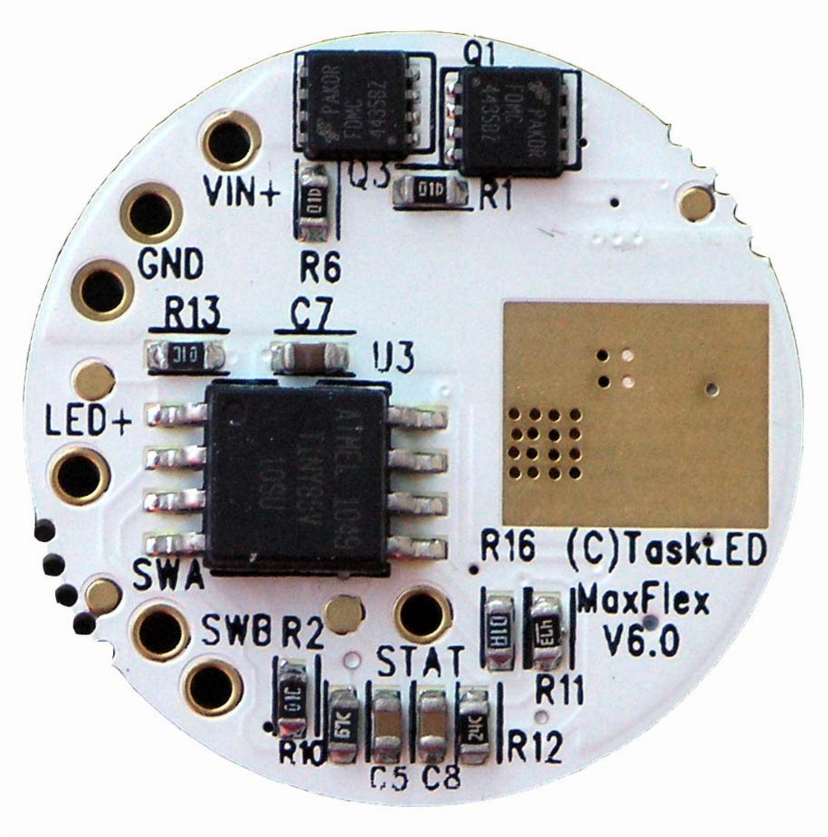
Thermal Design Guide for maxFlex4, maxFlex5 & maxFlex6 (V1.2)

Everything in this document also applies to maxFlex5 and maxFlex6.

Commencing with maxFlex4, the boards are made with 2oz copper and also have thicker plating of all holes/vias to provide a better thermal path through the PCB to the gold thermal pad area.

Maxflex5 added minor component value changes to the maxFlex4 design to provide higher output voltage capability (29V max output).

Maxflex6 uses different input power FETs (Q1 & Q3) to raise the input voltage capability to 24V (5 li-ion battery packs). Maxflex6 requires a minimum input voltage of 4V to ensure efficient operation.

