PERFORMANCE ENHANCEMENTS IN EDQUAD PLASTIC PACKAGES

Marcos Karnezos, N. Chidambaram (Raj) and Martin Goetz
ASAT Inc., 1010 Corporation Way, Palo Alto, CA 94303-4304
S.C. Chang and S.H. Ahn
ASAT Ltd., 138 Texaco Rd., Tsuen Wan, N.T., Hong Kong

ABSTRACT

The widespread use of plastic packages has extended into applications that require thermal and electrical performance not possible with the conventional packages. Edquad is a family of packages that provides up to 50% increase in power dissipation and significant reduction in electrical parasitics yet it is available in JEDEC standard body sizes in MQFP, TQFP, PLCC and SOIC formats with the heatspreader up or down. The packages have an integral heatspreader that carries most of the heat from the die attached directly on the bottom side to the top, which is exposed to the ambient. The heatspreader is also used as an electrical ground plane and the conventional die paddle is etched out to provide an internal power or ground ring. This arrangement provides for significant design flexibility to the device designer and has been demonstrated to result in lower package parasitics and higher clock frequency operation. The materials, the heatspreader design and surface preparation have been chosen to maximize adhesion and minimize stress at the interfaces. As a result these packages meet and exceed the accepted reliability standards of plastic packages.

PACKAGE DESCRIPTION

The cross section of Edquad [1] is shown in Fig.(1). Although the external dimensions are standard, there are three main differences in the construction as compared to standard plastic packages. First, there is an integral heatspreader on the bottom of which the die is attached with epoxy and the top is exposed to the ambient. Second, there is a ceramic window used as a dielectric between the leadframe and the heatspreader. Third, the die paddle center is etched out leaving only the perimeter section, from here on called the “interposer ring”. This is an integral part of the leadframe and is downset as a conventional die paddle. Both the ceramic window and the interposer ring are attached to the back of the heatspreader with epoxy which can be chosen to be conductive or non-conductive. The leadframe / ceramic / heatspreader sub-assembly is processed magazine-to-magazine using standard automated assembly equipment and processes.

THERMAL ENHANCEMENTS

The improved thermal performance is the result of design and material choices that are described in this section. The primary heat path Q1 is from the die to the ambient through the heatspreader, made out of oxygen free high conductivity copper and designed to the maximum possible size. The secondary heat path Q2 is through the overlapping area of the heatspreader and leadframe to the leadfingers attached to the motherboard. The choice of a thin ceramic window instead of the commonly used polyimide film is critical. The x400 higher thermal conductivity [2] of ceramic compared to polyimide is the main reason for reducing the Theta j-a of the package by at least 30%. Further improvement is achieved if any of the leads are fused to the interposer ring, as will be described later, thus providing a direct path for heat conduction between the heatspreader and the motherboard. The tertiary path Q3 is through the molding compound on both sides of the package. This critically depends on the thermal conductivity of the compound itself.

The effectiveness of the three heat paths described above is quantified by measuring the Theta j-a of a 208 lead Edquad MQFP. The package materials are listed in Table I.

TABLE I

Package size:	28x28x3.5mm
Package type:	208 lead Edquad MQFP
Leadframe:	Cu EFTEC 64T (Ag)
Die Paddle(mm):	6.0x16.0
Die size(mm):	10.4x10.4
Die Attach Epoxy:	Ablebond 84-1LMIS
Mold Compound:	EME7320CR
Heatspreader:	Cu, 99.99% OFHC
Ceramic:	Alumina, 96%
Adhesive:	Ablebond 965-1L

All Theta j-a measurements were done in a wind tunnel following the Semi Standard G38-87 method. All packages were mounted on a Semi Standard G42-88/JEDEC JC15.1 #1, FR4 PCB, 3.00x4.50x0.065 inch, single layer test board except where noted otherwise. The Theta j-c measurements were done following the MIL-STD-883D Method 1012.1.

