1825-901-01CD

OPERATION MANUAL

Model 1825 Power Sensor Calibrator

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Rev A

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SECTION I - INTRODUCTION AND GENERAL DESCRIPTION

PURPOSE

This manual provides operation instructions necessary to set up and operate the TEGAM Model 1825 Power Sensor Calibrator.

Figure 1-1 Model 1825 RF Power Sensor Calibrator

SCOPE

This manual is to be used in conjunction with the operation of the TEGAM 1825 Power Sensor Calibrator.

ARRANGEMENT

The information contained in this manual is tabulated in the Table of Contents, List of Illustrations, and List of Tables. The manual is divided into four sections, listed as follows:

SECTION I - Introduction and General Description

SECTION II - Installation and Shipment

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SECTION IV - Theory of Operation

CONTACTING TEGAM

In the event of an instrument malfunction, contact TEGAM. An apparent malfunction of an instrument or component may be corrected over the phone by contacting TEGAM. **DO NOT** send the instrument or component back to the factory without first obtaining a Return Material Authorization (RMA) number from TEGAM. When it is necessary to return an item, state the symptoms or problems, part or model number and description of the instrument or component, serial number of the item, and date of original purchase. Also write the company name, your name, phone number, and the (RMA) number on an index card. Then attach the card to the instrument or component to be returned. Contact TEGAM using the following:

TEGAM, INC.
TEN TEGAM WAY
GENEVA, OH 44041 USA

800-666-1010 toll-free
440-466-6110 fax
sales@tegam.com e-mail

SAFETY CONSIDERATIONS

The Model 1825 and all related documentation must be reviewed for familiarization with safety procedures and cautions before performing any operation. **WARNING** will precede all safety precautions in this manual. Following these simple safety precautions will ensure safe operation of the Model 1825.

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

DESCRIPTION OF EQUIPMENT

The following paragraphs provide a general description of the Model 1825 Power Sensor Calibrator (shown in Figure 1-1).

Functional Description

The Model 1825 is designed to calibrate power meter sensors in the 0.01 to 18.0 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 1825 precisely and accurately detects 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 the Model 1825.

Physical Description

Refer to Table 1-1 for the physical and electrical specifications of the Model 1825. The front contains the INPUT POWER switch as well as the SENSOR, RF IN, and VOLTMETER connectors. The rear panel contains the input power connector and fuse, FLOAT/GROUND switch, and vents for airflow. The Model 1825 was designed to sit on a bench but can be mounted in a 19” rack with rack mount kit RM-1825.

Specifications

Table 1-1 lists the physical and electrical specifications of the Model 1825.

Table 1-1 Physical and Electrical Specifications

Frequency Range	10 MHz to 18 GHz
Power Range	10 µW to 25 mW
Typical DC Power Measurement Accuracy	±(0.03% + 2 µW) when used with Fluke Model 8505A, 8506A, Agilent (HP) 3458A or equivalent voltmeters
DC Substitution Bridge Accuracy	±0.003%
RF Impedance	50 Ohms nominal
SWR	≤ 1.10
Insertion Loss (RF INPUT)	6 dB nominal, 8.5 dB max
Calibration	Individual calibrations traceable to NIST supplied at the following frequencies: 10 to 100 MHz in 10 MHz increments 100 MHz to 2 GHz in 50 MHz increments 2 GHz to 4 GHz in 100 MHz increments 4 to 12.4 GHz in 200 MHz increments 12.75 to 18 GHz in 250 MHz increments Recommended calibration interval: 1 year.
Connectors	
SENSOR	N-type Female
RF IN	SMA Female
VOLTMETER	Binding Post, standard 0.75” spacing for banana plugs
Temperature	
Operating	+12° to +32° C (+54° to +90° F)
Storage	-40° to +75° C (-40° to +167° F)
Warm up time	2 hours minimum from instrument power up
Power Requirements	12 Watts, 47 to 420 Hz, 105 to 125 Vac standard or 210 to 250 Vac with a factory installed option.
Fuse	Slo-Blo, ½ Amp for 110 Vac or ¼ Amp for 220 Vac
Weight	16.2 lbs (7.4 kg)
Physical Dimensions	
Height	88.9 mm (3.5 in)
Width	457.2 mm (18 in)
Depth	390.7 mm (15.4 in)
Rack Mounting	The Model 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. 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	10 MHz to 18GHz Frequency Range, Continuous Wave, 6dBm minimum power output.
DVM	DC Volts, 6 1/2-digit minimum.
RF Power Meter	Compatible with the sensor under test.

