RBK04U04GNS

Renesas BMS Shunt-less Solution

About this document

This document will discuss the Renesas BMS Shunt-Less solution for battery management systems (BMS). It will explore the shunt resistor-less and thermistor-less methods achieved through the use of selected MOSFETs and FGIC for operating and monitoring temperatures in the BMS.

Target Device

MOSFET: RBK04U04GNS

FGIC: RAJ240100GFP

Contents

1. Introduction

1.1 Overview

The Battery Management System (BMS) is an indispensable and essential component within the entire control system. It is used to manage and monitor the balance of supply and demand within the battery system. In the market, most of the products are using lithium-ion batteries as the DC power supply for the application. However, the high energy density and performance advantages of lithium batteries also bring about some potential risks, such as overcharging, over-discharging, and overheating.

To ensure the safe operation of the battery, it needs to be equipped with a circuit that can quickly detect the abnormal condition and take corresponding action to protect the battery's performance and lifespan.
By continuously monitoring the battery's state and performance in real-time, the BMS will intelligently adjust the charging and discharging process. It will take the necessary actions to minimize the risk of battery damage and prevent accidents from occurring.

1.2 Expectation and challenges

A good BMS should meet the user's minimal requirements, such as indestructible, producing little heat and reducing the Bill of Materials (BOM). The BMS is a critical device that cuts off the power supply line when an abnormality arises in the battery (e.g. overcurrent, overheating, overcharging, etc.) and it must be difficult to damage or break. Secondly, numerous amperes of current will flow through the circuit, resulting in the loss of the current route in the battery, which would generate heat and compromise the safety of lithium-ion battery operation. Finally, material reduction in design is essential while preserving product safety, as well as reducing the size for hardware design.

Considering the aforementioned expectations, it's evident that several challenges involve addressing issues such as heat generation reduction and optimizing material sizing within the battery. These challenges stem from the need to minimize current path loss and achieve optimal efficiency with low resistance. In response to these demands, Renesas has proposed the shunt-less solution for BMS.

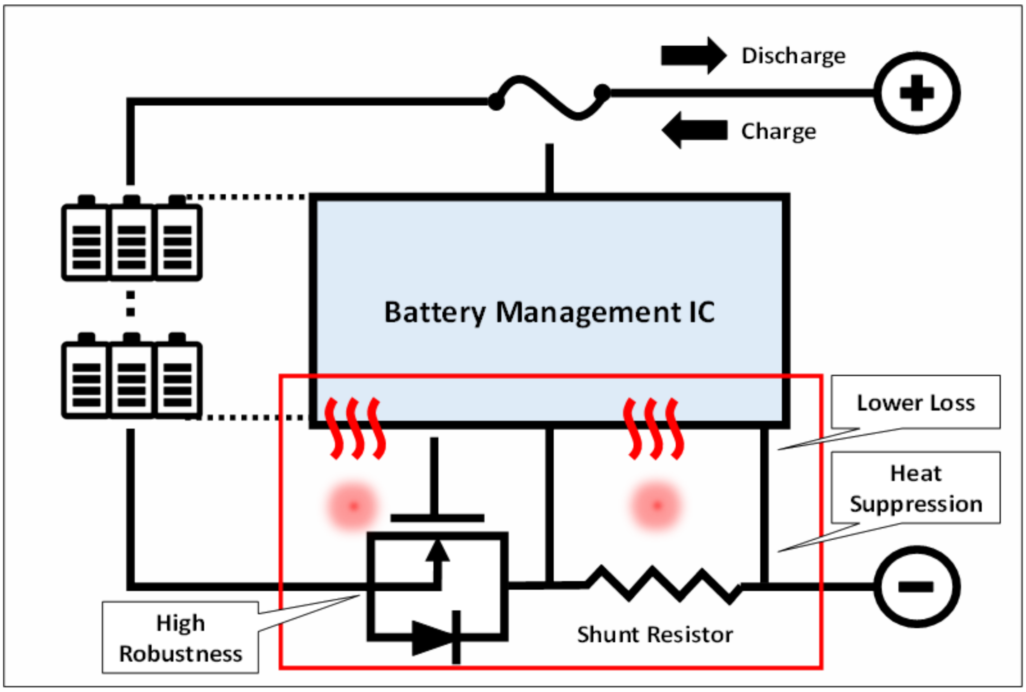

Figure 1-1 Current system configuration image of Li-ion battery pack

1.3 Target Application

There is a huge range of applications for BMS in the industrial and automotive sectors. These applications vary across different categories, ranging from low power to high power, as illustrated in the image below.

