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INSTRUCTION BOOK

# Terminating Power Sensors & Extended Frequency Terminating Power Sensors

Models 5011, 5011-EF,  
5015 and 5015-EF



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Instruction Book Part Number 920-5011S Rev. A

## Safety Precautions

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The following are general safety precautions that are not necessarily related to any specific part or procedure, and do not necessarily appear elsewhere in this publication. These precautions must be thoroughly understood and apply to all phases of operation and maintenance.

**WARNING**

**Keep Away From Live Circuits**

Operating Personnel must at all times observe general safety precautions. Do not replace components or make adjustments to the inside of the test equipment with the high voltage supply turned on. To avoid casualties, always remove power.

**WARNING**

**Shock Hazard**

Do not attempt to remove the RF transmission line while RF power is present.

**WARNING**

**Do Not Service Or Adjust Alone**

Under no circumstances should any person reach into an enclosure for the purpose of service or adjustment of equipment except in the presence of someone who is capable of rendering aid.

**WARNING**

**Safety Earth Ground**

An uninterruptible earth safety ground must be supplied from the main power source to test instruments. Grounding one conductor of a two conductor power cable is not sufficient protection. Serious injury or death can occur if this grounding is not properly supplied.

**WARNING**

**Resuscitation**

Personnel working with or near high voltages should be familiar with modern methods of resuscitation.


## Safety Symbols

**WARNING**

Warning notes call attention to a procedure, which if not correctly performed, could result in personal injury.

**CAUTION**

Caution notes call attention to a procedure, which if not correctly performed, could result in damage to the instrument.

 **Note:** *Calls attention to supplemental information.*

## Warning Statements

The following safety warnings appear in the text where there is danger to operating and maintenance personnel, and are repeated here for emphasis.

## Caution Statements

The following equipment cautions appear in the text and are repeated here for emphasis.

### CAUTION

Do not exceed 2 W average or 125 W peak power for 5  $\mu$ s when using the TPS or the TPS-EF. Doing so will render the sensor inoperative.

On page 1 and 3.

### CAUTION

Discharge all static potentials before connecting the TPS(-EF). Electrostatic shock could damage the sensor.

On page 3.

### CAUTION

When connecting the TPS or the TPS-EF, only turn the connector nut. Damage may occur if torque is applied to the sensor body.

On page 3.

## **Safety Statements**

### **USAGE**

ANY USE OF THIS INSTRUMENT IN A MANNER NOT SPECIFIED BY THE MANUFACTURER MAY IMPAIR THE INSTRUMENT'S SAFETY PROTECTION.

### **USO**

EL USO DE ESTE INSTRUMENTO DE MANERA NO ESPECIFICADA POR EL FABRICANTE, PUEDE ANULAR LA PROTECCIÓN DE SEGURIDAD DEL INSTRUMENTO.

### **BENUTZUNG**

WIRD DAS GERÄT AUF ANDERE WEISE VERWENDET ALS VOM HERSTELLER BESCHRIEBEN, KANN DIE GERÄTESICHERHEIT BEEINTRÄCHTIGT WERDEN.

### **UTILISATION**

TOUTE UTILISATION DE CET INSTRUMENT QUI N'EST PAS EXPLICITEMENT PRÉVUE PAR LE FABRICANT PEUT ENDOMMAGER LE DISPOSITIF DE PROTECTION DE L'INSTRUMENT.

### **IMPIEGO**

QUALORA QUESTO STRUMENTO VENISSE UTILIZZATO IN MODO DIVERSO DA COME SPECIFICATO DAL PRODUTTORE LA PROZIONE DI SICUREZZA POTREBBE VENIRNE COMPROMESSA.

## **SERVICE**

SERVICING INSTRUCTIONS ARE FOR USE BY SERVICE - TRAINED PERSONNEL ONLY. TO AVOID DANGEROUS ELECTRIC SHOCK, DO NOT PERFORM ANY SERVICING UNLESS QUALIFIED TO DO SO.

