Thermocouple Power Sensing Solutions from LadyBug Technologies

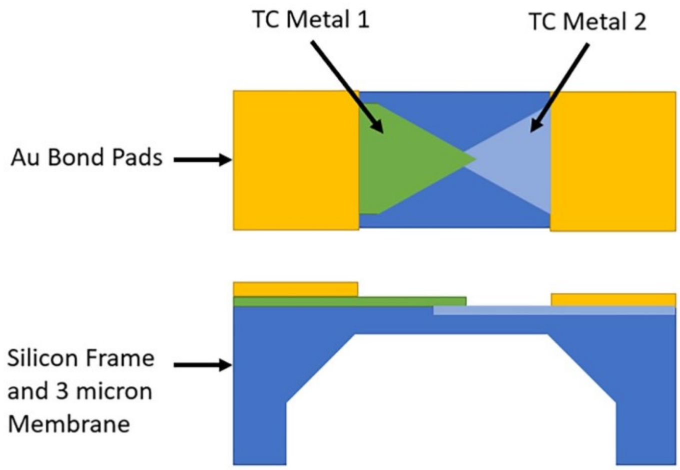
Introduction:

An RF power sensor is a device used to measure the power of RF signals. Applications range from avionics test systems, semiconductor test systems, telecom infrastructure, and medical systems to satellite communication systems, radar, and 5G. Systems typically measure power from various complex waveform adaptive modulation techniques, such as OFDM, CDMA, and QAM. Often, systems incorporate an internal reference sensor to establish an absolute power level for verifying proper operation. Understanding RF power levels at various points within a system ensures safe and proper functionality of test systems. To meet lightweight system requirements, LadyBug Technologies manufactures custom thermocouple-based RF sensors with better than 1% linearity and less than 0.2% readout movement per degree Celsius.

Technology Overview:

Modern RF sensor transducers are typically either diode-based or thermally-based. Diode based sensors rectify an RF signal to produce a DC voltage, while thermally based sensors convert RF energy to thermal energy for measurement by a secondary transducer. Thermal sensors are desirable due to their true RMS nature, allowing for high-accuracy power measurements independent of waveform characteristics. LadyBug has developed a process for producing semi-low volume custom thermal power sensors based on thermocouples to meet industry needs.

Thermocouple-based sensors leverage the Seebeck effect, a well-characterized phenomenon where a voltage is generated at the junction of two different metals when there is a temperature difference between the junction and the ends of the metals. This effect occurs because the electrons in the metals diffuse from the hotter to the colder metal, creating a potential difference. In LadyBug sensors, the RF load has an integrated thermocouple that generates a voltage proportional to the RF power input.



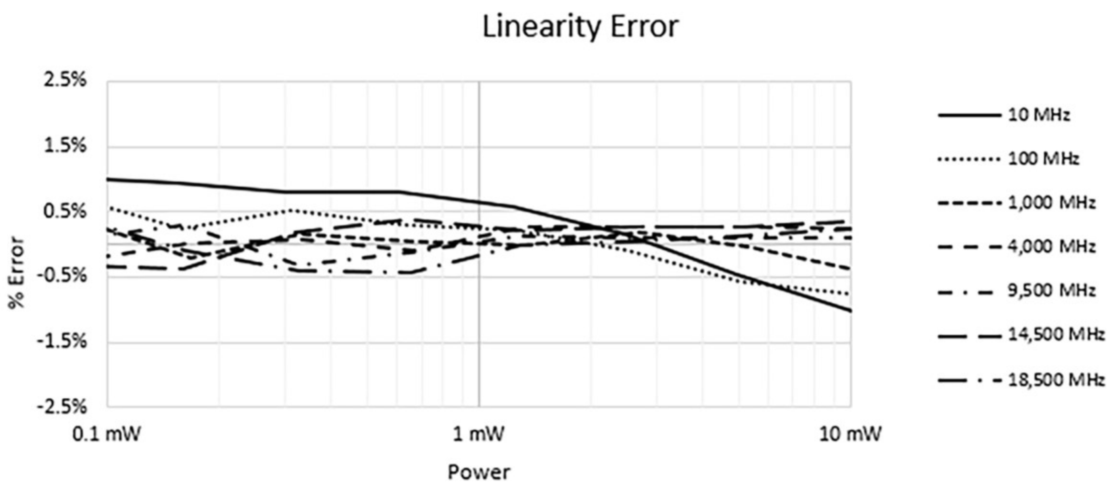
Due to the inherently small signals being measured, the thermal mass being heated must be minimal. A 3-micron silicon membrane device serves as the transducer substrate to minimize the thermal mass the RF energy must heat. A 50-ohm termination resistor is built on top of this substrate, serving two purposes: (1) RF termination with match characteristics meeting intended system requirements, and (2) functioning as a thermocouple built from metals selected to meet voltage output requirements for the targeted system.

