



Summary

Thermal resistance of SynQor DC-DC power converters for open-frame and baseplated or encased units is described.

Baseplated and encased converters have a consistent thermal resistance from case to ambient because they are essentially all at the same temperature. Open-frame converters have a wider variability of device temperatures and multiple components that are heat dissipaters, so a thermal resistance is not as meaningful, although one can be calculated.

Definition

Thermal resistance (Θ) is defined as the ratio of temperature rise along a thermal path to the heat flowing in that same path. It is described with the limits of the path length; for example junction-to-case (Θ_{j-c}) or junction-to-ambient (Θ_{j-a}) in a semiconductor device. In a monolithic semiconductor device, all the heat is dissipated at one point (the semiconductor chip), which is at the same temperature. Heat flows from that point to the package (or case) and then to the environment (or ambient), and that ratio of temperature drop to heat generated is the thermal resistance junction-to-case or junction-to-ambient.

Open-Frame Converter

In an open-frame power converter, there is not a single thermal path from a single dissipation source to the ambient environment, so the concept of thermal resistance cannot be correctly applied. An open-frame converter has multiple components at many temperatures, all conducting some of their heat to the PCB and some directly into the air stream from their packages. It could be described as multiple Θ_{c-a} paths all mixed together.

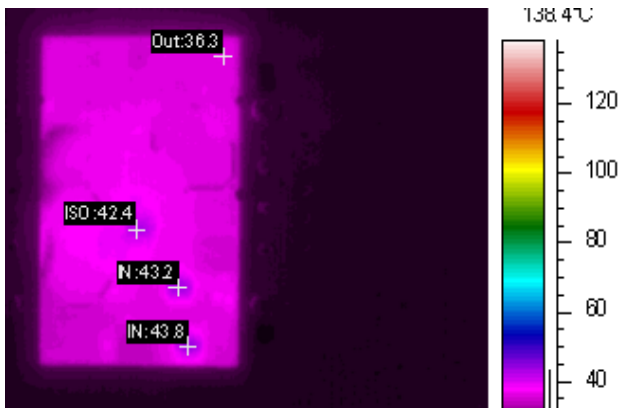
Furthermore, the power dissipated in any component as well as the proportion of the total module dissipation varies as the operating condition changes. For example, when input voltage is high, proportionally more power may be dissipated in the input section of the converter, but at low input voltage, less is dissipated in the input, so the input stage dissipation is then a smaller proportion of the total module dissipation and some other section is more dominant. The same can be said for load current levels. At light load, dissipation in magnetic cores may dominate the total dissipation and at high load, switching FETs would be greater.

Baseplated or Encased Converter

With a baseplated or encased SynQor converter, device temperatures are much more consistent because the thermally conductive encapsulant keeps device temperatures within a small range. The whole converter then appears to be the same temperature, and there is a single temperature drop between the baseplate and the ambient. In this case, a thermal resistance case-to-ambient (Θ_{c-a}) does make sense. Typically, converters of the same physical size will have very similar or identical Θ_{c-a} for a given air flow rate.

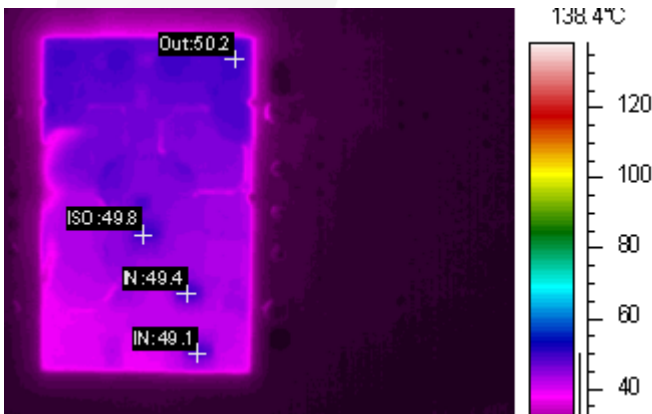
Examples

In Figure 1, a converter is operated at low input line voltage at full load with low ambient and the hottest devices are the isolation FETs.



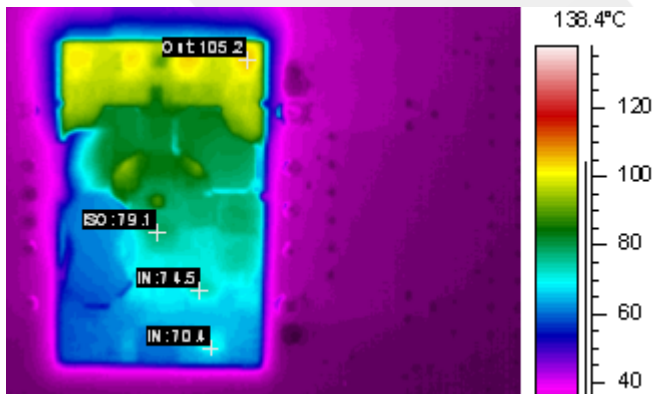
25% Load
Input FET hottest by 7°C margin

Figure 1: Thermal image of low-load operation of open-frame PQ60015QGA40 operated at 25°C and 25% load.



50% Load
Output FET hottest by 1°C margin

Figure 2: Thermal image of same converter at 50% load



100% Load
Output FETs are the hottest by 26°C

Figure 3: Thermal image of same converter at 100% load

In Figure 1, 2 and 3, the thermal image shows that the hottest component will vary from one operating point to another. In this case, all conditions are the same except for the load current. The hottest component, the one presumably used for calculating the thermal resistance, varies with the operating point, and by a sizeable temperature difference.