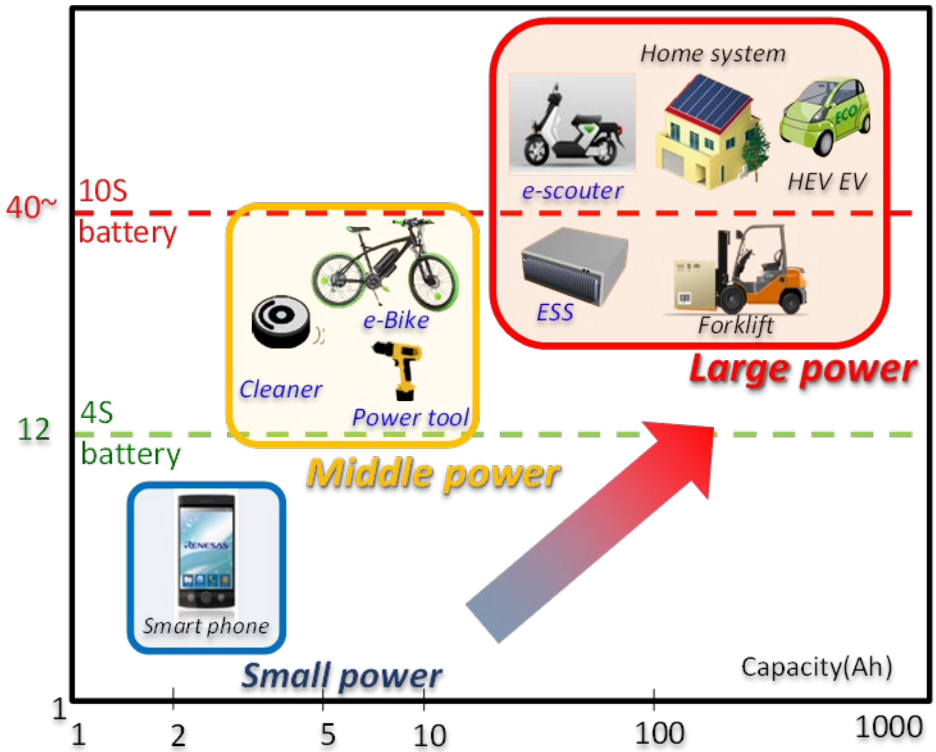

Figure 1-2 Illustration chart for BMS application

Note*: The nominal voltage of a 1S battery is typically around 3.7 volts.

2. Renesas BMS shunt-less solution

Renesas has introduced a solution to help improve the issues observed in the BMS, utilizing a combination methodology of a 'shunt resistor-less solution' and a 'thermistor-less solution'. This solution combines the benefits and features of battery FG-IC, MOSFET with current sensing, and thermal monitoring functions.

2.1 Shunt resistor less solution

As we know, power loss is influenced by current and resistance. When current flows through a resistor, it generates heat and will lead to power loss in the battery pack. If the battery pack is used in high-power tools, there is a potential risk of high temperatures, which can degrade battery performance and may even lead to short circuits or ignition.

Renesas is now offering a shunt resistor-less solution to minimize heat generation from the shunt resistor. As per the following formula, it's reducing the resistor value keeps power loss lower even with increasing current.

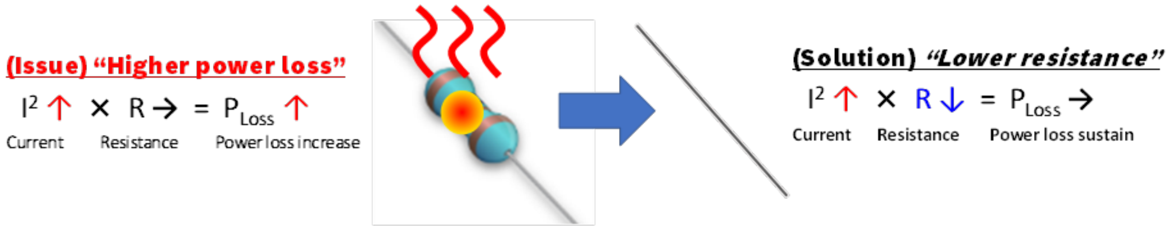

Figure 2-1 Shunt resistor less

2.2 Thermistor less solution

The thermistor was used to monitor temperature changes in the BMS and to protect the battery during charging. As the temperature rises, the resistance inside the thermistor changes will affecting the current or voltage readings to the microcontroller. Temperature readings can then be obtained through the ADC feature in the microcontroller after calculation.

