

## Measuring Temperature Compensating Thermistors with the TEGAM Model 1830A RF Power Meter (Replacing the Agilent 432A)



Figure 1 - TEGAM Model 1830A RF Power Meter

### Introduction

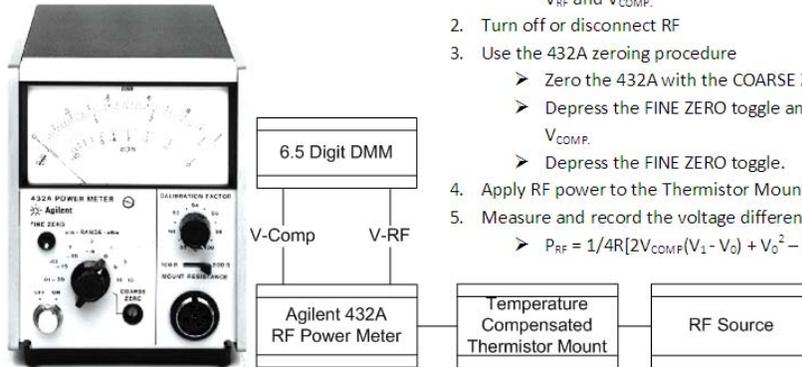
Application Note 217 explains the theory behind measuring power with a dual bridge Power Meter such as the Agilent 432A and shows the reader how to simplify the measurement with the TEGAM 1830A RF Power Meter by eliminating unnecessary test and measurement equipment and lengthy mathematical conversions.

### Background and Theory

#### Conventional RF Power Measurement

The Agilent 432A measures RF power with temperature compensated thermistor mounts such as the Agilent 478A and 8478B. Internally there are two bridges, one balances the RF thermistors and the other balances the temperature compensation thermistors. The 432A can display calibrated RF power to an accuracy of 1%. Higher accuracies (.25% @ 1mW) can be achieved by directly measuring the  $V_{COMP}$  and  $V_{RF}$  outputs on the rear of the unit and computing the RF power. This method is the only one employed in metrology applications. Figure 3 diagrams the complete process for making the lowest uncertainty RF power measurement with an Agilent 432A.

Measurement Procedure using the Agilent 432A



1. Connect  $V_{RF}$  and  $V_{COMP}$  to a 6.5 digit DMM
  - This will require 2 DMM's or a DMM with 2 isolated inputs that can be toggled between  $V_{RF}$  and  $V_{COMP}$ .
2. Turn off or disconnect RF
3. Use the 432A zeroing procedure
  - Zero the 432A with the COARSE ZERO controls.
  - Depress the FINE ZERO toggle and measure the differential voltage between  $V_{RF}$  and  $V_{COMP}$ .
  - Depress the FINE ZERO toggle.
4. Apply RF power to the Thermistor Mount
5. Measure and record the voltage differential to calculate incident RF
  - $P_{RF} = 1/4R[2V_{COMP}(V_1 - V_0) + V_0^2 - V_1^2]/\text{Effective efficiency}$

Figure 2 - Agilent 432A Method for Measuring Thermistor Mounts

This process does require the addition of at least a 6.5 digit DMM and a tool for recording and calculating the final results. The mathematics involved are fairly straightforward but can become tedious and prone to error when it is repeated for 20-30 frequency points. Often a spreadsheet is used to automate some of the process and record the final results.

**Simpler Power Measurement**

The TEGAM Model 1830A RF power meter is designed to directly read calibrated RF power with 100Ω and 200Ω thermistor sensors from manufacturers including Agilent, TEGAM, Weinschel, Hughes, General Microwave, EIP and Milltech. It includes 4 digit cal. factor resolution stored in multiple tables on a per sensor basis, 3-60 db attenuator support, LXI-C and USB communication interfaces for full remote programmability and heater control for ovenized sensors. The accuracy is ±0.05% of reading, ±0.5 μW and the thermistor balanced value may be adjusted from 50 Ω to 300 Ω resulting in a typical 50 Ω (nominal) sensor termination value being varied from 12.5 Ω to 75 Ω. This feature is useful in estimation if  $S_{22}$  parameters of calibration reference outputs.



