PCB layout tips for thermal vias

Paul Rako - September 17, 2013

I came across an article on PCB layout in Electronic Design magazine. It’s a pretty good article and I am glad to see the trade magazines realize we care as much about PCB layout as the bus-caching architecture of some DSP chip. The article talks about using vias to take heat away from the die-attach-paddle (DAP) of integrated circuits:

“To reduce operating temperatures easily, use more layers of solid ground or power planes connected directly to heat sources with multiple vias. Establishing effective heat and high-current routes will optimize heat transfer by means of convection. The use of thermally conductive planes to spread the heat evenly dramatically lowers the temperature by maximizing the area used for heat transfer to the atmosphere.”

Know there is a lot of caution you need to exercise when trying to get the heat out of a part just using a circuit board. You have to realize the guidelines in the datasheet are usually based on one part making heat, sitting on a standard board of certain dimensions. If you have a lot of hot components you can’t expect the same die temperatures for the part in question. Same goes if you have the board covered with some tight enclosure.

Texas Instruments' WEBENCH is a neat program, especially because it has Mentor Graphic’s FloTherm built in to help you see the hot spots in switching regulators. This is what taught me that a modern buck regulator will have more heat coming out of the catch diode than the pass FET. It made perfect sense once I saw the heat diagram. After all, a diode has 0.6 to 0.9V across it, while a modern FET has such low on-resistance it hardly drops any voltage at all.
WEBENCH can estimate thermal performance of a switching regulator, but it is just an estimate, highly dependent on your particular layout and application. Note the buck regulator catch diode is the hottest thing on the board, and how little heat is radiated out the bottom, despite the thermal vias.

But realize a simulation is just that, for both electrical and thermal designs. You have to rely on my brother’s maxim from Bell Labs: “An ounce of trial is worth a pound of opinion.” And any simulation is just that, a computer’s opinion on what your circuit will do. So I and several pals have learned a few things with real-world experience. One is that vias rarely work as well as you need them to. The first problem is that the amount of copper in the “barrel” is dependent on the circuit board fabricator. Thin plating means low heat transfer.

Here is a nice side-view of some thermal vias in a PCB. Note the thicker copper on the top and bottom helps to dissipate the heat, and the bigger the area, the better.

The best thing is to fill the vias, which really gets the heat out, but is an extra-cost option. Other than that, plan on a lot of vias under the part. The article excerpt above talks about using inner layers to get heat out, but in my experience that has limited usefulness. Do top-side and bottom-side copper pours. If you can get several square inches, that is great, but if you have a top-side pour, which you should, and a bottom-side pour, well there is not a lot of heat that can radiate from the inner layers unless you can dump heat into an entire ground plane. Remember you have to stop the CAD program from putting thermal reliefs in all the vias. And realize that without thermal reliefs, to de-solder the part you will need a Metcal hot-air rework station or a Hakko hot air gun, (or two). You will need a good iron to solder the part as well, and you have to tell the assembly house that they
may have to modify the thermal profiles of their IR reflow ovens so that the parts get soldered correctly.

As far as heat transfer to the atmosphere, it’s something like 100 times worse than getting the heat out of the leadframe. Even if the part does not have a die-attach paddle, you can figure out what pins are connected to the substrate of the die and make sure those pins have a lot of copper area. All the same tricks apply, you can pour topside copper from the pin and be sure to pave over any thermal reliefs the CAD program puts around the pin pad. Vias down through the board to copper pours on the bottom side will get more heat out. Raw copper, or copper with nickel or gold will dissipate more heat than copper covered with soldermask.

I sent the article to my pal Wayne Yamaguchi, who has worked on getting the heat out of LED flashlights for a decade. He learned that not all “rules of thumb” you read in datasheets will accurately forecast the heat you can dissipate into a circuit board. Regarding the article, Yamaguchi wisely notes: “Everything said is correct, but, practically speaking and implementing is something else.” Wayne then sent a link to a thermal calculator for vias that he likes. Wayne notes: “Playing with the via calculator you can determine that FR4 is some pretty awful stuff and also you will find out that 1 oz copper foil is not a good thermal conductor.” He notes the same site has some other great tools and also pointed me to a Cree technical article (pdf) about thermal vias for high-power LEDs.

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