Application Brief
Improving the Response Time of the TMP118

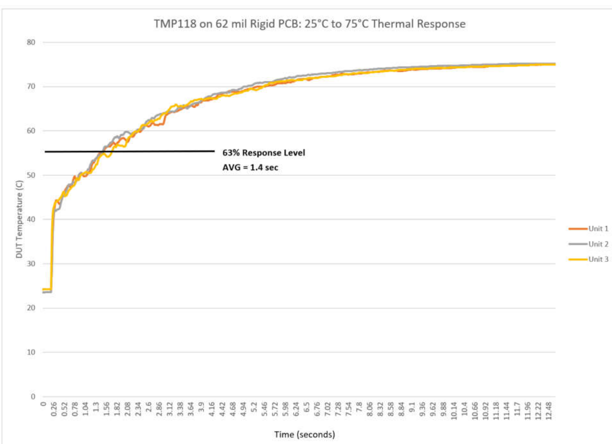
TEXAS INSTRUMENTS

Introduction

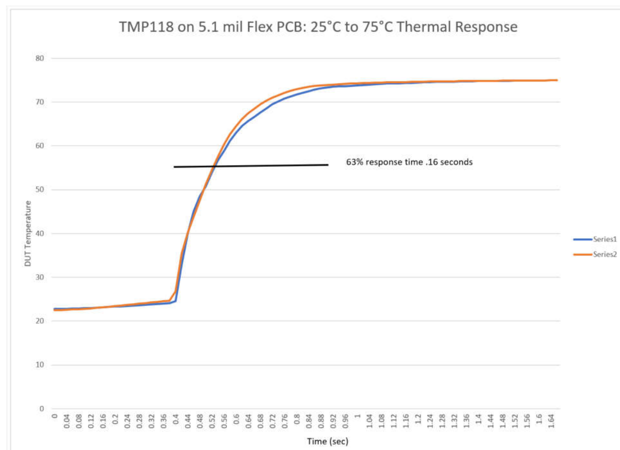
The response time of a temperature sensor can be a critical feature needed for applications such as smart watches, medical equipment, or gas meters. The benefits from a faster response time can range from allowing a system to make quicker adjustments to cooling, providing a more detailed range of data for a user's sleep pattern in a smart watch, or alerting medical staff to sudden changes in a patient's condition. The TMP118 comes in an ultra-small, ultra-thin PicoStar™ package, and the low thermal mass allows for competitive response times. This response time can be further improved through the implementation of a Flexible Printed Circuit (FPC) board.

Data

Figure 1 shows rigid and flex PCB response time data.



Unit 1	Unit 2	Unit 3	
0.2	0.2	0.2	Starting time for 25C
24.2891	23.6328	24.25	25C Values before 75C exposure
75.000	75.000	75.000	Value at 75C
56.237	55.994	56.223	63% of 25C resistance increase
1.55	1.51	1.73	Time at 63% increase
1.35	**1.31**	**1.53**	Time (Sec) to reach 63% above starting value
Average	**1.40**		**Seconds**
The average thermal response time is 1.4 seconds.			



Unit 1	Unit 2	
0.38	0.38	Starting time for 25C
24.055	24.672	25C Values before 75C exposure
75.000	75.000	Value at 75C
56.150	56.379	63% of 25C resistance increase
0.54	0.53	Time at 63% increase
0.16	**0.15**	Time (Sec) to reach 63% above starting value
Average	**0.16**	**Seconds**
The average thermal response time is .16 seconds.		

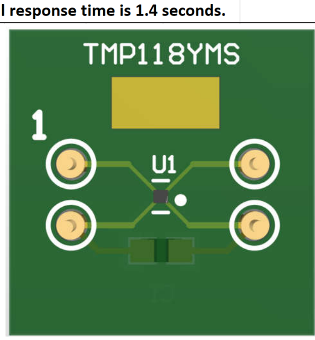


Figure 1. Rigid (Left) and Flex (Right) PCB Response Time Data

Thermal mass is a significant factor to consider when designing a system for speed and responsiveness. Not only does the IC need to have a small footprint, but for even greater response improvement, the circuit board needs to contain minimal thermal mass. Some possible ways to go about this are designing the sensor on a thinner FR4-based board with minimal layers; however, to maximize the capability of the TMP118, it is strongly recommended to consider an FPC board.

To better explain this, testing was conducted using a 62mil FR4-based prototype board and the TMP118EVM FPC sensor board (5.1mil) was conducted to collect data comparing the response time of each board when submerged into an oil bath running at 75°C. The TMP118 sensors on each board read an ambient temperature of nearly 25°C prior to submersion. In the testing for the Rigid (FR4-based) PCB, an average rise time of 1.4 seconds was observed. Meanwhile, the flex PCB was observed with an average rise time of 0.16 seconds, a nearly 87% improvement over the FR4-based board.

The significant improvement in the response time with the FPC Board is attributed to the low thermal mass, allowing the TMP118 sensor to quickly absorb the temperature of the environment (or surface) compared to a rigid board which takes longer due to the FR4 material absorbing some of the ambient heat in the environment, slowing the response time. The calculated thermal mass of the FPC board is approximately 0.769J/°C compared to 1.76J/°C for the Rigid board, over two times the mass of the FPC board. Both calculations included the thermal mass of the TMP118 device (0.14mJ/°C). The mass of these boards was found using the constants and equations in Table 1 and Equation 1.

Table 1. Board Dimensions and Constants

Board Dimensions (mm)		
Rigid PCB Board	12.7 (l) × 12.7 (w) × 0.76 (h/thickness)	
FPC Board	177.32 (l) × 2.5 (w) × 0.3 (h) at connector; 0.13 (h)	
Board Constants		
	Rigid PCB Board	FPC Board
Density	Copper: 8.96g/cm^3	
	FR4: 1.85g/cm^3 Solder Resist: 1.4g/cm^3	Polyimide: 1.43g/cm^3
Heat Capacity	Copper: 0.385J/g°C	
	FR4: 0.85J/g°C Solder Resist: 0.9J/g°C	Polyimide: 1.1J/g°C

Thermal Mass Formula for Rigid (FR4-Based) Board and FPC Board

$$\text{Mass}_{\text{Total}} = \text{Mass}_{\text{Copper}} + \text{Mass}_{\text{Substrate}}$$

$$\text{Mass}_{\text{Copper}} = \text{Length of Trace} \times \text{Width of Trace} \times \text{Thickness of Copper} \times \text{Density}$$

$$\text{Mass}_{\text{Substrate}} = \text{Area} \times \text{Thickness} \times \text{Density}$$

$$\text{Thermal Mass} = \left(\text{Mass}_{\text{Substrate}} \times \text{C}_{\text{Substrate}} + \text{Mass}_{\text{Copper}} \times \text{C}_{\text{Copper}}\right) + \text{Mass}_{\text{IC}}$$

$$\text{Mass}_{\text{IC}} \cong 0.14\text{mJ}/^{\circ}\text{C} \qquad (1)$$

Note

Substrate = Board material such as Polyimide, FR4 (and so forth) and
$C_{Substrate}$ = Heat Capacity of Material

The combination of a circuit board with low thermal mass and the TMP118 sensor can provide a meaningful and easy-to-implement answer to systems which require ultra-fast response times while maintaining accuracy.

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