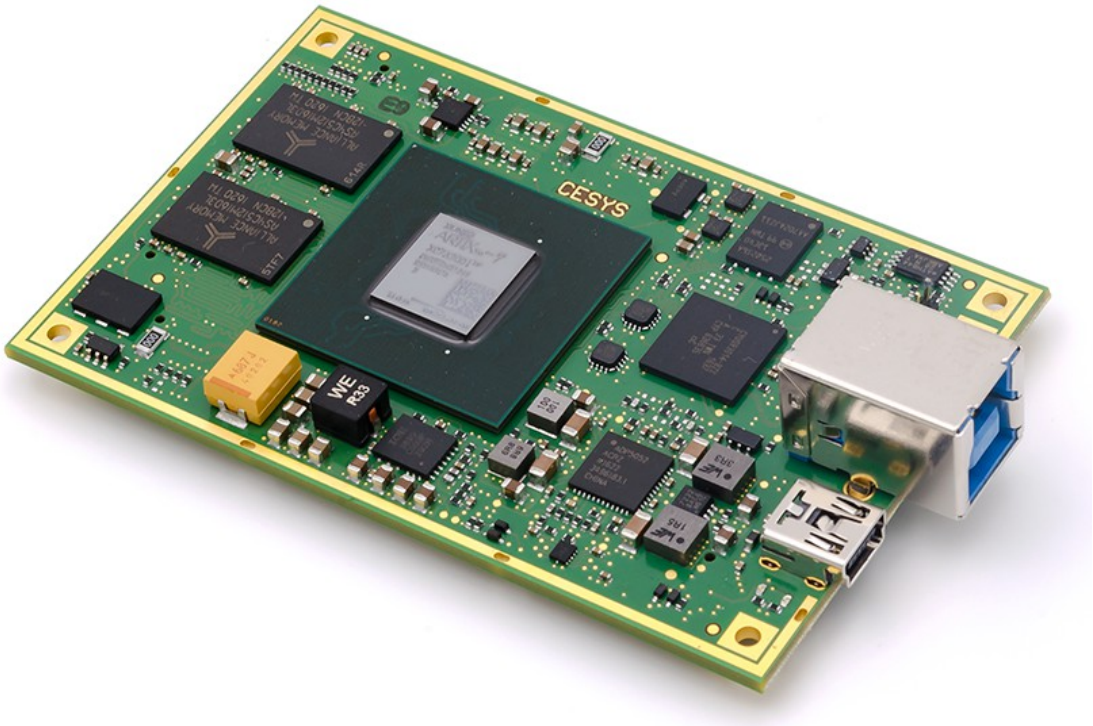
White Paper: EFM-03 Beastboard

Comparison of the efficiency of different cooling methods



Overview

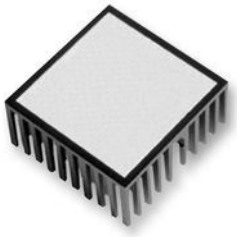
EFM-03 Beastboard is equipped with the Xilinx Artix-7 XC7A200T-2FBG676I FPGA. While this powerful device can deliver a lot of computing power, unleashing this power might result in high core temperatures.

The measurements presented here show temperature profiles of the EFM-03 Beastboard, ultimately the Artix-7 device. They are captured while operating the board continuously at high power levels. Different setups to enhance temperature performance are compared.