However, Renesas is able to provide a superior solution with high-speed thermal protection capability, eliminating the need for additional circuits. The MOSFET selected for this solution offers faster abnormal detection and reduces the thermal design margin.

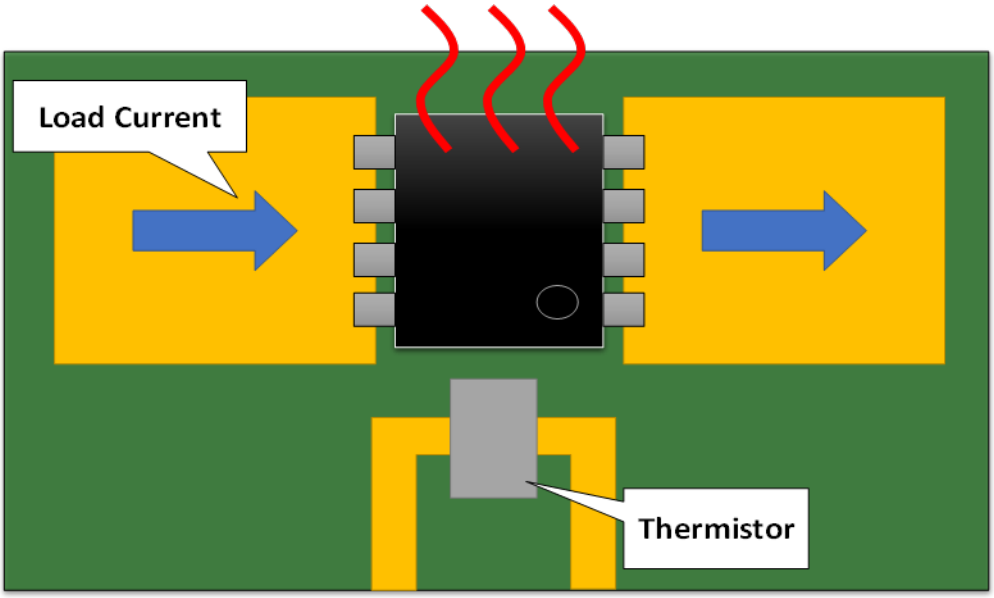

Figure 2-2 Traditional method for MOSFET temperature monitoring

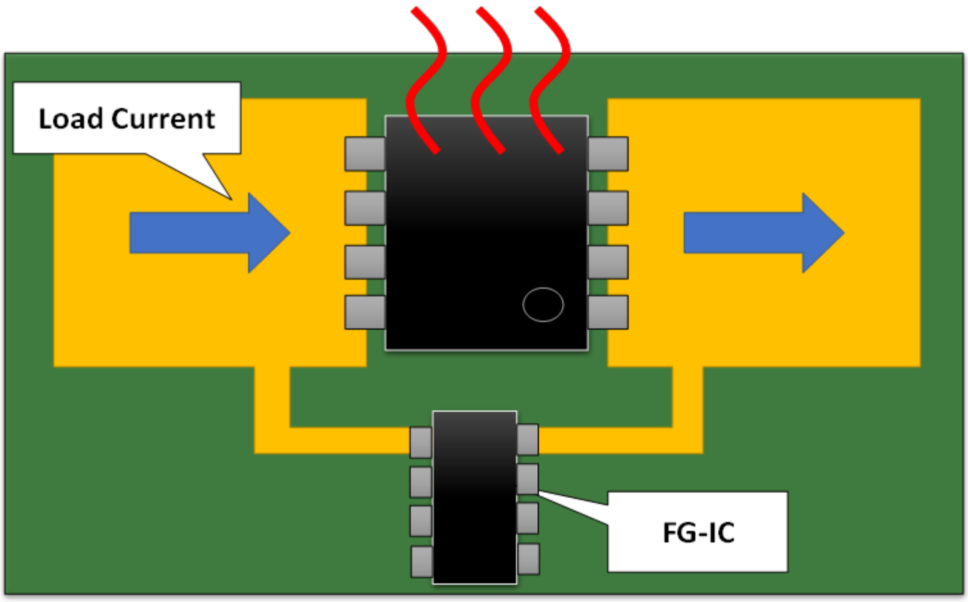

Figure 2-3 New method for MOSFET temperature monitoring

2.3 Advantage of Renesas BMS shunt-less solution

To achieve success, MOSFET are equipped with a current-sensing function, and FG-IC (Fuel Gauge IC) is used to develop a shunt resistor-less solution. This approach enables the reduction of "shunt resistance," a factor contributing to heat generation, resulting in significantly lower temperatures. Moreover, it reduces the BOM (Bill of Materials) of the MOSFET and shunt resistor by approximately 6%. These advancements enhance the safety of lithium-ion batteries and broaden their applications, enabling them to handle higher outputs while maintaining the same level of heat generation.

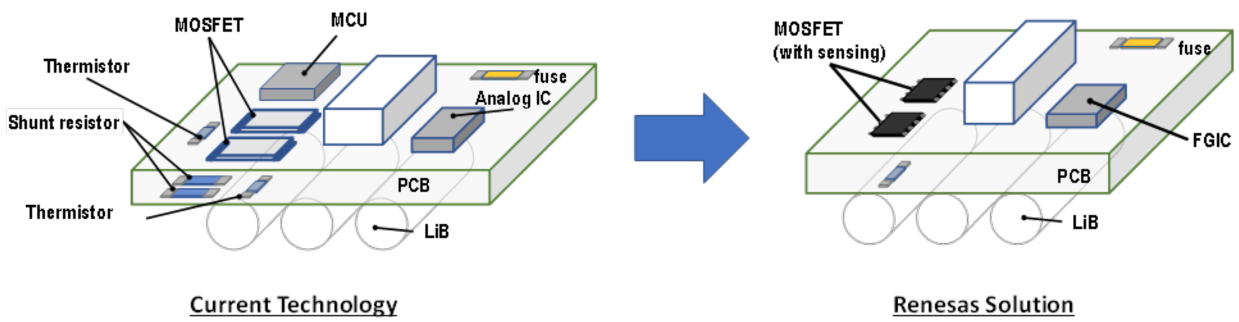

Figure 2-4 Shunt-less solution by kits of MOSFET with sensing and FGIC

From the diagram above, the PCB design can be shrinking about 5~8% due to additional component has been remove and replace by the Renesas solution.

Table 1. BOM List comparison

Item Require	Conventional Model	Renesas Solution Model
MOSFET	2	2
Thermistor	2	1
FG-IC	0	1
MCU	1	0
AFE	1	0
Shunt Resistor	2	0

The results of the comparison between the current technology and Renesas solution show significant improvements in thermal performance. Specifically, there is a decrease of approximately 15°C (or 14%) on the front side of the PCB and 34°C (or 29%) on the backside of the PCB. The load current for below result was taken at 60A.

Table 2. Temperature comparison

System Configuration	Heat Generation	
	MOSFET (Frontside of PCB)	Shunt Resistor (Backside of PCB)
Existing configuration with shunt resistor	105°C	115°C
Renesas Solution (Shunt-less)	90°C	81°C (*Note**)

Note*: Measure the surface of PCB since there is no shunt resistor

3. BMS Evaluation Board

This chapter mainly to discuss about the thermal performance with the Renesas shunt-less solution.

3.1 Renesas BMS Evaluation board “WS(0)”

Renesas has designed a shunt-less EVB to evaluate the performance of the shunt-less solution, ensuring that the concept is workable and applicable to other products.