## **SERVICIO**

LAS INSTRUCCIONES DE SERVICIO SON PARA USO EXCLUSIVO DEL PERSONAL DE SERVICIO CAPACITADO. PARA EVITAR EL PELIGRO DE DESCARGAS ELÉCTRICAS, NO REALICE NINGÚN SERVICIO A MENOS QUE ESTÉ CAPACITADO PARA HACERLO.

## **WARTUNG**

ANWEISUNGEN FÜR DIE WARTUNG DES GERÄTES GELTEN NUR FÜR GESCHULTES FACHPERSONAL. ZUR VERMEIDUNG GEFÄHRLICHE, ELEKTRISCHE SCHOCKS, SIND WARTUNGSARBEITEN AUSSCHLIEßLICH VON QUALIFIZIERTEM SERVICEPERSONAL DURCHZUFÜHREN.

## **ENTRETIEN**

L'EMPLOI DES INSTRUCTIONS D'ENTRETIEN DOIT ÊTRE RÉSERVÉ AU PERSONNEL FORMÉ AUX OPÉRATIONS D'ENTRETIEN. POUR PRÉVENIR UN CHOC ÉLECTRIQUE DANGEREUX, NE PAS EFFECTUER D'ENTRETIEN SI L'ON N'A PAS ÉTÉ QUALIFIÉ POUR CE FAIRE.

## **ASSISTENZA TECNICA**

LE ISTRUZIONI RELATIVE ALL'ASSISTENZA SONO PREVISTE ESCLUSIVAMENTE PER IL PERSONALE OPPORTUNAMENTE ADDESTRATO. PER EVITARE PERICOLOSE SCOSSE ELETTRICHE NON EFFETTUARRE ALCUNA RIPARAZIONE A MENO CHE QUALIFICATI A FARLA.

**RF VOLTAGE MAY BE PRESENT IN RF ELEMENT SOCKET - KEEP ELEMENT IN SOCKET DURING OPERATION.**

**DE LA TENSION H.F. PEAT ÊTRE PRÉSENTE DANS LA PRISE DE L'ÉLÉMENT H.F. - CONSERVER L'ÉLÉMENT DANS LA PRISE LORS DE L'EMPLOI.**

**HF-SPANNUNG KANN IN DER HF-ELEMENT-BUCHSE ANSTEHEN - ELEMENT WÄHREND DES BETRIEBS EINGESTÖPSELT LASSEN.**

**PUEDA HABER VOLTAJE RF EN EL ENCHUFE DEL ELEMENTO RF - MANTENGA EL ELEMENTO EN EL ENCHUFE DURANTE LA OPERACION.**

**IL PORTAELEMENTO RF PUÒ PRESENTARE VOLTAGGIO RF - TENERE L'ELEMENTO NELLA PRESA DURANTE IL FUNZIONAMENTO.**



## About This Manual

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This manual covers the operating and maintenance instructions for the following models:

5011	5011-EF
5015	5015-EF

### Changes to this Manual

We have made every effort to ensure this manual is accurate. If you discover any errors, or if you have suggestions for improving this manual, please send your comments to our Solon, Ohio factory. This manual may be periodically updated. When inquiring about updates to this manual refer to the part number and revision on the title page.

### Literature Contents

#### Chapter Layout

**Introduction** — Describes the features of the Terminating Power Sensor and Element Types.

**Installation** — Describes how to connection and install the Terminating Power Sensor into the system that is being monitored.

**Operation** — Describes how to run and maintain the Terminating Power Sensor.

**Specifications** - Describes the basic information, settings, and ranges of the Terminating Power Sensor.



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## Description

The Bird 5015 Terminating Power Sensor (TPS) is a diode-based power sensor that measures true average power from 40 MHz to 4 GHz and from  $-20$  dBm to  $+10$  dBm.

