APPLICATION NOTE 215

TEGAM

YOUR GLOBAL SOURCE FOR TEST AND MEASUREMENT SOLUTIONS

USING AGILENT TEMPERATURE COMPENSATED THERMISTOR MOUNTS WITH TEGAM TYPE IV POWER METERS

Thermistor-based RF power sensors are known by many names including thermistor mounts, thermistor sensors and bolometers. Thermistor sensors such as the Agilent (HP) 478A and TEGAM F1109 are dual thermistor based. In dual thermistor sensors, a pair of thermistor beads is used to detect RF power. When RF power is applied to the thermistor pair, their resistance decreases. This decrease can be measured and the amount of RF power applied can be determined.

There are differences, however, between the Agilent and TEGAM sensors. TEGAM Thermistor Sensors are ovenized; a heater element is used to raise the internal temperature of the mount and maintain it at a constant temperature. This thermally isolates the thermistor beads so they are not affected by ambient temperature changes within the operating specification, and results in accurate measurements and lower uncertainties.

Agilent sensors have two sets of thermistor beads. RF power is applied to the first set only; the second set is not affected by the incident RF power, but is in close thermal contact with the RF power sensing beads. The job of the second set of thermistor beads is to sense ambient temperature changes and allow corrections to be applied, and also to provide an offset or "bucking" voltage. This allows the DMM to be switched to a more sensitive scale, giving greater resolution and ultimately higher accuracy.

When used with the Agilent 432A power meter, the voltage across the second set of thermistor beads (V_{COMP}) allows the user to set up an RF power-off reference (V_O), which is used with the RF power-on voltage (V_{RF}) to calculate the applied RF power and is equivalent to the zero in a thermocouple-based power meter. The user can then make measurements and basically ignore any changes in ambient temperature that would affect the power-off reference of the RF beads.

The Agilent 432A manual has the following quote: "Normally, in a stable environment, the V_{COMP} output voltage remains constant, not being affected by external RF power; only the V_{RF} output varies during power measurement." What this signifies is that if the ambient environment is closely controlled, measurements and calibrations can be made without use of the second set of beads. With a suitable adapter cable (like TEGAM P/N 138-652), the Agilent thermistor mount can be hooked up to one bridge of the TEGAM Model 1806 Dual Type IV Power Meter or the TEGAM Model 1804 Single Type IV

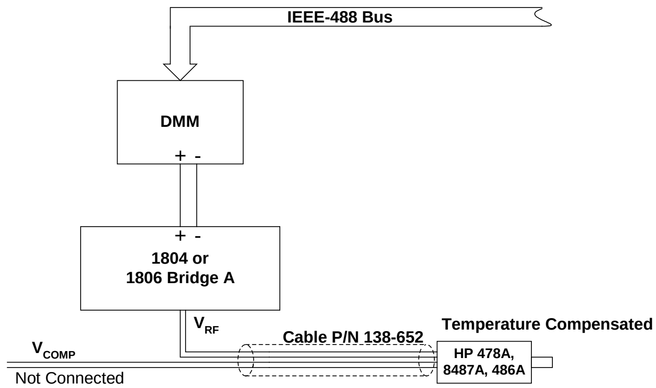

Figure 1

Power Meter and can be measured just as if it were a TEGAM M1110 Terminating Thermistor Mount. If V_{COMP} is not used, connect the mount to the TEGAM Type IV Power Meter as shown in Figure 1. Use the following procedure to make a power measurement:

a. With the RF power off, take a reference reading from the DMM. This is V_O.

b. Turn the RF power on and record the DMM reading V_{RF}.

c. The RF power (P_{RF}) measured by the thermistor mount is given by:

$$P_{RF} = \frac{(V_O^2 - V_{RF}^2)/R}{K_{1S}}$$

where K_{1S} is the calibration factor of the thermistor mount and R is the nominal value in of the thermistor beads which can be 100 or 200 Ohms. All TEGAM sensors and the Agilent 478A, 8478A and 486A are 200 Ohms. Since

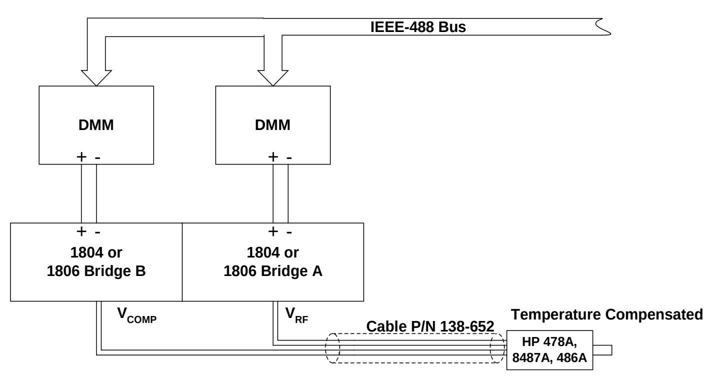

Figure 2

these are the most common thermistor mounts, 200 will be used for R.