Equipment

- EFM-03 Beastboard, CESYS, EFM03-200T-2I
- Windows-PC running CESYS, UDK3 Performance Monitor v1.6
- Flash Pen, Infrared-thermometer
- Digital thermometer, Typ: 568/NiCrNi

- Heat sink, 27x27x10 [mm], with self-adhesive pad
  AAVID THERMALLOY, 374324B00035G



- Fan, 25 x 25 x 10 [mm],
  NMB, 1004KL-01W-B40-B00

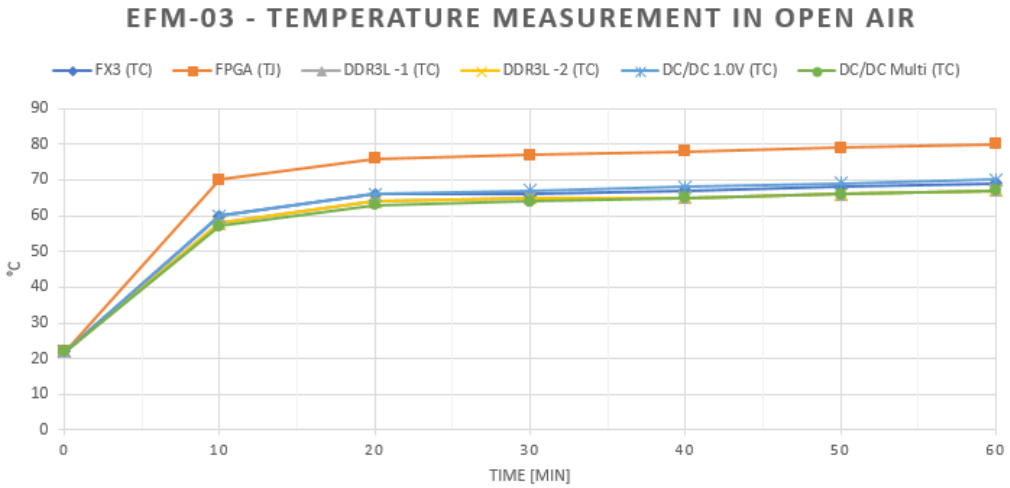
- Case fan, 70 x 70 x 15 [mm],
  FOXCONN, PVA070E12N

Measurements in open air

To investigate temperature behavior of the EFM-03 Beastboard in open air, the board was connected via USB3.0 to a Windows-PC running the latest UDK Performance Monitor. With version v1.6 a small routine has been added, that enables read out of the FPGA core temperature via the XADC module available in the EFM-03 reference design. EFM-03 power supply mode was set to bus-powered mode. While continuously running the Perfomance Monitor and recording the FPGA internal temperature, additionally the case temperatures of various devices used on the EFM-03 Beastboard were measured using an infrared-thermometer. The room temperature was 22 °C.

Time from start of test run [min]	FPGA TJ [°C]	FX-3 TC [°C]	DDR3L TC [°C]	DC/DC 1.0V TC [°C]	DC/DC Multi TC [°C]
0	22	22	22	22	22
10	70	60	58	60	57
20	76	66	64	66	63
30	77	66	65	67	64
40	78	67	65	68	65
50	79	68	66	69	66
60	80	69	67	70	67

Table 1: Temperature measurement for main devices on EFM-03 in open air



Device	Short name	Temperature grade (default mounting option)	Recommended temperature range
XC7A200T-2FBG676I	FPGA	Industrial	-40 °C to +100 °C (junction)
CYUSB3014-BZXC	FX-3	Commercial	0 °C to 70 °C (ambient)
AS4C512M16D3L-12BCN	DDR3L	Commercial	0 °C to +95 °C (case)
ADP5052ACPZ	DC/DC 1.0V	N/A	-40 °C to +125 °C (junction)
IR3895M	DC/DC Multi	N/A	-40 °C to +125 °C (junction)

Table 2: Recommended temperature range for main devices on EFM-03 Beastboard

In table 2 the recommended temperature ranges for the main devices used on the EFM-03 Beastboard are listed. With the room temperature kept at 22°C all devices are operated in their recommended temperature range, even when EFM-03 Beastboard is continuously performing the stress test included in the Performance Monitor.
But the headroom for some of the parts, for example the FX-3 or the FPGA, is quite small. To prevent these devices from failing for increasing ambient temperatures it is recommended to implement further heat management. Different setups to enhance temperature performance of the EFM-03 are tested in the following chapters.

