

Controller cooling in models

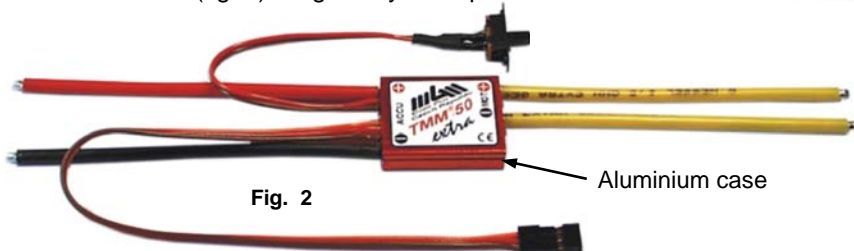
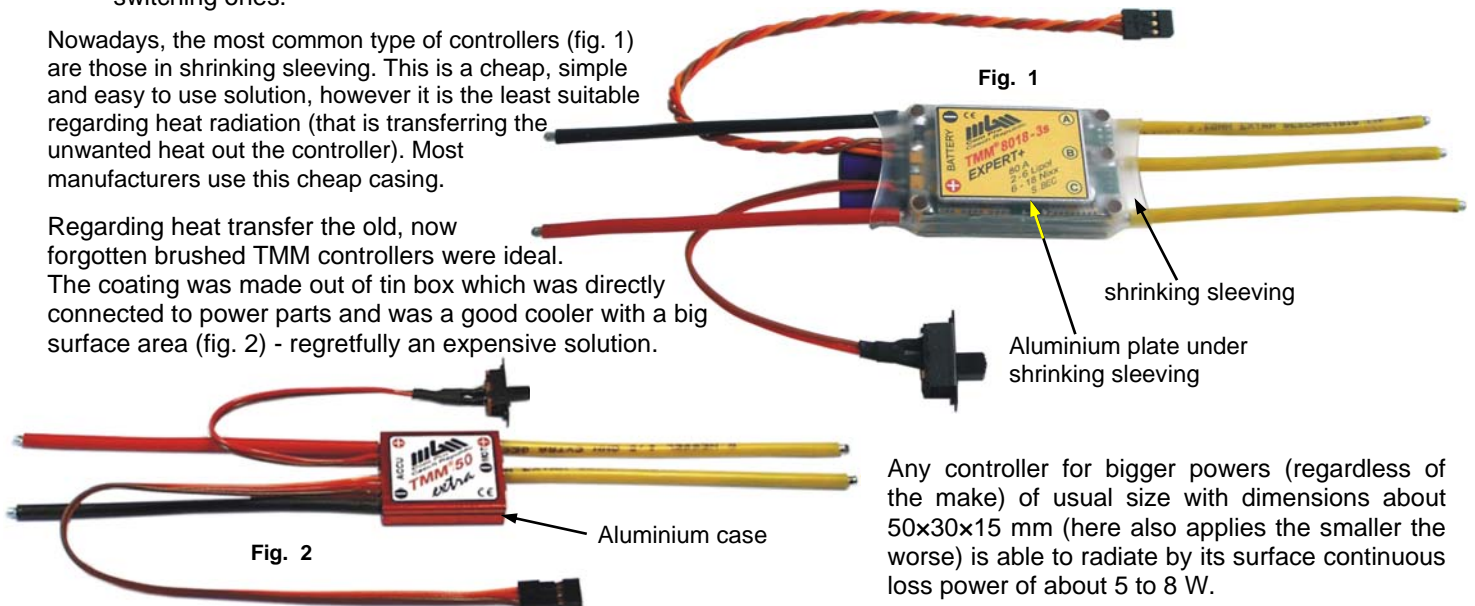
Controller cooling is a matter often forgotten and left out by many modelers. However, with growing power of "sensorless" model motors (BLCD motors) and controllers (100s W up to 10k W) the issue starts to be even more important. This is not the matter for 12A controllers for 3 Lipol cells, even though same laws and physics apply for those as well. Temperature inside the controller directly influences its reliability, maximal power and operating life. The temperature can be easily and significantly influenced. The reliability of the controller and its operating life grows with decreasing temperature, as well as the power and the effectively grows (smaller resistance of MOSFETs in switched state, and also of the PCB – *printed circuit board*). To sum it up, operating the controller with lower inner temperature is preferable.

