

Heatsink Testing

October 17th, 2017

Introduction

The Rubicon by OpenH is a weatherproof enclosure designed specifically for the Raspberry Pi platform. While most IP67 rated enclosures are great for outdoor or extreme environment applications, the potential disadvantage to these designs is that there is no way to dissipate heat, which can be disastrous for an electronics project. This is exactly why, amongst multiple other reasons, the Rubicon has an aluminum base plate. By having an entire face of the enclosure made of a high thermal conductivity material, the waste heat from the internal electronics can be directed to this face, and ultimately rejected to its surroundings.

The purpose of this test was to compare the performance of a quad-core Raspberry pi when mounted inside the Rubicon enclosure with and without a heatsink accessory. The heatsink accessory kit provides the hardware necessary to mount the Raspberry Pi such that its processor is thermally tied to the base plate with a copper riser. This should, in theory, allow the heat to flow directly from the processor to the base plate of the Rubicon, and then out to ambient. Tests were performed both indoors and outdoors, with assumed nominal and maximum thermal load scenarios.



(data logger top row no heat sink: plate temperature, internal air temperature; bottom row heatsink: plate temperature, internal air temperature)

Test Methods

First and foremost, we needed to get the Pi producing its maximum heat load. According to Christopher Stanton, who provided an excellent [writeup](#) on benchmarking the Raspberry Pi 3, “SysBench’s processor tests verify prime numbers by going through all possible divisions and only being satisfied when the result is zero.” Using sysbench allowed us to utilize all four cores of the Pi’s processor for an extended period of time, which produced a sustained heat load that pushed the Pi to thermal extremes. Sysbench can be installed using:

```
sudo apt-get install sysbench
```

And to get sysbench to utilize all 4 cores run:

```
sysbench --num-threads=4 --test=cpu --cpu-max-prime=100000 run
```

Next, we wrote a script to collect the self-reported CPU temperature, CPU speed, and time:

```
#!/bin/bash
echo "date, cpu temperature, cpu speed" > /home/pi/mycustomlog.txt
while :
do
cput=$(cat /sys/class/thermal/thermal_zone0/temp)
speed=$(cat /sys/devices/system/cpu/cpu0/cpufreq/scaling_cur_freq)
now=$(date +"%T")
echo "$now,$((cput/1000)),$((speed/1000))" | tee -a /home/pi/mycustomlog.txt
sleep 1
done
```

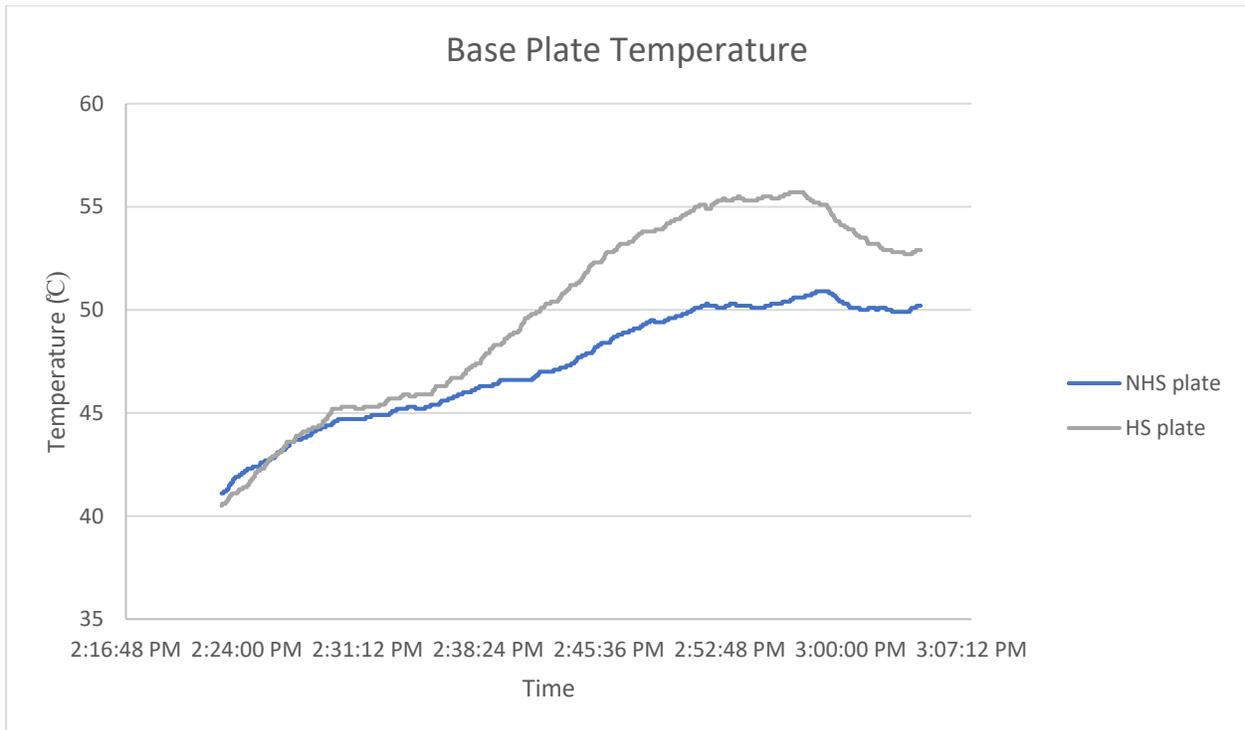
This script dumps the data into a file named mycustomlog.txt, which can be later lined up with the temperature logger’s data and plotted.