If there is concern over the ambient temperature changing, then the mount can be connected, as in Figure 2, with spade lugs marked V_{COMP} on the 138-652 cable connected to the other channel of the TEGAM Model 1806 or a second TEGAM 1804. The voltage (V_{COMP}) can then be monitored. Since RF power is not applied to the second set of thermistor beads, V_{COMP} can be used in place of Vo:

$$P_{RF} = \frac{(V_{COMP}^2 - V_{RF}^2)/200}{K_{1S}}$$

To get more precise power measurements, V_{COMP} can be used to set up an offset voltage so one of the voltmeters used can be set to a smaller scale for greater resolution. For this setup, connect Agilent thermistor mount to a TEGAM 1806 (or two 1804s) as in the previous setup. One of DMMs should be connected across the bridge that

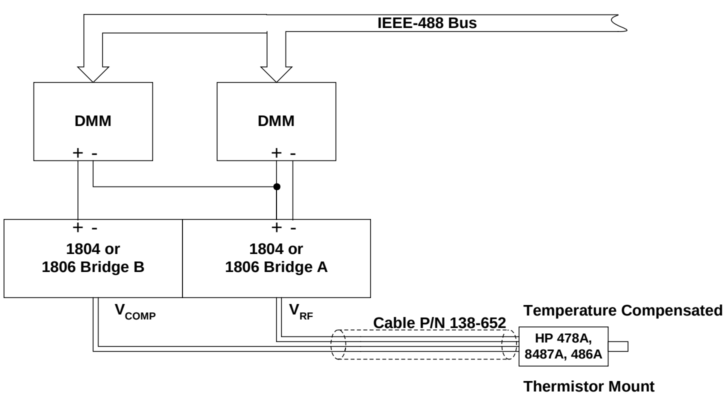

Figure 3

is connected to V_{RF} as normal. The other DMM should be connected as follows: the positive terminal to the V_{COMP} bridge red binding post and the DMM negative terminal to the V_{COMP} red binding post as shown in Figure 3. Using this setup, the voltage *difference* between V_{COMP} and V_{RF} is measured instead of V_{COMP}. This voltage difference (V_{DIFF}) is a much smaller value (less than 100 mV at 0 dBm), thus the DMM can be used at a lower scale, which means greater resolution. This would allow a DMM with lower resolution to measure V_{DIFF} than with V_{RF} and still maintain the same precision in the calculated power measurements. To calculate RF power using this setup, V_{DIFF} is the measured voltage difference between V_{RF} and V_{COMP}:

$$V_{DIFF} = V_{COMP} - V_{RF}$$

Solving for V_{COMP}:

$$V_{COMP} = V_{DIFF} + V_{RF}$$

From the previous equation for calculating power:

$$P_{RF} = \frac{((V_{COMP} - V_{RF})(V_{COMP} + V_{RF}))/200}{K_{1S}}$$

Substitute for V_{COMP}:

$$P_{RF} = \frac{((V_{DIFF} + V_{RF} - V_{RF})(V_{DIFF} + V_{RF} + V_{RF}))/200}{K_{1S}}$$

Simplify:

$$P_{RF} = \frac{(V_{DIFF}(V_{DIFF} + 2V_{RF}))/200}{K_{1S}}$$

The TEGAM Type IV Power Meter costs less than the Agilent 432A Power Meter and is just as accurate. The published accuracy of the Agilent 432A Power Meter is ±(0.2% ± 0.5 µW), while the TEGAM 1804 or 1806 Power Meter with an Agilent 3458 (or equivalent) DMM is ±(0.03% ± 2 µW). At 1 mW (0 dBm), the measurement accuracy of the Agilent 432A Power Meter is ±2.5 µW. The measurement accuracy of the TEGAM Type IV Power Meter with a 3458 DMM at 1 mW (0 dBm) is ±2.3 µW.

TEGAM System IIA owners can eliminate the need for an Agilent 432 power meter when using an Agilent temperature-compensated thermistor mount. The Agilent thermistor can be calibrated using the TEGAM System II by connecting it to the TEGAM Model 1806 Type IV Power Meter and using the 1806 to monitor the sensor. With this setup, an Agilent power meter is not required. Likewise, the Agilent thermistor mount can be used as a traceable power standard for calibrating other power sensors, such as the TEGAM F1109, using the TEGAM 1804 or 1806 Type IV Power Meter to provide power for the standard.

This method of measuring RF power can also be used for applications outside the calibration of power sensors. For example, the Agilent 478A with option H76 has very low VSWR (≤1.03) at 50 MHz which makes it a good power sensor to test a power meter's 50 MHz reference output. This sensor can be used with either the Agilent 432A Power Meter or with the TEGAM 1804 or 1806, using the procedures outlined previously, to accurately make that measurement.

TEGAM is the industry leader in RF Power Sensor Calibration products with a complete line of RF Sensor calibration solutions.

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