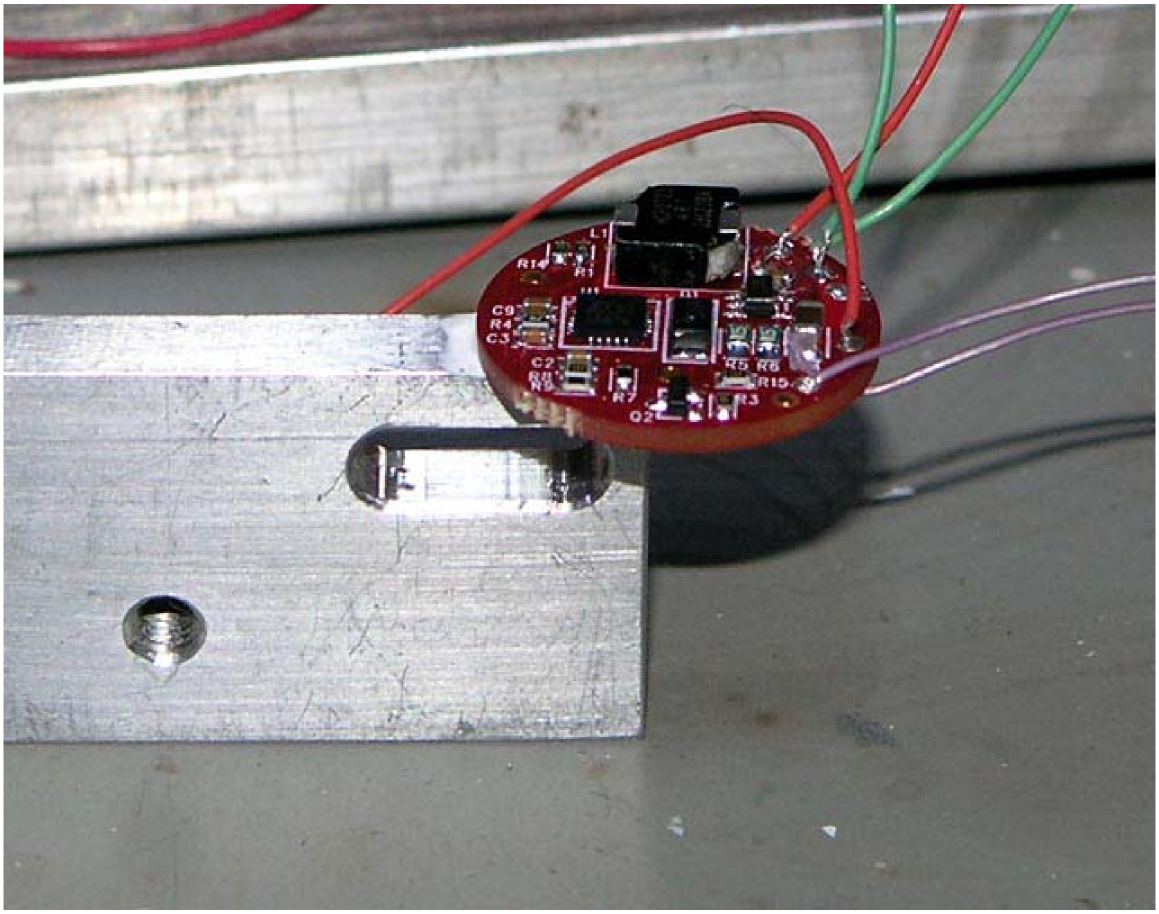


With the release of maxFlex4 with the new 2oz copper and heavier hole/via plating, an extensive set of thermal measurements were performed to determine various heatsink options at different power levels. A summary of the measurements and conclusions can be found below.

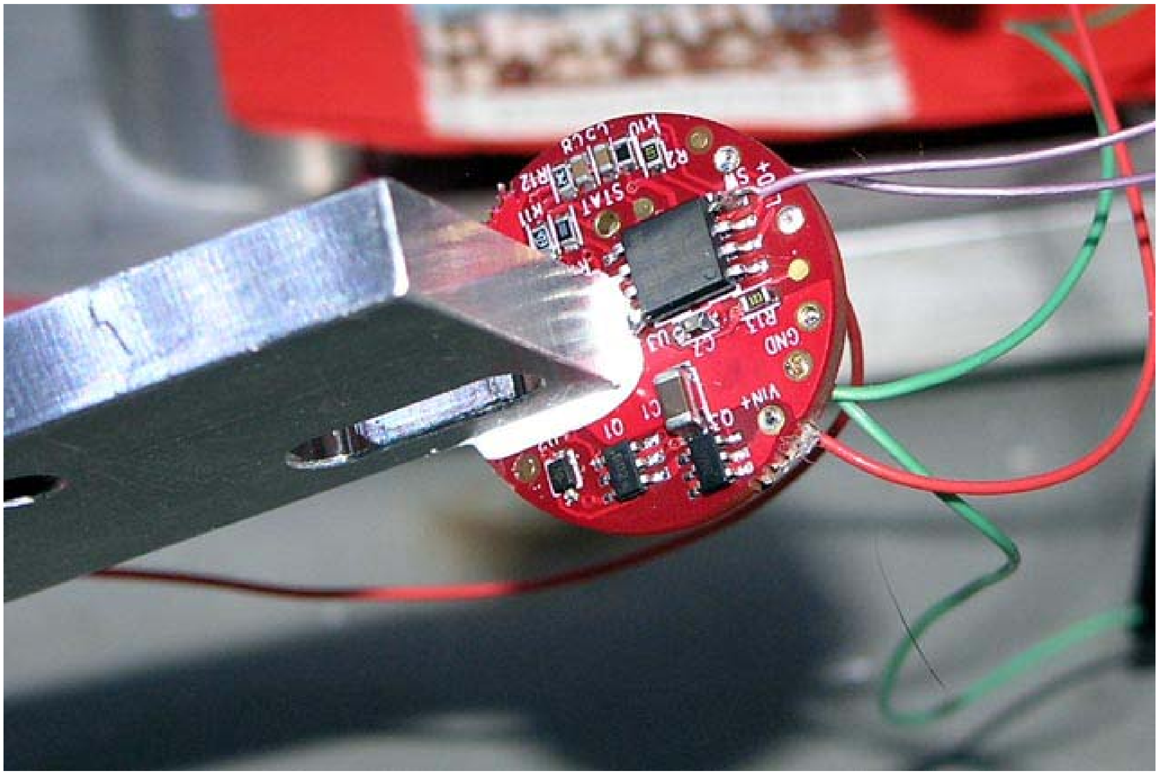
The most obvious first step is to mount the heatsink to the gold thermal attach area that is provided on the bottom side of the PCB. This gold area is directly beneath the switcher IC and the 16 vias from the bottom of the IC provide a thermal conduit through the PCB material to the gold area.