Fig.2 shows the measured Theta j-a vs airflow for the 208 lead Edquad MQFP under different conditions (b), (d), (e) and the standard equivalent plastic package (a), under exactly the same conditions for comparison. The thermal resistance of Edquad in still air 16.8 C/watt is 46% lower compared to the standard and improves further with increasing airflow. When only ten leads of the Edquad are soldered to the test board the thermal resistance is increased by more than 5.6 C/watt. This indicates that a significant portion, 33% of heat is conducted through the leads to the test board in still air. Graph (c) is for a thermally enhanced 28x28 mm, 208 lead MQFP produced by another vendor, but uses a polyimide dielectric instead of ceramic. The Theta j-a is 14% higher compared to Edquad, under exactly the same measurement conditions and the same die. From both of the above measurements it is clear that the thermal conductivity of the ceramic makes a significant contribution to the power dissipation of the package. The addition of an external heatsink and the use of 4-layer test board further reduces the thermal resistance to 11.5C/watt in still air. Under most common application environments this package is capable of dissipating 4 watts power without heatsink and up to 9 watts with external heatsink. The package can be assembled with the heatspreader down, in close proximity to the motherboard. If the heatspreader is reflowed or otherwise attached with a thermal conductive epoxy or tape, the thermal resistance can be reduced further by 50% , due to the heatspreading effect of the motherboard. This package configuration is popular in small size Edquads used in portable product applications which have no space for heatsink or fan and the only medium for heatspreading is the motherboard.

The thermal resistance of Edquads and the amount by which it is lowered, as compared to standard packages depends on the package size, the overlapping surface between heatspreader and leadframe, die size and other factors. Fig.3 shows the percent reduction in Theta j-a of numerous Edquads as compared to the equivalent standard packages, as measured under the same conditions. The improvements range from 50% for the larger packages, down to 23% for the small 10x10 mm body sizes.

Fig.4 shows the measured Theta j-a vs air flow for Edquad and standard MQFPs with three different molding compounds. Compounds (A) and (B) are conventional filled with fused silica, whereas compound (C) is filled with thermally conductive aluminum nitride. It is clear that in the standard package, where there is no low thermal resistance path to the ambient, significant heat is conducted through molding compound (C) thus decreasing Theta j-a by 26% to 23 C/watt. In contrast, the Theta j-a in Edquad is not noticeably affected by the molding compound, since most of the heat is conducted through the heatspreader and leads.

ELECTRICAL ENHANCEMENTS

The reduction in electrical parasitics is due to the presence of the heatspreader used as a ground plane and the interposer ring that can be used as an internal power plane. The interposer ring is attached with non-conductive epoxy to assure electrical isolation from the ground. In some applications where the die needs back-biasing, then the heatspreader is biased and the interposer ring is used for ground. When conductive epoxy is used then the interposer is at ground potential. Fig.5 shows the various wire bonding options available to the designer. Multiple ground and power connections can be made internal to the package with short wire bonds, thus obtaining lower inductance and higher effective leadcount. In addition any lead can be fused to the interposer ring to further reduce the inductance of power connections. Fig. 6 - 9 show the results of analysis performed on a die down, heatspreader-up configuration of a 208 lead MQFP. The analysis was performed using the IE3D EM software from Zeland. The analysis was performed from 100MHz - 1GHz. Fig. 6 compares the self inductance of a center lead within an EDQUAD package using the various bonding approaches. Clearly there is an advantage to using the interposer ring, and modifying the bonding geometry to reduce the the inductance. Fig. 7 shows the self and mutual inductance comparisons between a standard MQFP and an EDQUAD. The self inductance is nominally lower in the EDQUAD due to the presence of the heatspreader acting as a ground path. But, because the configuration is die down, the effective ground path from the heatspreader is still quite a distance from the reference ground on the PCB. The mutual inductance is reduced significantly between the leads due to the presence of the heatspreader.