APPLICATIONS

The TEGAM Model 1825 Power Sensor Calibrator was designed for the transfer of calibration factors to power meter sensors. Figure 1-2 shows a typical application. While the Model 1825 is not designed for remote programming, the process of calibrating power sensors can be automated if the additional equipment used can be remotely programmed.

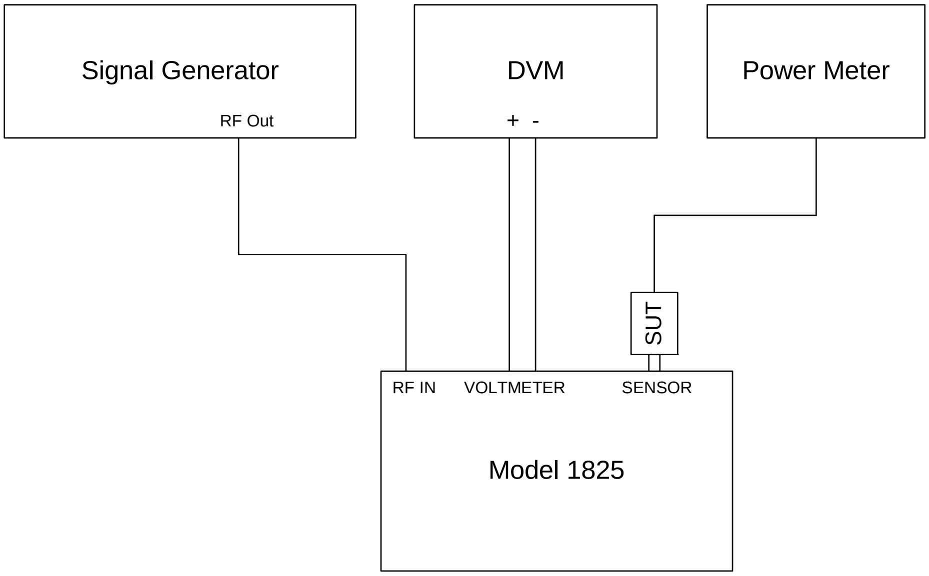

Figure 1-2 Typical Setup for Power Sensor Calibration

SECTION II - INSTALLATION AND SHIPMENT

GENERAL

This section contains all necessary instructions and information to install and interface the Model 1825 RF Power Sensor Calibrator. Included in this section are initial inspection; preparation for reshipment and storage; power, environmental, and mounting requirements; and installation instructions.

INITIAL INSPECTION

The Model 1825 was carefully inspected both mechanically and electrically before shipment. This instrument should be free of mars or scratches and in perfect electrical order upon receipt. After unpacking the instrument, do not discard the shipping and packing material until the instrument has been visually inspected and it is determined that reshipment is not necessary. Perform initial inspection in accordance with the following paragraphs.

Inspection

Perform the following procedures before removing any item from the shipping container.

a. Visually inspect the shipping container for any discoloration; stains; charring; or any other signs of exposure to heat, moisture, or liquid chemicals.
b. Check for any physical damage to the shipping container such as dents, large snags or rips, crushed sections or areas, and/or similar signs of excessive shock caused by careless handling.
c. Carefully remove the instrument and all other items from the shipping container.
d. Inspect the instrument for any dents, cracks, deep scratches, damaged or loose switches and/or knobs, and any other signs of careless handling.

