

Efficiency assessment of the Morpheus Razzmatazz case

Abstract

It is common practice to overclock the Raspberry Pi board in order to gain more performance. This operation has two main drawbacks: instability and overheating of the electronic components. In this report we tested the performance of the Morpheus Razzmatazz enclosure, an all-aluminium Raspberry Pi case designed to work as a passive heatsink for controlling the CPU and the chipset temperatures. The results show the Morpheus Razzmatazz enclosure significantly lowers the operating temperature, even under continuous computational stress.

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1. Introduction

In this experiment we tested the ability of the Morpheus Razzmatazz to dissipate heat from a Raspberry Pi 2 model B board.

The Razzmatazz is an enclosure for Raspberry Pi model B developed by MorpheusAV. (<http://www.morpheusav.com/>). Its primary function is dissipating heat from the the CPU and the chipset. This task is accomplished via the direct contact of the CPU and the chipset with the case.



Fig. 1. The Razzmatazz case is a Raspberry Pi enclosure made from a single aluminium block.

The case is milled from a single block of aluminum using the CNC process. The product is designed to maximize surface area for efficient heat dissipation with openings that keep the ports easily accessible from the outside. The case bottom

uses screws to tightly hold the Pi board in place and firmly secure the board against the built-in heat transfer sinks.

The tests presented in this paper were conducted to assess the Morpheus Razzmatazz's effectiveness in heat dissipation. Two test systems were setup with identical operating systems, stress parameters and overall conditions. We tested the Raspberry Pi boards under an extreme heavy computational load. The first test was made under nominal conditions, all the subsequent tests were made under overloaded conditions (overclocking and overvolting enabled). Please note that if this experiment is repeated independently, overclocking and overvolting the Raspberry Pi CPU will void the warranty of the product.

The report is arranged as follows. The first section introduces the device and the tests performed. The second section introduces the Raspberry Pi board, reasons for overclocking it, and how the Razzmatazz can increase its performance. The third section presents the initial setup for testing the Razzmatazz and the results. The fourth section shows the obtained results. In the last section five, the results are summarized.

2. The Morpheus Razzmatazz case

The Raspberry Pi is a “low cost, credit-card sized computer” [1]. In particular the model B, second generation is designed for didactical purposes. (technical specifications available at: <https://www.raspberrypi.org/products/raspberry-pi-2-model-b/>).

It is easy to push the performance of the Raspberry Pi over its nominal settings allowing the Raspberry Pi to be pushed to the brinks of its limits. Setting the performance above the nominal functioning is called Overclocking and Overvolting. Overclocking is the process of forcing a computer or hardware component to operate faster than the manufacturer-specified clock frequency. Overvolting provides the board with the electric power needed to achieve the overclocking. The warranty of the product is voided if the Overvolting goes over 1.375 V. Working with an overclocked device affects the operating temperature of the CPU and the chipset.

High temperatures may reduce the device lifetime. Hence, a heat sink can control the CPU temperature and safeguard the device from reducing its lifetime. With the Raspberry Pi encased in the Morpheus Razzmatazz, the overall temperature of the Raspberry Pi is decreased significantly allowing for a substantial increase in performance while maintaining a reasonable operating temperature.

3. Case setup

The presented tests assess the ability of the Raspberry Pi 2 model B to dissipate heat under a heavy computational load in two different configurations. The first configuration is without a heat sink, the second one is with the Morpheus Razzmatazz case with the built-in heatsink. The measurement parameter that we evaluated is the temperature of the CPU. We measured the CPU surface temperature using external sensors and calibrated measuring devices and the inner temperature by the built-in sensor. We measured the chipset temperature only for the case without the heat sink.

Two identical Raspberry Pi 2 model B were used for the test. The first one was tested without an enclosure. The second one was tested with the passive heat sink Razzmatazz as an enclosure.

The surface temperatures were calculated with the aid of both a calibrated infrared thermometer and a contact thermometer. They are shown in Fig. 2 and Fig. 3.



