Diode Series

Advantages of PMDE Compact Package with High Heat Dissipation for Automotive Schottky Barrier Diodes

In recent years, as mechatronic integration of automotive equipment has advanced, demand for downsizing of mounted devices has also increased. However, the package power is generally decreased if the package is downsized. Therefore, striking a balance between downsizing and the loss of package power is very challenging, especially for devices susceptible to the danger of thermal runaway due to overheating, including Schottky barrier diodes (hereafter SBD). To resolve this issue, ROHM offers a new package, “PMDE”. PMDE is a successor of the conventional “PMDU” package, which has been popular in the automotive market. Compared with PMDU, the size of PMDE is decreased by approximately 40% in the mounting area. While the dimensions of PMDU are 3.5x1.6x0.8 mm, those of PMDE are 2.5x1.3x0.95 mm. Nevertheless, a package power equivalent to PMDU is secured for PMDE by increasing the back electrode area (by approximately 1.5 times). Furthermore, the mounting strength is improved by approximately 40% in PMDE. This application note explains the physical differences from the conventional PMDU package, including the external shapes and internal structures. In addition, the advantages of PMDE are further discussed by introducing the results of thermal simulations and evaluations on actual equipment.

1. External shape and internal structure

1-1. Comparison of external shapes

Figure 1 shows a comparison of the external shapes between PMDE and PMDU.Compared with the conventional PMDU package, the mounting area of PMDE is decreased by approximately 40%. Nevertheless, an excellent mounting strength (approximately 1.4 times greater) is achieved because the back electrode area is extended by approximately 1.5 times.

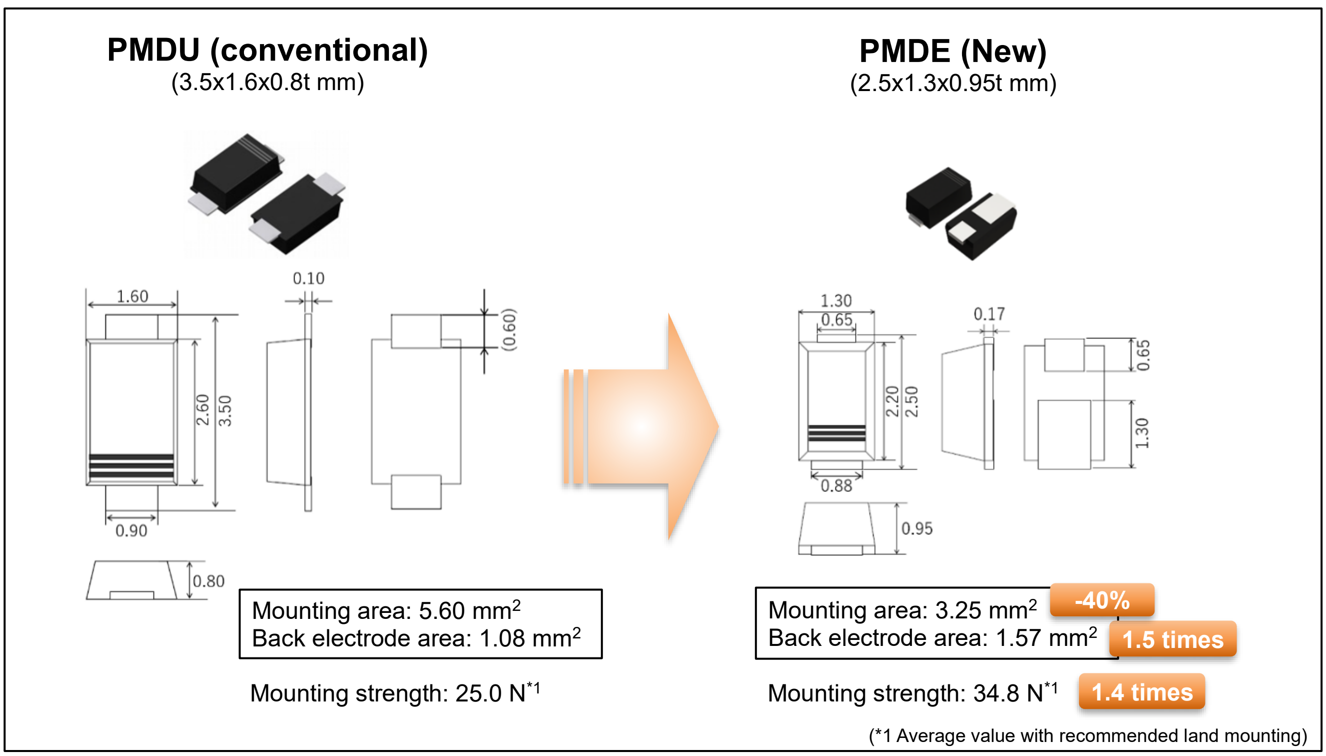


Figure 1. Comparison of the external shapes between PMDU and PMDE

1-2. Comparisons of internal structures and heat dissipation paths

Figure 2 shows comparisons between PMDE and PMDU for the internal structures and the heat dissipation paths.