The heatsink should be attached with a thin and uniform layer of high quality thermal epoxy. The thermal epoxy should be squeezed to ensure a thin layer without any air gaps that would impede the thermal path. Arctic Alumina, 2 part epoxy is highly recommended due to its electrical non-conductivity and non-capacitance. If a product like Artic Silver 2 part epoxy is used (partially conductive), it is necessary to ensure none of the epoxy squeezes out to ‘short/contact’ nearby components.

The following picture shows a maxFlex4 driver thermally epoxied with Arctic Alumina epoxy to an aluminium bar for the purpose of testing the performance of the driver’s gold thermal attach area.



The following picture shows how the aluminium bar has squeezed some of the thermal epoxy out. This is where the benefit of Artic Alumina’s electrical inertness is clearly an advantage since it has squeezed out to several of the uController’s pins (U3). It this was Artic Silver epoxy, it would have been necessary to clean the excess epoxy prior to it curing.



Again it is important to stress the need for the epoxy layer to be as thin as possible and uniformly applied without air gaps. The quality of the bonding between the heatsink and the gold thermal attach area will directly impact the temperature gradient between the switcher IC and the heatsink and a poor bond can contribute to overheating of the switcher IC.

With this level of heatsinking a thermal test was performed at a medium power dissipation level.

First test case:

The test case is a series of white LEDs driven at 1A. The total Vf of the string of LEDs was 21V. This means a total of 21W of output power.

Input voltage was set to 14V and overall driver efficiency was measured at 93.4%. Input power was measured at 22.5W. Input current was measured at 1.61A.

Power dissipated by driver was: 22.5W – 21W = 1.5W

The following table shows the time versus driver board temperature (measured with an IR thermometer and verified with a thermocouple).

Time (mins)	Temperature (C)
0	20
2	40
4	40
6	41
9	41
13	41
30	41
40	41

As can be seen, the driver heats up quickly to a stable operating temperature. The heatsink attachment is providing a sufficiently good thermal path to maintain stable operation.

<u>Second test case:</u>

The next test was with the same LED test configuration, 21V total Vf at 1A drive, 21W output power.

Input voltage was lowered to 10.67V causing input current to rise to 2.19A and efficiency dropping to 90%. Measured input power was 23.3W.

Overall driver losses was 23.3W – 21W = 2.3W

As can be seen, efficiency has dropped and power dissipation losses in the driver have increased dramatically. This is due to the larger input to output voltage discrepancy and larger input current.

The following table shows the time versus driver board temperature (measured with an IR thermometer and verified with a thermocouple).

Time (mins)	Temperature (C)
0	20
1	35
2	40
3	41
4	41
7	41
12	41
17	41
20	41

As can be seen, the driver heats up quickly to a stable operating temperature. The heatsink attachment is providing a sufficiently good thermal path to maintain stable operation.

Third test case:

The next test was with the same LED test configuration, 21V total Vf at 1A drive, 21W output power.