There are three types (when a bit simplified) of losses in controller (power loss is converted to unuseful heat during controller operation and it is necessary to get it out; do not confuse with power brought to the motor):

- 1) Firstly, it is losses on switching parts (MOSFET transistors) caused by current going through the transistor which resistance in switched state is not zero but fractions, units or tens of $m\Omega$). These losses also occurs due to the resistance of the PCB on which the power parts are placed - here, the biggest resistance and biggest losses feature controllers made by Chinese manufactures - these are the cheap PCBs with thin copper layers which are very under designed in this regard.
- 2) Other significant great loss occur due to switching (on and off) of MOSFET transistors during regulation of power and switching phases during turning the rotor. These losses may be bigger than losses of the 1st) type and they grow with higher switching frequency (on 32 kHz these losses are 4 times bigger than when operating on 8 kHz). This means that if your specialty "non-lead" motor does not require higher frequency (as for example motors TANGO, SAMBA by Kontronik), it is always better to use the lower frequency instead.
- 3) The last type of big power losses (and not insignificant) are losses on BECs, on both classic linear stabilizers and switching ones.

Nowadays, the most common type of controllers (fig. 1) are those in shrinking sleeving. This is a cheap, simple and easy to use solution, however it is the least suitable regarding heat radiation (that is transferring the unwanted heat out the controller). Most manufacturers use this cheap casing.

Regarding heat transfer the old, now forgotten brushed TMM controllers were ideal. The coating was made out of tin box which was directly connected to power parts and was a good cooler with a big surface area (fig. 2) - regrettably an expensive solution.



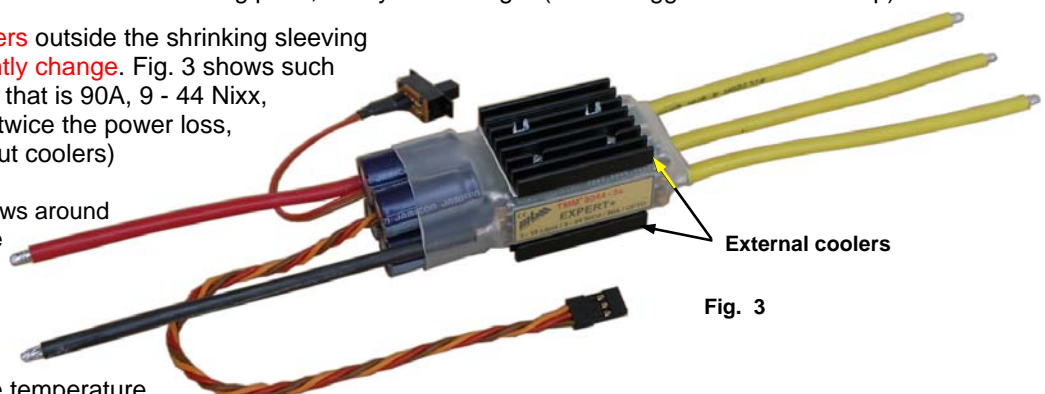
Any controller for bigger powers (regardless of the make) of usual size with dimensions about 50x30x15 mm (here also applies the smaller the worse) is able to radiate by its surface continuous loss power of about 5 to 8 W.

When a controller of this size is to radiate power loss of about 5 W (which really is not that much), its inner temperature rises gradually to ca 80°C above the ambient temperature (if that is 25°C, the temperature inside the controller is 105°C which is about the limit above which the temperature fuses of the controller swithes it off, provided the controller features such fuse. This applied to case when the controller is not exposed to flow of cooling air, that is in case of bad cooling. If the controller or its cooler(s) are exposed to at least a small flow of cooling air, the temperature inside the controller decreases of about 20 - 25°C compared to the case without cooling (that is from, 105°C to 80°C) and in case of big cooling air flow the decrease is of 30°C (to 75°C).

When a manufacturer uses big coolers but they are under **shrinking sleeving** (covered inside) not much is changed - temperatures rises to the same level as with small cooling plate, it only takes longer (for the bigger mass to heat up).

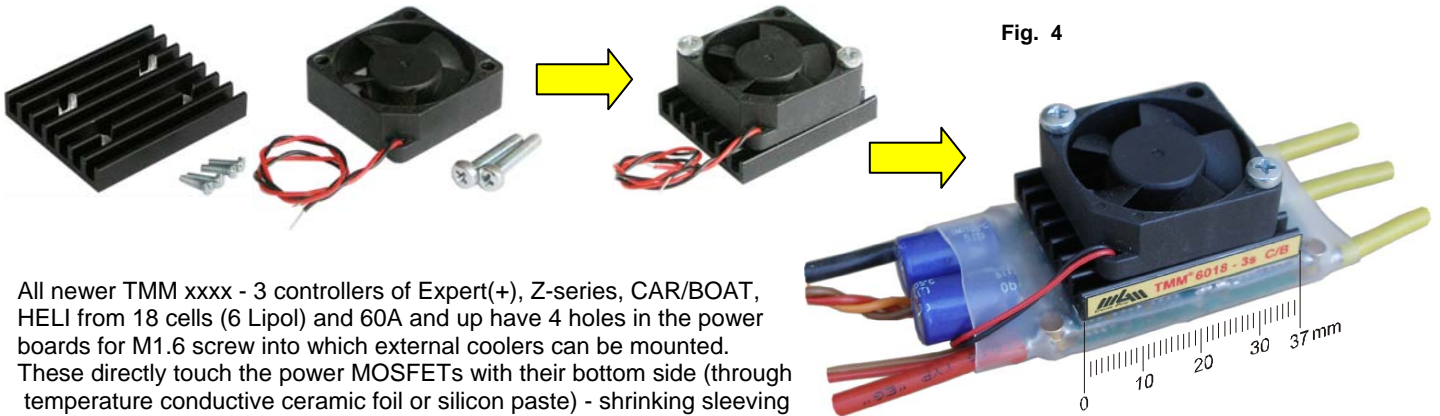
However, if additional **external coolers** outside the shrinking sleeving are used the **situation can significantly change**. Fig. 3 shows such solution - TMM 9044 - 3s controller, that is 90A, 9 - 44 Nixx, 3 - 15 Lipol. (2 coolers can radiate twice the power loss, that is 10W instead of the 5W without coolers)