Similar to the conventional PMDU package, PMDE adopts a “wireless structure” where the die is directly tucked between the frames without using wiring for electrical connection between the die and the frames. Since this structure eliminates the risk of wire melting due to a surge current, a high surge current rate (I_{FSM}) is achieved. For the SBD lineup introduced later (in Chapter 4), the guaranteed values of I_{FSM} are very high, ranging between 20 and 30 A.

In addition, regarding the heat dissipation path on the cathode side, the back of PMDU is mostly coated with mold resin. Therefore, thermal propagation mainly occurs through the lead frame horizontally. In contrast, PMDE adopts a structure where the back electrode is significantly exposed, allowing a more direct and efficient heat dissipation to the PCB. In this way, an arrangement is made for PMDE to prevent the allowable power dissipation from declining due to downsizing.

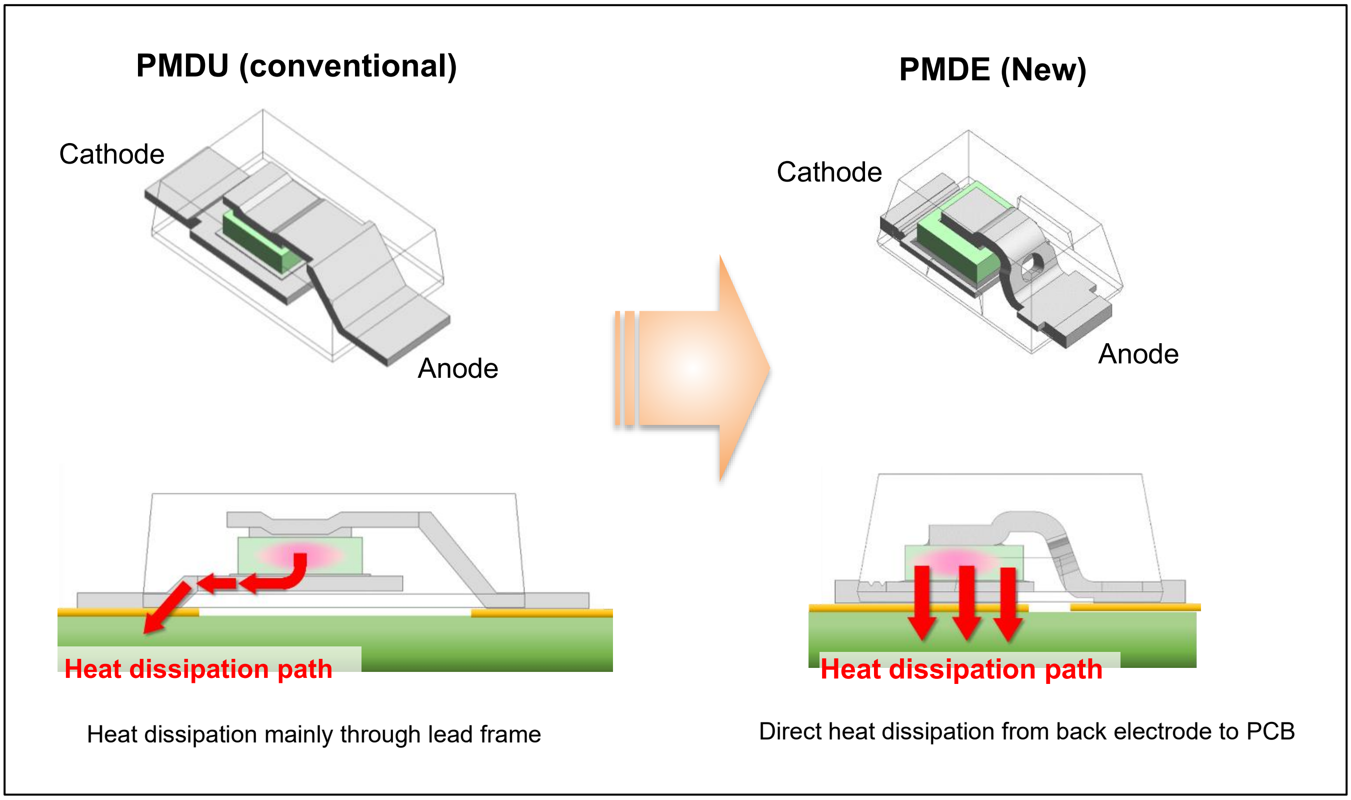


Figure 2. Comparisons of internal structures and heat dissipation paths

2. Comparison of heat dissipation performance (simulation)

2-1. Method of thermal simulation

As shown in Figure 3, a PCB of 50x50x0.8t (mm) is assigned with copper foil sizes (from 5x5 mm to 50x50 mm/single side) where the product is mounted. The junction temperature of die (Tj) and thermal transfer under these conditions are simulated. It can be seen that heat is spread to the surrounding area as the area of copper foil is increased. In other words, since the heat transfer to the glass epoxy part of the PCB is very limited, a large area of copper foil is critical to a sufficient heat dissipation from the product.

