Whitepaper

The Pros and Cons of Integrating Thin-Film Sensors into Polyimide Heaters

Many engineers add temperature sensors to a project later in development. Frequently this involves bolting a sensor to a neighboring piece of hardware like the chassis and routing the wires along the nearest wiring bundle.

This technique offers distinct disadvantages:

- **Challenging placement of sensor.** In ideal applications, sensors should measure the temperature of the heat sink. When a heater covers the heat sink, it may be hard to place a discrete sensor in such a way to gain an ideal reading. Placing the sensor on top of the heater returns the temperature of the heater, not the temperature of the heat sink, and can also expose wiring to the heater’s repeated cycles.

- **Exposure to hazardous conditions that would affect its performance.** Depending on sensor packaging and environmental conditions, exposed sensors can fail or deliver inaccurate results. In addition, extreme environments like high G forces, vibration, and vacuum can damage components and wiring.
- **Complicates installation and wiring.** Each set of wires routed through the project enclosure adds weight, increases the complexity of the manufacturing process, and creates a new a potential point-of-failure.

The ability to embed a sensor in a flexible polyimide heater, to create an integrated component, offers distinct advantages for many applications.

Advantages

Protected by the heater's polyimide cover and incorporated into the same package, the heater-sensor combo offers the following advantages as compared to employing discrete components:

- **Places the Sensor Perfectly:** With the heater covering the heat sink, embedding the sensor in the heater gives the opportunity to press the sensor directly against the heat sink while also maximizing the heating area. The sensor is placed in an area of the heater that does not have active heating – often the heater is designed with a small non-heated zone to accommodate the sensor. Not only does this technique allow engineers to choose the most ideal placement of the sensor, it improves time response and accuracy. A temperature sensor connected to another part of the enclosure – especially not even on the same thermal plane as the heat sink -- offers distinctly less reliable readings.
- **Simplifies Wiring and Installation:** Rather than relying on a separate set of wires for each component, the heater/sensor combo has one set of leads that can be connected to the rest of the assembly in the most efficient way possible. In addition, the components are welded together, rather than employing solder. This allows the assembly to be flexed during installation – or formed against a curved surface -- with less chance of component damage as compared to a PCB with surface mount components soldered to it. Finally, it prevents wires from being routed directly over a heater, which could affect their connectivity.
- **Vibration Tolerant:** Some applications expose a component to very high G-forces and vibration. Aerospace applications like commercial aircraft and communications satellites typically cannot accommodate any component that will be damaged by excessive vibrations or high G forces. The

combined heater-RTD, with a lower mass and laminated into a single unit, doesn't share the same vulnerability as discrete components.

- **Cover Protects Against Environmental Exposure:** The polyimide cover protects the sensor from acids and bases, oil, salt water, dirt, and airborne debris. Anything that can damage the sensor is likely to damage the entire component. Not only does this reduce ongoing maintenance expenses, it also prevents damage to or obstruction of sensors that affect measurements. Surface mounted sensors are less suitable for vibration and can be influenced by ambient air temperature if not encapsulated.
- **Useful for Many Applications:** This technique can be used for a wide range of applications including transparent heaters and large format flex circuits, and can be epoxied onto heat sinks and other surfaces with great results. While some specialized applications don't fit, such as medical analyzers that require high-temperature cycles, it's a great technique for a surprising number of applications.
- **Lower Cost of Ownership:** The bottom line is that a combined RTD/heater provides better readings with reduced assembly costs, simplification of wiring, and package flexibility. All of this lowers the total cost of ownership while delivering ideal results.

Disadvantages

While integrating heater with sensor makes a lot of sense in many applications, that doesn't mean there are scenarios where it doesn't fit. The following conditions may give engineers a second thought:

- **Some Sensors Won't Work:** Not all sensors can be laminated into the heater package without being damaged by the process and still working as expected. Thin, flexible, wire-wound sensors are ideal, thin-film RTDs are another obvious choice, but thermocouples will also work if the heater can be laminated in such a way that it is able to lay flat against the heat sink. Thermistors may not be a good fit due to those sensors' vulnerability to the extremes of temperature, though rugged glass-encapsulated thermistors will work. Collaborating with an engineering firm specializing in sensors will help engineers figure out the best option.
- **Maintenance Challenges:** The obvious challenge of combining the heater and sensor is that if maintenance personnel must replace one, they must replace both of them – you can't simply swap in another sensor. The good news is that the overall product is more robust, requiring little to no maintenance, and in the rare event that a re-install is necessary, it would be as simple as the original assembly.

- **Not Conducive to High Temperature Applications:** This technique is typically not used in applications where the heat sink is expected to rise to 500 degrees F (260°C) or more. Polyimide-based etched foil heaters typically max out at 392° to 500° F (200° to 260°C). Higher temperature applications require special manufacturing techniques that are not compatible with embedding sensors, although externally mounted ceramic thin-film RTDs and thermocouples are a viable option

Next Steps

The first step for creating one of these assemblies is to prototype during the design phase with discrete components, not only laying the groundwork for installation and wire routing but also testing that the right thermal characteristics have been achieved.

When it is time to manufacture, choose an engineering firm that is accustomed to designing and manufacturing both thin-film RTDs and polyimide heaters and combining them into integrated components.

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