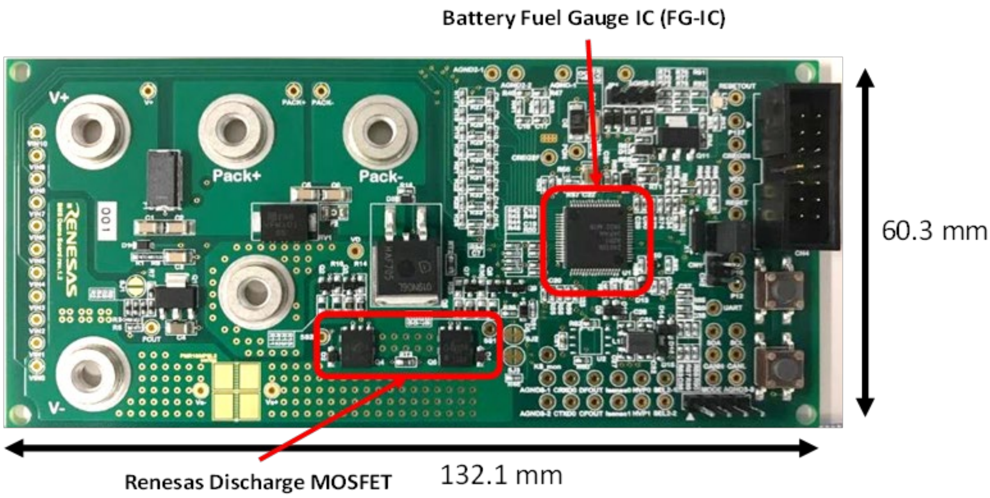

Figure 3-1 Renesas BMS Shunt-less Solution EVB

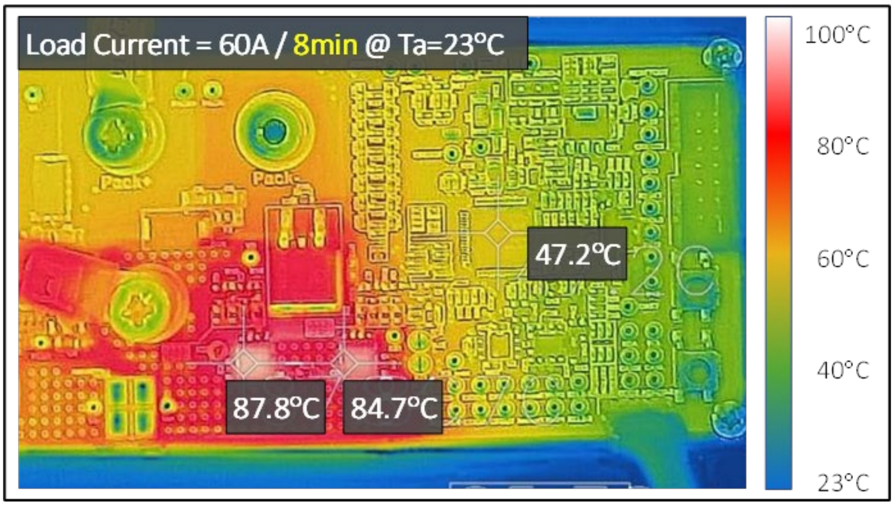

Figure 3-2 Thermograph Photo for Renesas BMS Shunt-less Solution EVB

Comparing the thermal performance change on the EVB to other competitor EVBs (MOSFET with a shunt resistor of 0.5mΩ), there is a significant improvement. The temperature change has seen a substantial decrease from 105.6°C to 87.8°C, which amounts to about a 16.8% reduction in heat generation.

3.2 Method Comparison

The product board design was developed by Renesas with incorporates the Renesas BMS shunt-less solution. Temperature changes on the board will be recorded and captured by using this product board for thermal measurements.

