Design Challenges of Wireless Patient Temperature Monitors

Introduction

Monitoring patient vitals in a clinical environment has traditionally been a job for expensive and heavily calibrated systems requiring patients to be tethered to bedside monitors. Wireless patient monitoring systems provide for both patient comfort and clinical convenience, provided they can still be made to operate within strict medical standards.

In the case of wearable temperature monitors, there are many design tradeoffs that must be considered for power consumption, size, system performance (in terms of both RF and accuracy), and patient comfort. Thinner flexible batteries provide greater comfort but may require more careful power management. Smaller, lower cost, designs suffer in terms of thermal isolation and RF performance. Optimal solutions for long term monitoring must make good use of board area to improve accuracy and signal integrity, while trying to keep current consumption as low as possible. System designers will have to balance these requirements alongside the comfort and experience of the patient.

Standard Compliance for Thermometers

The governing standards for intermittent electrical patient thermometers are given in ASTM E1112 and ISO-80601-2-56. For standard compliant clinical temperature measurement applications under ASTM E1112, human body temperature monitors must produce readings within ± 0.1 °C accuracy, and must read and display temperature from a minimum of 35.8°C to 41.0°C. At a bare minimum, any temperature monitoring design should include a sensing element able to meet these requirements after calibration.

TI recommends using the TMP117 ultra-high-accuracy digital temperature sensor for this purpose. The device itself has better than 0.1°C accuracy from 25 to 50 °C and requires no calibration to exceed the requirements of both ASTM E1112, and ISO-80601. Additionally, the TMP117's low overall current draw and one-shot mode are ideal for battery operated applications. The digital I2C output of this device also greatly simplifies system design when compared with RTD or thermistor based solutions.

Layout Considerations

Even with an appropriate sensing element, ensuring total system accuracy will still require care in terms of layout. For monitoring skin temperature an ideal layout will do all of the following:

1. Maximize thermal isolation between the sensing element and the other devices.
2. Minimize thermal mass surrounding the temperature sensing element for faster response.
3. Provide good thermal contact between the patient and the sensing element to minimize the temperature gradient between the sensor and the target.

Optimizing Thermal Isolation & Mass

For optimal thermal mass and isolation, the recommendations in Layout Considerations for Wearable Temperature Sensing should be followed. Figure 1 shows an example of this for a skin temperature monitoring system. The TMP117 measuring temperature is extended from the rest of the PCB using a narrow arm to minimize thermal conductance from the rest of the board. Figure 2 shows the stack up for the same 2-layer flex PCB. Using a flex-board also helps to reduce total thermal mass, which improves thermal response time of the patient monitor. Copper fills between the top and bottom side of the board should be ommitted to avoid drawing heat away from the TMP117, and increasing the thermal mass.

Figure 1. TMP117 (U1) on Flex PCB, using an extended arm isolates the IC from being influenced by heat from other devices.

Thermal Contact

Reliable measurement of the patient's skin temperature requires good thermal contact between the patient to be monitored and the sensing device. This works in conjunction with the thermal isolation from the rest of the board to ensure that the temperature being reported is as close as possible to the actual skin temperature of the patient. With the TMP117, a solid copper pour and contact vias can be used to provide a thermal path from the underside of the board as shown in Figure 3. The pad contacts the wearer's skin directly, and ensures the primary heat source for the device is from the person to be monitored.

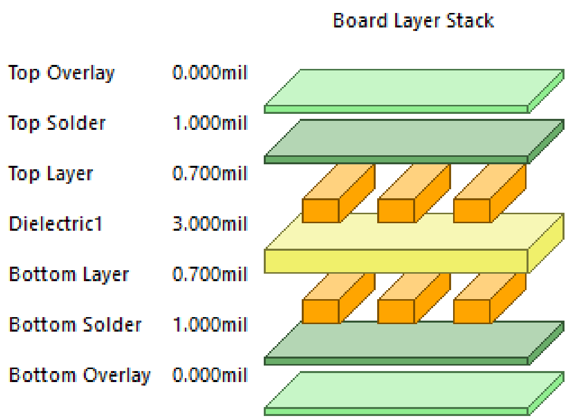

Figure 2. Example flex layer Stack, thickness should be minimized to reduce thermal mass.