Fig. 2. Thermometer By Comark: a Fluke Company



Fig. 3. Embedded digital thermometer XH-B302

In the Fig.4 the initial setup is shown. The two tested boards are connected with the input devices (mouse and keyboard) and the output device (monitor).

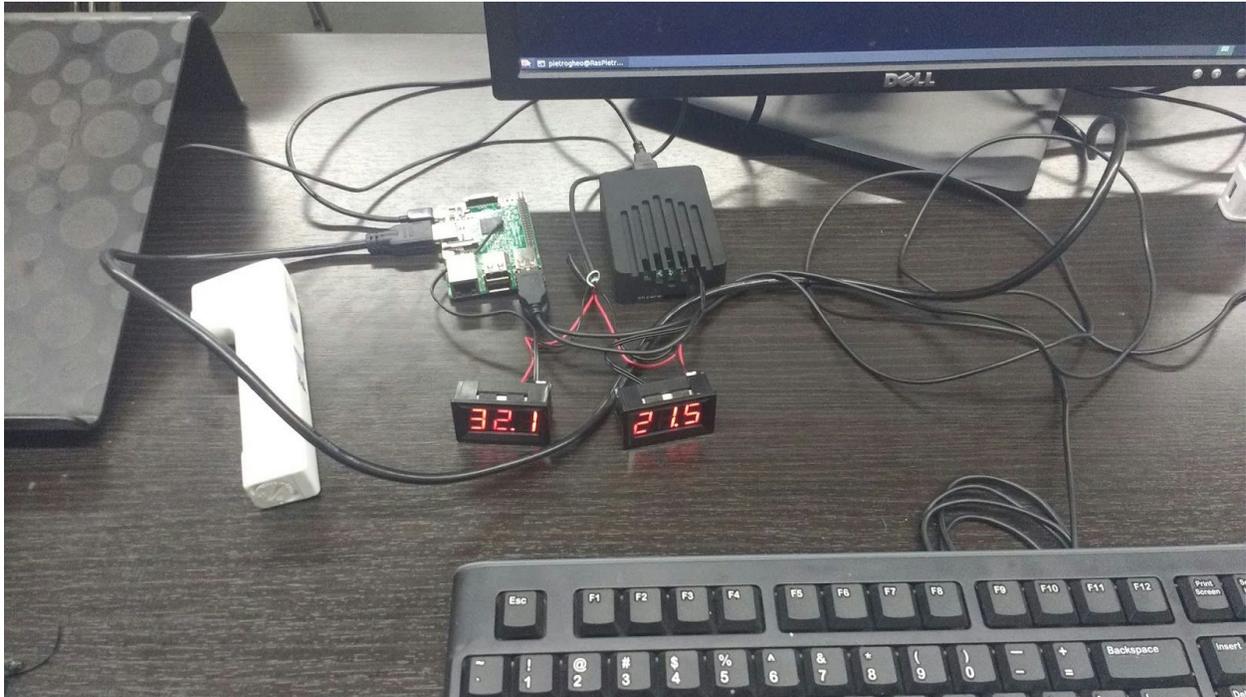


Fig. 4. The initial setup is presented. On the left, the board without the Razzmatazz enclosure, on the right, the board provided with the Razzmatazz enclosure. The temperatures displayed are at idle functioning.

We prepared our boards with Ubuntu MATE, release 15.10 [4]. Ubuntu MATE provides an easy way to overclock the Raspberry Pi. That can be done modifying the `/boot/config.txt` file. The chosen settings for the tests are available in the attached support documentation. The software employed for loading the CPU is Stress. It is a free software available for POSIX systems [3]. We checked the CPU usage during the experiments with the top linux command. For every test that we ran the average CPU usage was 100%.

The measurements of the cpu core temperature via the built-in sensor were read using the following command:

```
/opt/vc/bin/vcgencmd measure_temp
```

The following procedure has been applied for every test case we ran:

1. bringing the temperature to equilibrium with the surrounding environment (steady state);
2. temperature measurement;
3. running the stress test;
4. temperature measurement.

The temperature measurements were sampled via an infrared thermometer and a contact thermometer every two minutes during the experiments. The core temperatures were sampled right before the beginning of the test and at the end.

