MODELS 1825 & 1827

Economical Power Sensor Calibrators

Instruction Manual

TEGAM INC.

MODELS 1825 & 1827
ECONOMICAL POWER SENSOR CALIBRATORS

MODEL 1825   MODEL 1827

Instruction Manual
PN# 1825-901-01CD
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REV. E

NOTE: This user's manual was as current as possible when this product was manufactured. However, products are constantly being updated and improved. Because of this, some differences may occur between the description in this manual and the product received.

TEGAM is a manufacturer of electronic test and measurement equipment for metrology, calibration, and production test. We also provide repair, calibration, and other support services for a wide variety of test and measurement equipment including RF power sensor calibration systems, RF attenuation measurement systems, resistance standards, ratio transformers, arbitrary waveform generators, micro-ohmmeters, LCR meters, handheld temperature calibrators, thermometers, humidity and temperature control devices, and more.

TEGAM also repairs and calibrates test and measurement equipment formerly manufactured by Electro-Scientific Industries (ESI), Gertsch, Keithley Instruments, Lucas Weinschel, and Pragmatic Instruments. A complete list can be viewed on our Product Service Directory at www.tegam.com

For more information about TEGAM and our products, please visit our website at www.tegam.com: or contact one of our customer service representatives at sales@tegam.com or 800-666-1010.

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Abbreviations And Acronyms

The following list contains all abbreviations used throughout this manual. Abbreviations and acronyms that are not listed conform to MIL-STD-12D.

CW Continuous Wave
SUT Sensor Under Test
DVM Digital Voltmeter
ESDS Electrostatic Discharge Sensitive
NIST National Institute of Standards and Technology
RF Radio Frequency
DC Direct Current
UUT Unit Under Test

Figure 1.1 Model 1825

Figure 1.2 Model 1827

Description Of Equipment

Functional Description

The Model 1825 is designed to calibrate power meter sensors in the 10 MHz to 18 GHz frequency range. The Model 1825 does not have any settings or controls other than the POWER and FLOAT/GROUND switches. Measurements are made with an external DVM supplied by the user. The Model 1825 provides accurate measurements for standard calibration points that are directly traceable to the National Institute of Standards and Technology (NIST).

The Model 1827 calibrates power meter sensors in the 100 kHz to 18 GHz frequency range. Since most single RF signal generators do not cover this entire frequency band, it is usually necessary to use two. For this reason the Model 1827 has two RF signal generator inputs that are selected by a front panel switch. Measurements are made as with the Model 1825.

Both the Models 1825 and 1827 precisely and accurately detect RF power through a temperature controlled thermistor power standard and DC substitution bridge. This enables the operator to accurately calculate an RF power level which is then used for comparison with the power level measured by the Sensor Under Test (SUT). The ratio of the two power levels is the SUT's calibration factor. Refer to Section III for a more detailed discussion of the functionality of these instruments.

Physical Description

Refer to Table 1-1 for the physical and electrical specifications of the Model 1825 and 1827. The Model 1825 front panel contains the INPUT POWER switch as well as the SENSOR, RF IN, and VOLTMETER connectors. The Model 1827 front panel contains the same except there are two RF inputs, RF IN1 and RF IN2, with an LED indicator next to each, and a toggle switch to select which RF input is used. The rear panel of both contain the input power connector and fuse, FLOAT/GROUND switch, and vents for airflow. Both models are designed to sit on a bench but can be mounted in a 19″ rack with rack mount kit RM-1825 (sold separately, call TEGAM for details).

Specifications

Table 1.1 lists the physical and electrical specifications of the Model 1825 and 1827.

Table 1.1 Physical and Electrical Specifications

Model	1825	1827
Frequency Range	10 MHz to 18 GHz	100 kHz to 18 GHz
Power Range	0.01 to 25 mW (-20 to +14 dBm)	0.01 to 25 mW (-20 to +14 dBm)
DC Substitution Bridge Accuracy	±0.003%	±0.003%
RF Impedance	50 Ohms nominal	50 Ohms nominal
SWR (SENSOR)	≤ 1.14	≤ 1.14
Power Linearity	<0.1% from 1 to 10 mW	<0.1% from 1 to 10 mW
Insertion Loss (RF IN)	6 dB nominal, 9.5 dB max	6 dB nominal, 10 dB max
Individual calibrations traceable to NIST supplied at the following frequencies:	10 to 100 MHz in 10 MHz steps 0.1 to 2 GHz in 50 MHz steps 2 to 4 GHz in 100 MHz steps 4 to 12.4 GHz in 200 MHz steps 12.75 to 18 GHz in 250 MHz steps	100, 200, 455 kHz 1, 1.25, 3, 5 MHz 10 to 100 MHz in 10 MHz steps 0.1 to 2 GHz in 50 MHz steps 2 to 4 GHz in 100 MHz steps 4 to 12.4 GHz in 200 MHz steps 12.75 to 18 GHz in 250 MHz steps
Calibration Factor Accuracy	+/-1.00% from 0.01 to 10 GHz +/-1.10% from 10 to 18 GHz	+/-0.80% from 0.1 to 10 MHz +/-1.00% from 0.01 to 10 GHz +/-1.10% from 10 to 18 GHz
Calibration Factor Drift	<0.5% per year	<0.5% per year

Connectors
    SENSOR
    RF IN
    VOLTMETER
	N-type Female
	SMA Female
	Binding Post, standard 0.75"
	spacing for banana plugs
		N-type Female
		SMA Female (X2)
		Binding Post, standard 0.75"
		spacing for banana plugs

Temperature
    Operating
    Storage
	+12° to +32° C (+54° to +90° F)
	-40° to +75° C (-40° to +167° F)
		+12° to +32° C (+54° to +90° F)
		-40° to +75° C (-40° to +167° F)

Warm up time	2 hours minimum from instrument power up	2 hours minimum from instrument power up
Power Requirements	100VA, 50 to 400 Hz, 105 to 125 Vac standard or 210 to 250 Vac with a factory installed option.	100VA, 50 to 400 Hz, 105 to 125 Vac standard or 210 to 250 Vac with a factory installed option.
Input Power Fuse	Slo-Blo, 0.8 Amp for 110 Vac or 0.5 Amp for 220 Vac	Slo-Blo, 0.8 Amp for 110 Vac or 0.5 Amp for 220 Vac
Weight	16.2 lbs (7.3 kg)	17.7 lbs (8.03 kg)

Physical Dimensions
    Height
    Width
    Depth
	3.5 in (88.9 mm)
	18 in (457.2 mm)
	15.4 in (391.2 mm)
		3.5 in (88.9 mm)
		18 in (457.2 mm)
		15.4 in (391.2 mm)

Rack Mounting	Can be mounted in a standard 19" rack with rack mount kit RM-1825.	Can be mounted in a standard 19" rack with rack mount kit RM-1825.

Additional equipment

Table 1-2 lists the additional equipment required to calibrate RF power sensors with the Model 1825 and 1827. The description for each piece of equipment listed states the minimum recommended requirements for that piece of equipment. There may be many models that meet the minimum requirements; it is up to the operator to select the specific model. Measurement uncertainty will vary depending on the additional equipment used. Please refer to the specifications for the particular model number to get that information.

Table 1.2 Additional Equipment Required

Signal Generator	Continuous Wave, 6dBm minimum power output. 10 MHz to 18GHz Frequency Range for Model 1825. 100 kHz to 18 GHz Frequency Range for Model 1827, two may be required to cover entire Frequency Range.
DVM	DC Volts, 6½-digit minimum.
RF Power Meter	Compatible with the sensor under test.

APPLICATIONS

The TEGAM Model 1825 and 1827 Power Sensor Calibrator was designed for the transfer of calibration factors to power meter sensors. While neither model is designed for remote programming, the process of calibrating power sensors can be automated if the additional equipment used can be remotely programmed.