Damage

If it has been determined shipping damage has occurred, immediately contact the delivering carrier to perform an inspection and prepare a concealed damage report. Do not destroy any shipping or packing material until an agent of the carrier has examined it. Also notify TEGAM to report the nature and extent of damage to the instrument. When contacting TEGAM, please provide model and serial number of instruments received so that the necessary actions can be taken. DO NOT return the instrument until a claim for the damages has been established. If there is mechanical damage (not from shipping), the contents are incomplete, and/or the instrument does not function properly, refer to Section I and notify TEGAM.

Inventory

After inspection for obvious damage, inspect the carton for the following items:

Model 1825 RF Power Sensor Calibrator	
Model 1825 Operating Manual (CD)	P/N 1825-900-01A
Power Cord	P/N 068-21

PREPARATION FOR RESHIPMENT OR STORAGE

Reshipment

DO NOT return any instrument or component to TEGAM without receiving prior factory authorization. Contact the Sales Department at TEGAM for a Return Material Authorization (RMA) number. Perform the following procedure when reshipping an instrument or component to TEGAM.

a. Use the best available packing materials to protect the instrument during reshipment. When possible, use the original shipping container and packing materials.
b. Cover the front panel connectors with plastic connector covers.

c. Wrap instrument with sturdy paper or plastic.
d. Place all accessories, cables and loose hardware into a plastic bag.
e. Place the wrapped instrument into a strong container with a layer of shock absorbing material wrapped around all sides of the instrument to provide a firm cushion and to prevent movement inside the container.
f. Place bag of accessories and hardware into container.
g. If shipping the instrument for service, attach a tag to indicate the following:
  Model and serial number
  Service required
  Description of malfunction
  Return address
  Authorization to conduct repairs
  Instrument repair authorization (RMA Number)
  Name and Phone Number of Technical Contact
h. Thoroughly seal shipping container and mark it FRAGILE.
i. Ship to an authorized sales representative or:

TEGAM, Inc.
10 TEGAM Way
Geneva, OH 44041
USA

Storage

When the Model 1825 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 as follows:

Temperature: -40° to +75°C (-40° to +167°F)
Humidity: less than 95% non-condensing

POWER, ENVIROMENTAL, AND MOUNTING REQUIREMENTS

Power Requirements

The Model 1825 is supplied with a three-conductor power cord for connection to an AC power source. When plugged into an appropriate receptacle, the cord also grounds the instrument for the protection of operating personnel. If it is necessary to use a 2-contact electrical outlet, install a 3-to-2-conductor adaptor and connect the adaptor lead to ground. The Model 1825 may be operated from an AC power source of 12 Watts, 47 to 420 Hz. The input voltage is 105-125 Vac standard, or 210-250 Vac with a factory-installed option.

Environmental Requirements

The Model 1825 operates best within its specifications at an ambient temperature of +12° to +32°C (+54° to +90°F). Operating beyond these limits can affect the accuracy of the instruments and damage internal circuitry.

Recommended Operating Environment

Normal calibration laboratory best practice dictates that the environment should be closely controlled. This will minimize errors introduced by temperature and humidity changes. A nominal temperature of +22°C (+73.4°F) provides a good working condition. A tolerance of ±0.5°C gives allowable temperature spread. Controlled temperatures also stabilize the aging process of the standards.

Mounting

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

INSTALLATION

To install the Model 1825: Bench or rack mount the instrument in accordance with the mounting requirements described previously. Check the fuse, which is located on the rear panel as depicted in Figure 2-1, to make sure it is the proper type according to Table 1-1. Connect the ac power cord (P/N 068-21) to the AC POWER INPUT connector located on the rear panel of the instrument (refer to Figure 2-1). Make sure the ac power source meets the power requirements described previously. The power cord can then be plugged into the ac source.