Measurements in a closed box

Worst case condition regarding the temperature behavior of the EFM-03 Beastboard most likely is, when it is used inside a case where air flow might be limited. To measure the temperature behaviour under this condition, EFM-03 Beastboard was tested inside a closed box with no air flow. For a stress test EFM-03 was continuously running performance tests with our UDK3 Performance Monitor v1.6 using the preset 'EFM03(XC7A200T) SOC DDR3L RAM with temperature'. With this preset, together with the continuing high speed data transfer using USB3.0 and DDR3L memory, every one second the FPGA internal temperature is measured using the XADC module and shown in the lower part of the perfomance monitor.

During the test runs the EFM-03 will heat up the air inside the box and thus influence the measurement for the FPGA core temperature. To compensate for this effect, the temperature inside the box was measured, too. The difference between FPGA core temperature and ambient temperature inside the box then is used to compare the different setups.

Between the test for the different setups the EFM-03 Beastboard was unpowered for several hours to cool down again, before starting a new test run. In total four setups were tested:

1. EFM-03 Beastboard without heatsink,
2. EFM-03 Beastboard with heatsink,
3. EFM-03 Beastboard with heatsink and fan on top of the heatsink,
4. EFM-03 Beastboard with heatsink and case fan.

Setup 1: No heatsink (convection only)

For the first test run EFM-03 Beastboard was used without any additional cooling again to get some data the other setups to compare with. To limit cooling to convection only, EFM-03 was put inside a closed box to prevent any air flow. Performance monitor then was run continuously with the preset 'EFM03(XC7A200T) SOC DDR3L RAM with temperature' for DDR3L memory transfers and FPGA core temperature measurement.

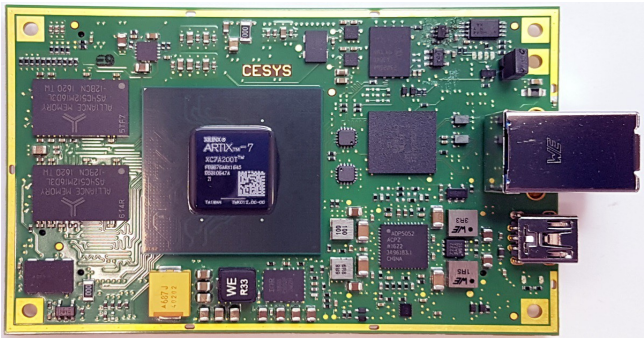
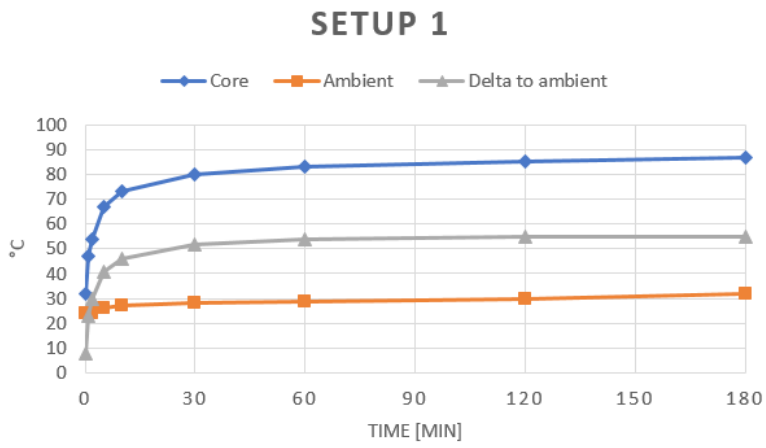


Figure 1: EFM-03 Beastboard with no heatsink (convection only)

Time from start of test run [min]	FPGA core temperature [°C]	Temperature inside the box [°C]	Difference between core temperature and ambient temperature inside the box [°C]
0	32	24	8
1	47	24	23
2	54	24	30
5	67	26	41
10	73	27	46
30	80	28	52
60	83	29	54
120	85	30	55
180	87	32	55

Table 3: Temperature profile for EFM-03 in a closed box



Setup 2: Heatsink (convection only)

For the second test run, EFM-03 Beastboard was equipped with a 27x27x10 [mm] heat sink from AAVID THERMALLOY, which comes with a self-adhesive thermal pad. Like with the first setup, Perfomance Monitor then was continuously run and the temperatures for the FGPA core and the ambient temperature inside the box recorded.

