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Operation Evaluation of Ultra Low ON-Resistance MOSFET Supporting Quick Charge for 1 Cell Lithium-ion Battery Protection

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APPLICATION NOTE

Overview

Currently, because LiB (Lithium Ion Battery) is superior in current density and electromotive force, it becomes mainstream of batteries for mobiles such as smart phone. However, because LiB is weak at over-charge and over-discharge, a control circuit is necessary to be used in combination with LiB. For the purpose of LiB current control, MOSFET is used.

This time, we would like to consider the operation and heat transfer of the CSP product, which is used for current control, with very small size and ultra-low ON resistance.

CSP (Chip Scale Package)

Embedded on small and thin device, its electrodes are connected on WF die directly with neither resin capsulation nor wire bond. ON Semiconductor's typical CSP product is shown in Figure 1. This device is specifically for LiB protection circuit with 2 MOSFETs in combination. VS_{SS} = 12 V, $R_{SS(on)}$ = 2.5 mΩ. Internal equivalent circuit is shown as Figure 2: drains are combined, G1, G2, S1, S2 are exposed as electrode.

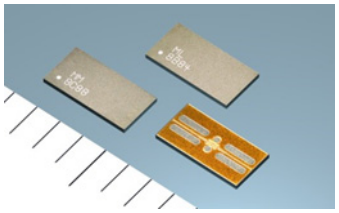


Figure 1. CSP Appearance

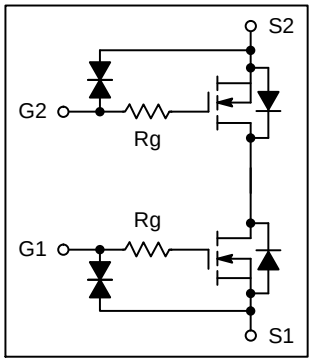


Figure 2. Internal Circuit

PCB Operation Temperature with the Assumption of Using in LiB

Operating Test Condition

Assume 1-Cell voltage V_{CELL} = 3.8 V, operation current I_{SS} = 6 A. Use an IC without sense resistance. In consideration of actual use, fuse resistor (3 mΩ) is installed.

At that time, the operating temperature is mainly observed in the case of using 1 device (Nch2 circuit) and using 2 devices in parallel. For circuit diagram, please refer to Figure 7.

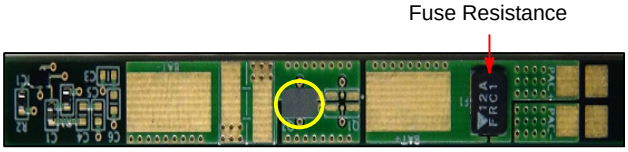


Figure 3. MOSFET 1 Device (A)

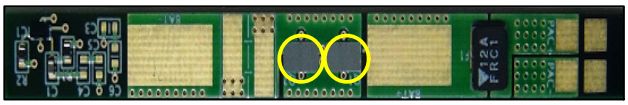


Figure 4. MOSFET 2 Devices (B)

MOSFET's Temperature Measurement

Because of electric current dispersion, MOSFET temperature decreased in the case of using two devices as we expected.

Table 1. MOSFET RISE TEMPERATURE

(After 30 min) (T_A = 26°C)

	1 Unit	2 Units
ΔT [Deg]	24.7	21.1

Observation of Heat Generation by Thermal Camera

As you observe heat generation in A PCB and B PCB, you can see MOSFET and fuse resistor: R ≈ 3 mΩ (which is needed in the circuit) are generating heat.

For the circuit diagram, refer to Figure 7.

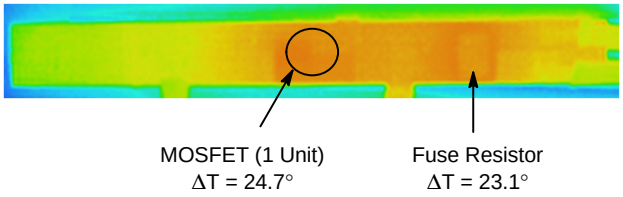


Figure 5. MOSFET-thermal Image when using 1 Device (A)