Figure 1.3 Typical Setup for Power Sensor Calibration using Model 1825
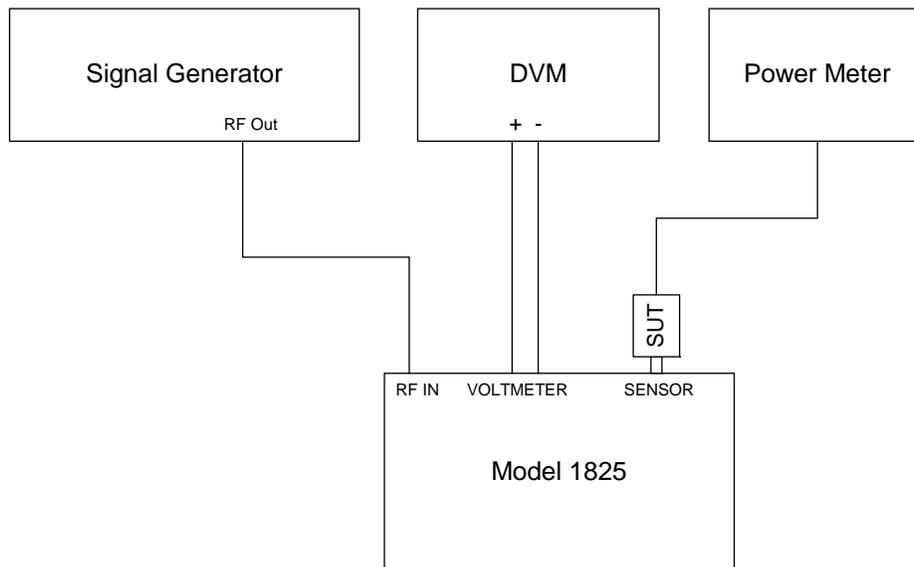
Figure 1.4 Typical Setup for Power Sensor Calibration using Model 1827
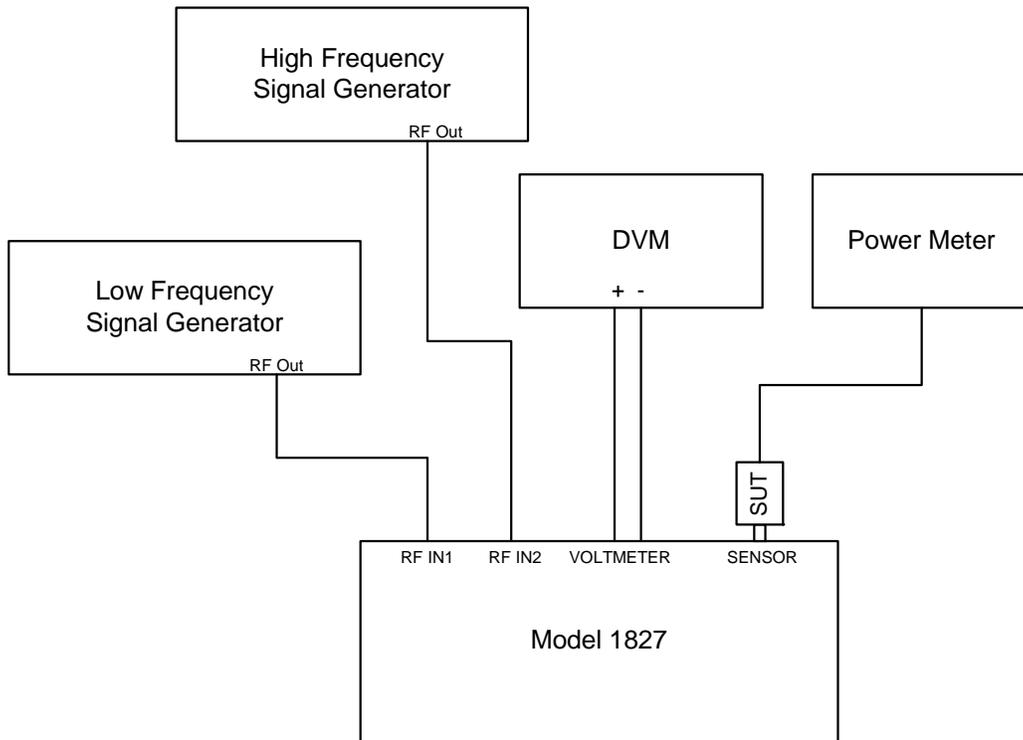
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Unpacking & Inspection:

Each 1825 and 1827 is put through a series of electrical and mechanical inspections before shipment to the customer. Upon receipt of your instrument unpack all of the items from the shipping carton and inspect for any damage that may have occurred during transit. Report any damaged items to the shipping agent. Retain and use the original packing material for reshipment if necessary.

Upon Receipt, inspect the carton for the following items:

Model 1825 or 1827 RF Power Sensor Calibrator
Model 1825 and 1827 Operating Manual (CD)   P/N 1825-901-01CD
3.5″ floppy disk with "Cal Factor Calculator"
  Microsoft Excel Spreadsheet
Power Cord   P/N 068-21

Mounting

The Model 1825 and 1827 are shipped with four plastic feet mounted to the bottom cover. When the Model 1825/1827 is placed on a bench or table, these feet support the instrument. The Model 1825 or 1827 can also be rack mounted in a standard 19″ rack using the optional rack adapter kit RM-1825.

⚠ Safety Information & Precautions:

The following safety information applies to both operation and service personnel. Safety precautions and warnings may be found throughout this instruction manual and the equipment. These warnings may be in the form of a symbol or a written statement. Below is a summary of these precautions.

Terms in This Manual:

<u>CAUTION</u> statements identify conditions or practices that could result in damage to the equipment or other property.

<u>WARNING</u> statements identify conditions or practices that could result in personal injury or loss of life.

Terms as Marked on Equipment:

<u>CAUTION</u> indicates a personal injury hazard not immediately accessible as one reads the marking, or a hazard to property including the equipment itself.

<u>DANGER</u> indicates a personal injury hazard immediately accessible as one reads the marking.

Symbols:

As Marked in This Manual:

⚠	This symbol denotes where precautionary information may be found.

As Marked on Equipment:

⚠	CAUTION – Risk of Danger
⚡	DANGER – Risk of Electric Shock
⏚	Earth Ground Terminal
I	On
O	Off
⏚	Frame or Chassis Terminal
⏚	Earth Ground Terminal
∿	Alternating Current

Grounding the Equipment
This product is grounded through the grounding conductor of the power cord.
WARNING: To avoid electrical shock or other potential safety hazards, plug the power cord into a properly wired receptacle before using this instrument. The proper grounding of this instrument is essential for safety and optimizing instrument operation.

Danger Arising from Loss of Ground
WARNING: If the connection to ground is lost or compromised, a floating potential could develop in the instrument. Under these conditions all accessible parts, including insulating parts such as keypads and buttons could develop a hazardous voltage and put the user at risk.

⚠

Use the Proper Fuse
To avoid fire hazard, use only the correct fuse type as specified for the AC power supply in the "Instrument Description" or "Service Information" sections of this manual. Please note that the fuse rating for 100/120-volt power supply is different than the rating for 200/240-volt power supply.

Refer fuse replacement to qualified service personnel.

Use in Proper Environment

Normal calibration laboratory practice dictates that the environment should be closely controlled. This will minimize errors introduced by temperature and humidity changes. A nominal temperature of +23°C (+73.4°F) provides a good working condition. A tolerance of ±1°C gives allowable temperature spread. Controlled temperatures also stabilize the aging process of the standards.

CAUTION: The Model 1825 and 1827 have a specified ambient temperature range of +12° to +32°C (+54° to +90°F). Operating beyond these limits can affect the accuracy of the instruments and damage internal circuitry.

CAUTION: When the Model 1825 or 1827 is to be stored for extended periods, pack the instrument into a container. Place container in a clean, dry, temperature-controlled location. If instrument is to be stored in excess of 90 days, place desiccant with items before sealing container. The safe environmental limits for storage are -40° to +75°C (-40° to +167°F) at less than 95% non-condensing relative humidity.

