Thermal Design Considerations—EL75XX

Application Note | March 20, 1998 | AN1096

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Elantec's EL7560/EL7561/EL7556 series of voltage regulators are highly integrated, simple to use and the most effective switching mode designs to power microprocessors such as Intel Corporation's Pentium® Pro, and Pentium. The EL7560/EL7561 is designed for classes of processors such as the Pentium Pro. EL7556 is designed primarily for Pentium class desktop models.

These devices are packaged in a 28-pin power SO package (28 PSOP 2) developed by Amkor Corporation. The 28 PSOP 2 is a 28-lead surface mount package with 50 mil lead centers. It includes a specially designed copper slug on which the die is attached. The copper slug provides the excellent power dissipation capability required for these devices. Two versions, “Slug up” and “Slug down”, are available for various board mounting and heatsink options. This application note describes the various package and heatsink combinations, which can be used with the EL75XX series.

Typical Applications Power Requirement

The typical power applications requirement for microprocessors is either a VRM (Voltage Regulator Module) or a direct mother board solution, both options operate under certain power dissipation, environmental, physical, and, of course, cost constraints. Table 1, below, summarizes the majority of typical applications requirements.

Several other variations in ambient temperature and airflow conditions may exist in practice, depending upon the user's board layout and system configurations.

Structure and Characteristics of the 28 PSOP 2

Figure 1 illustrates the structure of the Amkor PSOP 2 package. The copper slug is 535 x 170 mils in dimension and its thickness is optimized in order to arrive at a good compromise between biggest size possible for maximum thermal performance and the smallest foot print for the package. The die can either be soft soldered to the slug or attached using a thermally conductive epoxy.

TABLE 1.

APPLICATION	THERMAL REQUIREMENT	TYPICAL ENVIRONMENT	THERMAL RESISTANCE REQUIRED
VRM-Pentium Pro	Pdiss = 3.4W, T_J = 105°C	T_A = 60°C, 100 LFM	θ_{JX} = 13°C/W
VRM-Pentium P54/55	Pdiss = 2.4W, T_J = 105°C	T_A = 50°C, 100 LFM	θ_{JX} = 23°C/W
Laptop-Pentium P54	Pdiss = 1.6W, T_J = 105°C	T_A = 50°C, No Airflow	θ_{JX} = 34.3 C/W

PSOP 2—EXPOSED SLUG WITH COUPLED LEADS

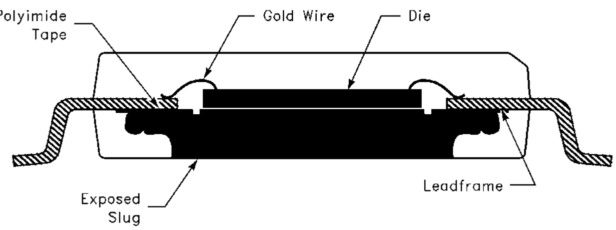

FIGURE 1. 28 PSOP 2 STRUCTURE

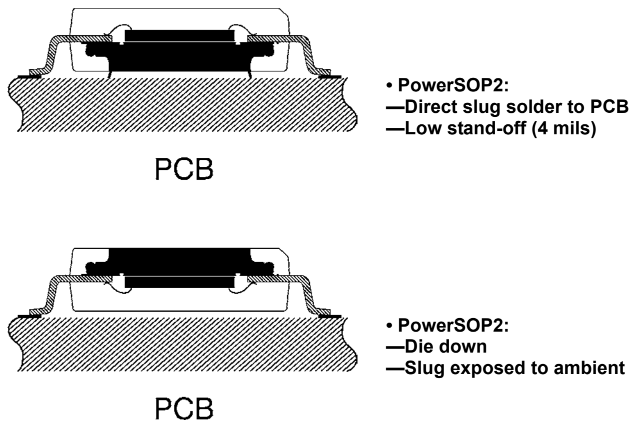

FIGURE 2. 28 PSOP 2 BOARD MOUNTING OPTIONS

The slug provides low thermal resistance from the die to the external heatsink and also through the leads. At the same time, it provides a large thermal capacitance to absorb power peaks during switching. Thermal resistance (θ_{JC}—junction to case) for a typical 100 x 100 mil die is 45°C/W. The electrical lead resistance is in the range (5) mmhos; inductance is typically (2nH) per lead and capacitance is about 1pF. The package comes in two different lead stand-offs: normal stand-off is 9 mils and low stand-off is 2 mils. The two board mounting options are shown in Figure 2.