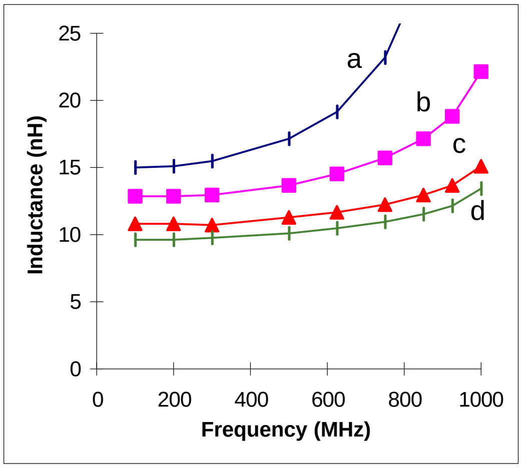

Fig.6 Frequency vs Inductance for various lead connections of a 208 lead EDQUAD MQFP.
a) Single Wirebond to Die, b) Single Wirebond to Interposer Ring to Die, c) Double Wirebond to Interposer Ring to Die, and d) Lead Attach to Interposer Ring and Double Wirebond from Interposer Ring to Die.

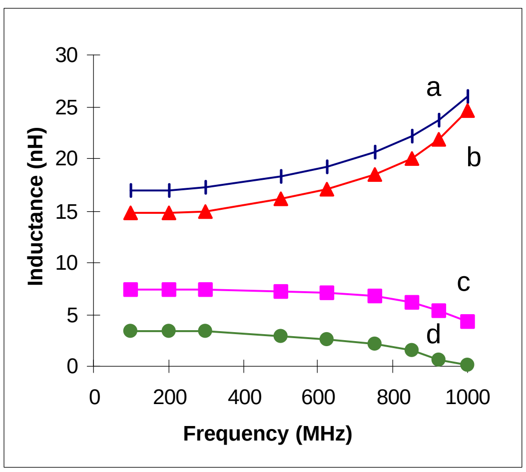

Fig.7 Frequency vs Inductance for standard 208 lead MQFP vs EDQUAD.
a) Self inductance, L11, standard package
b) Self inductance, L11, EDQUAD
c) Mutual inductance, L12, standard package
d) Mutual inductance, L12, EDQUAD

An interesting effect of the heatspreader on electrical parasitics is shown in Fig. 8. At lower frequencies, the capacitance is

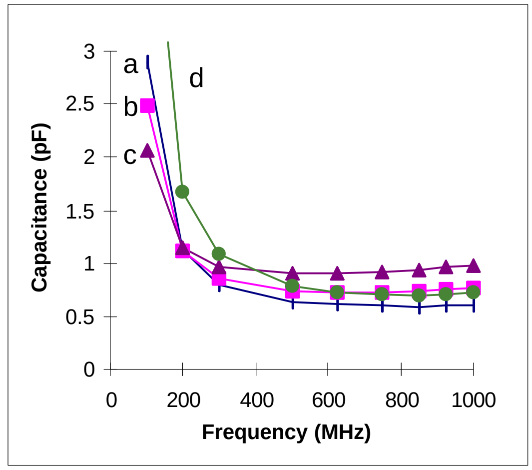

Fig.8 Frequency vs Capacitance for standard 208 lead MQFP vs EDQUAD.
a) Total capacitance, C11, standard package
b) Mutual capacitance, C12, standard package
c) Total capacitance, C11, EDQUAD
d) Mutual capacitance, C12, EDQUAD

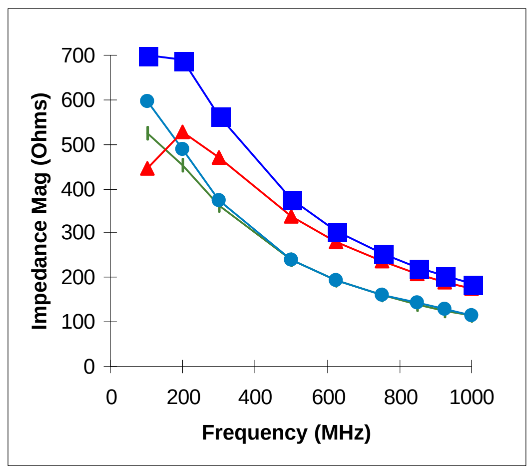

Table II gives the measured package parasitics........

The combination of the ground plane with the ceramic dielectric provide for a controlled impedance path along the overlapping length of leadframe to the heatspreader. For example in the case of the 208 lead package, the ceramic thickness of 0.25 mm and dielectric constant of 9.3, results in a 50 Ohm transmission line. The impedance will vary depending on the package type and leadframe design.