Do Not Use in Explosive Environments

CAUTION: The 1825/1827 is not designed for operation in explosive environments.

Do Not Block Air Vents on Rear Panel

CAUTION: The Model 1825 and 1827 have an air intake and exhaust on the back panel of the instrument. When installing the Model 1825/1827, ensure there is at least two inches of space behind the instrument for airflow. DO NOT set the instrument on its rear panel as its airflow will be restricted and may result in damage to the internal circuitry.

Do Not Operate Without Covers

WARNING: This device should be operated with all panels and covers in place. Operation with missing panels or covers could result in personal injury.

Figure 2.1 Model 1825 and 1827 AC INPUT POWER and FUSE location

FOR QUALIFIED SERVICE PERSONNEL ONLY

⚠ Servicing Safety Summary:

Do Not Service Alone

Do not perform service or adjustment on this product unless another person capable of rendering first aid is present.

Use Care When Servicing with Power On or Off

Dangerous voltages may exist at several points in this product. To avoid personal injury or damage to this equipment, avoid touching exposed connections or components while the power is on. Assure that the power is off by unplugging the instrument when removing panels, soldering, or replacing components.

WARNING: The instrument power source is electronically controlled meaning that there is power present throughout the instrument even when the instrument is in the OFF state.

Always unplug the instrument and wait 5 minutes before accessing internal components.

Power Source

This product is intended to connect to a power source that will not apply more than 250V RMS between the supply conductors or between either supply conductor and ground. A protective ground connection by way of the grounding conductor in the power cord is essential for safe operation.

⚠ Line Voltage Selection:

CAUTION: DO NOT APPLY POWER TO THE INSTRUMENT BEFORE READING THIS SECTION:

The standard power supply in a Model 1825 or 1827 operates with a line voltage of 105 to 125 Vac at 50 to 400 Hz. A 210 to 250 Vac power supply can be ordered as a factory installed option. Each power supply requires a different fuse. It is strongly recommended that the line voltage, frequency, and fuse type be verified for the type of power supply in the unit before powering it.

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Model 1825 and 1827 Front Panel Description
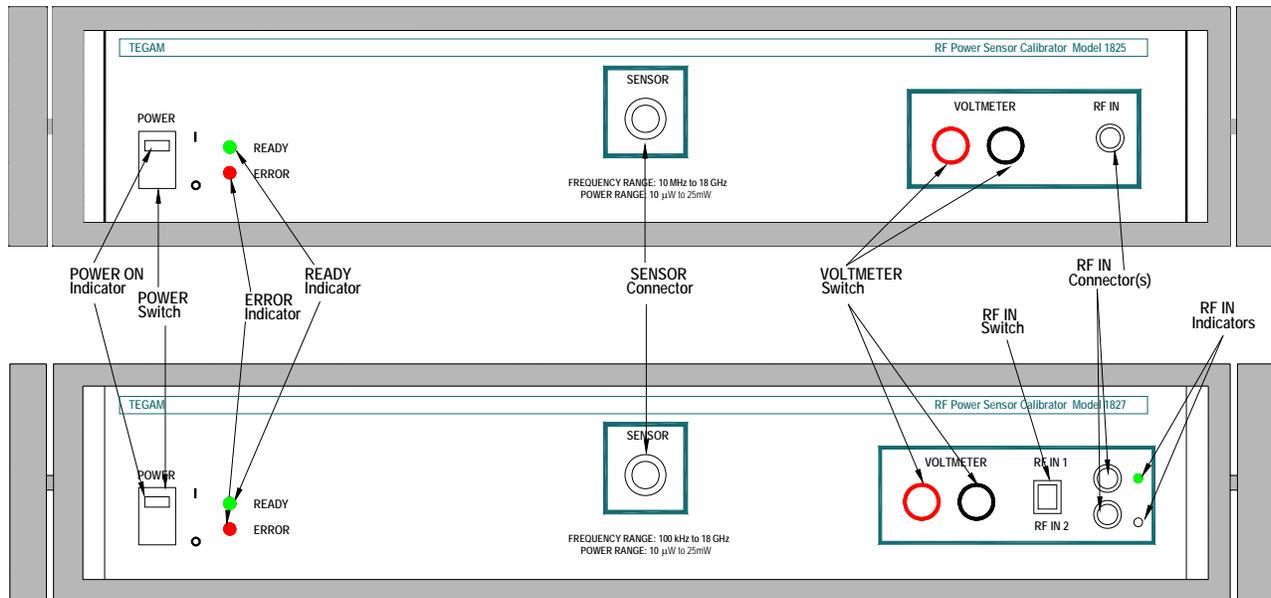
Figure 3.1 Model 1825(top) and 1827(bottom) Front Panel

POWER Switch (Both Models)
Switches the power input to the instrument on and off. Has a built-in indicator that is illuminated when power is on. See POWER ON indicator.

POWER ON Indicator (Both Models)
Illuminates when instrument power is on. It is built into the POWER switch.

READY Indicator (Both Models)
This green LED illuminates when the RF power standard has reached its internal operating temperature of 60°C. Allow two hours for the power standard to reach this temperature and ensure the READY indicator stays illuminated during RF power sensor calibrations.

ERROR Indicator (Both Models)
The ERROR indicator is a red LED that illuminates for any condition preventing the Type IV Bridge circuit from balancing. When the ERROR indicator becomes illuminated, stop any calibration and contact TEGAM for assistance.

SENSOR Connector (Both Models)

N-type female connector for the SUT. This connector provides the RF power to the SUT. The RF power applied to RF IN connector is applied equally to the SUT and the internal power standard. The fact that equal RF power is applied to both the power standard and the SUT is what allows the calibration factor of the SUT to be determined.

VOLTMETER Connectors (Both Models)

The VOLTMETER Connectors are spade-lug connecting posts/banana jacks. These connectors complete the DC path between the Model 1825 and a digital voltmeter with at least 6½-digit resolution. DC voltage present across the VOLTMETER connectors is equivalent to the voltage across the thermistor element. The red connector is for positive (+) DC voltage and the black connector is for negative (-) DC voltage.

RF IN Connector (Model 1825)

SMA female that connects to signal generator output. The RF power that comes in this connector is applied equally to the SUT and the power standard. The fact that equal RF power is applied to both the power standard and the SUT is what allows us to determine the calibration factor of the SUT. There is about 6 to 9.5 dB of insertion loss in the RF IN path.

RF IN 1 and RF IN 2 Connectors (Model 1827)

Both are SMA female that connects to signal generator outputs. Two inputs are provided because it is often necessary to use two different signal generators to cover the 100 KHz to 18 GHz frequency range of the Model 1827. The RF power that comes in this connector is applied equally to the SUT and the power standard. The fact that equal RF power is applied to both the power standard and the SUT is what allows us to determine the calibration factor of the SUT. There is about 6 to 10 dB of insertion loss in the RF IN path.

RF IN 1/RF IN 2 Switch (Model 1827)

Toggle switch that is used to select which RF Input is active. The switch position indicates which input is active. When the switch is up RF IN 1 is active, when the switch is down RF IN 2 is active. This switch allows RF sources to be changed without disconnecting and reconnecting cables.

RF IN 1 and RF IN 2 Indicators (Model 1827)

This green LED illuminates when the RF input next to it is active.