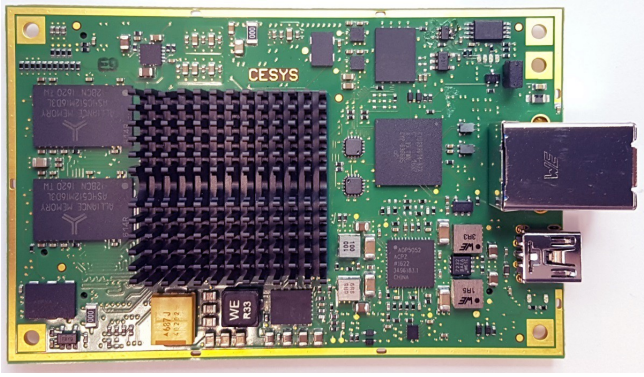
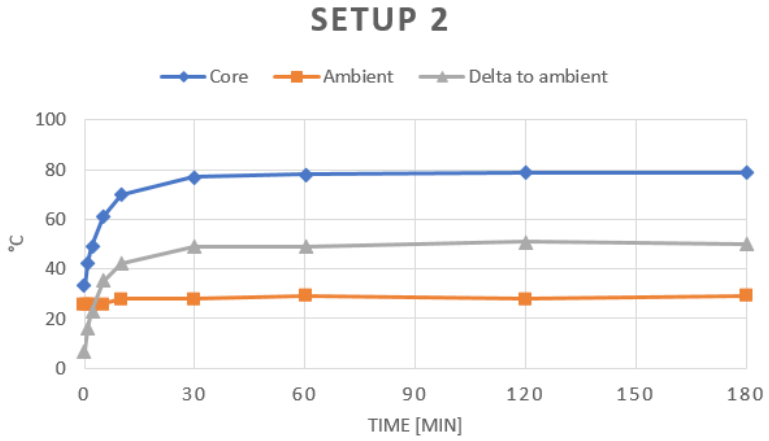


Figure 2: EFM-03 Beastboard with heatsink (convection only)

Time from start of test run [min]	FPGA core temperature [°C]	Temperature inside the box [°C]	Difference between core temperature and ambient temperature inside the box [°C]
0	33	26	7
1	42	26	16
2	49	26	23
5	61	26	35
10	70	28	42
30	77	28	49
60	78	29	49
120	79	28	51
180	79	29	50

Table 4: Temperature profile for EFM-03 with heatsink in a closed box



Setup 3: Heatsink + fan (~1.6 CFM)

To further improve the cooling for the third run a fan was added to the heat sink used in setup 2. Like before, Perfomance Monitor then was continuously run and the temperatures for the FGPA core and the ambient temperature inside the box recorded.