The nominal CPU clock frequency is 700 MHz. With the turbo mode enabled it can be brought up to 1000 MHz. For the last two tests we then increased the CPU frequency to 1100MHz.

4. Tests results

In this section we present the tests results. We monitored the change in temperature during the experiments. The complete list of results is provided in the support documentation.

We used the following physical quantities:

Nominal operating temperature. It is the core temperature calculated right before the beginning of the test when the system is in steady state.

Average temperature increase at 2 min intervals.

$$T_{var} = \frac{T_{core}[t_0] - T_{core}[t_f]}{\text{numbers of intervals}}$$

where T_{core} is the temperature of the CPU core measured by the built-in sensor, t_0 is the initial time of the experiment and t_f is the final time of the experiment.

Final Temperature after stress test. It is the core temperature calculated right after the end of the test.

We overclocked the board up to a CPU frequency of 1100 MHz ([Test 4](#)). For this clock speed it was necessary to drop the sdram frequency down to 450 MHz since we observed stability issues during the boot and idle states.

The ambient temperature in our experiments was not kept constant. During the night there is a considerable diminishing of the ambient temperature ($\sim 10^\circ\text{C}$). This phenomenon did not affect the short-time experiments (up to two hours), but it may be affected the long-time experiments (12 hrs, 24 hrs tests).

Test 1

The test we ran was:

```
stress -c 5000 -i 1 -t 20m
```

RAZZMATAZZ EFFICIENCY ASSESSMENT

where the c flag spawns 5000 workers spinning on sqrt(), the i flag spawns 1 worker spinning on sync() and t is the time in minutes.

Test 1 parameters:

Test time: 20 minutes

Overclock enabled: No

CPU Frequency: 700 MHz

Ambient room temperature: 23.5°C

Config file: Unchanged from the default configuration of Ubuntu MATE 15.10

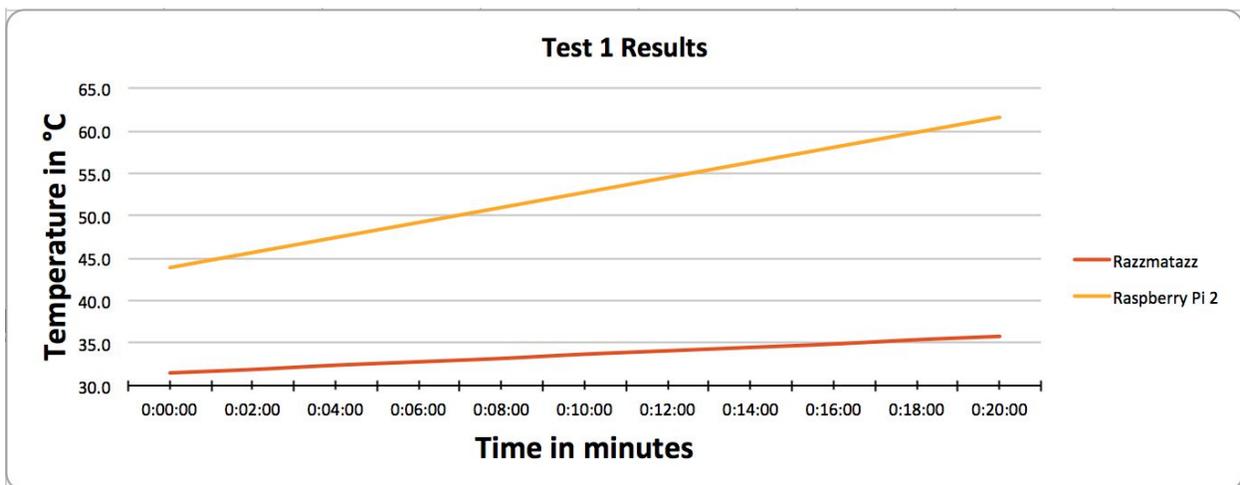
Test 1 results:

	Raspberry Pi 2	Razzmatazz
Idle operating temperature:	43.9°C	31.5°C
Average temperature increase at 2 min intervals:	1.77°C	0.43°C
Final Temperature after stress test:	61.6°C	35.8°C

Comparison results for test 1:

Idle operating temperatures difference: 12.4°C

Final Temperature difference after stress test: 25.8°C



Graph 1. Comparison between the Raspberry Pi with Razzmatazz board and without Razzmatazz board.