Model 1825 and 1827 Rear Panel Description
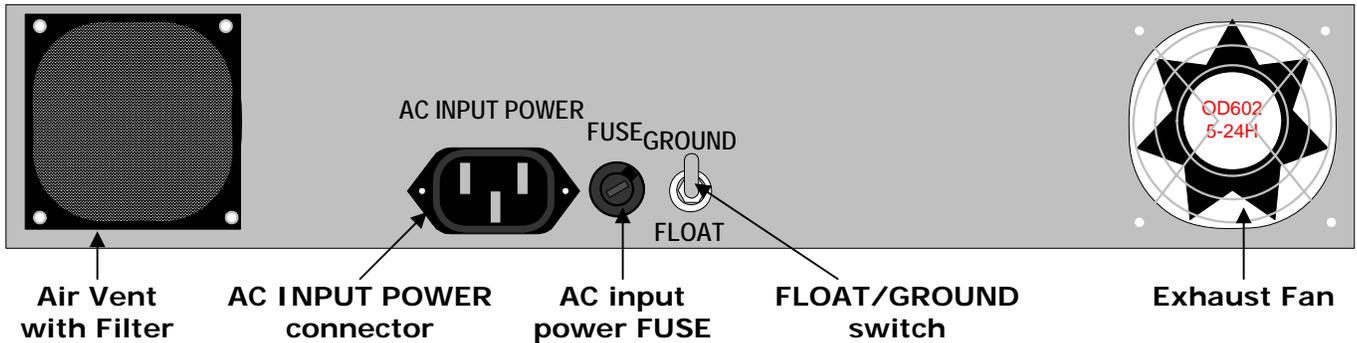
Figure 3.2 Model 1825 and 1827 Rear Panel

Air Vent with Filter
Air Vent allows air to flow into the Model 1825/1827 to keep the internal components from overheating. The filter keeps debris from entering the instrument. Ensure there is at least two inches of space behind the instrument for proper airflow.

AC INPUT POWER connector
Three prong connector mates with AC power cord supplied with unit.

AC input power FUSE
Protects instrument from an over-current condition. A 0.8 Amp fuse is used with the standard 110 Vac power supply, a 0.5 Amp is used with the optional 220 Vac power supply.

FLOAT/GROUND Switch
The FLOAT/GROUND Switch is a two position toggle switch located on the rear panel. This switch connects and disconnects the bridge board ground to chassis ground; the up position connects the bridge board to ground and the down position disconnects the bridge board from ground (floats). Normal operation is with the switch in the GROUND (up) position. If the LO (-) input of the external DVM is grounded, then the switch should be in the FLOAT (down) position.

Exhaust Fan
The Exhaust Fan causes air to flow out of the Model 1825/1827 to keep the internal components from overheating. Ensure there is at least two inches of space behind the instrument for proper airflow.

RF Power Sensor Calibration
To determine the calibration factor (the percentage of power applied to a power sensor that will actually be measured by the power meter), the power measured by the sensor is compared to a known power level. The known power level can either be set to a known level by a highly accurate source, such as with the System II Automatic Calibration System, or it can be accurately measured as with the Model 1825 or 1827. Contact TEGAM for more information on the System IIA. Once the power level is known, the calibration factor can be calculated. The following paragraphs describe this process.

Connecting The Model 1825 RF Power Sensor Calibrator
Before any measurements are taken, the Model 1825 must be connected as shown in Figure 3.3. The RF IN is connected to the output of the chosen signal generator, which should be 50 Ohm

nominal impedance. The RF IN is a female SMA connector; any adapters used to connect it to the signal generator output are referenced out and should not affect the sensor calibration. However, proper care, cleaning, and torquing of coaxial connectors should be practiced to reduce insertion loss and extend the life of the connectors. Also, a low loss coaxial cable is recommended to avoid an excessive power loss. The VOLTMETER red and black connectors are connected to the DVM DC voltage positive and negative input connectors respectively. The VOLTMETER connectors are binding posts/banana jacks so banana plugs or spade lugs will mate with them.

Connect the Sensor Under Test (SUT) to an appropriate power meter. Zero and "cal" the power meter and sensor in accordance with the manufacturer's operating instructions. The input of the SUT connects to the 50 Ohm N-type female SENSOR connector on the Model 1825. If any adapters, attenuators, or matching pads are needed they should be characterized and taken into account as described later in this chapter.
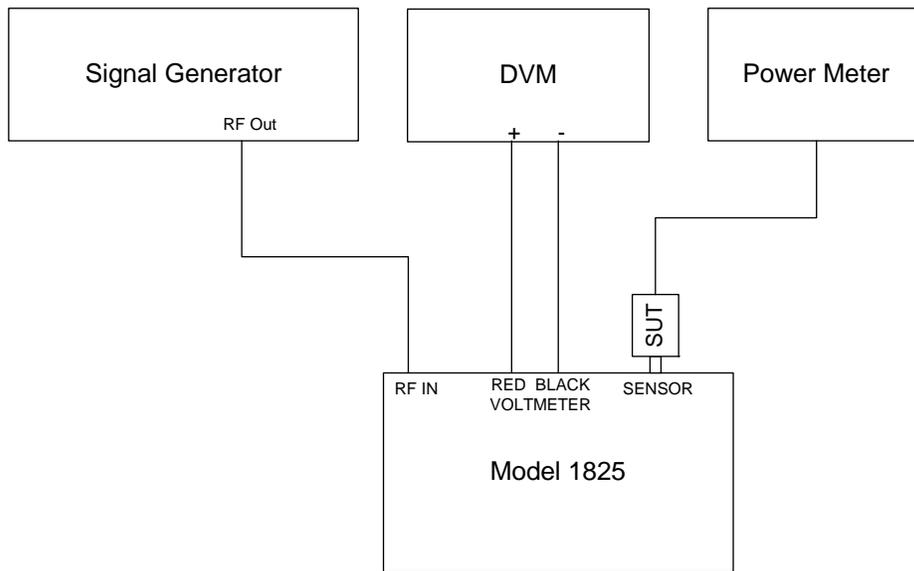
Figure 3.3 1825 Connections for Power Sensor Calibration

Connecting The Model 1827 RF Power Sensor Calibrator

The Model 1827 is connected much the same way as the Model 1825. The only difference is the fact that the Model 1827 has two RF IN connectors. The purpose of having two RF IN connectors is to accommodate two signal generators. Often, it is necessary to use two signal generators to cover the entire frequency range of the 1827. The RF inputs are activated using a toggle switch and an LED next to each output indicates which is active. This way signal sources can be changed just by flipping a switch without disconnecting and reconnecting RF cables.
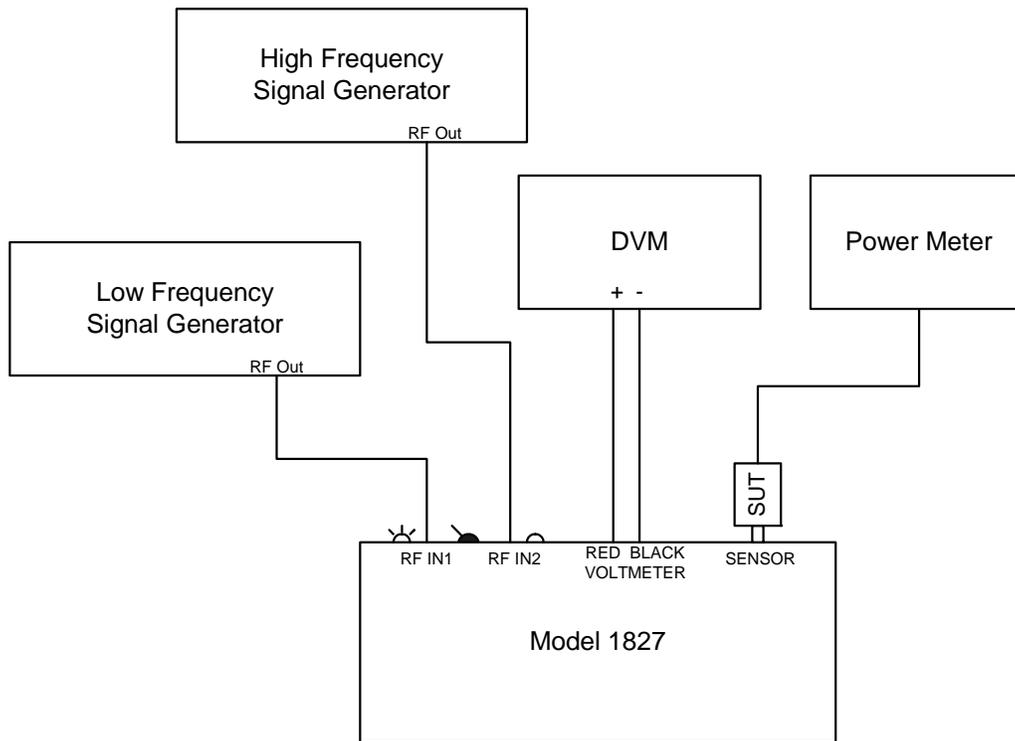
Figure 3.4 1827 Connections for Power Sensor Calibration

RF Power Level Measurement

The Model 1825 and 1827 precisely measure RF power in terms of a DC voltage change across the Model 1825/1827 bridge circuit. This instrument measures the voltage change with a (at least) 6½-digit resolution digital voltmeter (DVM) or the same DVM and reference voltage generator (RVG) to obtain greater precision. The following paragraphs describe these two methods of measurement.

