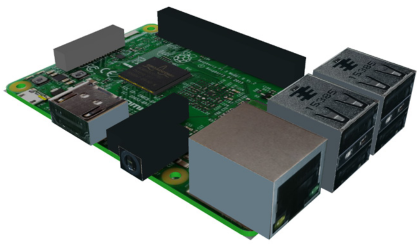
Thermal Management of the Raspberry Pi 3

6SigmaET by Future Facilities

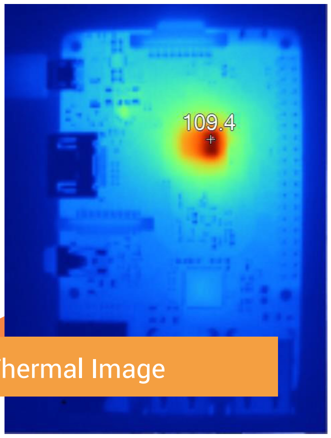
Introduction

Soon after the launch of the Raspberry Pi 3 in February 2016 users started reporting overheating issues with the new version. Users on forums such as Reddit highlighted that the new processor on the Pi 3 gets very hot when operating at full CPU load. As a result, the 6SigmaET team decided to investigate these reports through thermal simulation and measurements to provide some insight and advice on the best cooling strategies for users planning to operate the Pi 3 at maximum capacity. Based on the available information, we created a simulated model of the Pi 3 and analyzed the component temperatures in various conditions. The simulation was then calibrated against measurements from a thermal image camera and sensors.



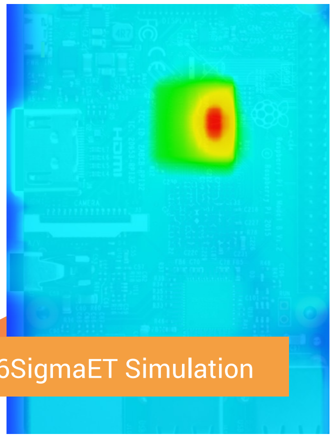
The Raspberry Pi 3

Simulation and Measurement of the Raspberry Pi 3



Thermal Image

The simulation and measurements both showed that the CPU runs very hot at ~110ºC. The component continues to operate at this temperature, but because the component is operating over 85ºC it is likely to impact the part's longevity if run constantly in these conditions.



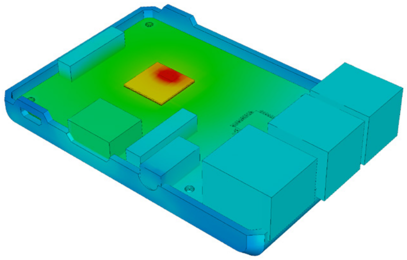
6SigmaET Simulation

Through simulation we were also able to test how the device would operate at an ambient temperature of 45ºC. At this temperature the processor was predicted to reach 132ºC in operation, so it is highly unlikely that the Pi 3 would operate at full load under these conditions.

Raspberry Pi 3 in a Standard Case

Next we put the Pi 3 in a standard, small form factor plastic case at an ambient temperature of 22ºC. Our simulation predicted the processor will operate at over 120ºC when the case is fitted. This is too high for prolonged use.

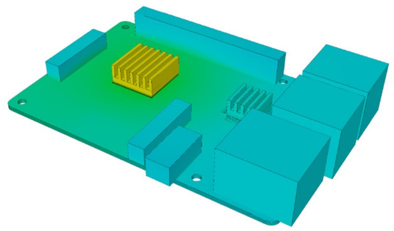
At the higher ambient temperature of 45ºC we predict the processor component temperature will reach about 140ºC - far too high for the processor to operate correctly. We then used the simulation model to investigate the optimum strategy for reducing the processor's temperature.



The Raspberry Pi 3 enclosed in a plastic case at ambient temperature of 22ºC

Adding a Heat Sink

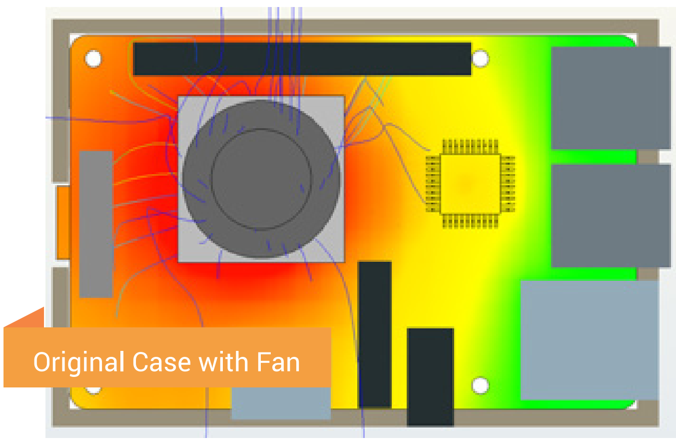
By adding a heat sink to the Pi 3, we can no longer use thermal imaging to analyze component temperatures, which makes simluation essential to predicting thermal activity. With a heat sink at ambient temperature and without a case, our simulation showed that the processor would operate at 80ºC (almost 30ºC cooler than without the heat sink). This also means the Pi 3 would be able to operate at full load, for at least short periods of time, at up to 55ºC ambient temperature. With a case the processor with heat sink operates at 92ºC, much lower than the 123ºC without the heat sink.

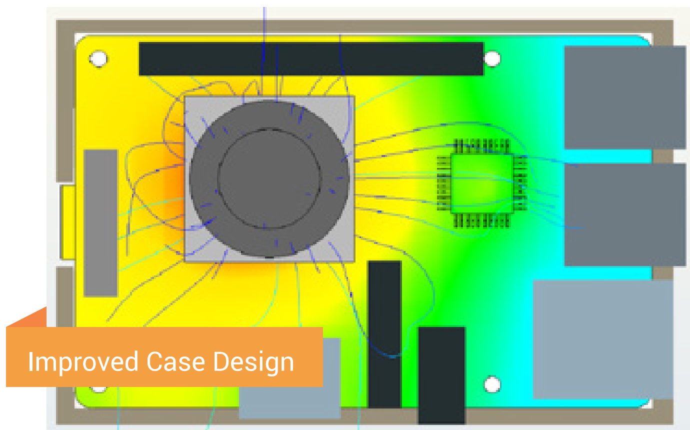


6SigmaET thermal simulation of Raspberry Pi 3 with heat sink

Is a Fan Useful?

We selected a different Raspberry Pi case, which included a fan. The fan was run off the 5V supply from the Raspberry Pi. Adding the fan only reduced the process by about 4ºC. This meant it did not enable the Raspberry Pi to be used at high temperature at full load. We even tried experimenting with case design changes by adding additional vents to improve the airflow with the fan. This did improve the cooling of the device but only by a few degrees so the fan was still not as effective as adding a heat sink.





Conclusion: Operating at Full Load? Use a Heat Sink

Our investigation confirmed that there is an overheating problem with the Raspberry Pi 3 when being used at full CPU load. In terms of dealing with this issue a heat sink is clearly the optimal route, providing far better cooling than the more complex option of adding a fan. Ultimately, this experiment highlights how thermal simulation can enable better engineering decisions. Simulation can predict thermal issues and identify problems at a range of environmental conditions, allowing engineers to build and test multiple product simulations for a fraction of the cost of developing a real-world prototype.

6SigmaET, a computational fluid dynamics (CFD) simulation tool, brings new levels of productivity to electronics cooling design. Thanks to its ease-of-use, it overcomes many of the problems that have plagued analysis tools from the beginning. Boasting substantial automation and intelligence, 6SigmaET is already being used by a global community of design engineers.