RENESAS

Thermal Characteristics of IDT'S PES12T3G2 and PES16T4G2 PCI Express® Switches

Application Note
AN-548

Notes

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Introduction

An effective thermal management strategy is a critical part of any system design. It is therefore essential that IC vendors provide system designers with pertinent thermal characteristics for their devices. IDT provides basic thermal data for each PCI Express switch in the device data sheet, available from IDT. For most usage scenarios, the information contained in the device data sheet is sufficient to determine the proper thermal management strategy. This application note contains all of the information in the data sheets, as well as additional details on the thermal characteristics of each device.

The purposes of this application note, with respect to each device in the IDT PCI Express switch family, are:

- Present relevant thermal parameters (raw data).
- Provide detailed reference tables, exhibiting PCB (Printed Circuit Board) size vs. number of layers vs. air flow, which customers can use to quickly ascertain heat sink requirements.
- Enable customers to determine the appropriate thermal management strategy for their specific usage scenarios using the raw data.

Important Thermal Parameters and Relationships

This section defines the relevant thermal parameters that are used throughout this application note. Also, equations are introduced in order to show the relationships between the parameters.

Thermal Parameters

Table 1 summarizes key thermal parameters that are used throughout this application note.

Symbol	Parameter	Units	Notes
$T_{J(max)}$	Maximum Junction Temperature	^oC	Specifies the highest allowable junction temperature of the die. Fixed value, given in the device data sheet (125^oC for IDT PCIe switches).
T_A	Maximum Ambient Temperature	^oC	Specifies the highest allowable ambient temperature of the system. 70^oC is the value for commercial temperature range devices.
θ_{JA}	Junction-to-Ambient Thermal Temperature	$^oC/W$	Applicable when no external heat sink is used. Absolute value is specific to each IC package. Effective value is dependent upon PCB parameters and air flow.
θ_{JB}	Junction-to-Board Thermal Temperature	$^oC/W$	Value is specific to each IC Package. Assumes that all heat flows through the board.

Table 1 Relevant Thermal Values Defined (Page 1 of 2)

Notes

Symbol	Parameter	Units	Notes
θ_{JC}	Junction-to-Case Thermal Temperature	$^oC/W$	Applicable when an external heat sink is used. Value is specific to each IC package. Assumes all heat is dissipated through the surface with the heat sink.
θ_{CS}	Case-to-Sink Thermal Resistance	$^oC/W$	Applicable when an external heat sink is used. Comes from the substance used to adhere the heat sink to the case. Value ranges between: 0.1 and 1.0 °C/W.
θ_{SA}	Sink-to-Ambient Thermal Resistance	$^oC/W$	Applicable when an external heat sink is used. Value is specific to the heat sink. Dependent upon the amount of air flow in the system. The dimensions of the heat sink should match those of the package.
P	Power Dissipation of the Device	W	Specific to each device and equal to the power consumption of the device as published in the device data sheet.

Table 1 Relevant Thermal Values Defined (Page 2 of 2)

Useful Formulas

The junction-to-ambient thermal resistance is a measure of a device's ability to dissipate heat from the die to its surroundings in the absence of a heat sink. The general formula to determine θ_{JA} is:

$\theta_{JA} = (T_J - T_A)/P$ *Equation 1(a)*

A variation on Equation 1(a) can be used to find the actual value of TJ in a system, given the effective θ_{JA}, P, and T_A:

$T_{J(actual)} = TA + P * \theta_{JA(effective)}$ *Equation 1(b)*

This value is useful as a comparison to the maximum T_J as a gauge of reliability. Note that the effective θ_{JA} accounts for the necessary PCB characteristics and air flow.

The formula is also useful from a system design perspective. It can be used to determine if a heat sink should be added to the device based on some desired value of T_J:

$T_{A(allowed)} = T_{J(desired)} - (P * \theta_{JA(effective)})$ *Equation 1(c)*

The variations of Equation 1 are used to determine if a heat sink is required, considering all of the relevant parameters. If a heat sink is necessary, then Equation 2 is used to arrive at the necessary value of θ_{SA} for the heat sink.

$\theta_{SA} = (T_J - T_A)/ P - (\theta_{JC} - \theta_{CS})$ *Equation 2*

Notes

PES12T3G2 Thermal Considerations

This section describes thermal considerations for the PES12T3G2 (19mm x 19mm 324-ball BGA package).

PES12T3G2 Thermal Parameters

The data in Table 2 contains information that is relevant to the thermal performance of the PES12T3G2.