The thermocouple device is manufactured using standard MEMS processes followed by flip-chip bonding to a low-loss substrate.

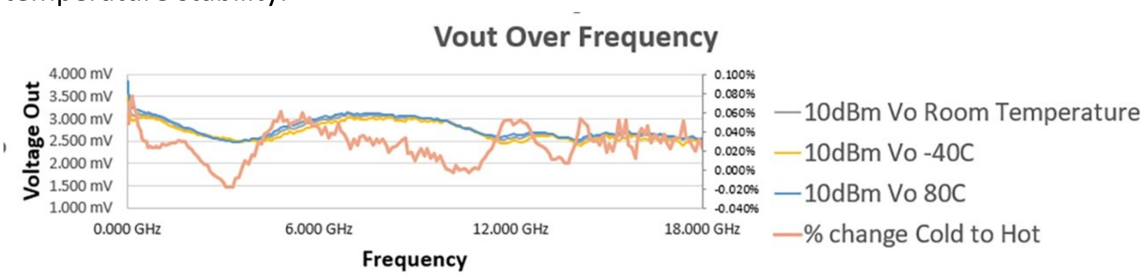
Design Considerations:

Key requirements for custom thermocouple-based RF power sensors include:

1. Sensitivity: The sensor must produce an output voltage that provides resolution for the desired RF signal—typical sensitivity is around 0.1 millivolts per milliwatt.
2. Linearity: The sensor output should be proportional to the power input over a wide range. LadyBug sensors achieve exceptional 1% linearity due to their thermocouple-based technology.



3. Temperature Stability: The sensor should maintain accuracy over a wide temperature range. Thermocouple sensors are inherently immune to ambient temperature changes as thermal gradients within the sensor remain intact, resulting in exceptional temperature stability.



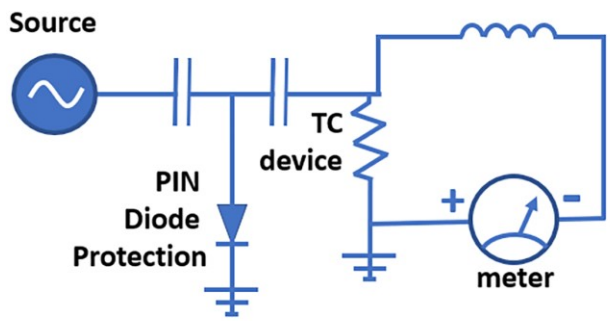
4. Maximum Power Rating: Thermocouple-based power sensors generate voltage proportional to RF power through thermal transduction. For every 3dB power increase,

the thermal gradient across the detector doubles in temperature. Consequently, the thermal gradient within the sensor can exceed hundreds of degrees Celsius. Careful balancing of dynamic range and sensitivity is crucial.

LadyBug thermocouple power sensors meet these requirements and provide optimal performance when integrated into embedded systems.

Implementation:

The custom thermocouple-based RF power sensor uses a thermocouple to detect temperature changes, which are then converted into voltage changes. To prevent device temperatures from exceeding safe levels (around 20dBm), a protection diode is added to mitigate risk and enable full dynamic range use by shunting away high-power RF signals, thus maintaining device temperature and protecting silicon and metal films.



When bonding the device to the carrier PCB, a highly thermally conductive silver solder compound is used. Thermal energy dissipated within the thermocouple device is efficiently transferred.

Devices are encased in a waterproof package after mounting to the RF circuit, maximizing durability.

Following final assembly, each unit undergoes testing to ensure proper functionality and is accompanied by a full traceability report.

Conclusion:

LadyBug Technologies designs and implements custom thermocouple-based RF power sensors within customer specifications using a unique development and assembly process. By utilizing cutting-edge industry standards for calibration, design, and implementation, LadyBug provides customized solutions to address unique customer requirements in RF power sensing.