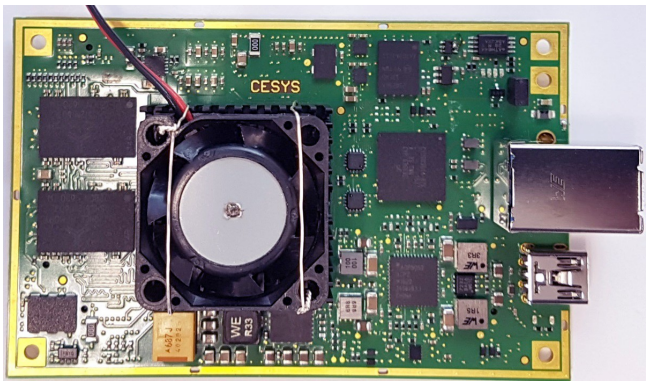
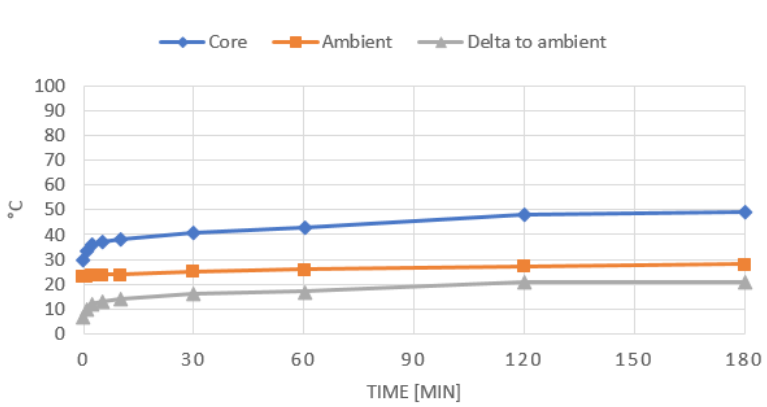


Figure 3: EFM-03 Beastboard with heatsink and thermal fan

Time from start of test run [min]	FPGA core temperature [°C]	Temperature inside the box [°C]	Difference between core temperature and ambient temperature inside the box [°C]
0	30	23	7
1	33	23	10
2	36	24	12
5	37	24	13
10	38	24	14
30	41	25	16
60	43	26	17
120	48	27	21
180	49	28	21

Table 5: Temperature profile for EFM-03 with heatsink and fan in a closed box



Setup 4: Heatsink + case fan (~20 CFM)

To test, if it was sufficient to use a case fan instead of the fan directly mounted on top of the heat sink, the cooling fan was removed again in the fourth setup. Only with a small

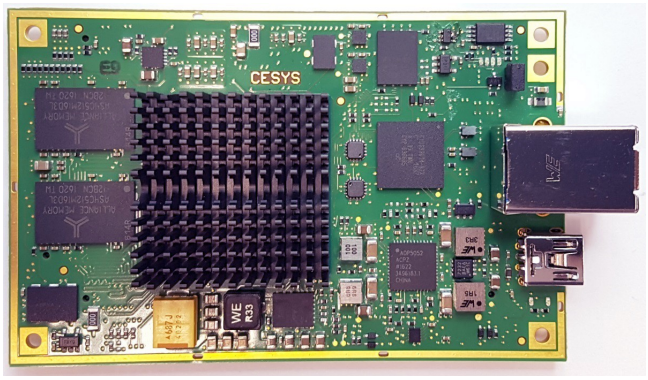
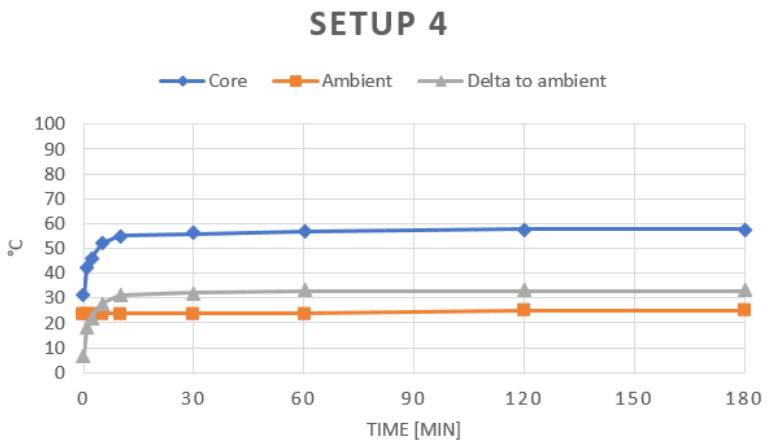


Figure 4: EFM-03 Beastboard with heatsink and case fan

opening for the 70 x 70 x 15 [mm] fan PVA070E12N from FOXCONN, the box otherwise was kept closed. Once again, Perfomance Monitor then was continuously run and the temperatures for the FGPA core and the ambient temperature inside the box recorded.