Symbol	Parameter	Value	Units	Conditions
$T_{J(max)}$	Junction Temperature	125	^oC	Maximum
$T_{A(max)}$	Ambient Temperature	70	^oC	Maximum for commercial-rated products
θ_{JB}	Junction-to-Board Thermal Resistance	14.5	$^oC/W$	19mm x 19mm 324-ball package
θ_{JC}	Junction-to-Case Thermal Resistance	7.6	$^oC/W$	19mm x 19mm 324-ball package
P	Power Dissipation of the Device	2.83	W	Maximum

Table 2 PES12T3G2 Thermal Specifications, 19x19 mm 324-ball BGA Package

Table 3 provides effective θ_{JA} values based on air flow, number of PCB layers, and PCB size.

Note: In Table 3, θ_{JA} is obtained from JEDEC EIA/JESD 51-2 and JESD 51-6.

12T3G2		2.7" x 6.6" Low Profile (17.82in)	3.9" x 6.2" Express Module (24.22in)	4.3" x 6.6" Standard Height Half Length (28.42in)	4.3" x 12.2" Standard Height Full Length (52.52in)
Airflow	PCB Layers	θJA (°C/W)	θJA (°C/W)	θJA (°C/W)	θJA (°C/W)
0	4	25.5	24.1	23.6	22.8
0.5	4	17.8	17.6	17.5	17.5
1	4	17.1	16.9	16.8	16.8
2	4	15.5	15.3	15.4	15.4
3	4	14.7	14.5	14.6	14.6
0	6	21.7	20.2	19.9	18.4
0.5	6	15	14.4	14.3	14.1
1	6	14.3	13.7	13.6	13.4
2	6	13.3	12.7	12.5	12.4
3	6	12.7	12.1	11.9	11.8
0	10	16.4	15.7	14.7	13.7
0.5	10	13	13.3	12.6	12.3
1	10	12.3	12.6	11.9	11.6
2	10	11.2	11.6	11	10.8
3	10	10.7	11.1	10.5	10.3
0	14	15.3	14.2	13.7	12.6
0.5	14	12.2	11.9	11.7	11.4
1	14	11.2	10.9	10.7	10.4
2	14	10.4	10.1	9.9	9.6
3	14	9.9	9.6	9.4	9.1
0	20	14.6	13.2	13	11.8
0.5	20	11.5	11	11.1	10.6
1	20	10.5	10	10.1	9.6
2	20	9.7	9.2	9.3	8.8

Table 3 PES12T3G2 Effective Junction-to-Ambient Thermal Resistance Values - $\theta_{JA(effective)}$

Notes

Note: The parameter $\theta_{JA(effective)}$ is not the absolute thermal resistance for the package as defined by JEDEC (JESD-51). Since it varies with the number of PCB layers, size of the PCB, and airflow, it is the effective thermal resistance.

PES12T3G2 Heat Sink Requirements

The charts in Figures 1 and 2 specify which scenarios need a heat sink based on common combinations of air flow, PCB size, and number of PCB layers. A heat sink is required above 125°C. As Figure 1 shows, the PES12T3G2 does not require a heat sink for most usage scenarios. As the chart in Figure 2 suggests, the introduction of 0.5 m/s of air flow will eliminate the need for a heat sink for any practical board size.

