Design Criteria for Optimum Cooling and Shielding of Enclosures

Why package electronics? The obvious and simple answer is; to provide an electro-mechanical housing that will support and protect the electronics in their intended application. Like most engineering problems, however, the details of meeting this straightforward objective creates a wide range of challenges for the packaging engineer. In order to satisfy the demands of a given environment the engineer must consider: mechanical constraints, cooling requirements, EMI/RFI restrictions, shock/vibration, power distribution, cable management, system monitoring, high availability (HA), reliability (MTBF), maintainability (MTTR), and a myriad of less obvious concerns. Addressing any one of these issues is a difficult design task, but it is the balancing of these requirements, while working to hit a specified cost target under time-to-market pressures, that illustrates the importance of experienced packaging design.

This article will focus on two of the more difficult challenges: cooling and shielding, and illustrates the complexity of choices and design criteria associated with optimizing the design.

Thermal Management: The need for greater density of electronics and increasing processor speeds (Moore's Law) has placed tremendous amounts of heat into smaller packages making the demand for proper cooling a priority. Although new technologies such as liquid or vapor cooling are emerging, forced air, convection using fans or blowers still cool the vast majority of systems. Understanding the systems total power dissipation and localized "hot spots" is critical in selection and locating fans or blowers. Before the type of air mover can be chosen, the CFM or LFM required must be determined. The airflow needed is a function of the total heat to be dissipated and the allowable temperature rise and is governed by:

Q = mcðÄT (Q=watts, m=cfm)

If air is the medium: m(cfm) = 1.76 x Q/ÄT (T in °C)

Knowing the air volume required to cool the fans is the starting point, however, many design aspects still must be consider. They include:

- Air velocity required (LFM)
- Static pressure (inches of water)
- Acoustic limits
- Type of air mover (Tubeaxial vs Impeller)
- Positive or negative pressure (intake vs. exhaust or a combination of both)
- Power source (AC vs. DC)
- Air filtration
- Variable speed air movers
- EMC

Fans or blowers give their performance as a function of static pressure. (See typical fan curve) A good rule of thumb is to select a model that will perform at > 60% of its "free air" maximum, based on estimated static pressure. To reduce pressure losses in a system the designer needs to limit the number of bends in the airflow path and maximize the intake and exhaust openings. Use of honeycomb filter for EMC allows > 90% airflow opening but is more expensive than simple perforations. Most systems require the use of an air filter to protect electronics, but this is an additional hindrance to the airflow. The db (acoustic) must also be considered, although this will be in conflict with maximizing airflow. To reduce noise variable speed temperature regulated fans can be employed. To increase the maintainability of the system tachometer output fans to monitor fan fail conditions can be used.

Some Dos and Don'ts

- Avoid radical bends in air flow path
- Objects in the air inlet area should be located more than ½ the fan diameter
- Air flow cutout on fan mounting plate should be larger than inlet diameter of fan
- Minimize air leakage in fan mounting area
- Minimize restrictions in airflow path & route cables/wires appropriately.
- Employ air baffles, plenums to optimize air flow and eliminate hotspots

A useful tool available to the designer is thermal simulation software. This software enables the designer to input all of the variables into a program to verify that the cooling for the system is adequate prior to fabrication. Better yet, if time and budget allow, building and testing a thermal "mock up" unit will give the best evidence that the goals have been achieved.

Electromagnetic compatibility (EMC): Simply put, it is the packaging designers responsibility to ensure that the system does not interfere with, and is not susceptible to electrical interference from other electronics equipment. The goal should be to enhance the shielding effectiveness (db) of the enclosure. Shielding effectiveness (db) is a measure of the degree of attenuation that an enclosure provides. In order to ensure equipment compatibility in the market many agency and standards must be complied with such as: FCC (class A, B), CISPR class B, CE, NEBS (L3) and MIL-STD-461, depending on the application environment.

Design for EMC should focus on suppression, isolation and desensitization. To control electromagnetic interference (EMI) the shielding for EMC must address both immunity and emissions (conducted & radiated). A list of good design practices is given below.

EMC Design Guidelines

- Select optimum metal thickness and specify a compatible conductive plating or surface finish
- Integrate high performance EMI gaskets (low ¿), EMI contact points, spring fingers etc on all seams to ensure a continuous ground (conductive) path
- Design enclosure with overlapping seams and bends for the access covers and panels etc
- Provide wave-guides for large openings like disk drives etc.
- Use good wiring practices: minimizing the length of Ground wires, routing AC wires away from DC and provide adequate ground points
- Use high performance line filters for suppression of conducted EMI
- Use power supplies that meet or exceed FCC class B, CISPR class B etc
- Use shielded cables and connectors for I/O cabling. This is critical in preventing antenna effect. Ferrite beads are proven in mitigating EMI
- Incorporate EMC compliant components into system configuration like switches, LEDs, fuses, fans etc

- Provide optimum aperture size (based on offending frequency and wavelength) for air intake and exit openings. Military applications will mandate the use of honeycomb EMC filters

The guiding principle for maximum aperture size is 1/50?. Because electromagnetic waves travel at the speed of light (3 x 10*8 m/s) wavelength is given by: Wavelength, ?(cms) = (3 x 10*4)/ f, where f is the frequency in MHz. As an example; for f=1Ghz, the maximum aperture should not exceed 6mm.

The goal is to create ground continuity over the outer skin of the enclosure and to block given wavelengths from passing through any openings. As this list of guidelines suggests, to ensure compliance a wide range of issues must be considered. These include: material type and thickness, conductive plating, vent hole size, seam length, gasketing, power filtering, access panels and AC cable routing. The primary focus of the design should be to use conductive material, limit the number and size of openings and eliminating seams to the extent possible. Achieving these objectives, however, is often in conflict with cooling, maintainability and cost.

The challenges of the electronic packaging engineer are many. In an effort to maximize cooling he may jeopardize EMI integrity. The needs of maintainability may conflict with marketing's need for the unit to meet a specific size footprint. It is how the designer balances these trade offs and makes critical choices to optimize the final solution that separates an adequate design from a superior solution.