Input voltage was lowered to 9.7V causing input current to rise to 2.54A and efficiency dropping to 87%. Measured input power was 25W.

Overall driver losses was 24.6W – 21W = 3.6W

As can be seen, efficiency has dropped and power dissipation losses in the driver have increased dramatically. This is due to the larger input to output voltage discrepancy and larger input current.

The first test that was performed was a temperature runtime test with the same heatsink attachment to the gold thermal attach area as in the first test case.

Within 8 minutes the driver overheated and the switcher IC shut down (failure mode) and the LEDs went out. This test was repeated and both times the driver failed after 8 minutes. The temperature continued to rise during the 8 minutes and never stabilized.

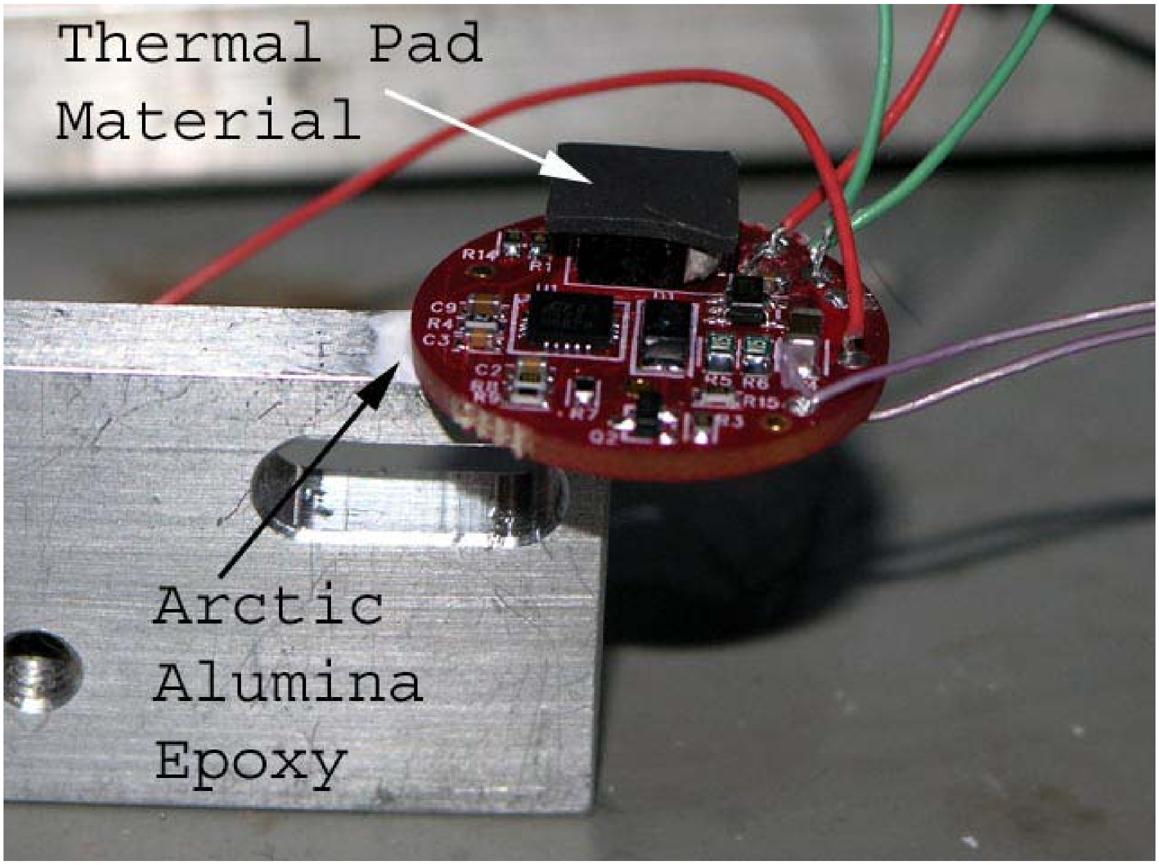
So, for the case of 3.6W dissipation losses, the heatsink attached to the bottom of the maxFlex4 driver was insufficient to enable stable operation.

It was determine by measurements that in this more extreme dissipation case that the inductor was also heating up and was contributing to the overall losses (and overheating) of the driver board.

To run a fourth test case it was determined that adding a heat sink to the inductor would allow testing to see if this would help reach stable operation.