Open-frame converters derive much of their advantage from spreading the power dissipation over many components that are physically distributed around the converter PCB. Different components dissipate differing amounts of power depending on the operating points of line and load. So, the concept of a single thermal impedance cannot be properly applied since the heat doesn't come from a single source to the surrounding ambient air for an open-frame device.

Baseplated vs Open-Frame Converter Comparison Example

In the following two examples, the same model converter at the same operating point and under the same cooling conditions is imaged with both an open-frame model (Figure 4) and a baseplated model (Figure 5). You can see that the thermal behavior is very different and also that the baseplated design achieves a single temperature for the whole surface.

This illustrates that the open-frame converter can't be correctly characterized by a single thermal resistance parameter.

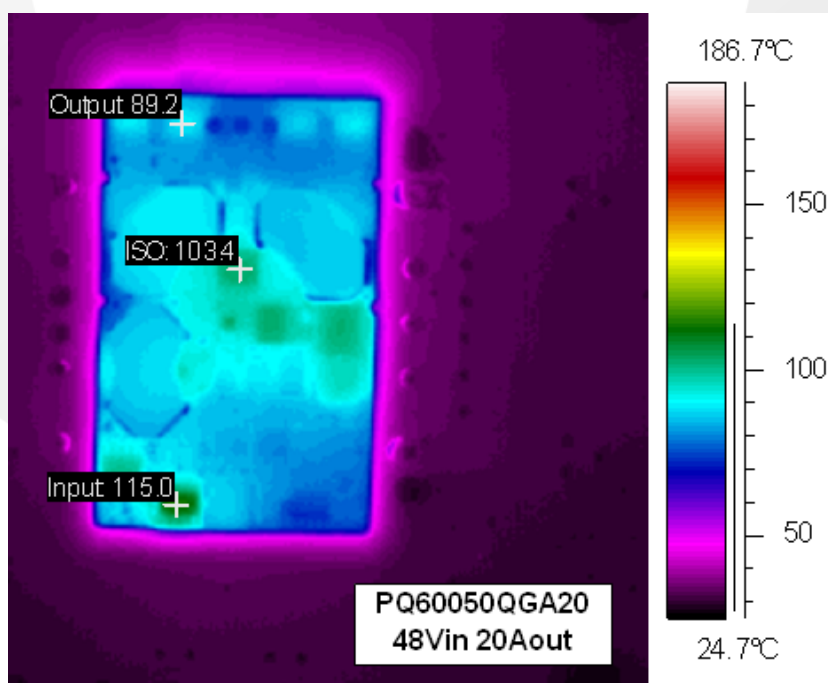


Figure 4: Open-frame converter operating at full load in 25°C ambient and 200lfm air flow

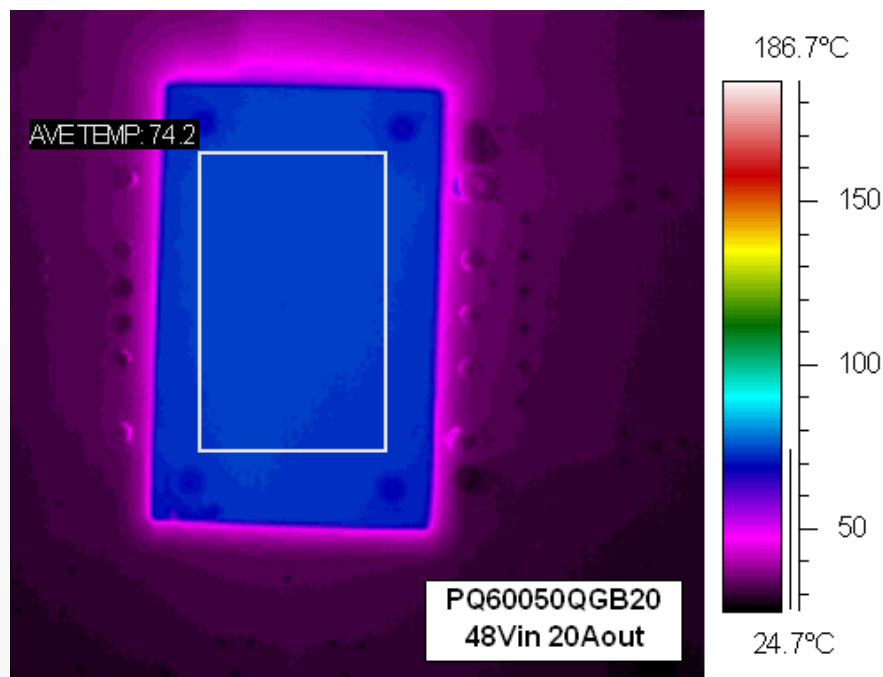


Figure 5: Same product as in Figure 4, operating at same conditions, but a baseplated model.

In this example, a thermal resistance can be applied, because there is a single temperature at the baseplate. Since the dissipated power is $\sim 13\text{W}$ and the baseplate/module temperature is 74°C with a 25°C ambient, the Θ_{c-a} of this example is $49^\circ\text{C}/13\text{W} = 3.8^\circ\text{C}/\text{W}$ at this air flow rate of 200lfm . Higher air flow rates would yield a lower temperature rise and a lower Θ_{c-a} .

Conclusion

The use of a single thermal resistance parameter for an open-frame converter is not valid because temperatures are not sufficiently uniform amongst the heat-dissipating components, and the hottest component is something that is not uniform between various operating points of line and load. For encased converters, a single thermal resistance number from case to ambient is valid because the baseplate has a consistent temperature.