Figure 3 - TEGAM 1830A Method for Measuring Thermistor Mounts

## How the TEGAM 1830A Makes a Calibrated RF Power Measurement

The Model 1830A RF Power Meter combines a resistance “bridge” balancer with a digital voltmeter system.

Because of the circuit construction, a “four-wire” circuit is used to sense bolometer resistance<sup>1</sup>, allowing the user to use nearly any practical cable length without recalibrating the 1830A1.

The balancer is composed of a controllable source that allows current to flow through Rref and the bolometer. Identical precision instrument amplifiers feed the bolometer voltage and the voltage across a reference resistor<sup>2</sup> to a servo-amplifier that has been adjusted for low offset. The servo amplifier controls the main supply transistor and therefore regulates power to the combined reference/bolometer circuit. The 1830A is connected to support NTC devices. When the bolometer voltage is higher than the reference resistor voltage, indicating that the bolometer’s resistance is higher than desired, power is increased to heat the bolometer and decrease resistance. When the bolometer voltage is lower than the reference resistor voltage, power is decreased. At balance, the reference resistor voltage and the bolometer voltage match closely. Since their currents are the same, the resistances also match closely<sup>3</sup>.

The 1830A computes power from changes in the voltage across the reference resistor as follows: When ZERO is pressed, the voltage across the Reference resistor is stored in a combination of DAC settings and software variables. This is done on both the “RF” channel and the “Compensating” channel. For any subsequent readings, the actual values of the voltages are used.

When an uncompensated mode is selected, change in substituted DC power is computed as

$$P = \frac{V_{Off}^2 - V_{On}^2}{R}$$

And when a compensated mode is used, change in DC substituted power is computed using the complicated methodology described in the H-P 432 Manual<sup>4</sup>.

<sup>1</sup> Limited by the resistive drop in the source leads. The small currents involved make circuits of 100 meters or more possible, although electromagnetic coupling issues could compromise measurements in some cases.

<sup>2</sup> The reference resistor is either 100 or 200 Ohms. Additionally, in some modes, the reference resistor voltage is multiplied by a variable to produce the variable resistance feature. At resistances other than 100 or 200 Ohms, the multiplication adds some uncertainty.

<sup>3</sup> Except in the case of multiplication, in which the resistances balance at a ratio selected to achieve the set resistance.

<sup>4</sup> Which gives the identical answer to the uncompensated equation in the case that the compensating thermistors do not have a change in voltage (caused by a change in environment).