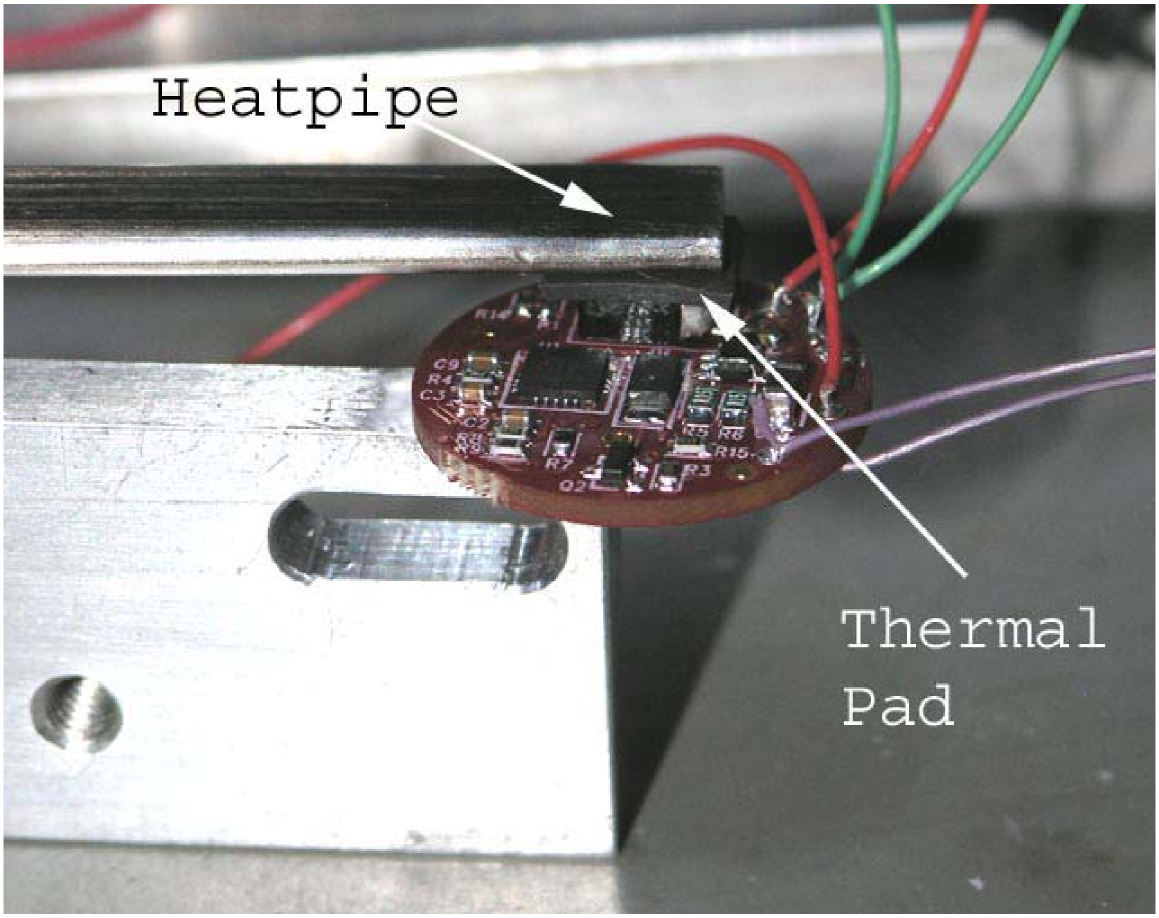
Fourth test case:

The picture below shows how the heatsink would be attached to the top of the inductor to run the fourth test case. A small piece of silicone thermal pad (electrically neutral) was placed on top of the inductor. The same heatsink attachment via the gold thermal attachment area was left in place.



To allow ease of temperature measurements with an IR thermometer and thermocouple it was decided to use a heat pipe to transfer heat from the thermal pad to a remote heatsink. This would provide a good heatsink connection while minimizing the ‘covering’ of the driver board.

This picture shows the heat pipe resting against the thermal pad material. A small amount of downward pressure was applied to ensure a reasonable thermal connection between the heat pipe, the thermal pad and the top of the inductor.