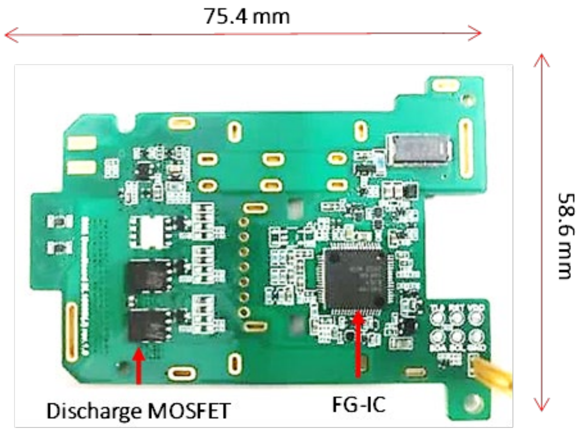

Figure 3-3 Front side of the Evaluation Board

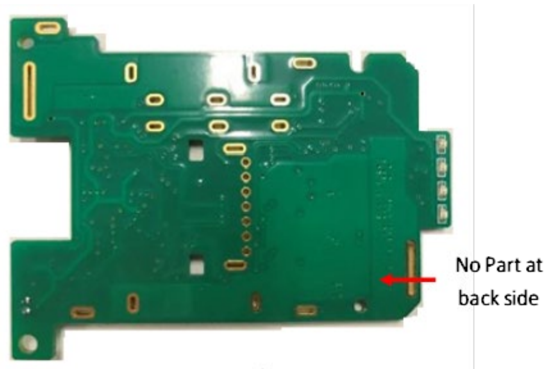

Figure 3-4 Back side of the Evaluation Board

3.2.1 Heat suppression Effect

The figure below depicts the thermograph photo obtained by measuring the Renesas solution board. The thermal results will be used for comparison with the competitor configuration (MOSFET + Shunt resistor). Measurements will be taken on the MOSFET surface at the front side of the board and under the MOSFET at the back side of the board.

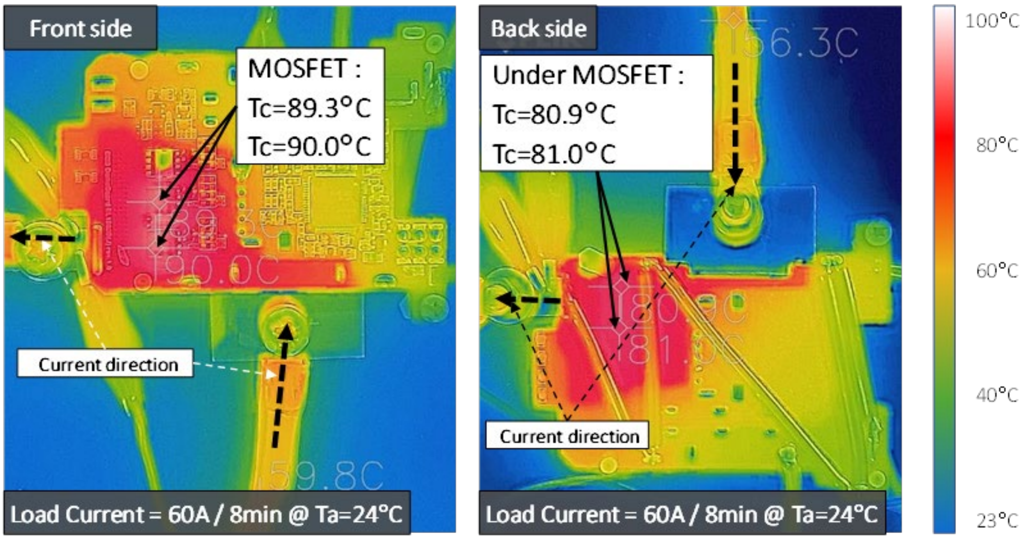

Figure 3-5 Thermograph Photo

The table shows the results comparing the Renesas solution to the competitor's design. The temperature has significantly improved for both the front and back sides, by nearly 15% to 30%. These results were measured under a load current of 60A with an energization duration of 8 minutes, utilizing 2 parallel MOSFETs on the board.

Table 3. Temperature comparison

Measurement Point	Competitor (Tc)	Renesas (Tc)	Delta (ΔTc)	Delta (%)
Front Side of Board	105.4 °C	90.0 °C	15.4 °C	14.6%
Back Side of Board	115.4 °C	81.0 °C	34.4 °C	29.8%

3.2.2 Heat suppression effect (High power model)

For the higher power model, Renesas has developed a solution featuring 3 units of MOSFETs in parallel. This will be compared with Renesas' 2-unit MOSFET parallel board. The temperature has significantly reduced from 90°C to 74.7°C, representing a reduction of about 15.3°C or 17%.