RF Power Measurement With DVM Only

The Model 1825 and 1827 do not measure the RF power level directly. Instead, a DVM measures DC voltages before and after the application of RF power to the thermistor in the Model 1825/1827. This necessitates calculation of the RF power level using data obtained from the DVM measurements. To calculate the RF power level applied to the thermistor element, configure the Model 1825 or 1827 and the DVM according to Figure 3.3 or 3.4 and measure the voltage across the bridge with the DVM before the application of RF power and record it as V_1. Then, measure the voltage across the bridge after applying RF power and record that measurement as V_2. Determine the RF power level using the following steps:

First, calculate the level of proportional DC substituted power from the operating resistance and DVM readings with the equation:

$$P_{dc} = \frac{(V_1)^2 - (V_2)^2}{200}$$

Where:

V_1 = DVM reading across the bridge in the absence of RF power,
V_2 = DVM reading across the bridge with RF power applied,
200 = nominal resistance of the 1825 thermistor in Ohms,
P_{dc} = DC substituted power which is proportional to the applied RF power

Next, calculate the applied RF power level using the applicable calibration factor provided with the Model 1825 or 1827 and the level of DC substituted power:

$$P_{RF} = \frac{P_{dc}}{K_2}$$

Where:

P_{RF} = Level of applied RF power,

P_{dc} = DC substituted power which is proportional to the applied RF power,

K_2 = calibration factor of Models 1825 or 1827 traceable to NIST

RF Power Level Measurement With DVM And Reference Voltage Generator

When the applied RF power level becomes small, the change in voltage across the bridge also becomes very small. In this situation, even a high-accuracy voltmeter magnifies measurement uncertainties because the large DVM measurement scale has limited resolution. Use of a reference voltage generator (RVG), like the one in Figure 3.5, minimizes voltmeter uncertainties by enabling use of a measurement scale that has better resolution.
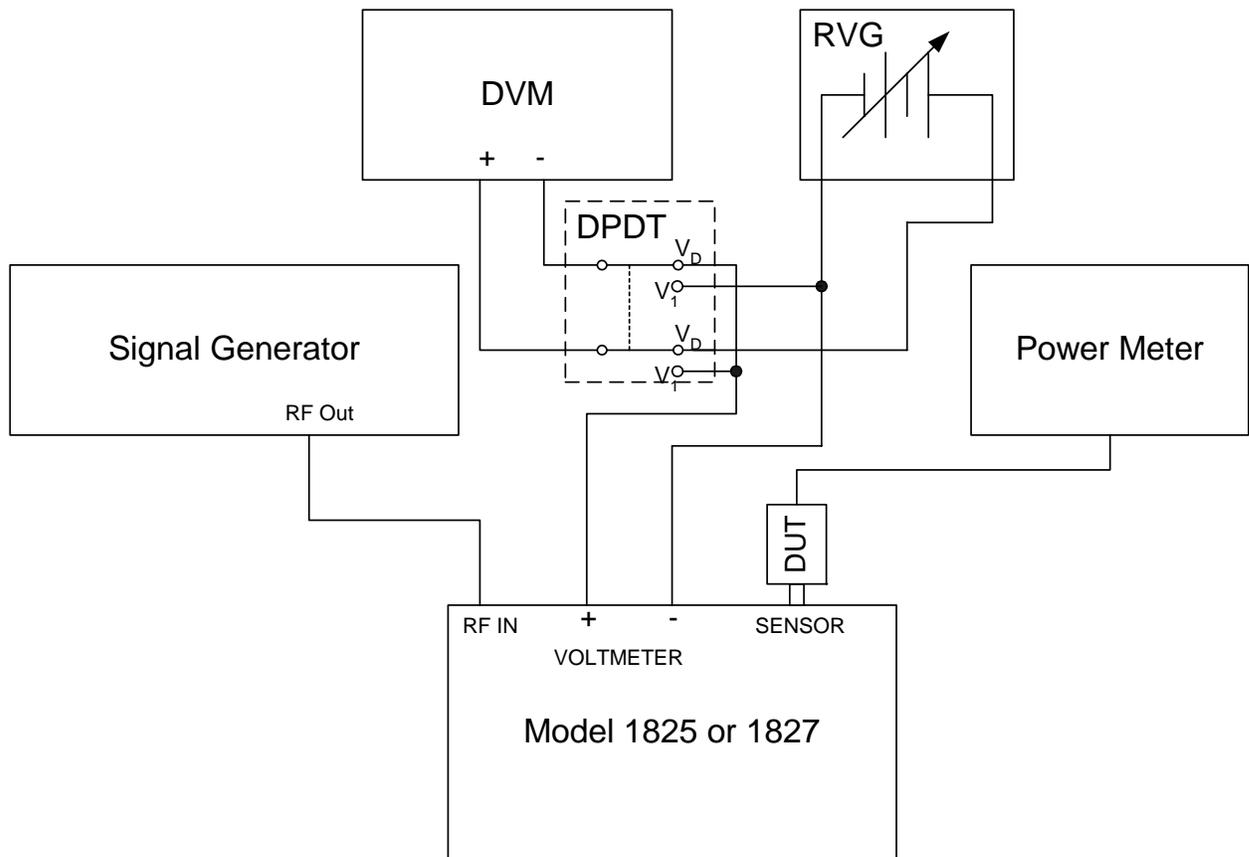

Figure 3.5 Connections for Using the Model 1825 or 1827 with an RVG

When a reference voltage generator is used with the DVM, calculation of the RF power level requires a different process. First, adjust the reference voltage generator to a voltage level approximately equal to the Model 1825/1827 bridge output measured by a DVM when no RF power is applied. Ensure stabilization of the RVG output throughout the entire measurement period. Next, record the DVM reading with no RF power applied to the bridge and the double-pole, double-throw switch in the "Measure V_1" position. This value is (V_1). Switch the DVM to a scale with improved resolution for smaller power levels. Record the DVM reading with no RF power applied and the double-pole, double-throw switch in the "Measure V_D" position. This reading is the difference between the Model 1825/1827 bridge output and the setting of the reference voltage source (VD1). Finally, apply RF power to the bridge and record the voltmeter reading with the double-pole, double-throw switch in the "Measure V_D" position. This value is the difference between the Model 1825/1827 output and RVG output including the proportional RF power effect on the bridge circuit (VD2). Use these values and the following method to calculate the applied level of RF power.