WARNING

Sufficient current to constitute a HAZARD to the operator exist at the line fuse. Ensure that POWER CORD is DISCONNECTED from the AC POWER SOURCE PRIOR to checking or changing the line fuse.

Figure 2-1 Model 1825 AC INPUT POWER and FUSE location

IMPORTANT!

The Model 1825 has an air intake and exhaust on the back panel of the instrument. When installing the Model 1825, 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.

SECTION III - OPERATION

INTRODUCTION

Operation of the Model 1825 consists of: (1) cabling the unit to the device for testing, (2) grounding or ungrounding the Model 1825, (3) monitoring indicators located on the front panel of the unit, (4) using a digital voltmeter (DVM) or a DVM and a reference voltage generator (RVG) to measure substituted dc bias, (5) calculating the amount of RF power, and (6) calculating the calibration factor of the SUT. Figure 3-1 shows the front panel location of the indicators, switches and connectors that are used in the operation of the Model 1825. Refer to this figure throughout the discussion in Section III.

MODEL 1825 INDICATORS, SWITCHES & CONNECTORS

The Model 1825 contains a Power Switch that controls power for the entire unit. An LED built in to the switch indicates whether the power is on or not. As shown in Figure 3-1, the Model 1825 has dual binding post connectors, two light-emitting diode (LED) indicators, an N-type connector for the SUT, and an SMA connector for the RF input.

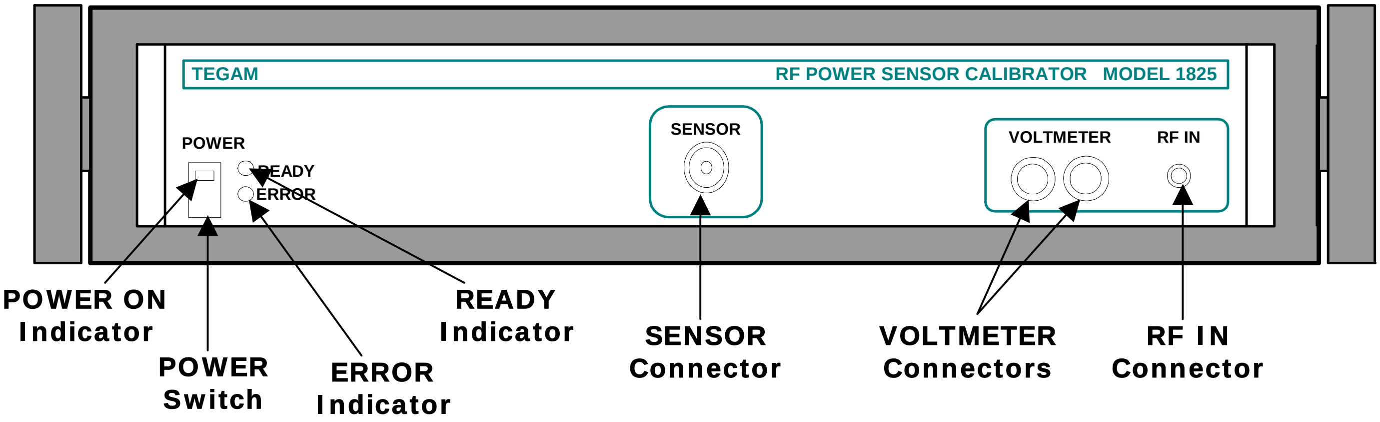

Figure 3-1 Model 1825 Front Panel Switches, Indicators, and Connectors

POWER Switch

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

Illuminates when instrument power is on. It is built into the POWER switch.

READY Indicator

This green LED illuminates when the RF power standard has reach 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

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

N-type female connector for 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 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

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

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 8.5 dB of insertion loss in the RF IN path.