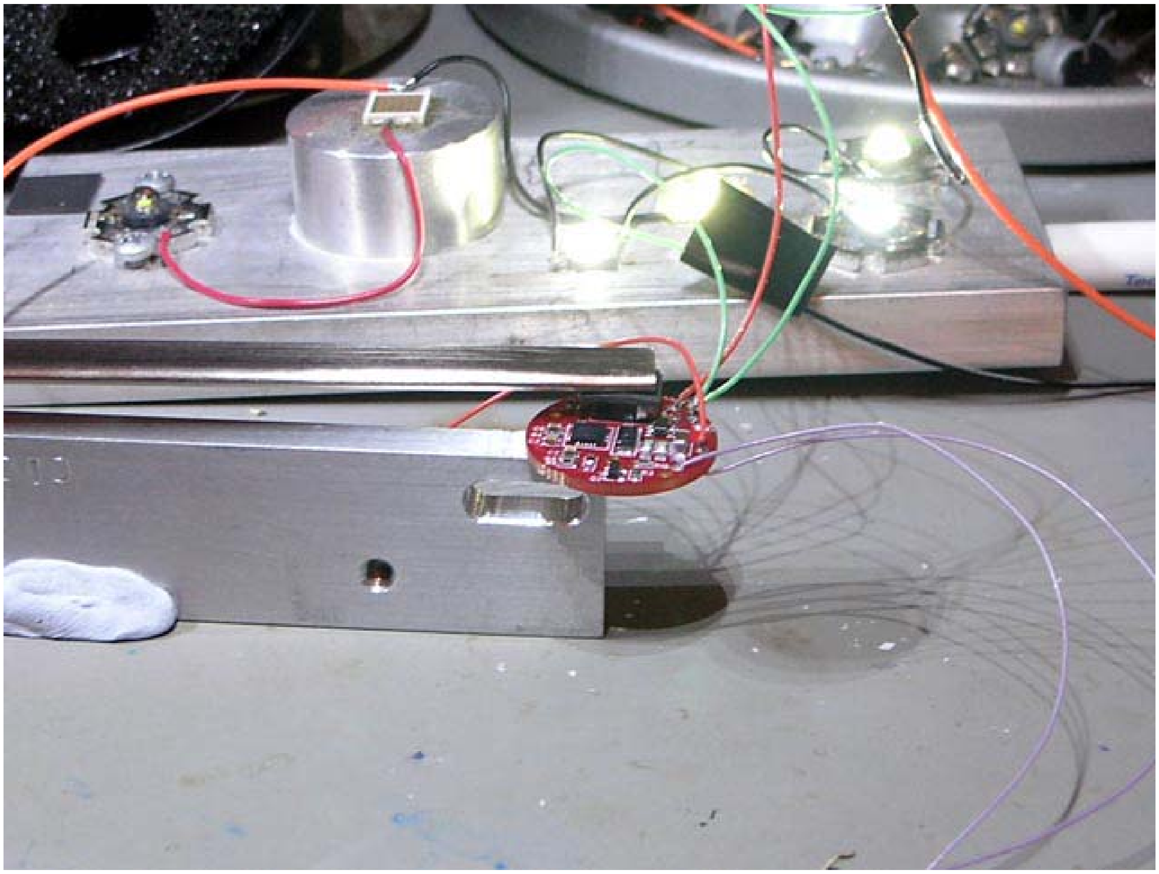


The same electrical conditions of the third test case were applied and runtime versus temperature was recorded. The results are shown in the table below.

Time (mins)	Temperature (C)
0	20
2	36
5	41
8	41
14	43
22	43

As can be seen, the temperature stabilized within 5 minutes. The slight increase in temperature (from 41C to 43C) was due to the heatsink heating up. This test was run several times and stable operation occurred each time, even when allowed to run beyond 30 minutes.

Picture showing stable operation of the driver with heat losses of 3.6W while utilizing 2 heatsink connections, 1) heatsink attached to gold thermal attachment point and 2) heatsink attached via heat pipe and thermal pad to the top of the inductor.



Summary:

At power levels with driver heat losses in the 2W range, it is sufficient to utilize a single heatsink attached to the gold thermal attachment area. As heat losses increase beyond 2W it may be necessary to provide heatsinking of the inductor to prevent shutdown and possible damage of the switcher IC.