First, determine the level of DC substituted power using the measurements taken above with the equation:

$$P_{dc} = \frac{(2V_1 - V_{D2} + V_{D1})\ (V_{D2} - V_{D1})}{200}$$

Where:

    V_1 = DVM reading across the bridge in the absence of RF power,
    V_{D1} = Difference between 1825/1827 bridge output with no RF applied and RVG output,
    V_{D2} = Difference between 1825/1827 bridge output with RF applied and RVG output,
    200 = nominal resistance of the 1825/1827 thermistor in Ohms,
    P_{dc} = DC substituted power which is proportional to the applied RF power

Next, apply the mount calibration factor to find the level of RF power using the second equation:

$$P_{RF} = \frac{P_{dc}}{K_2}$$

Where:

    P_{RF} = Level of applied RF power,
    P_{dc} = DC substituted power which is proportional to the applied RF power,
    K_2 = calibration factor of Models 1825 or 1827 traceable to NIST

RF Power Sensor Calibration Factor

Once the power level being applied to the SUT is measured, the sensor's calibration factor can be determined. Simply take a power reading (in mW) from the SUT's power meter and divide that by the power level obtained from the previous section (P_{RF}). This ratio is the sensor's calibration factor. The calibration factor of the sensor is defined by:

$$K_{1S} = \frac{P_m}{P_{RF}}$$

Where:

    K_{1S} = cal factor of the SUT,
    P_m = power reading from the power meter,
    P_{RF} = Level of applied RF power,

That equation can also be written:

$$K_{1S} = \frac{(P_m)(K_2)}{P_{dc}}$$

Where:

   K_{1S} = cal factor of the SUT,
   P_m = power reading from the power meter,
   K_2 = calibration factor of Model 1825 or 1827 traceable to NIST
   P_{dc} = DC substituted power which is proportional to the applied RF power

The cal factor can also be expressed as a percentage. To do this, simply multiply the cal factor (K_{1S}) by 100.

Calibrating Sensors With A Reference CF

Often, power sensors are calibrated with a Reference Calibration Factor (CF). This Reference CF is used to align the meter and the sensor using the power meter's "reference output" (typically 50 MHz). When the sensor is calibrated with a Reference CF, all the calibration factors of the sensors are relative to a power meter's reference output.

There are essentially two methods of calibrating sensors with a Reference CF. The first involves applying the offset mathematically. To do this, measure the RF power level and determine the sensor's calibration factor at the reference frequency (usually 50 MHz). Then determine the ratio of the desired reference cal factor to the cal factor that was calculated.

The ratio is an offset calculated by:

$$K_{off} = \frac{K_{ref}}{K_{1S}}$$

Where:

   K_{off} = the calibration factor offset,
   K_{ref} = desired reference cal factor,
   K_{1S} = cal factor of the SUT

The rest of the sensor's calibration factors are multiplied by K_{off}.

The second method of calibrating a power sensor with a Reference CF involves using the calibration offset of the power meter itself. Simply set the calibration offset of the power meter to the desired reference cal factor and cal adjust the meter using the reference output. Once the power meter is adjusted, the rest of the cal factors can be obtained as described in the previous sections; no further calculations are necessary.

Calibrating Sensors Using an Adapter or Attenuator

It may be necessary to use an adapter or attenuator to calibrate a particular power sensor with the Model 1825 or 1827. If the sensor's power range is less than the power range of the Model 1825/1827 (-20 to +14 dBm), then an attenuator is needed. If the sensor does not have an N-type male connector then an adapter would be needed. A 50 to 75 Ohm matching pad is needed to calibrate 75 Ohm sensors. Any device placed between the SENSOR connector and the SUT will affect the calibration results and its loss (attenuation) must be characterized and corrected for.

In order to correct for the loss of a device (adapter or attenuator), the attenuation of the device must be measured at each frequency it will be used. There are many ways to measure attenuation, a network analyzer is probably the most precise. Once the attenuation of the device is measured, the "loss factor" at a particular frequency must be determined by:

$$K_A = 10^{A/10}$$

Where:

   K_A = the loss factor of the attenuator or adapter,
   A = the measured attenuation in of the device in dB (should be a negative value)

To determine the calibration factor of the SUT, measurements are taken as previously described in this chapter. The formula to determine the sensor's calibration factor is slightly different:

$$K_{1S} = \frac{(P_m)(K_2)}{(P_{dc})(K_A)}$$

Where:

   K_{1S} = cal factor of the SUT,
   P_m = power reading from the power meter,
   K_2 = calibration factor of Model 1825 or 1827 traceable to NIST,
   P_{dc} = DC substituted power which is proportional to the applied RF power,
   K_A = the loss factor of the attenuator or adapter

Additional Information

Repeat the process for each frequency the SUT is to be calibrated. It is not necessary to get a DVM reading across the bridge with the RF power off (V_1) at each different frequency point. As long as the Model 1825/1827 has been turned on for at least two hours, it should be thermally stable and this value should not change during a calibration. Check V_1 often during the first few calibrations, and then determine how often it should be checked for the most time efficient and accurate calibration possible.

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Principle Of DC Substitution

The Model 1825 and 1827 use the principle of DC substitution to measure RF power. DC substitution refers to the measurement of RF power according to the amount of DC power that must be substituted for the RF power in a bolometer in order to cause equivalent thermal effects. Since some of the RF power applied to the input of the power standard is lost by reflection and other causes before it is applied to the thermistor element, the calibration factor of the standard is applied by the following formula to determine the actual level of RF power:

$$P_{RF} = \frac{P_{dc}}{K_2}$$

Where:

P_{RF} = Level of applied RF power,
P_{dc} = DC substituted power which is proportional to the applied RF power,
K_2 = calibration factor of Model 1825/1827 traceable to NIST

Precision Power Measurement

The Model 1825 and 1827 RF Power Sensor Calibrators and a digital voltmeter with a 6½-digit resolution combine to provide the precision power measurement system. This system features the Model 1825/1827 closed-loop, self-balancing Type IV Bridge circuit consisting of two legs - a precision resistance leg 200 ohms and a leg linked to a thermistor element in the Model 1825/1827 power standard. A thermistor is a type of bolometer whose resistance decreases as a function of increasing heat associated with ambient temperature or applied power.

This system also features the Model 1825/1827 temperature control circuitry that temperature stabilizes the thermistor element. This eliminates changes in the thermistor element's resistance due to ambient temperature changes and thus isolates the causes of thermistor variation to the application of RF and DC power only.

Self-Balancing Bridge Circuits

The Model 1825 and 1827 contain a bridge circuit that performs DC substitution. Figure 4.1 shows a simplified schematic of the bridge circuit in the Model 1825 and 1827.

The self-balancing bridge circuit, in a closed-loop configuration, consists of two legs: a precision resistance leg 200-ohm and a leg containing a thermistor element. The precision resistance leg maintains a constant effective resistance value of 200 ohms. When the power standard is temperature stabilized by the temperature control circuit, thermistor resistance varies solely due to the application of RF and DC power.

Each leg uses an operational amplifier (U1 or U2) to sense voltage imbalances and to drive transistors (Q1 and Q2) to correct them. The power supply assembly provides isolated ±15 volt biasing to each op-amp. Since the voltage differential at the input stage of op amp U2 is negligibly small, it provides a virtual common reference to op amp U1 (i.e., it acts as a virtual common ground since the voltage approaches zero with respect to either ground). This forces the current through the thermistor to equal the current through the precision resistance leg.