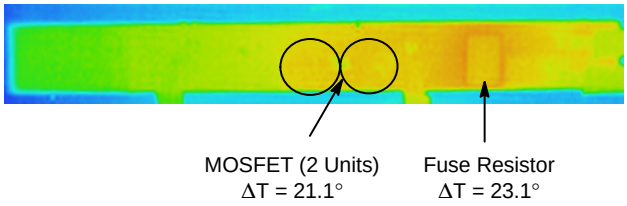
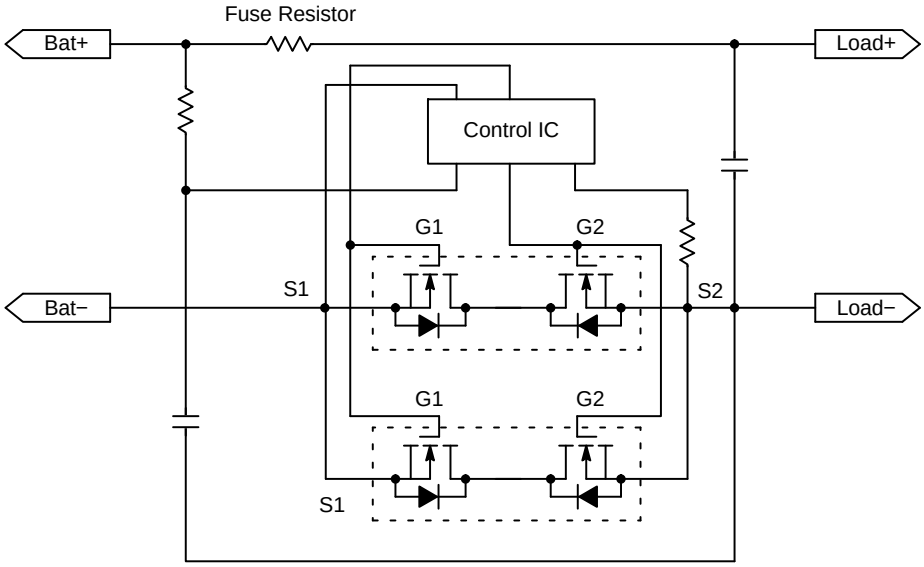


Figure 6. MOSFET-thermal Image when using 2 Devices (B)



Note: In the circuit, 2 MOSFETs are connected in parallel.

Figure 7. Protection Circuit (A Part Diagram)

Considerations on Protection Circuit Board

For LiB, the higher its temperature is, the shorter its lifetime tends to be. So, it is necessary to avoid heat as much as possible. Therefore, it is necessary to preferably prevent the heat transferring from the board to the LiB. And the point is how to make the heat from the board transfer to the peripheral atmosphere the most efficiently.

Heat transfer mechanism depends on:

1. Heat Conduction (heat conduction by the vibration free electron between molecules).
2. Convection (as heat transfers from solid to fluid by heat conduction, the fluid accepting the heat moves, and the heat moves too).
3. Radiation (heat energy releases through electromagnetic wave).

Due to the board area limitation, together with the influence of fuse resistor's heat transfer, the MOSFET operating temperature becomes higher than in the case of operating MOSFET singly (board temperature also rises).

If you want to decrease the board overall temperature as much as possible, it will be effective if you use 2 MOSFET devices.

Heat radiation from heat generator (MOSFET, fuse resistor) to PCB, the above *1*. is the main reason. In case of heat radiation from the PCB, the above *2*. is dominant. In mechanism of *2*., heat transfers from the PCB (solid) to atmosphere (gas). It is known that this heat radiation is not related to the materials of the heat radiation at all, and becomes constant value which is proportional to the unit area and the difference of temperature. Therefore, the key point is how to obtain the PCB area as large as possible within allowed range. To address the need of electric current increase and quick charge, it is also important how to suppress the loss during charging and discharging. For MOSFET, lower and lower $R_{SS(on)}$ is required. This time, because current-controlling IC is a type without the need of sense resistor, the loss arising from sense resistor also decreases, which contributes to the PCB temperature reduction.

Summary

To address the need for increasing capacity and fast charging, LiB current is increasing. The PCB temperature increases due to the losses arising from the devices mounted on the PCB, so total loss reduction is being required. Naturally, the MOSFET used for current control is required to have very low $R_{SS(on)}$. $R_{SS(on)}$ of the device we introduced this time used for 1 cell is 2.5 mΩ. Even though 1 device sufficiently demonstrates the performance for mobile LiB control, when you want to suppress the increase of your PCB temperature, or in case of large current application, use of 2 devices in parallel will contribute to loss reduction and heat dispersion, and therefore helps suppress the increase in PCB temperature.

Table 2. COMPARISON IN LOSS (MOSFET 1 OR 2 UNITS) (When I_S = 6 A, Fuse Resistance = 3 mΩ)

	1 Unit	2 Units
MOSFET Loss	0.09 W	0.045 W
Total Loss	0.198 W	0.153 W

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