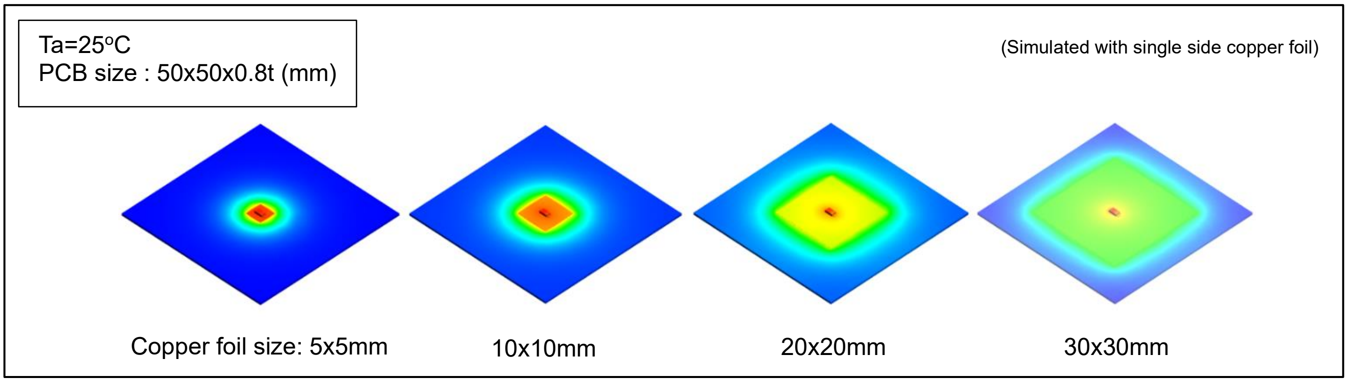


Figure 3. Example of thermal simulation

2-2. Thermal resistance $R_{th}(j-a)$ and copper foil area

From the results of thermal simulation in section 2-1, the relations of the thermal resistance between the junction and the ambient R_{th}(j-a) and the copper foil area are shown in Figure 4 for PMDE and PMDU. In addition, Figure 5 shows the relative error in R_{th}(j-a) (PMDE) when PMDU is used as the standard.

If the copper foil area is small, the effect of the back heat dissipation for PMDE is not sufficiently realized, making the value of R_{th}(j-a) (PMDE) larger than that of PMDU. As the copper foil area is increased, the heat dissipation effect is improved and the difference from PMDU is decreased. When the copper foil thickness "t" is 35um and 70um, the copper foil area is approximately 90 mm^2 and 60 mm^2, respectively, resulting in the values of thermal resistance equivalent to PMDU. As the copper foil area is further increased, the difference between PMDE and PMDU is increased (as the heat dissipation performance of PMDE is further improved), and starts saturating from approximately 2,000 mm^2.

Therefore, when using PMDE, it is important to secure an appropriate area of the copper foil to achieve a heat dissipation performance exceeding that of PMDU. If the copper foil area is too small, the heat dissipation performance is worse than PMDU. On the other hand, if the copper foil area is too large, no improvement in the heat dissipation performance is achieved, wasting the board area. In addition, a thicker copper foil can achieve a sufficient heat dissipation performance for PMDE with a smaller area, and can also increase the difference from PMDU.