Next, the temperatures of the base plate and internal air needed to be recorded. Using an AZ Instruments 4 channel temperature logger (model 88598), we were able to monitor and record these temperatures to a SD card. Holes were drilled through the side of the Rubicon, and one thermocouple was attached to the base plate using aluminized tape, while the other was bent such that it was not in contact with any surface and could measure the internal air temperature. This operation was performed on both Rubicons with and without the heatsink. A hole in each Rubicon was also drilled to provide a power cable for the Pis. All holes were sealed with silicone caulking to prevent air leakage.

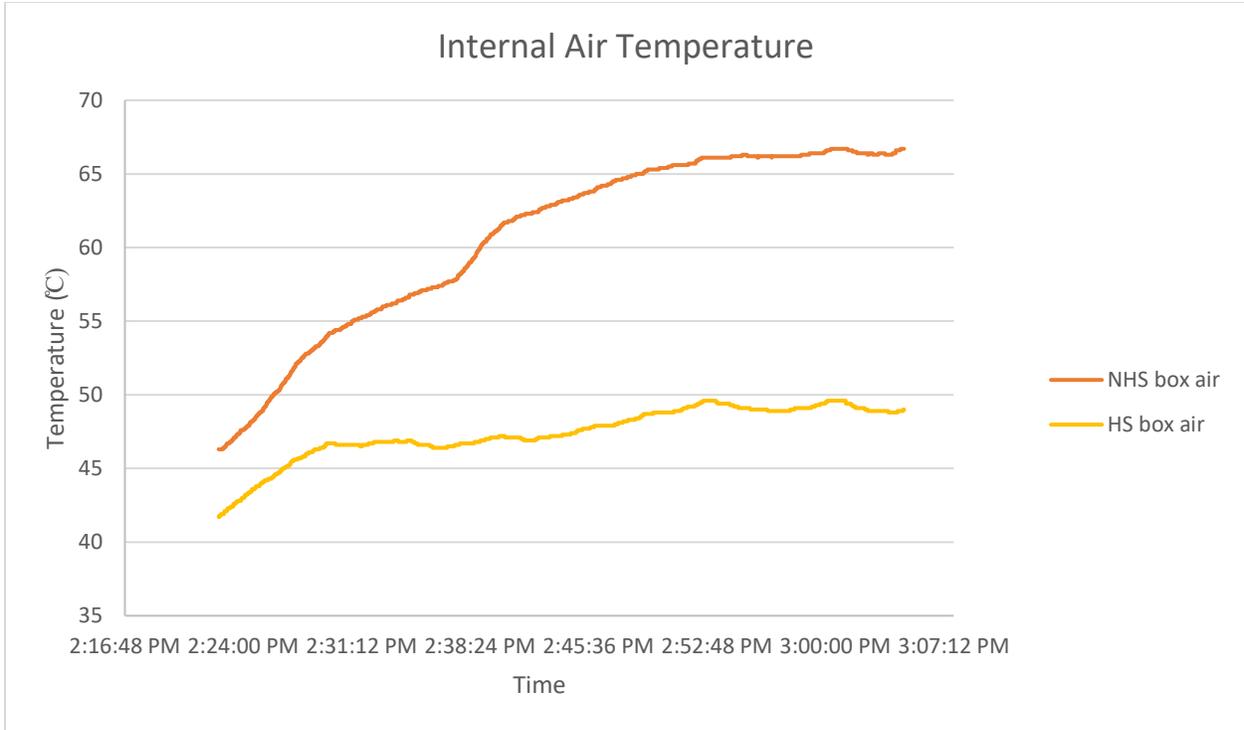
The test Rubicons were placed side-by-side on a table on their edges such that the base plate was not fully contacted by the table (see test setup picture). The temperature logger was set to record and then the Pis were powered up and allowed to reach steady-state operating temperatures. Finally, the sysbench command was issued and the recording script executed.