Test 2 (Overclocked)

The test we ran was:

RAZZMATAZZ EFFICIENCY ASSESSMENT

```
stress -c 5000 -i 1 -t 20m
```

where the c flag spawns 5000 workers spinning on sqrt(), the i flag spawns 1 worker spinning on sync() and t is the time in minutes.

Test 2 parameters:

Test time: 20 minutes

Overclock enabled: Yes

CPU Frequency: 1000 MHz

Ambient room temperature: 23.5°C

Config.txt file: force_turbo=1; temp_limit=85; arm_freq=1000; arm_freq_min=1000; core_freq=500; core_freq_min=500; sdram_freq=500; sdram_freq_min=500; over_voltage=6; over_voltage_min=6

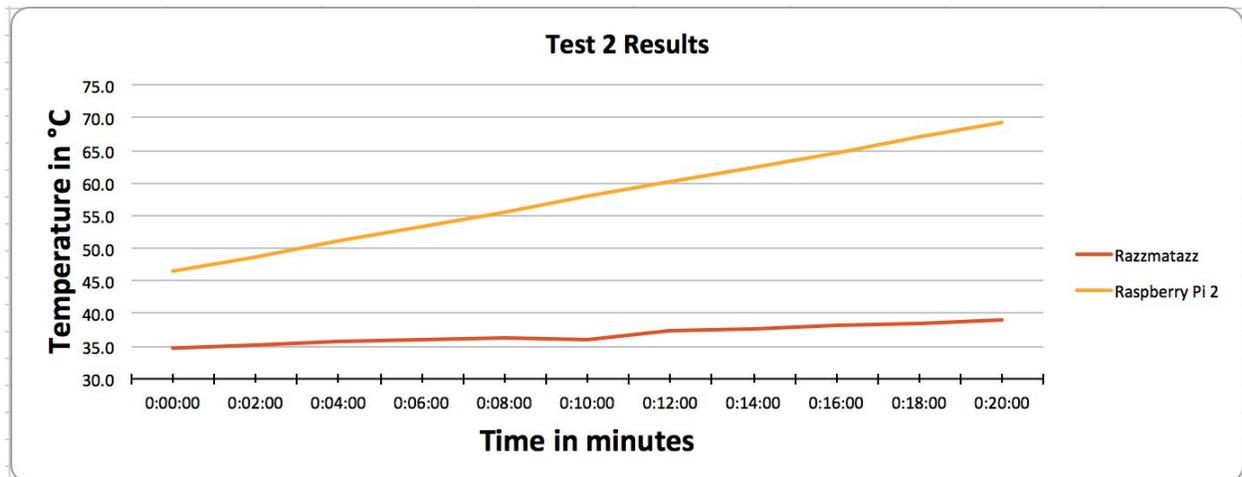
Test 2 results:

	Raspberry Pi 2	Razzmatazz
Idle operating temperature:	46.5°C	34.7°C
Average temperature increase at 2 min intervals:	2.28°C	0.43°C
Final Temperature after stress test:	69.9°C	39.0°C

Comparison results for test 2:

Idle operating temperatures difference: 11.8°C

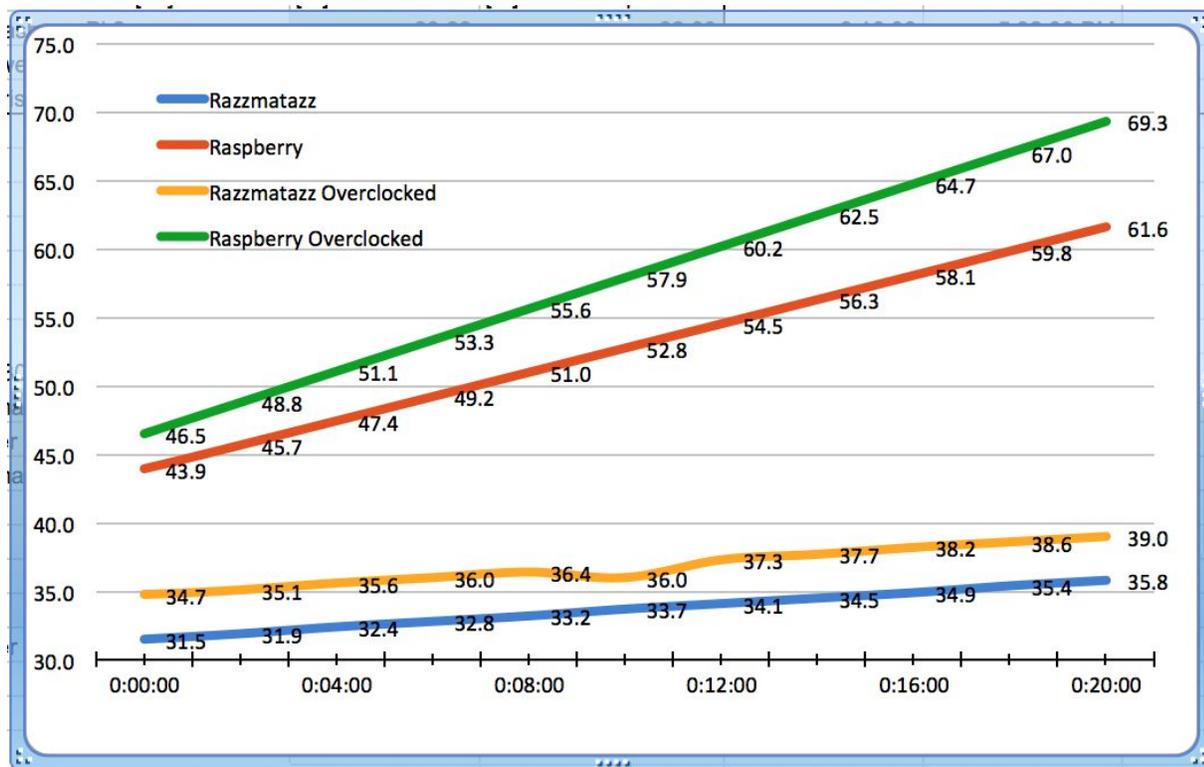
Final Temperature difference after stress test: 30.3°C



Graph 2. Comparison between the Raspberry Pi with Razzmatazz board and without Razzmatazz board.

Test 1 & 2 Comparison

Graph 3 displays a visual interpretation of the results between the two tests over a 20 minutes test period. The y-axis represents the Temperature in celsius degrees, the x-axis represents the time expressed in minutes. The Blue and orange lines are the data results of the Razzmatazz and the Red and Green are the data results of the Raspberry Pi 2 model B. The temperature increasing ratio is constant for every tests we ran, therefore we can say that 20 minutes are not enough to reach the steady state of the CPU. The long-term simulations were necessary both to test the boards under more stress and to reach the steady state.



Graph 3. Comparison between the two different configurations of the board. The y-axis represents the temperature [°C] while the x-axis represents the time [min].

Additional stress tests for the Raspberry Pi with the Razzmatazz enclosure

Test 3 (Overclocked, Razzmatazz only)

The test we ran was:

```
stress -c 5000 -i 1 -t 2h
```

where the c flag spawns 5000 workers spinning on sqrt(), the i flag spawns 1 worker spinning on sync() and t is the time in hours.

Test 3 parameters:

Test time: 2 Hours

Overclock enabled: Yes

CPU Frequency: 1000 MHz

Ambient room temperature: 23.5°C

Config file: force_turbo=1; temp_limit=85; arm_freq=1000; arm_freq_min=1000; core_freq=500; core_freq_min=500; sdram_freq=500; sdram_freq_min=500; over_voltage=6; over_voltage_min=6

Test 3 results:

Idle operating temperature: 34.7°C

Final Temperature after stress test: 37.9°C

Final Temperature difference after stress test: 3.2°C

Test 4 (Overclocked, Razzmatazz only)

The test we ran was:

```
stress -c 5000 -i 4 -t 20m
```

where the c flag spawns 5000 workers spinning on sqrt(), the i flag spawns 4 workers spinning on sync() and t is the time in minutes.