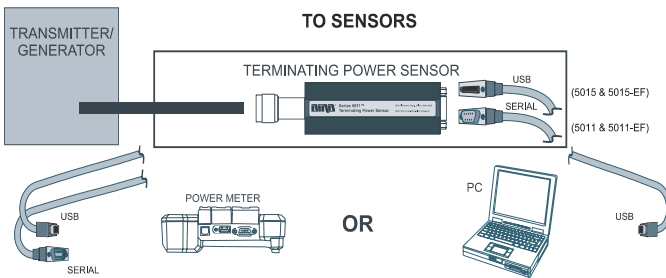
For best results, wait 5 minutes after applying power to the sensor before taking readings.

**CAUTION**

Do not exceed 2 W average or 125 W peak power for 5  $\mu$ s when using the TPS or the TPS-EF. Doing so will render the sensor inoperative.



## Connecting Terminating Power Sensor (TPS)



### CAUTION

Discharge all static potentials before connecting the TPS(-EF). Electrostatic shock could damage the sensor.

### CAUTION

When connecting the TPS or the TPS-EF, only turn the connector nut. Damage may occur if torque is applied to the sensor body.

### CAUTION

Do not exceed 2 W average or 125 W peak power for 5  $\mu$ s when using the TPS or the TPS-EF. Doing so will render the sensor inoperative.

**Note:** Connections are the same for the Bird 5011 and 5011-EF.


1. Do one of the following:
  - To connect to a Digital Power Meter:
    - For Models 5011 and 5011EF:  
Connect the Bird TPS to the “Sensor” serial port on the DPM using the sensor cable provided.
    - For Models 5015 and 5015-EF:  
Connect the Bird TPS to the “Sensor” USB port on the DPM using the sensor cable provided.
  - 🔊 **Note:** *An attenuator or directional coupler should be used with the TPS in most applications.*
  - 🔊 **Note:** *For an RF source with output between 0.1 and 50 W, use a 40 dB, 50 W attenuator.*
  - To connect to a PC with VPM2 software (5015 and 5015-EF ONLY):
    - Connect the Bird TPS to the a USB port on the PC using the sensor cable provided.
2. Connect the TPS RF input to the source (using an attenuator, if appropriate).
  - 🔊 **Note:** *Only connect the TPS directly to a source if the RF power will be less than 10 mW.*



### Zeroing Sensor

Over time, the sensor's "zero value" (reading with no applied RF power) can drift, making all readings inaccurate by this value. For example, if the zero value is  $-0.02$  W, measuring a 50 W signal will give a reading of 49.98 W, a 0.04% error. Measuring a 1 W signal will give a reading of 0.98 W, a 2% error. If the drift would be a significant error, rezero the sensor:

1. Ensure the sensor has reached a stable operating temperature.
2. Ensure no RF power is applied to the sensor.
3. Press "Zero" to begin Calibration.

 **Note:** Calibration will take about 40 seconds. Do not interrupt the calibration! A bar on the screen will display calibration progress.

### Power Measurement Accuracy

#### Accuracy

The Bird power sensors are highly accurate. Accuracy is specified for each sensor type is typically given as a percent of reading or of full-scale.

**Example** - If a sensor has a specified accuracy of 5% of reading + 1.0  $\mu\text{W}$ , then for a 10 mW signal the uncertainty is  $\pm 0.501$  mW. For a 1 mW signal the measurement uncertainty is  $\pm 0.051$  mW.

### Sensor Uncertainty

While this value is a good estimate, the sensor is actually more accurate. The sensor's accuracy also depends on the temperature, and the power and frequency of the source; Table 1 lists some examples of uncertainty factors. If an uncertainty is given as a power, divide this value by the measured RF power and convert to a percentage. For example, an uncertainty of  $\pm 0.25$   $\mu\text{W}$  with a RF power of 10  $\mu\text{W}$  is a 2.5% uncertainty. Table 2 lists external factors, such as using attenuators or using a cable to connect the TPS to the transmitter, which could affect the measurement uncertainty.

