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APPLICATION NOTE 3930

Package Thermal Resistance Values (Theta JA, Theta JC) for Temperature Sensors and 1-Wire Devices

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Abstract: Two common thermal-resistance values measured for IC packages are junction to ambient (Theta JA) and junction to case (Theta JC). These parameters are useful for calculating maximum power dissipation and self-heating, and for comparing package types. Theta JA and Theta JC values are presented here for select Maxim temperature sensors and 1-Wire® devices. Examples for calculating the values are given.

Introduction

Managing heat in electronic systems is crucial for ensuring product reliability. Integrated circuits (ICs) exposed to high temperatures can fail or malfunction in the field, thus requiring costly repair or redesign. Typical thermal-resistance parameters give the resistance from the IC junction to some external reference point. Two popular measured parameters are the junction to ambient (Theta JA) and junction to case (Theta JC) values. These parameters have units of °C/W, indicating the temperature rise in °C for a given power dissipation. Knowing these package thermal-resistance values can help the system designer evaluate the thermal performance of different package types.

This application note lists Theta JA and Theta JC values for select Maxim temperature sensors and 1-Wire® devices organized by package and device type. Some example calculations are presented.

Theta JA and Theta JC Values

Tables 1 and **2** show the Theta JA and Theta JC values available for select Maxim temperature sensors. The values were obtained using the JEDEC standard test methodology for two- and four-layer boards. Board sizes, trace layouts, and environmental conditions were all measured. Further information on the JEDEC standards can be found at www.jedec.org under the JESD51 standard.

Table 1. Theta JA and Theta JC Values for 1-Wire Devices

		8-Pin DIP .300	8-Pin SO.150	8-Pin SO.208	3-Pin PR-35	3-Pin T0-92	3-Pin SOT23	5-Pin SOT23	8-Pin µSOP/ µMAX®	8-Pin µSOP Ex. Pad	24-Pin TSSOP .173	6-Pin TSOC .150
Two-Layer Board	Theta JA	110	170						221	97	82	166
	Theta JB						250	140				
	Theta JC	40	40				130	82	41.9		15	37
Four-Layer Board	Theta JA		128.4	27.72					206.3		72	126.7
	Theta JB											
	Theta JC		40	3.12					41.9		13	37
1-Wire Devices	DS18B20		X			X			X			
	DS18B20-PAR					X						
	DS18S20		X			X						
	DS18S20-PAR					X						
	DS1821			X	X							
	DS1822		X			X						
	DS1822-PAR					X						
	DS1825								X			
	DS28EA00								X			
	DS2431					X						X

Table 2. Theta JA and Theta JC Values for Other Temperature Sensors												
		8-Pin DIP.300	8-Pin SO.150	8-Pin SO.208	3-Pin PR-35	3-Pin T0-92	3-Pin SOT23	5-Pin SOT23	8-Pin µSOP/ µMAX	8-Pin µSOP Ex. Pad	24-Pin TSSOP.173	6-Pin TSOC .150
Two-Layer Board	Theta JA	110	170						221	97	82	
	Theta JB						250	140				
	Theta JC	40	40				130	82	41.9		15	
Four-Layer Board	Theta JA		128.4	27.72					206.3		72	
	Theta JB											
	Theta JC		40	3.12					41.9		13	
2-Wire Devices	DS1621	X	X	X								
	DS1624	X		X								
	DS1629		X									
	DS1631	X	X	X					X			
	DS1631A								X			
	DS1721		X						X			
	DS1731								X			
	DS1775							X				
	DS1780										X	
	DS75		X						X			
	DS75LV		X						X			
	DS620									X		
3-Wire and SPI Devices	DS1620	X		X								
	DS1626								X			
	DS1720			X								
	DS1722		X						X			
	DS1726								X			
Analog Devices	DS60						X					
	DS600									X		

Precautions for Using Theta Values

Using the values in Tables 1 and 2 for any conditions that differ from the JEDEC standard will nearly always result in calculation errors. In fact, the JEDEC standard 51-3 specifically states, "It should be emphasized that values measured with these test boards cannot be used to directly predict any particular system application performance but are for the purposes of comparison between packages."[1]

The values do not account for irregular board sizes, enclosed packages, heating from nearby ICs, all factors which can all affect application-specific temperature changes. When using application-specific boards, actual temperature measurements and further analysis are needed.[2]

Self-Heating Calculations

Occasionally the power dissipation of a temperature sensor causes the device to measure a temperature greater than ambient. This phenomenon is known as self-heating. By using Equation 1, the Theta JA value can be used to estimate the IC's internal temperature rise:

$$\text{JunctionTemperature} - \text{AmbientTemperature} = \text{ThetaJA} \times \text{PowerDissipated} \qquad \text{(Eq. 1)}$$

The DS1620, for example, is packaged in an 8-pin, 208 mil SO and has a Theta JA of 27.72°C/W. The data sheet indicates that the maximum conversion current for this device is 1mA and the maximum supply voltage is 5.5V. Assuming a worst-case conversion duty cycle of 100%, the power dissipation is 5.5mW. For true worst-case power consumption, assume that the device is also sinking 4mA into both TH and TCOM pins. The data sheet specifies the V_{OL} level at 0.4V for 4mA, which adds an additional 1.6mW per pin for a total power dissipation of 8.7mW. The resulting temperature rise is:

$$0.241°\text{C} = 27.72°\text{C/W} \times 8.7\text{mW} \qquad \text{(Eq. 2)}$$

For the worst-case scenario, the DS1620 junction temperature rises less than 1/4°C, so self-heating is only a minor concern for this particular packaged device.