Components of Thermal Resistance and Heat Dissipation

Long term reliability of the semiconductor device is enhanced by keeping the junction temperature (T_J) as low as possible consistent with the given application. (See Elantec “Reliability and the Electronic Engineer” Tutorial #1.)

T_J—Junction temperature is a function of the amount of heat dissipated, the thermal resistance between the junction and the ambient air, and the ambient air temperature.

Integrated thermal resistance (θ_{IT}) is the sum of the following individual thermal resistances.

θ_{JC}—Thermal resistance from junction to case (die size, d/a, package dependent).

θ_{CH}—Thermal resistance from case to heatsink (interface—package to heatsink dependent).

θ_{HA}—Thermal resistance from heatsink to ambient (heatsink dependent).

Thus,

$\theta_{IT} = \theta_{JC} + \theta_{CH} + \theta_{HA}$ (°C/W)

As stated in section 2, the thermal resistance required is the total integrated thermal resistance θ_{IT} under the “In Situ” applications condition.

θ_{JC}—Thermal resistance from junction to case depends on the die size, Cu slug size, the die attach material and the lead frame. In the case of PSOP 2 package, almost all the heat from the die is conducted through the Cu slug and very little through the leads.

Figure 4 shows the relationship between θ_{JC} and die size for a given package and die attach material.

θ_{CH}—Thermal resistance from case to heatsink is dependent upon the thermal properties of the interface used to attach the heatsink to the copper slug of the package. Various types of heat conducting pads, thermal greases and thermal epoxy bonding materials are available from several manufacturers. Table 2 shows estimated values of θ_{CH} for several types of epoxy bonding materials.

θ_{HA}—Thermal resistance from heatsink to ambient is a function of the conduction through heatsink material to the dissipating surface area; convection (natural or forced); and radiation from the heatsink surface area. Different designs of the sizes of heatsinks are available to achieve maximum conduction and convection. Forced air can be used to improve convection and black anodizing can improve heat dissipation through radiation.

Thermal Resistance—28 PSOP 2

The 28 POSP 2 is available in two versions—the "Slug down" in a low stand-off version (2 mils) and a "Slug up" version with a standard stand-off of 9 mils. The slug down version is suitable for direct mounting onto the PCB by using surface mount solder technique. The heat dissipating copper area on the circuit board can be configured in various shapes and sizes depending upon the particular application. Figure 3 shows a typical configuration for heat dissipating copper clad. Thermal resistance measurements for the slug down version are listed in Table 3. Medium power dissipations of up to 2W are easily obtainable in practice with this configuration. The slug up version offers more heat sinking options. One of the most beneficial options is to epoxy bond a suitable heatsink to the package slug as shown in Figure 5 and Figure 6.

Another heat sinking option is to use a mounting clip to secure the heatsink to the PCB, as shown in Figure 7 adding mechanical strength against shock and vibration. Heatsink arrangements shown in Figure 5 and Figure 6 offer very effective heat dissipation under forced air condition of 100 LFM–200 LFM in a typical PC system application. (See Figure 8 for effect of forced air convection on thermal resistance.) The methods shown in Figure 5 and Figure 6 allow power dissipations in the 2W–9W range, as shown in Table 3. Figure 9 graphically summarizes the power dissipation capability of the 28 PSOP 2.