**Table 1 - Example Uncertainty Factors**

Error Source	Conditions	Uncertainty
Calibration Uncertainty		$\pm 1.13\%$
Frequency Response	40 MHz to 4 GHz	$\pm 3.42\%$
Temperature Linearity	-10 to +50 °C	$\pm 3.43\%$

Other <sup>a</sup>	< 40 °C or > 100 MHz	± 0.50%
Resolution	± ½ smallest displayed digit (e.g. for a mW scale, three decimal places are displayed. ½ the smallest is 0.5 µW)	
Zero Set <sup>†</sup>		± 0.125 µW
Noise <sup>b</sup>	above 1.05 mW	± 0.7 µW
	105 µW to 1.05 mW	± 0.4 µW
	below 105 µW	± 0.2 µW

- a. Above 40 °C, when making measurements at frequencies between 40 and 100 MHz, add 1.1%.
- b. After a 5 minute warm-up, measured over a 5 minute interval and 2 standard deviations

**Table 2 - External Factors**

Error Source	Conditions
Attenuator Uncertainty	Frequency dependent
Cable Uncertainty	Frequency and length dependent (± 5% at 1 GHz for a 'reasonable' 1.5 m cable)

The root sum square (RSS) uncertainty is the industry standard method for combining independent uncertainties. To determine the TPS's RSS uncertainty:

1. Square each uncertainty factor.
2. Add these values together.
  - a. Take the square root of this sum.

Table 3 has two examples of uncertainty calculations. The first is a 10 mW signal at room temperature. The second is a 10  $\mu$ W, 40 MHz signal at 50°C. Since this measurement is at both low frequency *and* high temperature, the uncertainty will be increased. Note that the RSS uncertainties are smaller than the values from the rough estimate. This will always be the case.

**Table 3 - Uncertainty Examples**

Error Source	Example 1 (10 mW, Room Temp)		Example 2 (10 $\mu$ W, 40 MHz, 50°C)	
	Percent Uncert.	RSS Term	Percent Uncert.	RSS Term
Cal. Uncert.	1.13 %	1.28	1.13 %	1.28
Freq. Resp.	3.42 %	11.70	3.42 %	11.70
Temp. Lin.	3.43 %	11.76	3.43 %	11.76
Other	0.5 %	0.25	1.6 %	2.56
Res.	0.005 %	0.00	0.5 %	0.25
Zero Set	0.00125 %	0.00	1.25 %	1.56
Noise	0.007 %	0.00	2 %	4.00
Sum Uncert.		24.99		33.11
RSS Uncert.		5.00 %		5.75 %
Quick Uncert.		5.01 %		16 %

## Mismatch Uncertainty

Another factor of measurement accuracy is mismatch uncertainty. When a source and a load have different impedances, some signal will be reflected back to the source. This uncertainty depends on both the VSWR of the TPS and the VSWR of the rest of the system. For a system VSWR of 1.0, the mismatch uncertainty would be 0. For a VSWR of 5.0, the mismatch uncertainty would be 12.5%. Given the VSWR of the TPS and the source, the mismatch uncertainty can be calculated as follows.

Mismatch uncertainty (MU) is related to the reflection coefficient ( $\rho$ ) by the formula:

$$MU(\text{percent}) = [(1 + \rho_s \rho_l)^2 - 1] \times 100$$

**Note:** where  $\rho_s$  = reflection coefficient of the source, and  $\rho_l$  = reflection coefficient of the load (the TPS)

The reflection coefficients can be calculated from the VSWR by the formula:

$$\rho = (\text{VSWR} - 1) / (\text{VSWR} + 1)$$

**Example** - If a source with a 1.50:1 VSWR with the Terminating Power Sensor was used, which has a max VSWR of 1.20:1, the mismatch uncertainty would be calculated as follows:

$$\rho_s = (1.50 - 1) / (1.50 + 1) = 0.200$$

$$\rho_l = (1.20 - 1) / (1.20 + 1) = 0.091$$

$$MU = [(1 + 0.200 \times 0.091)^2 - 1] \times 100 = \pm 3.67$$

**Note:** If a source with a 1.30:1 VSWR was used instead, the mismatch uncertainty would be:

$$\rho_s = (1.30 - 1)/(1.30 + 1) = 0.130$$

$$\rho_1 = (1.20 - 1)/(1.20 + 1) = 0.091$$

$$MU = [(1 + 0.130 \times 0.091)^2 - 1] \times 100 = \pm 2.39$$

Using a lower VSWR source can drastically reduce the mismatch uncertainty. Keep in mind that the typical VSWR of the Model 5011 is 1.03:1, which gives a much lower mismatch uncertainty.

**Example -** With the 1.50:1 source, the mismatch uncertainty would be:

$$\rho_s = (1.50 - 1)/(1.50 + 1) = 0.200$$

$$\rho_1 = (1.03 - 1)/(1.03 + 1) = 0.015$$

$$MU = [(1 + 0.200 \times 0.015)^2 - 1] \times 100 = \pm 0.59$$

To determine the total uncertainty of the measurement, combine the RSS uncertainty with the mismatch uncertainty using the RSS method. Square the RSS uncertainty, add it to the square of the mismatch uncertainty, and take the square root.

Using Example 1 in Table 3 with a source VSWR of 1.50 and a TPS VSWR of 1.20, the total uncertainty would be:

$$\sqrt{5.00^2 + 3.67^2} = 6.20(\text{percent})$$

For example 2, the total uncertainty would be 6.82 %.

## 5011 Specifications

Power Measurement Characteristics	
<b>General</b>	Terminated average power
<b>Frequency Range</b>	40 MHz to 4 GHz
<b>Power Measurement Range</b>	-20.0 to +10.0 dBm (10 $\mu$ W to 10 mW)
<b>Maximum Power</b>	2 W avg., 125 W peak for 5 $\mu$ s
<b>Peak/Average Ratio</b>	12 dB maximum
<b>Accuracy</b>	$\pm$ (5% of reading <sup>a</sup> + 1.0 $\mu$ W) (excluding mismatch uncertainty) No correction factors necessary
<b>Input Impedance</b>	50 Ohms (nominal)
<b>Input VSWR:</b> <b>Typical</b> <b>Maximum</b>	1.03 (36.6 dB return loss) 1.20 (20.8 dB return loss)
<b>Input Connector</b>	Precision N Male
<b>Output Connector</b>	Male DB-9 to host instrument
<b>Power Supply</b>	From host instrument via cable connection

a. Above 40 °C, when measuring frequencies between 40 and 100 MHz, add 1%.

<b>Physical and Environmental Specifications</b>	
<b>Operating Temp.</b>	-10 to +50 °C (+14 to +122 °F)
<b>Storage Temp.</b>	-40 to +80 °C (-40 to +176 °F)
<b>Mechanical Shock</b>	IAW MIL-PRF-28800F class 3
<b>Vibration</b>	IAW MIL-PRF-28800F class 3
<b>Humidity</b>	95% maximum (non-condensing)
<b>Altitude</b>	15,000 ft. operating
<b>Dimensions</b>	6" long max (including connectors); 1.5" diameter nominal
<b>Weight</b>	3/4 lb. max.
<b>Recommended Calibration Interval</b>	12 months