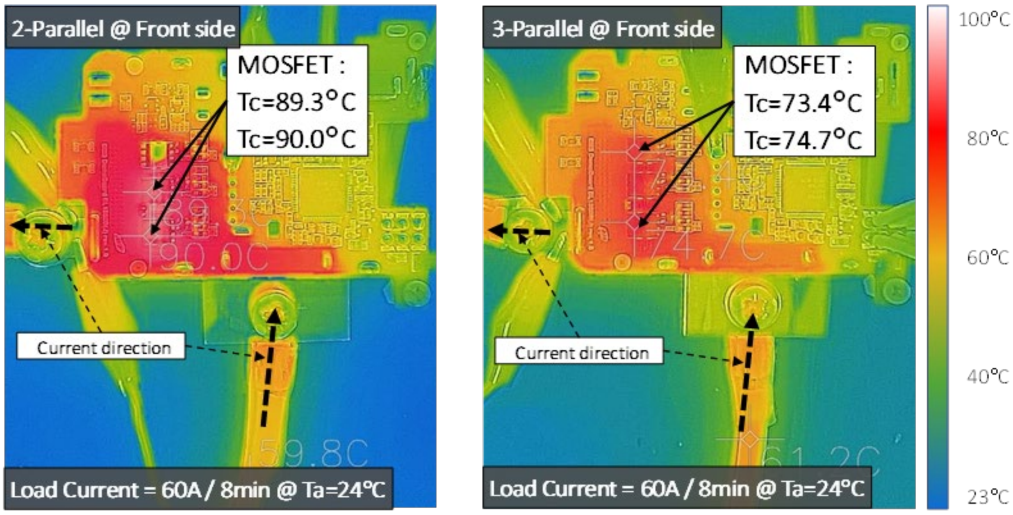

Figure 3-6 Thermograph Photo compare between 2-Parallel & 3-Parallel

3.2.3 Advantage of Renesas BMS Configuration

The table below illustrates how the Renesas configuration holds an advantage over conventional systems in the market (e.g., power tools) regarding heat generation.

Table 4. Temperature comparison

Comparison Items	Condition	Renesas	Competitor
R_{DS}(ON) @ MOSFET	40V MOSFET @ 2-Parallel	0.6 mΩ	0.17 mΩ
Resistance of Shunt Resistor	Shunt Resistor @ 2-Parallel	0 mΩ (Shunt-less)	0.5 mΩ
System Total Resistance		0.6 mΩ	0.67 mΩ
Heat Generation (Surface Temp. of MOSFET)	Discharge Current = 60A DC / 8 min	90.0 °C	105.4 °C
Mount Size @ MOSFET	Only MOSFET Area	63.4 mm^2	127.4 mm^2

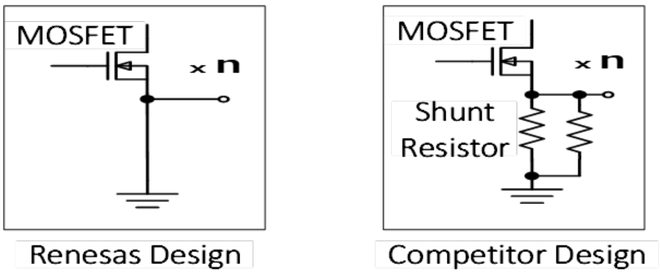

Figure 3-7 Configuration design

4. MOSFET for shunt-less solution

4.1 MOSFET Introduction

The MOSFET (RBK04U04GNS) selected for this solution is suitable for use in Li-ion battery management systems. This MOSFET has a capability of 40V with 35A N-Channel Power MOSFET.

The main reasons for selecting this MOSFET are its features:

- Low on-state resistance RDS (on) of 1.2mΩ typ. (at VGS = 10V, ID = 18A)
- Built-in current sensing feature, useful for:
    - Over Current Protection (OCP)
    - Static current monitoring
- HSON-8 pin, surface mount package (5 x 6 mm)

This MOSFET is targeting mid-voltage products such as power tools, cleaners, e-bikes, drones, and other industrial products. It is suitable for use as a low-side protection switch for BMS, BLDC inverters, and DC-DC inverters.