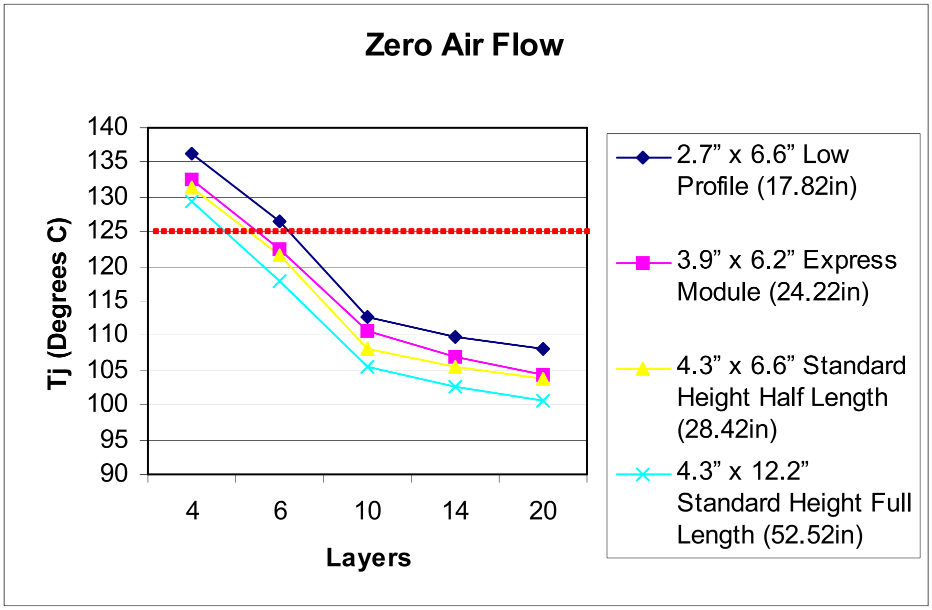

Figure 1 PES12T3G2 Heat Sink Requirements without Air Flow

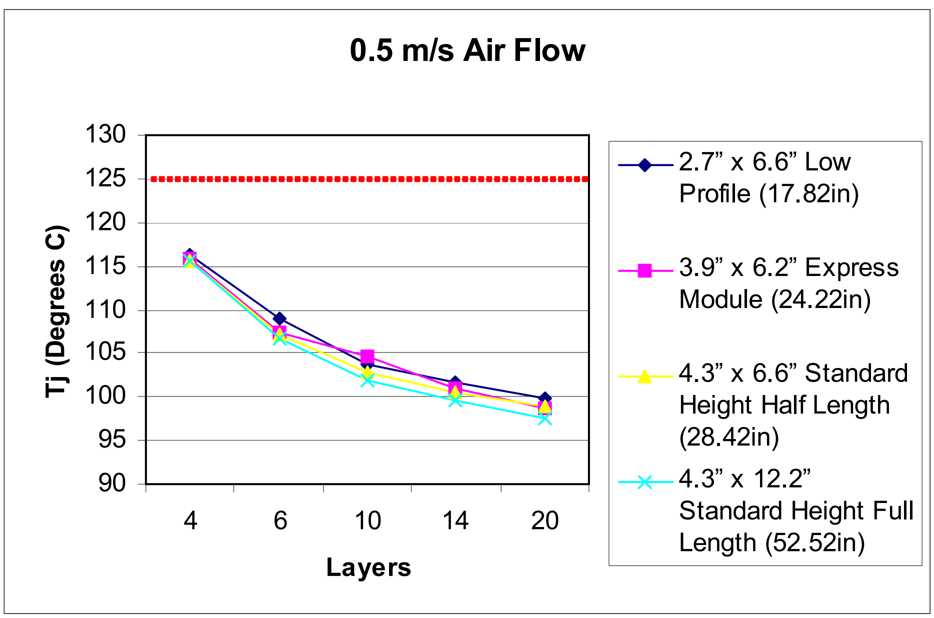

Figure 2 PES12T3G2 Heat Sink Requirements with Air Flow

Notes

Note: The charts above are based on the values of effective θ_{JA} in Table 3 and assume $T_{J(max)}$ = 125°C, $T_{A(max)}$=70°C, and PCB temperature equal to T_A.

PES12T3G2 Heat Sink Calculations

Consider an application that requires the use of a 10-layer, standard height, full length add-in card in a system with no air flow. According to Figure 1, the PES12T3G2 device does not require a heat sink and we can stop the investigation. But let us suppose that, for the same application, we wish our maximum operating T_J to be 100°C instead of 125°C. We can use Equation 1(a) to determine the highest acceptable junction-to-ambient thermal resistance.

$$\theta_{JA(required)} = (T_J - T_A)/P$$

$$\theta_{JA(required)} = (100^oC - 70^oC)/2.83W$$

$$\theta_{JA(required)} = 10.6^oC/W$$

So, to sustain a maximum operating T_J of 100°C, the value of $\theta_{JA(effective)}$ cannot be greater than 10.6°C/W. From Table 3, the value of $\theta_{JA(effective)}$ is 13.7°C/W. Therefore, a heat sink is required in this case. In order to select an adequate heat sink, we must calculate its maximum sink-to-ambient thermal resistance value. To do so, we use Equation 2:

$$\theta_{SA(max)} = (T_J - T_A) / P - (\theta_{JC} - \theta_{CS}) \qquad \text{assuming that } \theta_{CS} = 1.0\ ^oC/W$$

$$\theta_{SA(max)} = (100^oC - 70^oC) / 2.83W - (7.6^oC/W - 1.0^oC/W)$$

$$\theta_{SA(max)} = 2.0^oC/W$$

This value indicates the need for a 19mm x 19mm heat sink with a sink-to-ambient thermal resistance of 2.0°C/W or less, assuming no air flow.

PES16T4G2 Thermal Considerations

This section describes thermal considerations for the PES16T4G2 (23mm x 23mm 288-ball BGA package).