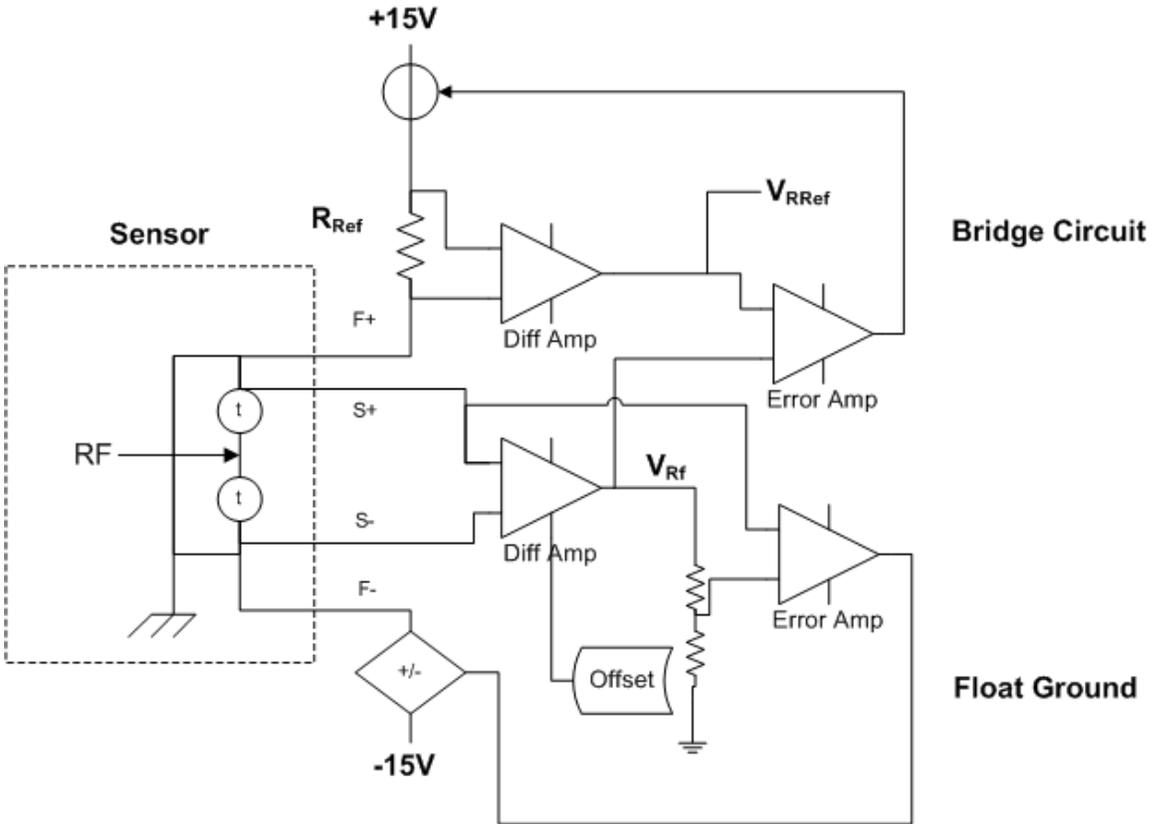


Figure 4 - Basic 1830A RF Power Measurement Diagram

## RF Power Measurement Procedure

CAUTION: UNDER NO CIRCUMSTANCES APPLY MORE THEN 30 mW TO THE MOUNT<sup>5</sup>.

### **Equipment:**

- TEGAM Model 1830A RF Power Meter
- Agilent 478A or 8478B Power Sensor
- Suitable RF Signal Generator (Frequency Range dependant on sensor)
- TEGAM 1830A to Sensor Connector Cable

### **Connections: (Refer to Figure 4 for connections)**

1. Plug in all Test and Measurement Equipment
2. Connect specialized TEGAM cable (P/N CA-6-48) to the Model 1830A and Power Sensor<sup>6</sup>
3. Allow necessary warm up time for each piece of equipment<sup>7</sup>
4. Connect RF Source to input of sensor (DO NOT TURN RF ON)

### **Procedure:**

1. Turn RF OUTPUT “OFF” on the RF Signal Generator
2. Using the CF (Calibration Factor) soft-key enter the calibration factor for the desired frequency. (Typically this can be found on the sensor)
3. Using the ZERO soft-key, ZERO the 1830A. (This may take a few seconds)
4. Turn RF OUTPUT “ON” on the RF Signal Generator
5. Read calibrated power from the front panel of the Model 1830A<sup>8</sup>

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<sup>5</sup> This caution pertains to Weinschel type coaxial thermistor bolometers designed to balance at RF off with approximately 30mW. DC Substitution bolometry requires removal of DC to indicate applied power, so application of more RF than there is DC applied originally will inevitably result in an incorrect reading or even overheated thermistor. Refer to the manual of whichever sensor is being used for specific power limits.

<sup>6</sup> This is the point at which the sensor begins to warm up.

<sup>7</sup> The 1830A itself will warm up in approximately one hour, depending on airflow conditions. A well-insulated thermistor bolometer can require two to four hours to stabilize.

<sup>8</sup> Allow the reading from the 1830A to settle before recording a reading. In most conditions, a few seconds after applying RF is adequate.