4.2 Product Outline

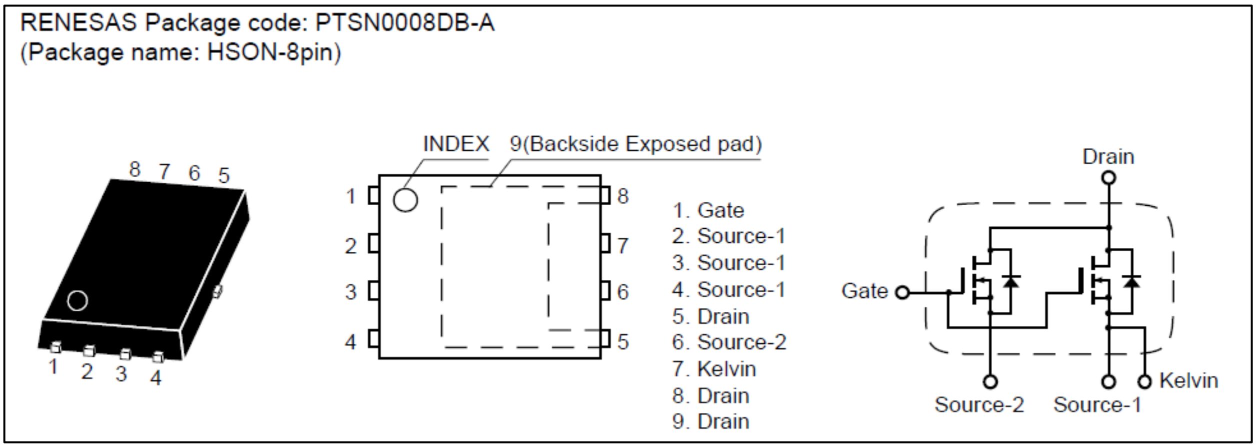

Figure 4-1 RBK04U04GNS MOSFET outline

4.3 Product Maximum Rating

Table 5. RBK04U04GNS Absolute Maximum Rating

Item	Symbol	Ratings	Unit
Drain to source voltage (V_{GS} = 0 V)	V_{DSS}	40	V
Gate to source voltage (V_{DS} = 0 V)	V_{GSS}	±20	V
Drain current (DC) Notes2	$I_{D(DC)}$	35	A
Drain current (Pulse) Notes1, 2	$I_{D(pulse)}$	320	A
Body diode forward current Notes2	I_F	35	A
Single avalanche current Notes3	I_{AS}	45	A
Single avalanche energy Notes3	E_{AS}	202	mJ
Total power dissipation (T_C = 25 °C)	P_{T1}	83	W
Channel temperature	T_{ch}	150	°C
Storage temperature	T_{stg}	–55 to +150	°C

Note: The details of the MOSFET can refer to datasheet at Renesas webpage.

5. FGIC for shunt-less solution

5.1 FGIC (Fuel Gauge IC) Introduction

The FGIC (RAJ240100GFP) selected for this solution is suitable for use in Li-ion battery management systems. It comprises an MCU device and an AFE device in a single package, equipped with a variety of battery management features. It incorporates the Renesas RL78 CPU core, which offers multiple low-power modes and enables high performance in ultra-low power operation.

The RAJ240100 contains control firmware stored in embedded flash memory. This firmware controls attached embedded analog and digital circuits to perform battery voltage/current/temperature measurements, estimate remaining capacity, and provide overcurrent/voltage/temperature protection, along with other battery management operations.

5.2 Product Outline

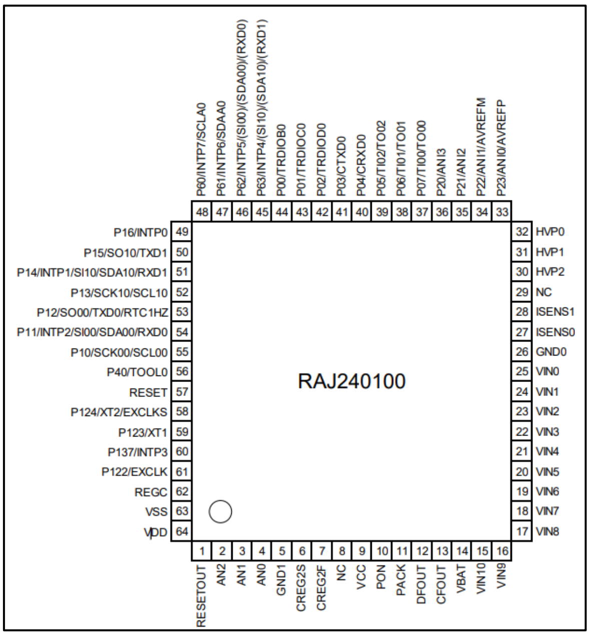

Figure 5-1 RAJ240100GFP FGIC outline

Note: The details of the FGIC can refer to datasheet at Renesas webpage.

6. Conclusion

In conclusion, the Renesas BMS shunt-less solution stands out as one of the best methods for monitoring the overall system and reducing thermal heat generation, thereby ensuring safer system operation.

This solution not only aids in cost reduction and hardware design miniaturization but also prioritizes accuracy in current measurement and thermal protection with shorter detection times.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jul.24.24	-	First edition

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