Float/Ground Switch

The FLOAT/GROUND Switch is a two-position toggle switch located on the rear panel. This switch grounds or ungrounds (floats) the Model 1825 depending on whether or not the DVM is grounded. The up position grounds the Model 1825. The down position floats the Model 1825. If the DVM is grounded, place the FLOAT/GROUND Switch in the FLOAT position.

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 produced by a highly accurate source, such as with the System II Automatic Calibration System, or it can be accurately measured like with the Model 1825. 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 3-2. 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 should not affect the sensor calibration. 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 the meter and set it to read correctly when attached to the reference level within the power meter. The input of the SUT connects to the 50 Ohm N-type female SENSOR connector on the Model 1825. Any adapters, attenuators, or matching pads could affect the accuracy of the calibration and should be taken into account.

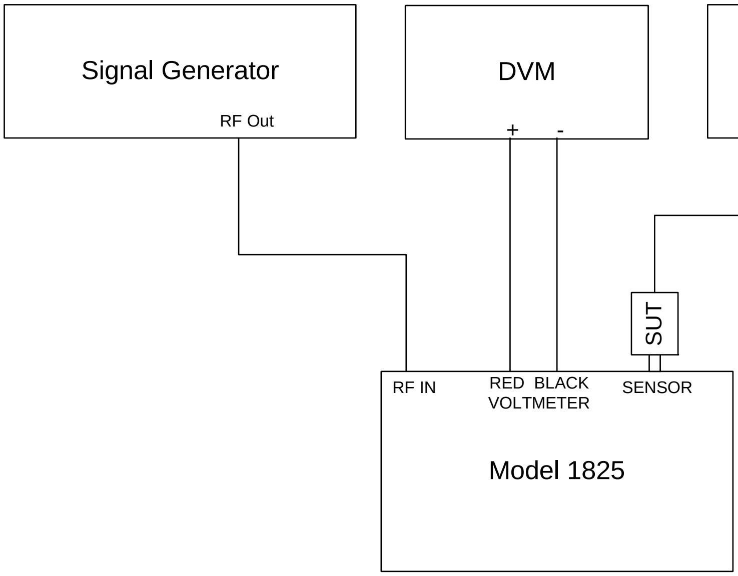

Figure 3-2 Connections for Power Sensor Calibration

RF POWER LEVEL MEASUREMENT

The Model 1825 precisely measures RF power in terms of a dc voltage change across the Model 1825 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 does 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 bridge. 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 and the DVM according to Figure 3-2 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 and the level of dc substituted power:

$$P_{RF} = \frac{P_{dc}}{K_1}$$

Where:

P_{RF} = Level of applied RF power,
P_{dc} = dc substituted power which is proportional to the applied RF power,
K_1 = calibration factor of Model 1825 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 3-3, minimizes voltmeter uncertainties by enabling use of a measurement scale that has better resolution.