## 5011-EF Specifications

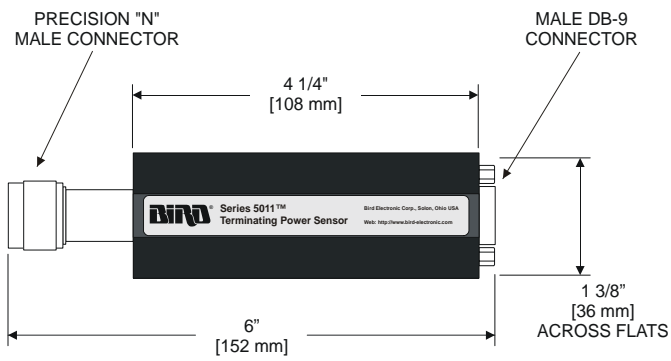
<b>Power Measurement Characteristics</b>	
<b>General</b>	Terminated average power
<b>Frequency Range</b>	40 MHz to 12 GHz
<b>Power Measurement Range</b>	-20.0 to +10.0 dBm (10 $\mu$ W to 10 mW)
<b>Maximum Power</b>	2 W avg., 125 W peak for 5 $\mu$ s
<b>Peak/Average Ratio</b>	12 dB maximum
<b>Accuracy After Correction</b>	$\pm$ (5% of reading <sup>a</sup> $\pm$ 1.0 $\mu$ W) (excluding mismatch uncertainty)



<b>Input Impedance</b>	50 Ohms (nominal)
<b>Input VSWR:</b> <b>Typical</b> <b>Maximum</b>	1.05 (32.0 dB return loss) 1.25 (19.1 dB return loss)
<b>Input Connector</b>	Precision N Male
<b>Output Connector</b>	Male DB-9 to host instrument
<b>Power Supply</b>	From host instrument via cable connection

a. Above 40 °C or below 10 °C add 1%.

<b>Physical and Environmental Specifications</b>	
<b>Operating Temp.</b>	-10 to +50 °C (+14 to +122 °F)
<b>Storage Temp.</b>	-40 to +80 °C (-40 to +176 °F)
<b>Mechanical Shock</b>	IAW MIL-PRF-28800F class 3
<b>Vibration</b>	IAW MIL-PRF-28800F class 3
<b>Humidity</b>	95% maximum (non-condensing)
<b>Altitude</b>	15,000 ft. operating
<b>CE</b>	CE compliant
<b>ROHSS</b>	ROHSS compliant
<b>Dimensions</b>	6" long max (including connectors); 1.5" diameter nominal
<b>Weight</b>	3/4 lb. max.
<b>Recommended Calibration Interval</b>	12 months



## 5015 Specifications

<b>Power Measurement Characteristics</b>	
<b>General</b>	Terminated average power
<b>Frequency Range</b>	40 MHz to 4 GHz
<b>Power Measurement Range</b>	-20.0 to +10.0 dBm (10 $\mu$ W to 10 mW)
<b>Maximum Power</b>	2 W avg., 125 W peak for 5 $\mu$ s
<b>Peak/Average Ratio</b>	12 dB maximum
<b>Accuracy</b>	$\pm$ (5% of reading <sup>a</sup> + 1.0 $\mu$ W) (excluding mismatch uncertainty) No correction factors necessary
<b>Input Impedance</b>	50 Ohms (nominal)
<b>Input VSWR:</b> <b>Typical</b> <b>Maximum</b>	1.03 (36.6 dB return loss) 1.20 (20.8 dB return loss)
<b>Input Connector</b>	Precision N Male
<b>Output Connector</b>	SeaLatch <sup>®</sup> USB type to host instrument
<b>Power Supply</b>	From host instrument via cable connection

a. Above 40 °C, when measuring frequencies between 40 and 100 MHz, add 1%.

<b>Physical and Environmental Specifications</b>	
<b>Operating Temp.</b>	-10 to +50 °C (+14 to +122 °F)
<b>Storage Temp.</b>	-40 to +80 °C (-40 to +176 °F)
<b>Mechanical Shock</b>	IAW MIL-PRF-28800F class 3
<b>Vibration</b>	IAW MIL-PRF-28800F class 3
<b>Humidity</b>	95% maximum (non-condensing)
<b>Altitude</b>	15,000 ft. operating
<b>Dimensions</b>	6" long max (including connectors); 1.5" diameter nominal
<b>Weight</b>	3/4 lb. max.