Maximum Power Dissipation

The theta values can also be used to approximate the maximum power dissipation allowed for a specific packaged device. This calculation can help determine whether the package alone dissipates enough heat, or if an external heat sink is necessary. Equation 3 can be used to calculate the maximum power dissipation allowed by the device:

$$MaxPower = \frac{MaxDeviceTemperature - MaxAmbientTemperature}{ThetaJA} \quad \text{(Eq. 3)}$$

Assume, for example, that your application has a maximum ambient temperature of +110°C. The DS1620 data sheet lists a maximum operating temperature of +125°C. Using these values in Equation 3 yields the maximum power dissipation allowed:

$$541mW = \frac{125°C - 110°C}{27.72°C/W} \quad \text{(Eq. 4)}$$

To safely use the DS1620 in an SO package, therefore, the maximum power must be limited to 541mW. Power consumption greater than that would require reducing the ambient temperature or adding a heat sink to dissipate more heat. The maximum power consumed by the DS1620 was already shown to be 8.7mW, so this application is safe in the SO package.

Comparing Package Types

Theta values are defined so a designer can compare different package types for a specific application. This analysis requires that the actual junction temperature be measured in the specific application. This measurement can be done for a temperature sensor by simply reading the temperature from the part. An accurate reading of the ambient temperature must then be known. With these two temperature measurements, the actual delta above ambient is known. This information and the Theta JA values can be used to compare two package types. By using Equation 5, the temperature rise of a different part can be estimated.[3]

$$\Delta Temperature2 = \frac{\Delta Temperature1 \times ThetaJA2}{ThetaJA1} \quad \text{(Eq. 5)}$$

Assume, for example, that the DS1620 had a temperature rise of +0.241°C in an application. Then the designer wanted to estimate the temperature rise of another smaller device like the DS1626 in the same application. The values shown in Equation 6 would apply:

$$1.79°C = \frac{0.241°C \times 206.3°C/W}{27.72°C/W} \quad \text{(Eq. 6)}$$

As shown in Equation 6, the temperature rise in the DS1626's smaller package is significantly more than for the DS1620. Yet, the temperature rise is proportional to the ratio of Theta JA values. This comparative method of analyzing temperature and power dissipation between devices is why the theta values were created. The resulting calculations are reliable.[3]

Summary

The package thermal-resistance values, Theta JA and Theta JC, can be useful in determining the thermal response of ICs in a JEDEC-constrained environment. Under any other conditions, the calculations are likely to deviate from measured parameters. While the theta values can be useful in approximating self-heating characteristics and maximum power dissipation, their primary purpose is to compare the thermal performance of one package to another.

References

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2. Actel, Application Note, "Package Thermal Characteristics," at www.actel.com/documents/Pack_Therm_AN.pdf, Internet, 2/2005.
3. Sarang Shidore, Application Note, "Our Old Friend Theta-JA", at www.coolingzone.com/library.php?read=519, 12/2005.

Related Parts		
DS1620	Digital Thermometer and Thermostat	Free Samples
DS1621	Digital Thermometer and Thermostat	Free Samples
DS1624	Digital Thermometer and Memory	Free Samples
DS1626	High-Precision 3-Wire Digital Thermometer and Thermostat	Free Samples
DS1629	Digital Thermometer and Real-Time Clock/Calendar	Free Samples
DS1631	High-Precision Digital Thermometer and Thermostat	Free Samples
DS1631A	High-Precision Digital Thermometer and Thermostat	Free Samples
DS1720	Econ-Digital Thermometer and Thermostat	Free Samples
DS1721	Digital Thermometer and Thermostat	Free Samples
DS1722	Digital Thermometer with SPI/3-Wire Interface	Free Samples
DS1726	High-Precision 3-Wire Digital Thermometer and Thermostat	Free Samples
DS1731	High-Precision Digital Thermometer and Thermostat	Free Samples
DS1775	Digital Thermometer and Thermostat in SOT23	Free Samples

DS1780	CPU Peripheral Monitor	Free Samples
DS1821	Programmable Digital Thermostat and Thermometer	Free Samples
DS1822	Econo 1-Wire Digital Thermometer	Free Samples
DS1822-PAR	Econo Parasite-Power Digital Thermometer	
DS1825	Programmable Resolution 1-Wire Digital Thermometer With 4-Bit ID	Free Samples
DS18B20	Programmable Resolution 1-Wire Digital Thermometer	Free Samples
DS18B20-PAR	1-Wire Parasite-Power Digital Thermometer	
DS18S20	1-Wire Parasite-Power Digital Thermometer	Free Samples
DS18S20-PAR	Parasite-Power Digital Thermometer	
DS2431	1024-Bit 1-Wire EEPROM	Free Samples
DS28EA00	1-Wire Digital Thermometer with Sequence Detect and PIO	Free Samples
DS60	Analog Temperature Sensor	
DS600	±0.5°C Accurate Analog-Output Temperature Sensor	Free Samples
DS620	Low-Voltage, ±0.5°C Accuracy Digital Thermometer and Thermostat	Free Samples
DS75	Digital Thermometer and Thermostat	Free Samples
DS75	Digital Thermometer and Thermostat	Free Samples
DS75LV	Low-Voltage Digital Temperature Sensor	Free Samples
MAX31820	1-Wire Ambient Temperature Sensor	Free Samples
MAX31820PAR	1-Wire Parasite-Power, Ambient Temperature Sensor	
MAX31826	1-Wire Digital Temperature Sensor with 1Kb Lockable EEPROM	Free Samples

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