The application of RF power to the thermistor element creates a decrease in the voltage drop across the thermistor element due to its negative temperature coefficient. This decreased voltage drop, in turn, creates an unbalanced bridge condition. When resistance in the thermistor element leg of the bridge changes due to the application of RF power, op amp U1 senses a voltage difference between V_a and V_a' and causes V_a' to equal V_a. When V_a' equals V_a, the voltage across the thermistor element leg equals the voltage across the precision resistance leg. Also, the closed loop circuit configuration maintains equal current throughout the bridge. Since the voltage and current throughout the circuit is equal, the resistance in both halves is also equal. Therefore, when the thermistor mount's temperature is stabilized and RF power is applied, a change in voltage across the precision resistance leg is proportional to the amount of RF power applied to the thermistor element.
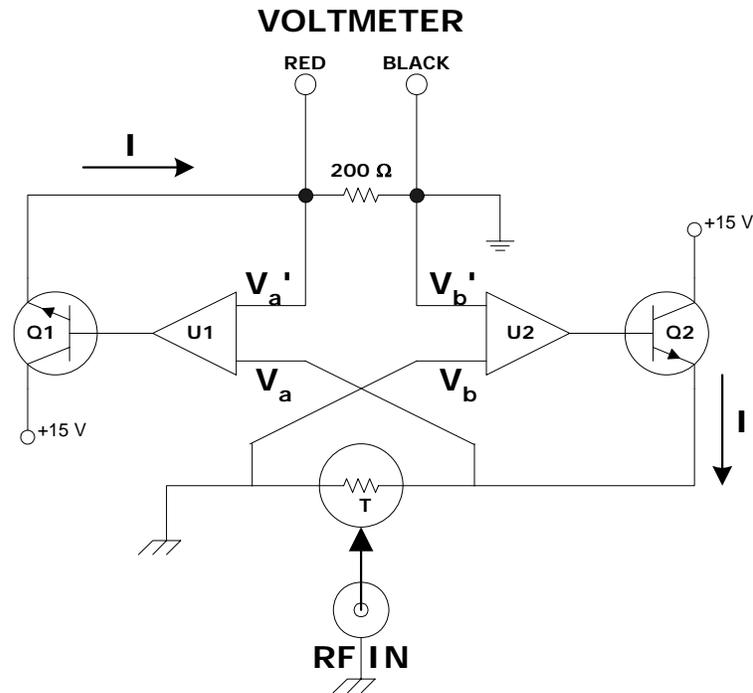
VOLTMETER

Figure 4.1 Simplified Schematic of the Model 1825/1827 Bridge Circuit

Power Measurements

The precision measurement system measures RF power in terms of a power change across the precision resistance leg. A digital voltmeter measures voltage across the precision resistance leg which can be used to determine the power by the following equation:

$$P = \frac{V^2}{200}$$

Where:

   P = power across the precision resistance leg
   V = voltage measured across the precision resistance leg
   200 = resistance value of precision resistance leg

The RF power introduced to the thermistor is directly proportional to the change in DC power across the precision resistor. The change in DC power across the precision resistor leg is given by:

$$\Delta P = P_1 - P_2$$

Where:

   ΔP = the change in power across the precision resistance leg when RF power is applied to the thermistor leg,
   P_1 = power across the precision resistance leg without RF power applied,
   P_2 = power across the precision resistance leg with RF power applied

To determine the power across the precision resistance leg without RF power applied, measure the voltage before the application of RF power (V_1). To determine the power across the precision resistance leg with RF power applied, measure the voltage during the application of RF power (V_2). Once these two voltage measurements are made, the power can be determined by using the first equation. By substituting for P_1 and P_2 from the previous formula:

$$\Delta P = \frac{(V_1)^2}{200} - \frac{(V_2)^2}{200}$$

Combining terms:

$$\Delta P = \frac{(V_1)^2 - (V_2)^2}{200}$$

Where:

   ΔP = the change in power across the precision resistance leg when RF power is applied to the thermistor leg,
   V_1 = DVM reading across the bridge in the absence of RF power,
   V_2 = DVM reading across the bridge with RF power applied,
   200 = nominal resistance of the 1825/1827 thermistor in Ohms,

Since the change in power across the precision resistor is DC power, ΔP is also represented as P_{dc}. The change in DC power across the precision resistor is directly proportional to the RF power introduced to the thermistor. Like all RF power sensors, some of the RF power applied to the input of the Model 1825/1827's power standard is lost by reflection and other causes before it is applied to the thermistor element. Thus, calibration factors based on frequency are associated with the Model 1825 and 1827 and are applied in the following formula to determine the actual level of RF power:

$$P_{RF} = \frac{P_{dc}}{K_2}$$

Where:

   P_{RF} = Level of applied RF power,
   P_{dc} = DC substituted power which is proportional to the applied RF power,
   K_2 = calibration factor of Model 1825 or 1827 traceable to NIST

Controlling Thermistor Temperature

The Model 1825 and 1827 contain a thermistor which is a temperature-sensitive device. In order to provide precise measurements, the effects of changes in the ambient temperature upon the thermistor must be eliminated or minimized. The Model 1825/1827 temperature controller accomplishes this by raising the power standard's internal temperature to a level higher than the ambient temperature (approximately 60° C) and maintaining that level by controlling the current applied to the power standard's heater element. This prevents any thermistor imbalance due to ambient temperature change. Therefore, all temperature changes are due to the application of RF and DC power.

The temperature control circuit performs two basic functions: control the temperature of the thermistor element and illuminate the READY LED when the power standard has reached its operating temperature. Refer to Figure 4.2 for the following discussions concerning the temperature control circuit. The Wheatstone Bridge composed of R1, R2, R3, and R4 is actually wire wound around a thermal mass and not only heats the mass but also detects the temperature of it. The wiring heats the mass to a temperature above the ambient temperature. The thermistor beads are mounted on this thermal mass and insulation surrounds the assembly to improve temperature stability. Two windings, represented as R1 and R2, of zero temperature coefficient wire (manganin) make up two legs of the bridge. The remaining two bridge windings, R3 and R4, have a positive temperature coefficient wire (nickel). When the operating temperature is reached, the heater windings provide equal resistance and the bridge balances. The temperature is determined such that the thermistor bead bias power is 30mW ± 0.7 mW.

Figure 4.2 Simplified Schematic of the Model 1825/1827 Heater Circuit

U1, a high-gain amplifier with excellent offset drift characteristics, senses imbalances across the bridge. U1/U2 interaction provides a varying response to thermal bridge imbalances according to the relationship between the voltage differential inputs. U1/U2 amplifies an imbalance signal from a cold bridge that forces the series pass transistor Q3 to pass a current proportional to the imbalance signal. This current drives the bridge to restore balance. As the bridge nears the steady-state condition, Q3 causes the READY LED to illuminate. If the mount is cold, the READY LED does not illuminate since the Darlington pair configuration made up by Q1 and Q4 is not in a conducting state. U1/U2 responds to an imbalance signal from an overheated mount by turning off Q3 so that it passes no current to the heater or READY LED. Transistor Q2 and Resistor R16 combine to provide circuit protection by limiting current in the event of an output short circuit.

Calculating Uncertainty
Measurement uncertainty when using the Model 1825 or 1827 can be calculated with the following formula:

$$U_P = \sqrt{U_C{}^2 + I_E{}^2 + M_{ER}{}^2}$$

Where:
   U_P = uncertainty of the power measurement of the Model 1825 or 1827,
   U_C = uncertainty of the cal factor for the Model 1825 or 1827 which is frequency dependent,
   I_E = the random part of the uncertainty of the instrumentation,
   M_{ER} = mismatch error which is frequency dependent.

Mismatch Uncertainty (M$_{ER}$)

Device mismatch is the term used to describe the differences in impedance between RF devices. This difference in impedance causes some of the RF power to be reflected back from one device to another; thus, not all applied RF power is transferred from one device to another. The amount of power that is not transferred can be characterized as the reflection coefficient, or Γ. The reflection coefficient for the Model 1825 and 1827 is included as part of the calibration data. Mismatch error (M$_{ER}$) is determined from the reflection coefficients of both the Model 1825 or 1827 and the SUT as follows:

$$M_{ER} = 1 - \frac{1}{(1 \pm |\Gamma_1| \times |\Gamma_2|)^2}$$

Where:

  M$_{ER}$ = residual mismatch error,
  Γ_1 = reflection coefficient for the Model 1825,
  Γ_2 = reflection coefficient for the SUT.

Reflection Coefficient is a complex number expressed as a vector quantity. A vector quantity has two components a magnitude and phase angle. The magnitude of the reflection coefficient is symbolized by the Greek letter rho ρ and the phase angle by the Greek letter phi ϕ. Often, the magnitude is the only part of the reflection coefficient used, which will yield a "worse case" mismatch uncertainty. Sometimes the Standing Wave Ratio (SWR) of a device is given rather than the reflection coefficient (Γ). SWR is a scalar quantity and related to ρ follows:

$$\rho = \frac{S - 1}{S + 1}$$

Where:

  ρ = magnitude of the reflection coefficient,
  S = Standing Wave Ratio (SWR).