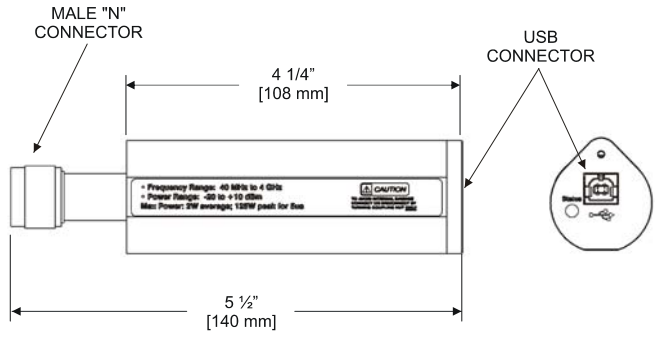
### 5015-EF Specifications

<b>Power Measurement Characteristics</b>	
<b>General</b>	Terminated average power
<b>Frequency Range</b>	40 MHz to 12 GHz
<b>Power Measurement Range</b>	-20.0 to +10.0 dBm (10 $\mu$ W to 10 mW)
<b>Maximum Power</b>	2 W avg., 125 W peak for 5 $\mu$ s
<b>Peak/Average Ratio</b>	12 dB maximum
<b>Accuracy After Correction</b>	$\pm(5\%$ of reading <sup>a</sup> $\pm 1.0 \mu$ W) (excluding mismatch uncertainty)
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<b>Input VSWR:</b> <b>Typical</b> <b>Maximum</b>	1.05 (32.0 dB return loss) 1.25 (19.1 dB return loss)
<b>Input Connector</b>	Precision N Male
<b>Output Connector</b>	SeaLatch USB type to host instrument
<b>Power Supply</b>	From host instrument via cable connection

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<b>CE</b>	CE compliant
<b>ROHSS</b>	ROHSS compliant
<b>Dimensions</b>	6" long max (including connectors); 1.5" diameter nominal
<b>Weight</b>	3/4 lb. max.
<b>Recommended Calibration Interval</b>	12 months



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## Limited Warranty

All products manufactured by Seller are warranted to be free from defects in material and workmanship for a period of one (1) year, unless otherwise specified, from date of shipment and to conform to applicable specifications, drawings, blueprints and/or samples. Seller's sole obligation under these warranties shall be to issue credit, repair or replace any item or part thereof which is proved to be other than as warranted; no allowance shall be made for any labor charges of Buyer for replacement of parts, adjustment or repairs, or any other work, unless such charges are authorized in advance by Seller.

If Seller's products are claimed to be defective in material or workmanship or not to conform to specifications, drawings, blueprints and/or samples, Seller shall, upon prompt notice thereof, either examine the products where they are located or issue shipping instructions for return to Seller (transportation charges prepaid by Buyer). In the event any of our products are proved to be other than as warranted, transportation costs (cheapest way) to and from Seller's plant, will be borne by Seller and reimbursement or credit will be made for amounts so expended by Buyer. Every such claim for breach of these warranties shall be deemed to be waived by Buyer unless made in writing within ten (10) days from the date of discovery of the defect.

The above warranties shall not extend to any products or parts thereof which have been subjected to any misuse or neglect, damaged by accident, rendered defective by reason of improper installation or by the performance of repairs or alterations outside of our plant, and shall not apply to any goods or parts thereof furnished by Buyer or acquired from others at Buyer's request and/or to Buyer's specifications. Routine (regularly required) calibration is not covered under this limited warranty. In addition, Seller's warranties do not extend to the failure of tubes, transistors, fuses and batteries, or to other equipment and parts manufactured by others except to the extent of the original manufacturer's warranty to Seller.

The obligations under the foregoing warranties are limited to the precise terms thereof. These warranties provide exclusive remedies, expressly in lieu of all other remedies including claims for special or consequential damages. SELLER NEITHER MAKES NOR ASSUMES ANY OTHER WARRANTY WHATSOEVER, WHETHER EXPRESS, STATUTORY, OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS, AND NO PERSON IS AUTHORIZED TO ASSUME FOR SELLER ANY OBLIGATION OR LIABILITY NOT STRICTLY IN ACCORDANCE WITH THE FOREGOING.