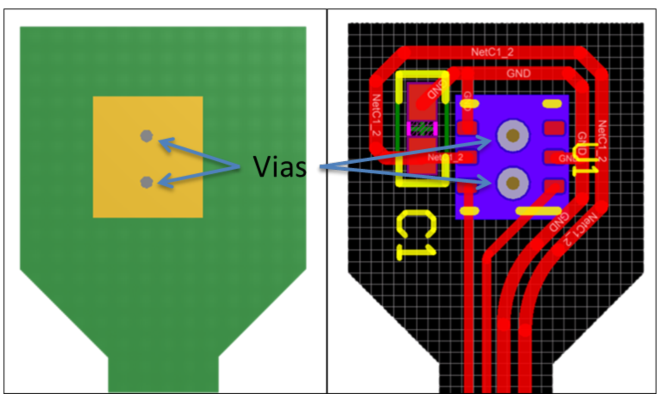

Figure 3. Copper pour underneath TMP117 (Left), topside layout for TMP117 (U1, Right). The vias underneath the TMP117 and the copper pour provide a thermal path between the patient's skin and the device.

Self-Heating

Regardless of the choice of sensing element and proper layout, the stringent accuracy requirements for medical thermometers will require that device self-heating be taken into consideration. Some self-heating will always be present from the resistive losses of the chosen sensing element. The TMP117, may be configured for one-shot mode conversion and be kept in shutdown mode between successive reads, to minimize self-heating. Individual temperature readings (using a configurable number of averaged readings) can be triggered using the one-shot feature of the device. Human body temperature will not conventionally exhibit change on the order of seconds, so taking these readings at 10 to 60 second intervals is sufficient to monitor patient temperature over long periods. This method has the added benefit of extending the active-battery life of the system.

System Power

Power requirements will vary based on overall system design, but most wireless patient monitors will need to have enough energy storage for several years of shelf life, and at least 48-72 hours of active life. Coin-cell batteries can easily exceed these requirements for energy capacity, but they are entirely rigid and may be uncomfortable to device wearers. In the case of patches which are not intended to be reused, a coin-cell based solution can also be extremely wasteful.

An alternative option for energy storage is to use thin-film, flexible batteries. Due to small storage capacities, using these batteries will require that total system power consumption be minimal. For only intermittent temperature monitoring, systems powered with flexible batteries can exceed the requirements for multiple years of shelf-life and 48-72 hours active time. The design trade off between current consumption and additional features must be made by the system designer.

Making System Tradeoffs

If the system is required to meet the requirements of ASTM E1112 and ISO ISO-80601-2-56 following the recommendations on layout is essential, but there are other system design considerations to be made. For patient comfort, non-temperature-sensing devices and the RF region should be kept in as small an area as possible. Keeping the populated region of the board compact will reduce the portion of the monitor which feels rigid to the wearer.

For RF communication, any wireless protocol that can be made to work on a flex PCB is acceptable. Since most wearable patient monitors will want to keep power consumption low, a BLE wireless communication link is recommended. If the information being transmitted from the monitor is only temperature, the monitor can be configured to broadcast the temperature reading alongside it's pairing ID. Sending the information in this manner removes the requirement for an actual connection to be made and maintained, and will reduce system power consumption even further.

To get more information on these topics, or for general tips when measuring temperature, please see the additional resources linked to in Table 1.

Table 1. Related Materials

Document Type	Description
Application Report	Wearable Temp-Sensing Layout Consideration Optimized for Thermal Response
Tech Note	Layout Considerations for Wearable Temperature Sensing
Tech Note	Precise Temperature Measurements with TMP116

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