Results

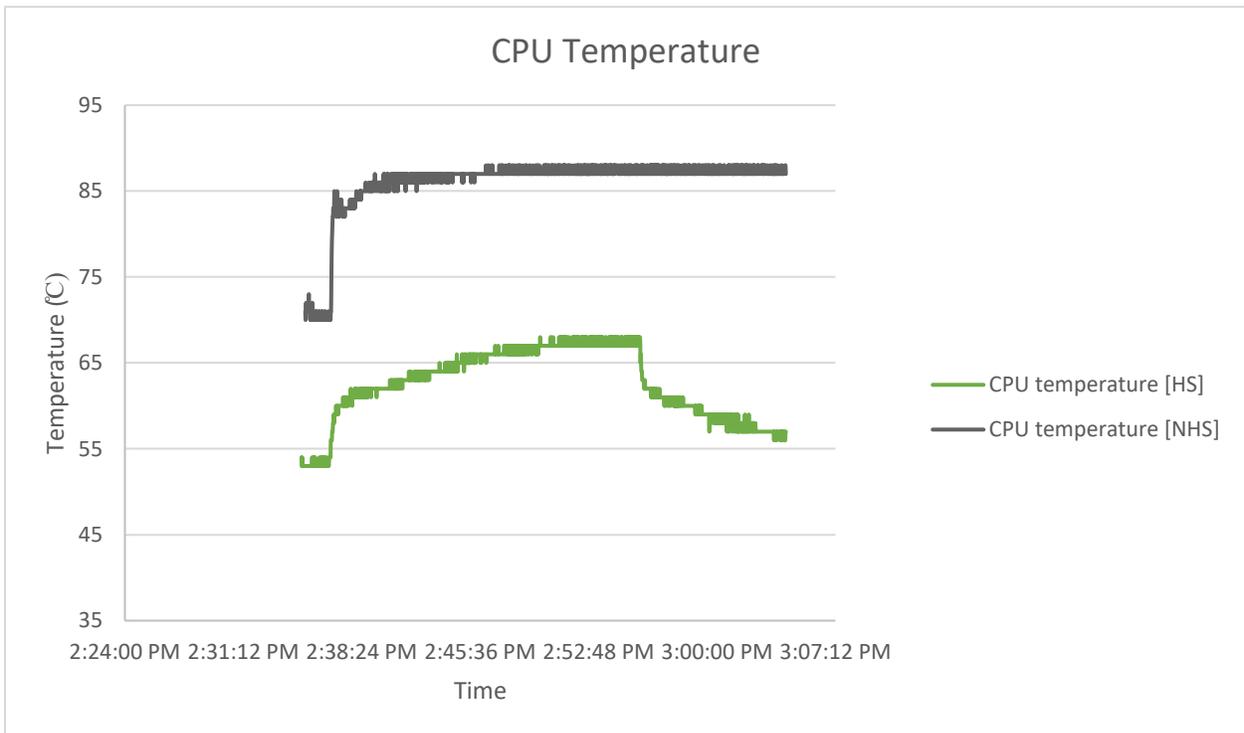
The Rubicons were sitting in the sun, so the ambient temperature was recorded using a bare type-K thermocouple sitting in the sun. It registered 34.9°C and is generally assumed the ambient conditions did not significantly fluctuate over the 45 minutes of testing. Wind speeds were under 5 mph and there were no consistent gusts, so it is assumed the heat dissipated from the base plate is dominated by natural convection. The Rubicons were at no point in the shade. The following plots compare results between the Rubicon with a heatsink (HS) and the Rubicon without a heatsink (NHS).



Clearly, the base plate with the heatsink is being heated by the thermal connection to the Pi, as originally intended.



The air temperature inside of the Rubicon without the heatsink is much higher than the one with a heatsink. This increase in temperature can significantly affect any other electronics inside of the box.



The CPU temperature is lowered by approximately 20°C with the use of a heatsink. Also, the transient response is much better, showing that for small spikes in CPU usage, the heatsink provides an even higher temperature difference. The significant drop-off in temperature with the heatsink at the end of the test is due to the fact the CPU did not need to throttle its clock speed, showing just how much of a performance gain the heatsink provides. Both CPUs were performing the same tasks, but the Pi with a heatsink could perform at full speed because of the heatsink, thus completing the task much quicker.

Conclusions

The heatsink reduced the processor temperatures by over 20° C thus showing that the heatsink functioned as intended, by moving the heat from the processor to the base plate, and ultimately to ambient. Even in direct sunlight, with ambient temperatures at 34.9°C, the Raspberry Pi was able to run at full load for over 20 minutes without needing to throttle, specifically because of the addition of the heatsink. The original design intent, using a metallic base plate, has been proven to be effective in heat rejection, making the Rubicon a superior choice for applications that require a weatherproof and dustproof enclosure.

Summary

- Compared two sealed Rubicons, one with heatsink and one without, each with Raspberry Pi 3
- Ran sysbench and used custom script to collect data on each Pi
- Measured ambient air temperature, internal air temperature, base plate temperature, and CPU temperature for each Rubicon
- The heatsink reduced the processor temperatures by over 20° C
- The heatsink functioned as intended, by moving the heat from the processor to the base plate, and ultimately to ambient