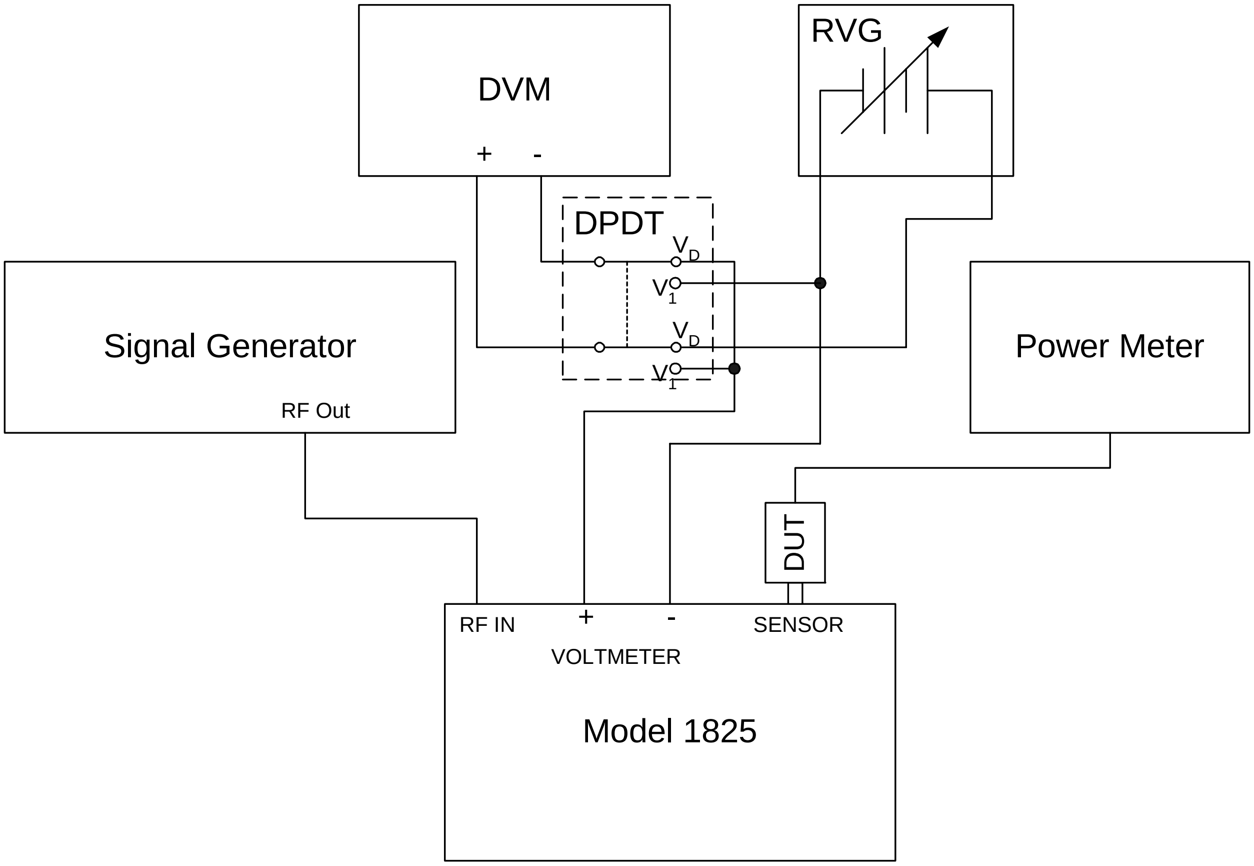

Figure 3-3 Connections for Using the Model 1825 with an RVG

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 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 bridge output and the setting of the reference voltage source (V_{D1}). 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 output and RVG output including the proportional RF power effect on the bridge circuit (V_{D2}). 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 bridge output with no RF applied and RVG output,
V_{D2} = Difference between 1825 bridge output with RF applied and RVG output,
200 = nominal resistance of the 1825 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:

$$P_{RF} = \frac{P_{dc}}{K_1}$$

Where:

P_{RF} = Level of applied RF power,
P_{dc} = dc substituted power which is proportional to the applied RF power,
K_1 = calibration factor of Model 1825 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. This ratio is the sensor 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,

This equation can also be written:

$$K_{1S} = \frac{(P_m)(K_1)}{P_{dc}}$$

Where:

K_{1S} = cal factor of the SUT,
P_m = power reading from the power meter,
K_1 = calibration factor of Model 1825 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

To calibrate a power sensor with a reference, measure the RF power level and determine the sensor's calibration factor at the reference frequency. 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

Once K_{off} is determined, the cal factors at the rest of the frequency points will be multiplied by this ratio.

Alternately, if the power being used has a manual offset adjustment, then set the signal generator to the reference frequency, calculate the RF power level as described previously, and calculate what the power meter should read to achieve the desired reference cal factor.

To determine what to adjust the power meter to:

$$P_m = P_{RF} \times K_{ref}$$

Where:

P_m = reading to adjust the power meter to,
P_{RF} = Level of applied RF power,
K_{ref} = desired reference cal factor

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.