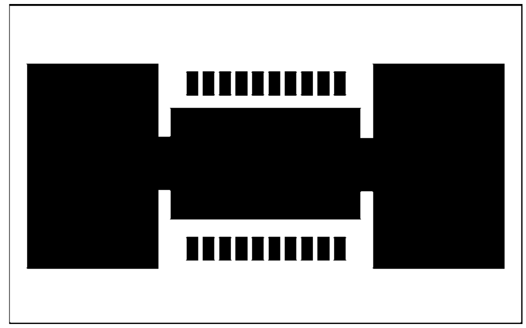

FIGURE 3. TYPICAL FOOTPRINT FOR A HEAT DISSIPATING COPPER CLAD

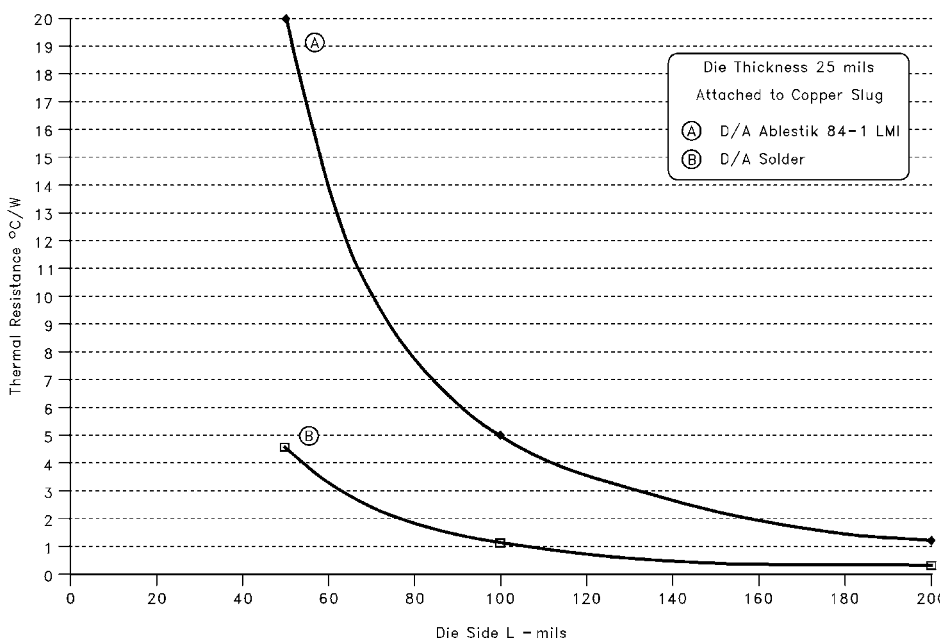

FIGURE 4. THERMAL RESISTANCE—θ_{JC} 28 PSOP 2

TABLE 2. THERMALLY CONDUCTIVE BONDING MATERIALS

MANUFACTURER	TYPE	THERMAL CONDUCTIVITY	STRENGTH MECHANICAL (BOND SHEAR)	THICKNESS APPLIED	θ_{CH}–°C/W THERMAL RESISTANCE
Ablestik	84-1LMIT	4.3w/mk	6000 psi	2 mils	0.2
Wakefield	120	0.74w/mk	—	2 mils	1.1
Thermagon (Elastomer)	T-pill 210	6w/mk	—	10 mils	0.14
Wakefield Deltabond	152-B4	0.9w/mk	2300 psi	2 mils	0.95