RELIABILITY ENHANCEMENTS

The heatspreader shown in Fig.9 has been designed with mold locking features and round corners and the copper is surface treated to minimize delamination from the molding compound. The holes in the four corners lock the molding compound on both sides together and the cones on the periphery prevent delamination from the exposed edge of the heatspreader. This design presents a long path to moisture ingression along the copper surface on top and bottom, before it reaches the die. Reliability testing results [1] show that this package meets the same criteria as most plastic packages.

Moisture sensitivity level classification was also completed following JEDEC specification A112/113. The packages used are the same as described in Table I, but the die size of 10.4x10.9 mm is slightly larger. Table II shows that this package passes Level #3 with floor life of 168 hrs under conditions of <30C/60%RH. It is also worth noting that Level #3 testing followed by Autoclave Test for 168 hrs did not result in any failures. The moisture gain shown at different levels is given as percentage of total package weight (a) as well as a percentage of package weight, not including the heatspreader weight (b). Since metal does not absorb moisture, comparison with standard plastic packages using the (b) numbers yield better agreement. Fig.10 shows the moisture absorption and desorption rate in this package. Absorption process steps are: (1) Dry Bake 125C for 48 hrs, (2) 85C/85RH for 168 hrs with measurements at 24 hr intervals. Desorption process steps are: (1) 85C/85RH for 168 hrs, (2) Dry bake at 125C for 168 hrs with measurements at 12 hr intervals. From this graph it is clear that baking for 24 hours is more than adequate to remove the moisture before reflow soldering.

CONCLUSIONS

Edquad is a family of thermally enhanced packages whose thermal resistance varies with the body size and is 23-50% lower compared to the equivalent standard plastic package. The electrical parasitics are lower as well due to the internal ground and power plains present in all body sizes. The reliability and moisture absorption is the same or better compared to equivalent plastics. The packages are built is standard JEDEC body sizes with die-up or die-down configurations using standard automated assembly equipment and process.

ACKNOWLEDGMENTS

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REFERENCES

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[2] Multichip Module Technologies and Alternatives, edited by Daryl Ann Doane and Paul D. Franzon, Van Nostrand Reinhold 1993, p.573
[3]
[4]

CAPTIONS TO FIGURES

Fig.1 Cross section of Edquad package with die down.

Fig.2 Thermal resistance vs air flow for 208 lead, 28x28x3.5 mm MQFP standard or Edquad as indicated, except (c) as noted below.
(a) 3 watt, standard, (b) 3 watt, Edquad with only 10 leads soldered to test board, (d) 3 watt, Edquad with all leads soldered to test board, (e) 10 watt Edquad with external aluminum pinfin heatsink (1.1x1.1 inch, 9x7 array), mounted on 4-layer, 1.75x1.50 inch test board.
(f) Theta j-c=0.28C/watt
(c) 3 watt, 28x28mm, 208 lead thermally enhanced package with exposed heatsink from a different vendor. Uses polyimide instead of ceramic as a dielectric.

Fig.3 Thermal resistance comparison of Edquad vs standard packages. Theta j-a(ED) is for Edquad and Theta j-a(STD) is for standard MQFP.

Fig.4 Thermal resistance comparison of standard and Edquad packages with three molding compounds. Standard 208 lead MQFP with molding: (a) Compound (A), (b) Compound (B), (c) Compound (C). Edquad 208 lead MQFP with molding: (d) Compound (A), (e) Compound (B), (f) Compound (C)

Fig.5 Edquad assembly before molding. In either die-up or die-down configuration there are five different internal bonding options: die-to-heatspreader ground, die-to- interposer ring power, die-to-signal lead and lead-to-interposer ring.

Fig.6

Fig.7

Fig.8

Fig.9 Edquad heatspreader etched out of copper. The mold locking cone tops are below the top surface of the package covered with molding compound. The round part exposed to air is plated with nickel, the rest is surface treated for better adhesion to molding compound.

Fig.10 Moisture absorption and desorption vs time for 208 lead, 28x28x3.5 mm Edquad MQFP. (a) Total package weight, including the heatspreader, (b) Package weight, not including heatspreader.