Time from start of test run [min]	FPGA core temperature [°C]	Temperature inside the box [°C]	Difference between core temperature and ambient temperature inside the box [°C]
0	31	24	7
1	42	24	18
2	46	24	22
5	52	24	28
10	55	24	31
30	56	24	32
60	57	24	33
120	58	25	33
180	58	25	33

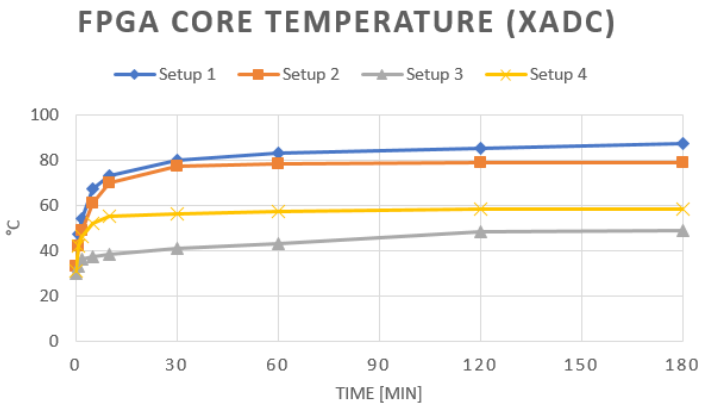
Table 6: Temperature profile for EFM-03 with heatsink and case fan in a closed box

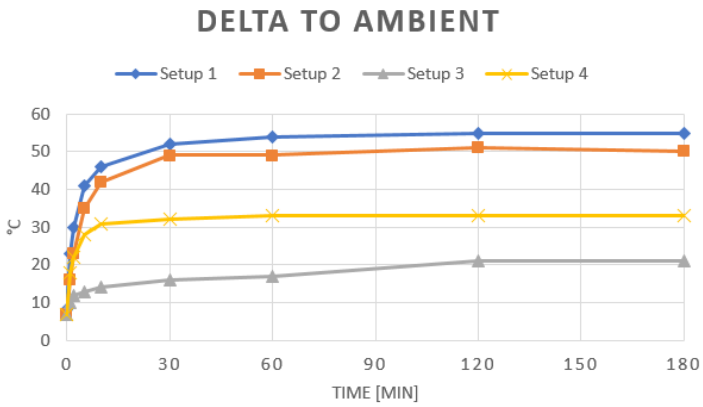


Conclusion

While with all tested setups the EFM-03 Beastboard performed as expected, the measured temperatures greatly differed. Using the EFM-03 Beastboard continuously at the high temperatures shown in setups one or two might ultimately influence lifespan of the EFM-03 Beastboard or one of its components in a negative manner and therefore should be limited to short test periods or where the ambient temperature is controlled and limited to acceptable values.

If continuous high performance of the EFM-03 Beastboard or high ambient temperatures or both are required, it is recommended to add some heat management. With only a passive heatsink and no air flow, like in setup 2, FPGA core temperature is only slightly lower than compared to not using any heatsink at all. While setup 3 with forced cooling directly at the FPGA heatsink clearly shows the best results, using a case fan together with a heatsink will work in all but the toughest use conditions equally well.





- Setup 1: No Heatsink (convection only)
- Setup 2: Heatsink (convection only)
- Setup 3: Heatsink + fan (~1.6 CFM)
- Setup 4: Heatsink + case fan (~20 CFM)

Revision history

Version	Date	Comment	Author	Approved by
pre-0	August, 2017	First preliminary approach	mh	mh
v1.0	October, 2017	Removed preliminary	mh	mk

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