PES16T4G2 Thermal Parameters

The data in Table 4 contains information that is relevant to the thermal performance of the PES16T4G2.

Symbol	Parameter	Value	Units	Conditions
$T_{J(max)}$	Junction Temperature	125	°C	Maximum
$T_{A(max)}$	Ambient Temperature	70	°C	Maximum for commercial-rated products
θ_{JB}	Junction-to-Board Thermal Resistance	9.5	°C/W	23mm x 23mm 288-ball package
θ_{JC}	Junction-to-Case Thermal Resistance	1.1	°C/W	23mm x 23mm 288-ball package
P	Power Dissipation of the Device	3.24	W	Maximum

Table 4 PES16T4G2 Thermal Specifications, 23x23 mm 288-ball BGA Package

Notes

Table 5 provides effective θ_{JA} values based on air flow, number of PCB layers, and PCB size.

Note: In Table 5, θ_{JA} is obtained from JEDEC EIA/JESD 51-2 and JESD 51-6.

16T4G2		2.7" x 6.6" Low Profile (17.82in)	3.9" x 6.2" Express Module (24.22in)	4.3" x 6.6" Standard Height Half Length (28.42in)	4.3" x 12.2" Standard Height Full Length (52.52in)
Airflow	PCB Layers	θJA (°C/W)	θJA (°C/W)	θJA (°C/W)	θJA (°C/W)
0	4	21.8	20.3	19.8	19
0.5	4	14.2	14	13.9	13.7
1	4	13.6	13.4	13.3	13.1
2	4	12.1	11.9	11.8	11.7
3	4	11.2	11.15	11.1	11
0	6	20.1	18	17.8	16.8
0.5	6	13	12.7	12.6	12.4
1	6	12.4	12.1	12	11.8
2	6	11.1	10.95	10.9	10.7
3	6	10.3	10.25	10.3	10.1
0	10	16	14.3	14.1	13.3
0.5	10	12.3	11.9	11.8	11.6
1	10	11.7	11.3	11.2	11
2	10	10.5	10.2	10.1	10
3	10	9.7	9.6	9.55	9.4
0	14	15.3	13.7	13.6	12.6
0.5	14	11.7	11.4	11.3	11.1
1	14	11.3	11	10.9	10.7
2	14	10.2	10	9.9	9.7
3	14	9.4	9.35	9.3	9.2
0	20	15	13.5	13.3	12.3
0.5	20	11.5	11.1	11	10.8
1	20	11.1	10.7	10.6	10.4
2	20	10	9.7	9.6	9.5

Table 5 PES16T4G2 Effective Junction-to-Ambient Thermal Resistance Values - $\theta_{JA(effective)}$

Note: The parameter $\theta_{JA(effective)}$ is not the absolute thermal resistance for the package as defined by JEDEC (JESD-51). Since it varies with the number of PCB layers, size of the PCB, and airflow, it is the effective thermal resistance.

PES16T4G2 Heat Sink Requirements

The charts in Figures 3 and 4 specify which scenarios need a heat sink based on common combinations of air flow, PCB size, and number of PCB layers. A heat sink is required above 125°C. As Figure 3 shows, the PES16T4G2 does not require a heat sink for most usage scenarios. As the chart in Figure 4 suggests, the introduction of 0.5 m/s of air flow will eliminate the need for a heat sink for any practical board size.