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 has been turned on for at least two hours, it should be thermally stable and this value should not change during calibration. However, V_1 should be checked every ten to twenty frequency points to verify that it has not changed.

SECTION IV - THEORY OF OPERATION

INTRODUCTION

This section contains information that describes the basic circuitry and functions of the Model 1825 RF Power Sensor Calibrator that measures high-frequency or microwave power in the .01 to 18 GHz range for calibrating power sensors. The key concept of the Model 1825 is the principle of dc substitution. The Model 1825 contains two printed circuit (PC) boards and a temperature controlled thermistor mount. The two PC boards are a temperature control board and a bridge board. The functions of each of these boards are detailed in this section.

PRINCIPLE OF DC SUBSTITUTION

The Model 1825 uses 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:

$$P_{RF} = \frac{P_{dc}}{K_1}$$

Where:

P_{RF} = Level of applied RF power,
P_{dc} = dc substituted power which is proportional to the applied RF power,
K_1 = calibration factor of Model 1825 traceable to NIST

PRECISION POWER MEASUREMENT

The Model 1825 RF Power Sensor Calibrator and a digital voltmeter with a 6½-digit resolution combine to provide the precision power measurement system. This system features the Model 1825 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 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 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 contains a bridge circuit that performs dc substitution. Figure 4-1 shows a simplified schematic of the bridge circuit in the Model 1825.

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.

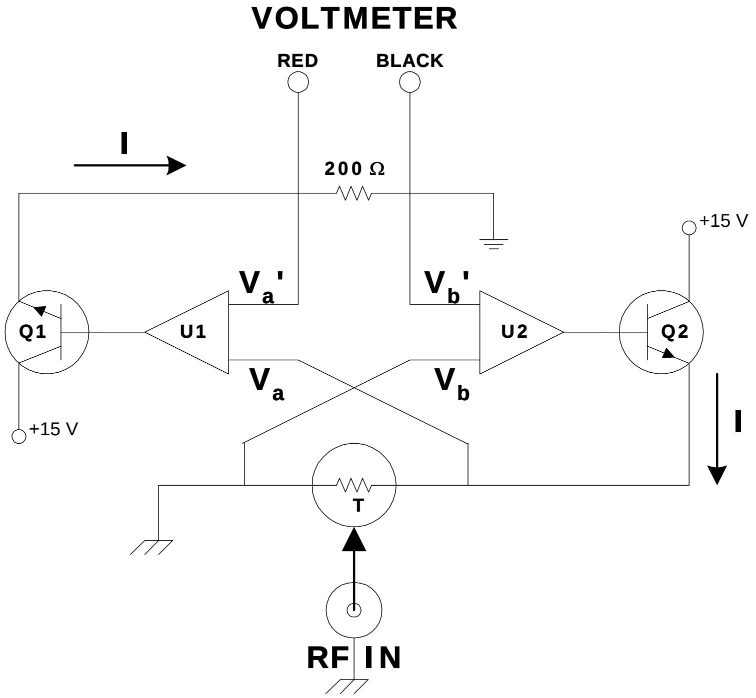

Figure 4-1 Simplified Schematic of the Model 1825 Bridge Circuit

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 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'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 are applied in the following formula to determine the actual level of RF power:

$$P_{RF} = \frac{P_{dc}}{K_1}$$

Where:

P_{RF} = Level of applied RF power,
P_{dc} = dc substituted power which is proportional to the applied RF power,
K_1 = calibration factor of Model 1825 traceable to NIST

CONTROLLING THERMISTOR TEMPERATURE

The Model 1825 contains 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 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.