Test 4 parameters:

Test time: 20 minutes

Overclock enabled: Yes

CPU Frequency: 1100 MHz

RAZZMATAZZ EFFICIENCY ASSESSMENT

Ambient room temperature: 23.5°C

Config file: force_turbo=1; temp_limit=85; arm_freq=1100; arm_freq_min=1100; core_freq=500; core_freq_min=500; sdram_freq=450; sdram_freq_min=450; over_voltage=8; over_voltage_min=8

Test 4 results:

Idle operating temperature: 33.6°C

Average temperature increase at 2 min intervals: 0.245°C

Final Temperature after stress test: 38.5°C

Final Temperature difference after stress test: 4.9°C

Test 5 (Overclocked, Razzmatazz only)

The test we ran was:

```
stress -c 5000 -i 4 --vm-bytes 1028M -t 1d
```

where the c flag spawns 5000 workers spinning on sqrt(), the i flag spawns 4 workers spinning on sync(), vm-bytes mallocs 1028 Mb per vm worker and t is the time in days.

Test 5 parameters:

Test time: 1 day

Overclock enabled: Yes

CPU Frequency: 1000 MHz

Ambient room temperature: 20.5°C

Config file: force_turbo=1; temp_limit=85; arm_freq=1000; arm_freq_min=1000; core_freq=500; core_freq_min=500; sdram_freq=500; sdram_freq_min=500; over_voltage=8; over_voltage_min=8

Test 5 results:

Raspberry Pi 2 model B with Razzmatazz™

Idle operating temperature: 32.0°C

Final Temperature after stress test: 35.8°C

Final Temperature difference after stress test: 3.8°C

Test 6 (Overclocked, Razzmatazz only)

The test we ran was:

```
stress -c 5000 -i 4 --vm-bytes 1028M -t 12h
```

where the c flag spawns 5000 workers spinning on sqrt(), the i flag spawns 4 workers spinning on sync(), vm-bytes mallocs 1028 Mb per vm worker and t is the time in hours.

Test 6 parameters:

Test time: 12 hours

Overclock enabled: Yes

CPU Frequency: 1000 MHz

Ambient room temperature: 20°C

Config file: force_turbo=1; temp_limit=85; arm_freq=1000; arm_freq_min=1000; sdram_freq=500; sdram_freq_min=500; over_voltage=8; over_voltage_min=8

Test 6 results:

Idle operating temperature: 34.7°C

Final Temperature after stress test: 37.9°C

Final Temperature difference after stress test: 3.2°C

5. Conclusions

The average idle operating temperature difference between the two configuration is 12 °C or a 28% decrease in temperature of the Raspberry Pi with the Razzmatazz enclosure compared to the standard configuration.

The results of the test number 2 conclude that with the Morpheus Razzmatazz case there is a significant dissipation of heat with 30.3°C temperature difference at a 43% decrease in heat. Another thing to note with the Razzmatazz is that even though the core temperatures increase between the tests due to the increase in CPU frequency, the rate at which the temperature increases did not change between tests.

Testing the Razzmatazz beyond the recommended limits by increasing the various test parameters for a period 24 hours tests under overclocked conditions showed that the steady state temperature is totally within the limits for operating in a safe mode.

6. Bibliography

- [1] “What Is a Raspberry Pi?” *Raspberry Pi What is a Raspberry Pi Comments*. Web. 15 Dec. 2015. <<https://www.raspberrypi.org/help/what-is-a-raspberry-pi/>>
- [2] “Introducing turbo mode: up to 50% more performance for free” *Eben Upton* Sept 2012<<https://www.raspberrypi.org/blog/introducing-turbo-mode-up-to-50-more-performance-for-free/>>
- [3] Stress website <<http://people.seas.harvard.edu/~apw/stress/>>
- [4] Ubuntu MATE website <<https://ubuntu-mate.org/>>