Notes

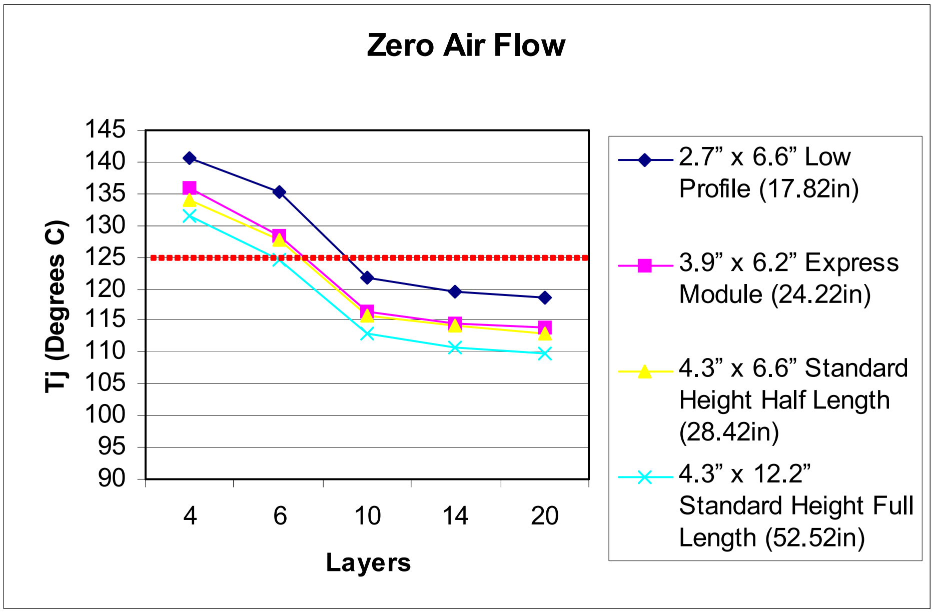

Figure 3 PES16T4G2 Heat Sink Requirements without Air Flow

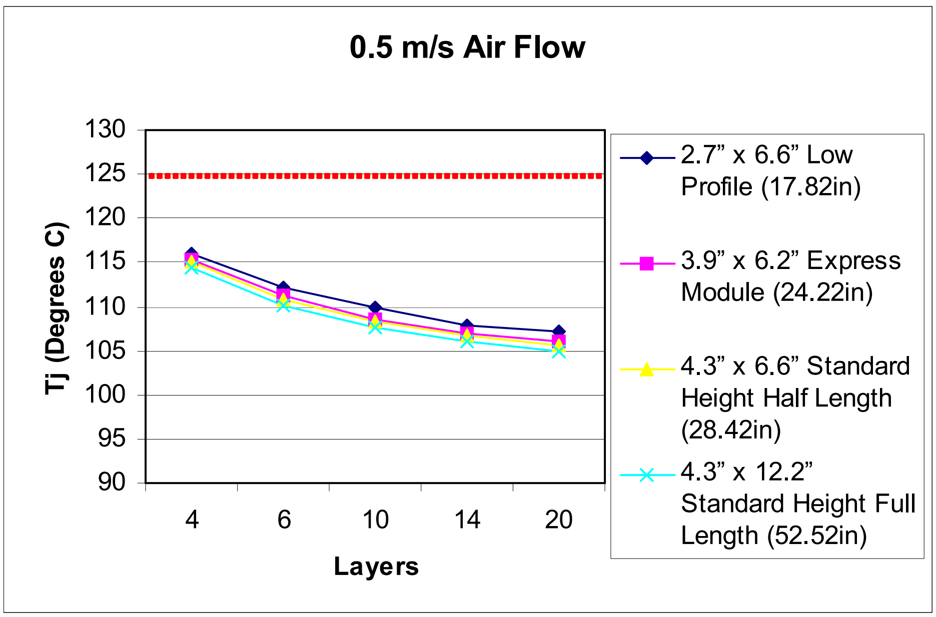

Figure 4 PES16T4G2 Heat Sink Requirements with Air Flow

Note: The charts above are based on the values of effective θ_{JA} in Table 5 and assume $T_{J(max)} = 125^oC$, $T_{A(max)} = 70^oC$, and PCB temperature equal to T_A.

PES16T4G2 Heat Sink Calculations

Consider an application that requires the use of a 10-layer, standard height, full length add-in card in a system with no air flow. According to Figure 3, the PES16T4G2 device does not require a heat sink and we can stop the investigation. But let us suppose that, for the same application, we wish our maximum operating T_J to be 100^oC instead of 125^oC. We can use Equation 1(a) to determine the highest acceptable junction-to-ambient thermal resistance.

Notes

$\theta_{JA(required)} = (T_J - T_A)/P$
$\theta_{JA(required)} = (100^oC - 70^oC)/3.24W$
$\theta_{JA(required)} = 9.26^oC/W$

So, to sustain a maximum operating T_J of 100^oC, the value of $\theta_{JA(effective)}$ cannot be greater than $9.26^oC/W$. From Table 5, the value of $\theta_{JA(effective)}$ is $13.3^oC/W$. Therefore, a heat sink is required in this case. In order to select an adequate heat sink, we must calculate its maximum sink-to-ambient thermal resistance value. To do so, we use Equation 2:

$\theta_{SA(max)} = (T_J - T_A) / P - (\theta_{JC} - \theta_{CS})$ assuming that $\theta_{CS} = 1.0^oC/W$
$\theta_{SA(max)} = (100^oC - 70^oC) / 3.24W - (1.1^oC/W - 1.0^oC/W)$
$\theta_{SA(max)} = 7.16^oC/W$

This value indicates the need for a 23mm x 23mm heat sink with a sink-to-ambient thermal resistance of $7.16^oC/W$ or less, assuming no air flow.

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