveguide band, use a directional coupler and detector selected for the band of interest. The directional coupler should have a directivity greater than 40 dB. The detector should have greater than 0.4 mV/μW sensitivity and should be calibrated with a rotary vane attenuator with an accuracy of 2%. Incident power should be less than –20 dBm. A convenient source is a frequency tripler driven by a Keysight 8350B and a Keysight 83594A.

To check the calibration factor, the power sensors should be compared with another recently calibrated power sensor. The source should be leveled with reference coupler that has low SWR and high directivity to monitor or level the incident power (which should be less than –30 dBm).

For reflection measurements, we suggest Keysight Application Note 183 *"High Frequency Swept Measurements"*. For calibration factor and error analysis, we suggest Keysight Application Note 64-1 *"Fundamentals of RF and Microwave Power Measurements"*

NOTE **While the flange of the Keysight R8486D is similar to the one described in MIL F-3922/54C-003, the Keysight Q8486D has been modified to mate with greater precision to MIL-3922/67B-006 flanges. The true position of the holes relative to each other are held to a diameter tolerance of 0.0254 mm (0.001). The holes are held to 1.664 mm (0.0655) minimum diameter while the pins are held to 1.61 mm (0.0634) maximum diameter.**

Zero set performance verification

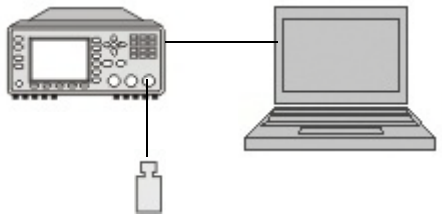
This performance verification is carried out to verify that a minimal amount of residual offset error is present after zeroing has been performed. The offset error is caused by contamination from several sources including the noise of the device-under-test (DUT) itself. Zero set is the difference between the power levels indicated by the DUT, after executing zeroing and the true zero power. Ideally, this difference should be zero.

This performance test requires a compatible Keysight power meter with the DUT and a computer with the Keysight IO Libraries Suite installed.

System specification	:	±30pW(for Q/R8486D), tested at 50 MHz
Recommended power meter	:	EPM (N1913A/ 14A, E4418B/ 19B), EPM-P (E4416A/ 17A), and P-series (N1911A/ 12A) power meters
Recommended 50 MHz, 30 dB attenuator pad APC-3.5mm to Type-N	:	11708A adapter (Used with R8486D/Q8486D)

Procedure

1 Connect the DUT (R8486D/Q8486D) to the power meter as shown in Figure 2-1.



2 Warm up the DUT for approximately 30 minutes.

3 Launch the Interactive IO on the Keysight IO Libraries Suite to send SCPI commands to the DUT.

4 Reset the power meter in a known state by sending "`*RST`" command, followed by "`SYST:PRES`" command to pre-set the meter's output to defaults value.

5 Connect the DUT to the power meter 1 mW calibrator and perform zeroing for the DUT by sending "`CAL:ZERO:AUTO ONCE`". (Use the recommended adapter for respective model)

6 Perform calibration for the DUT by sending "`CAL:AUTO ONCE`".

7 Set the frequency of the DUT to 50 MHz by sending "`FREQ 50MHz`".

8 Enable auto-averaging for the DUT by sending "`AVER:COUN:AUTO ON`".

9 Change the power measurement unit of the DUT to watt by sending "`UNIT:POW W`".

10 Disconnect the DUT from the power meter 1 mW calibrator.

11 Perform zeroing for the DUT by sending "`CAL:ZERO:AUTO ONCE`".

12 Set the DUT to the single trigger mode by sending "`INIT:CONT OFF`".

13 Read the noise level of the DUT by sending "`READ`" and then record the

14 Repeat step 13 for 10 times and then calculate the mean value of the readings.

15 Compare the calculated mean value to the system specification. If the test fails, refer to "Repair and adjustments" on page 29.

Power linearity performance verification

The power linearity performance verification measures the relative linearity error of the R8486D/Q8486D. All measurements are performed at 50 MHz. The reference power level for the linearity measurement is 0 dBm for the Q8486D and R8486D.

This performance verification requires the following equipment:

- signal generator (N5182A)
- diode- based average power sensor, as a reference sensor (8481/5/7D)
- power meter (E4416/7A)
- power splitter (11667A)
- amplifier
- step attenuators (8494H and 8496H)
- attenuator/switch driver (11713B)
- 50 Mhz, 30 dBm attenuator pad (11708A)

Procedure

1 Turn on the signal generator and power meter. Connect the DUT (R8486D/Q8486D) to the channel A and the reference sensor(8481/5/7D) to channel B of the power meter. Allow them to warm up for approximately an hour.

2 Zero and calibrate the DUT using the reference sensor with the power meter. Please use the 50 Mhz, 30 dBm attenuator pad (11708A).