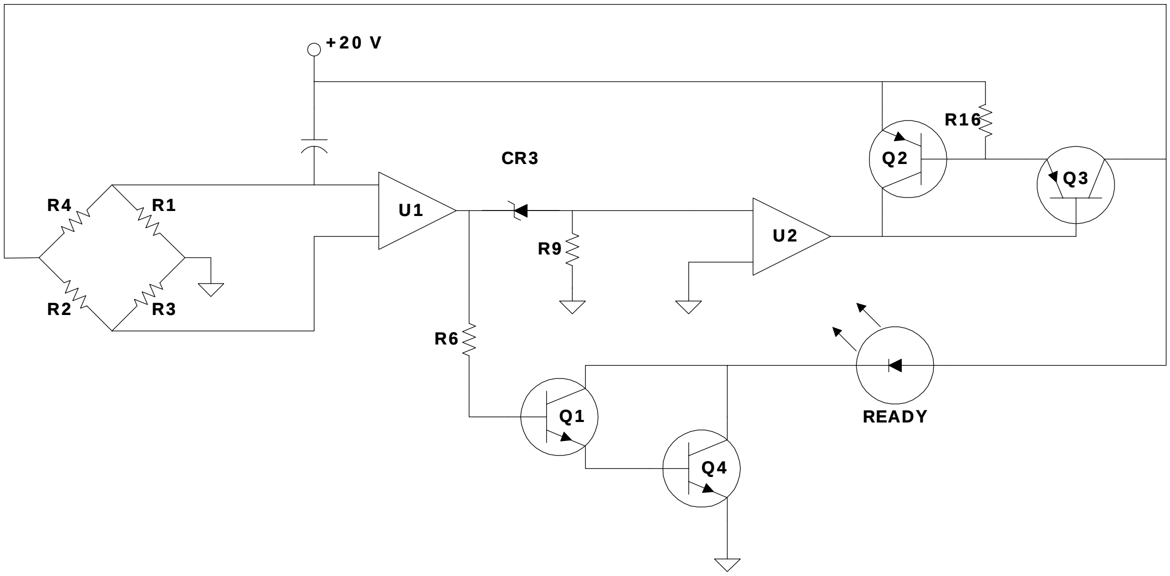

Figure 4-2 Simplified Schematic of the Model 1825 Heater Circuit

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.

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 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,
U_C = uncertainty of the cal factor for the Model 1825 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 is included as part of its calibration data. Mismatch error (M_{ER}) is determined from the reflection coefficients of both the Model 1825 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.

Sometimes the Standing Wave Ratio (SWR) of a device is given rather than the reflection coefficient (Γ). Γ relates to SWR as follows:

$$|\Gamma| = \frac{S - 1}{S + 1}$$

Where:

Γ = reflection coefficient,
S = Standing Wave Ratio (SWR).

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		
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	

It should be noted that the Model 1825 is 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.

Warranty

TEGAM, Inc. warrants this product to be free from defects in material and workmanship for a period of one year from date of shipment. During the warranty period, we will, at our option, either repair or replace any product that proves to be defective.

TEGAM, Inc. warrants the calibration of this product for a period of one year from date of shipment. During this period, we will recalibrate any product that does not conform to the published accuracy specification.

To exercise the warranty, contact TEGAM, Inc., 10 TEGAM Way, Geneva, Ohio 44041, phone 440-466-6100, fax 440-466-6110, M-F, 8 a.m.-5 p.m. ET. You will be given prompt assistance and return instructions. Send the instrument, transportation prepaid, to the indicated service facility. Repairs will be made and the instrument returned, transportation prepaid. Repaired products are warranted for the balance of the original warranty, or at least 90 days, whichever is longer.

Limitation of Warranty

TEGAM, Inc.'s warranty does not apply to defects resulting from unauthorized modification or misuse of any product or part. This warranty also does not apply to fuses, batteries, or damage from battery leakage.

This warranty is in lieu of all other warranties, expressed or implied, including any implied warranty of merchantability or fitness for a particular use. TEGAM, Inc shall not be liable for any indirect, special or consequential damages.

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 that is calibrated at planned intervals by comparison to certified standards maintained in the laboratories of TEGAM, Inc.

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