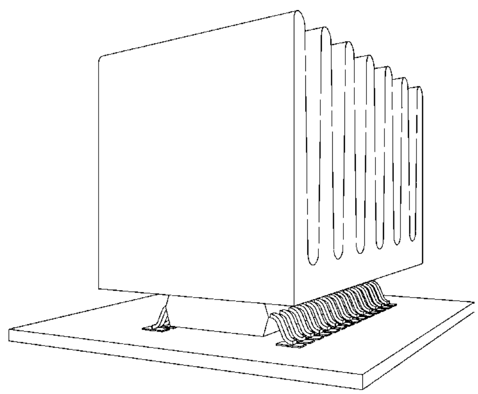

FIGURE 5. PSOP 2 WITH WAKEFIELD # 8052-60 HEATSINK

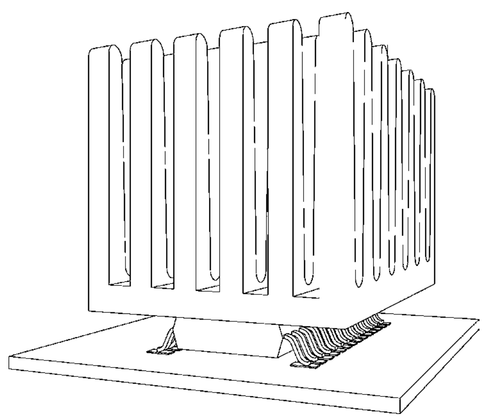

FIGURE 6. PSOP 2 WITH WAKEFIELD PENGUIN # 658-60A HEATSINK

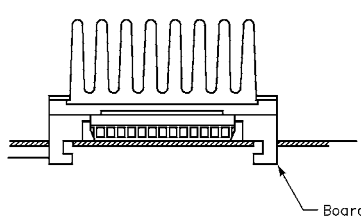

FIGURE 7. PSOP 2 WITH HEATSINK AND A MOUNTING CLIP

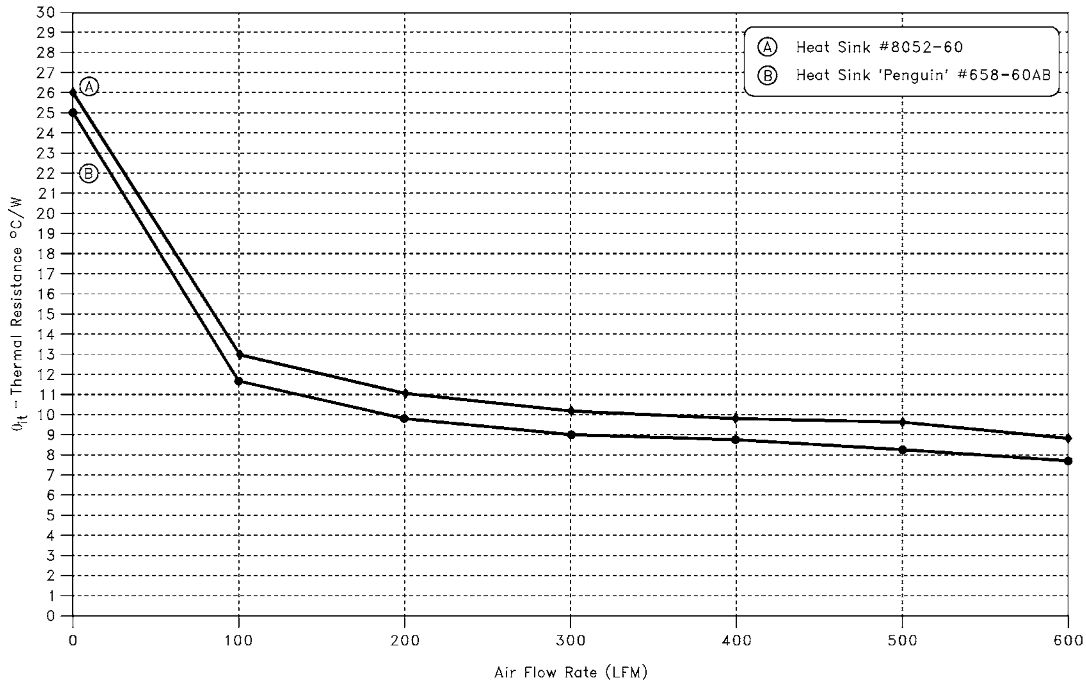

FIGURE 8. THERMAL RESISTANCE vs AIR FLOW-LFM

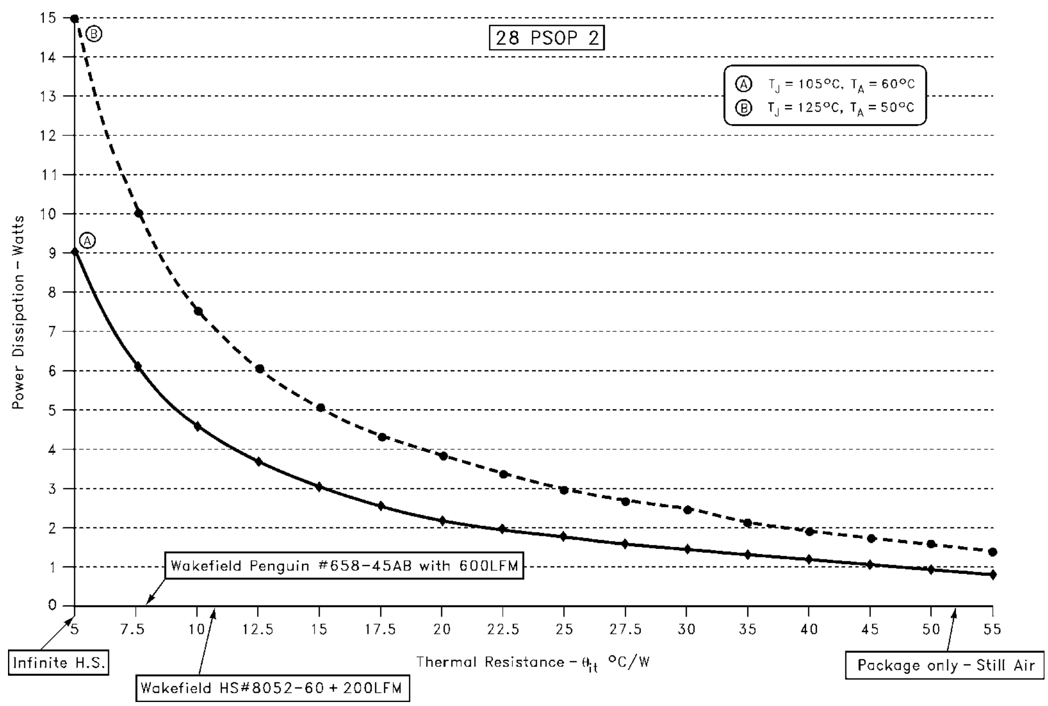

FIGURE 9. POWER DISSIPATATION vs THERMAL RESISTANCE

TABLE 3. POWER DISSIPATION CAPABILITY OF 28 PSOP 2

MOUNTING CONDITION		AMBIENT CONDITION	THERMAL RESISTANCE °C/W	POWER DISSIPATION-WATTS			
				ΔT 45°C A	ΔT 55°C B	ΔT 60°C C	ΔT 75°C D
I. Slug Up	Package Only	Still Air	52	0.87	1.05	1.15	1.44
	Package + Wakefield H.S. #8052-60	Still Air	25	1.8	2.2	2.4	3
	Package + Wakefield H.S. #8052-60	Air Flow 100 LFM	12.9	3.5	4.3	4.65	5.8
	Package + Wakefield H.S. #8052-60	Air Flow 200 LFM	11	4	5	5.45	6.8
	Package + Wakefield H.S. Penguin #658-60AB	Air Flow 600 LFM	7.7	5.8	7.2	7.8	9.8
II. Slug Down	Package Soldered to 3” sq Cu PCB	Still Air	33.4	1.3	1.65	1.8	2.2
	Package Soldered to 3” sq Cu PCB	Air Flow 100 LFM	30	1.5	1.8	2	2.5

NOTES:

1. A—TJ = 105°C, TA = 60°C
2. B—T_J = 105°C, T_A = 50°C
3. C—T_J = 110°C, T_A = 50°C
4. D—T_J = 125°C, T_A = 50°C

All thermal resistance measurements were done with a thermal die size of 100 x 100 mils. The actual die size of the EL7560/61 is larger than the thermal die therefore, the thermal resistance of the EL7560/61 will be 1-3°C/W lower than the numbers in the table.

Conclusions

Powering of the Pentium Pro and *Pentium microprocessors presents a challenge in thermal management. It has been demonstrated that by utilizing special power dissipating capability of the 28 PSOP 2 package and an appropriate heatsink, the EL7560/EL7561 and the EL7556 DC regulators will successfully power Pentium and Pentium Pro microprocessors. Power dissipations from 2W to 6W can easily be achieved, while keeping the junction temperature as low as 105°C.

Acknowledgments

The Author wishes to thank Ratnaji Arumilli for his work on thermal modeling, Mas Kobashi and Dave Mabrey for their efforts in thermal resistance measurements and also Amkor Ltd for their support in supplying thermal die packaged in PSOP 2 packages.

References

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