Impedance mismatch between all devices connected to the SENSOR port of the 1825/1827 should be included in M$_{ER}$. That means the reflection coefficient or VSWR of any adapter, attenuator, or matching pad used should be known. To include these devices, use the equations above to determine the mismatch uncertainty between each device that is connected together. M$_{ER}$ is the sum of those mismatch uncertainties.

Gamma Correction

If both the ρ and ϕ of the reflection coefficient are known for both the SUT and 1825/1827 (TEGAM provides this data as part of the calibration for the 1825/1827), then Gamma corrections can be applied to the calibration factor of the SUT. Applying Gamma corrections to the calibration factor reduces the total uncertainty of the calibration by eliminating M$_{ER}$. Gamma corrections are applied to the SUT's cal factor as follows:

$$\text{Corrected } K_{1S} = \frac{K_{1S}}{|1 + \Gamma_1\Gamma_2|^2}$$

Where:

  Corrected K$_{1S}$ = cal factor of the SUT after Gamma correction are applied,
  K$_{1S}$ = cal factor of the SUT before Gamma correction is applied,
  Γ_1 = reflection coefficient of the 1825 or 1827,
  Γ_2 = reflection coefficient of the SUT

That equation can be "simplified" to :

$$\text{Corrected } K_{1S} = \frac{K_{1S}}{(1 - \rho_1\rho_2 \cos(\phi_1 + \phi_2))^2 + (\rho_1\rho_2 \sin(\phi_1 + \phi_2))^2}$$

Instrumentation Uncertainty (I_E)

These uncertainties are limited by the quoted accuracies of the various equipment involved. Refer to Table 4-1 for an analysis.

Table 4.1 A Typical Instrumentation Error Analysis (I_E)

Item	Specified Accuracy	Effect on Uncertainty
Model 1825/1827		
DC Substitution Bridge Accuracy	±0.003%	±0.003
Connector Repeatability	±0.1%	±0.1
Temperature drift	±0.05%	±0.05
Power Linearity (1 to 10 mW)	±0.1%	0 at 1mW
Calibration Factor Drift with Time	±0.5%	±0.5
Total RSS Uncertainty		**±0.51%**
Other Instruments		
Digital Voltmeter Accuracy	See manufacturer's specifications	
Digital Voltmeter Nonlinearity	See manufacturer's specifications	
Power Meter Accuracy	See manufacturer's specifications	

It should be noted that the Model 1825 and 1827 are calibrated at 1 mW. If the transfer to the SUT is also performed at 1 mW, then the Power Linearity has zero effect. Otherwise, to determine Power Linearity, multiply the nominal power level by ±0.01% up to a nominal power level of 10 mW. From 10 to 25 mW, the additional Power Linearity becomes negligible.

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Warranty:

TEGAM, Inc. warrants this product to be free from defects in material and workmanship for a period of 1 year from the date of shipment. During this warranty period, if a product proves to be defective, TEGAM, Inc., at its option, will either repair the defective product without charge for parts and labor, or exchange any product that proves to be defective.

TEGAM, Inc. warrants the calibration of this product for a period of 1 year from date of shipment. During this period, TEGAM, Inc. will recalibrate any product, which does not conform to the published accuracy specifications.

In order to exercise this warranty, TEGAM, Inc., must be notified of the defective product before the expiration of the warranty period. The customer shall be responsible for packaging and shipping the product to the designated TEGAM service center with shipping charges prepaid. TEGAM Inc. shall pay for the return of the product to the customer if the shipment is to a location within the country in which the TEGAM service center is located. The customer shall be responsible for paying all shipping, duties, taxes, and additional costs if the product is transported to any other locations. Repaired products are warranted for the remaining balance of the original warranty, or 90 days, whichever period is longer.

Warranty Limitations:

The TEGAM, Inc. warranty does not apply to defects resulting from unauthorized modification or misuse of the product or any part. This warranty does not apply to fuses, batteries, or damage to the instrument caused by battery leakage.

Statement of Calibration:

This instrument has been inspected and tested in accordance with specifications published by TEGAM, Inc. The accuracy and calibration of this instrument are   traceable to the National Institute of Standards and Technology through equipment, which is calibrated at planned intervals by comparison to certified standards maintained in the laboratories of TEGAM, Inc.

Contact Information:

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PH: 440.466.6100
FX: 440.466.6110
EMAIL: sales@tegam.com

Changing the Power Fuse

Different fuses must be used for different power supplies:
For the standard 105-125 Vac power supply use a 0.8A Slo-Blo fuse.
For the optional 210-250 Vac power supply use a 0.5A Slo-Blo fuse.
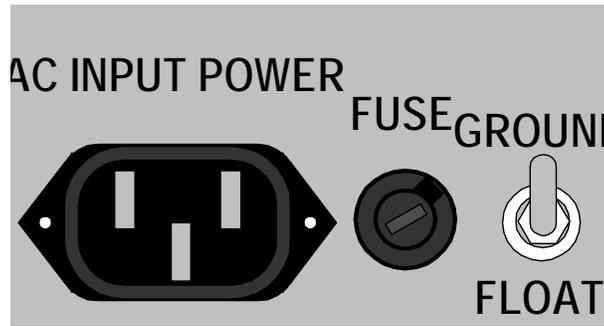
Figure 5.1 Location of the FUSE

The fuse is located between the AC INPUT POWER connector and the FLOAT/GROUND switch on the rear panel as depicted in Figure 5.1. To replace the fuse, remove the fuse cap by inserting a flat screwdriver into the slot in the cap and rotate about ¼ counter-clockwise. The cap and fuse will spring out; replace the fuse. Align the tab on the fuse cap with the notch on the fuse housing, push the cap and fuse into the housing, and turn the cap ¼ clockwise with a flat screwdriver to lock the cap down.

Preparation for Repair or Calibration Service:

Once you have verified that the cause for the Model 1825 or 1827 malfunction cannot be solved in the field and the need for repair and calibration service arises, contact TEGAM customer service to obtain an RMA, (Returned Material Authorization), number. You can contact TEGAM customer service via the TEGAM website, www.tegam.com or by calling 440.466.6100 OR 800.666.1010.

The RMA number is unique to your instrument and will help us identify your instrument and to address the particular service request by you which is assigned to that RMA number. Of even more importance is a detailed written description of the problem, which should be attached to the instrument. Many times repair turnaround is unnecessarily delayed due to a lack of repair instructions or lack of a detailed description of the problem.

The detailed problem description should include information such as measurement range, trigger mode, type of components being tested, is the problem intermittent?, when is the problem most frequent?, has anything changed since the last time the instrument was used?, etc. Any detailed information provided to our technicians will assist them in identifying and correcting the problem in the quickest possible manner. Use the Expedite Repair & Calibration form provided on the next page to provide detailed symptoms of the instrument's problem.

Once this information is prepared and sent with the instrument and RMA number to our service department, we will do our part in making sure that you receive the best possible customer service and turnaround time possible.

Expedite Repair & Calibration Form

Use this form to provide additional repair information and service instructions. The completion of this form and including it with your instrument will expedite the processing and repair process.

RMA#:		Instrument Model #:	
Serial Number:		Company:	
Technical Contact:		Phone Number:	
Additional Contact Info:			

Repair Instructions:

☐ Evaluation ☐ Calibration Only ☐ Repair Only ☐ Repair & Calibration ☐ A2LA Accredited Calibration (Extra Charge)

Detailed Symptoms:

Include information such as measurement range, instrument settings, type of components being tested, is the problem intermittent? When is the problem most frequent?, Has anything changed with the application since the last time the instrument was used?, etc.