Notice that, if no or little cooling air flows around the coolers the temperature inside the controller drops only a few degrees which does not help.



However, if the cooling air flows around both coolers sufficiently, the temperature inside the controller is lowered by ca 45°C with loses of 10W compared to the case 5W without cooling and coolers which is from ca 105°C to 60°C (this greatly depends on the intensity of cooling air flow). Such increase of cooling efficiency significantly improves the situation and temperature situation inside the controller which is unobtainable without coolers.

If good and intensive cooling air flow around coolers cannot be ensured (e.g. models of cars, jets, etc.) it is possible to mount small fan (fig.4) on cooler(s). The figure also shows an example of a car controller TMM 6018 - 3 C/B SLIM (60A, 6 - 18 Nixx, 2 - 6 Lipol, switched BEC). Fan (dimensions 30x30x10 mm) is fed 5V from BEC or receiver batteries (for OPTO versions) and draws current of about 190 mA. This fan intensively flows the air around cooler and the temperature inside controller decreases of 65°C compared to the state without coolers and airflow, that is to 40°C (with ambient temperature still 25°C) - which is a significant temperature decrease.



All newer TMM xxxx - 3 controllers of Expert(+), Z-series, CAR/BOAT, HELI from 18 cells (6 Lipol) and 60A and up have 4 holes in the power boards for M1.6 screw into which external coolers can be mounted. These directly touch the power MOSFETs with their bottom side (through temperature conductive ceramic foil or silicon paste) - shrinking sleeving is taken out of this place and the power parts (main source of unwanted heat) are very well cooled. It is possible to also mount the previously described fans using two M3 screws.

An example of two cooler with vents on TMM 22418 - 3 (224A, 6 -18 Nixx, 2 -6 Lipol, switched BEC) is in fig. 5.



On the other hand, it is also possible to cool off much bigger power losses while keeping the same inner temperatures of the controller.

If for example we allow the inner temperature of the controller to be maximally ca 105°C, it is possible to cool off on a controller with cooler and fan a continuous power loss of not only 5W but 20W, that is 4 times more than without cooling! This means that controllers with power boards on both sides, with two coolers and two fans can cool off up to 40W of power loss, which a great difference compared to the situation without coolers and cooling air flow (5W) - that is up to 8 times more !

Such values of power loss without active cooling are almost impossible to allow in operation.

If on the other hand, the controller is wrapped in some kind of protective foil or is placed in a pocket inside polystyrene, the situation will get even worse and the controller will be overheated by even smaller power losses.

Table of temperatures for radiated power loss of ca 5W and ambient temperature of 25°C:

| | air flow [l/min] | ΔT (compared to 25°C) | inner temperature |
|---|---------------------|--------------------------|----------------------|
| Controller without coolers and without air flow | | 80°C | 105°C |
| Controller without coolers with a light cooling air flow | → ~30 | 55°C | 80°C |
| Controller without coolers with a heavy cooling air flow | →→ ~70 | 50°C | 75°C |
| Controller with external cooler with a light cooling air flow | → ~30 | 50°C | 75°C |
| Controller with external cooler with a heavy cooling air flow | →→ ~70 | 35°C | 60°C |
| Controller with external cooler and a fan | →→→ ~150 | 15°C | 40°C |

Note: power loss of 5W applies to controllers without coolers or with one cooler and possibly a fan. For controllers with a couple of cooler and possibly fans these ratios apply for double the power loss - 10W.

From the above stated measurements, it is obvious that the inner temperature of the controller depends on good outside cooling, which was expected. Also interesting ratios are shown - e.g. in which it is possible to reduce the inner temperature or to increase the power. It is obvious how to significantly decrease the inner temperature if a suitable cooling is provided.

The same applies for boat models and controllers. Here, an intense cooling is done by flowing water, e.g. fig. 6 - TMM 12032 - 3RB(Race Boat, water cooling, 120A, 9 - 32 Nixx, 3 -10 Lipol).



Fig. 6