3 Connect the power splitter to the RF output of the signal generator. The equipment setup is as shown in Figure 2-2.

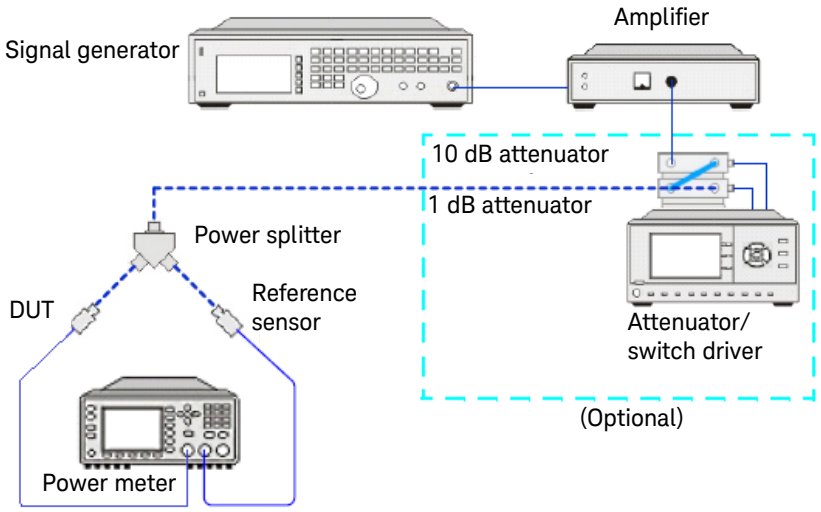


Figure 2-2 Power linearity performance verification equipment setup

4 Set the continuous wave signal frequency of the signal generator, DUT, and reference sensor to 50 MHz. Set DUT to AVERAGE ONLY mode.

5 Start tuning the signal generator and/or attenuator/switch driver (optional) until the DUT measures the power level as close as 0 dBm. Record the values as P_{DUT} at 0 dBm and P_{ref} at 0 dBm.

CAUTION Do not exceed the maximum input power (27 dBm) of the power splitter to avoid damage to the power splitter.

6 Record the power measured by the power meter for both DUT and Reference power sensor as P_{DUT} as P_{ref} respectively.

7 Normalize both P_{DUT} and P_{ref} to the power measured at 0 dBm, based on the following equation.

$$\text{Normalization} = \text{Measured power } (P_{DUT/ref}) - \text{Measured power at 0 dBm } (P_{DUT/ref \text{ at } 0 \text{ dBm}})$$

8 Calculate the linearity error of the DUT for the power level using the following equations.

$$\text{Linearity error (dB)} = [P_{DUT}]_{\text{norm to 0 dBm}} - [P_{ref}]_{\text{norm to 0 dBm}}$$

$$\text{Linearity error (\%)} = \left[\text{Antilog}\left(\frac{[P_{DUT}]_{\text{norm to 0 dBm}} - [P_{ref}]_{\text{norm to 0 dBm}}}{10}\right) - 1\right] \times 100$$

9 Compare and record the calculated linearity error against the system linearity error specifications.

10 Repeat step 6 to step 9 by sweeping through the warranted power levels for power linearity test as in the datasheet at 50 MHz.

11 Repeat step 5 to step 10 for NORM mode. If the verification fails, refer to "Repair and adjustments" on page 29.

12 The linearity system specification is calculated using the root sum of the squares (RSS) method by considering the error caused from reference sensor used and the DUT error in the system at 50 Mhz. The error specification caused by the reference sensor and the DUT can be found in their respective datasheet. The RSS error specification calculation is computed by using the following equation.

$$\text{System linearity error specification} = \pm\sqrt{\text{DUT error}^2 + \text{Ref sensor error}^2}$$

Example for the DUT measured at 50 Mhz, 20 dBm:

- DUT used is 8481D
- Reference sensor used is Q8486D

$$\text{System linearity error specification} = \pm\sqrt{(3\%)^2 + (1\%)^2} = \pm 3.16\%$$

Replaceable parts

The Keysight 11708A 30 dB attenuator, the hex ball driver, the flange covers, and the hardware are the only replaceable parts. A listing of Keysight Technologies sales and service offices is located inside the front cover of this manual.

Repair and adjustments

Do not attempt to repair or adjust the power sensors. Due to the extreme static sensitivity of the power sensors, customer repair is not recommended. If your power sensor should feel or need calibration, return it to Keysight Technologies.

CAUTION **Do not disassemble the power sensors. The power sensors are extremely static sensitive and can be easily damaged. If the power sensors show evidence of attempted customer repair, the warranty may be voided.**

Adjustments are usually required on a yearly basis. They are normally performed only after a performance verification has indicated that some parameters are out of specification. Performance verification must be completed after any repairs that may have altered the characteristics of the R8486D/Q8486D power sensors.

The R8486D/Q8486D power sensors can be adjusted using the Keysight N7800 Series calibration software or can be returned to Keysight for adjustments. To arrange the return, contact the Keysight Service Center.

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