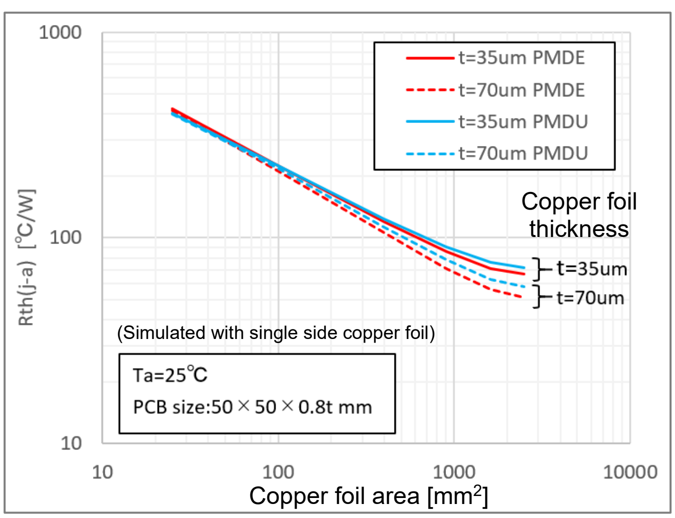


Figure 4. R_{th}(j-a) vs. copper foil area

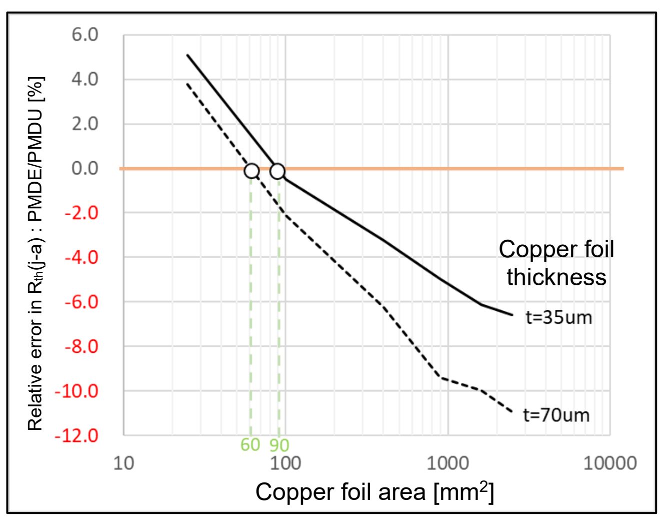


Figure 5. Relative error in R_{th}(j-a) (PMDE/PMDU)

3. Actual evaluations (ROHM Automotive LED Driver BD81A44EFV-M)

Using the ROHM Automotive LED Driver BD81A44EFV-M and its evaluation board, the heating and efficiency of PMDU and PMDE are compared and evaluated.

3-1. Circuit diagram and PCB layout

Figure 6 shows the LED drive circuit (DC-DC part) for the evaluation board. The LED driver uses a buck-boost DC-DC converter to control the output current. Here, either of the PMDE package product "RBR2VWM40ATF" or the PMDU package product "RBR2MM40ATF" is used for both of diodes D1 and D2. These products have the same dies and only their packages differ.

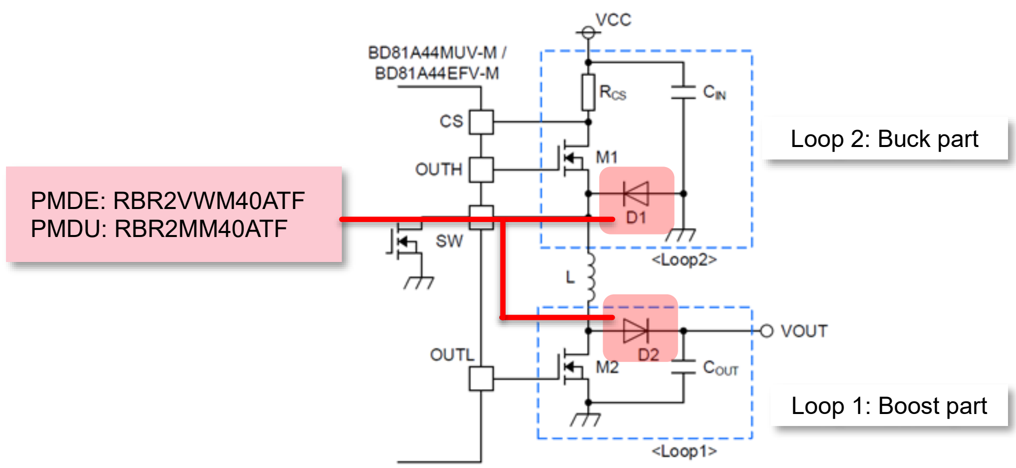
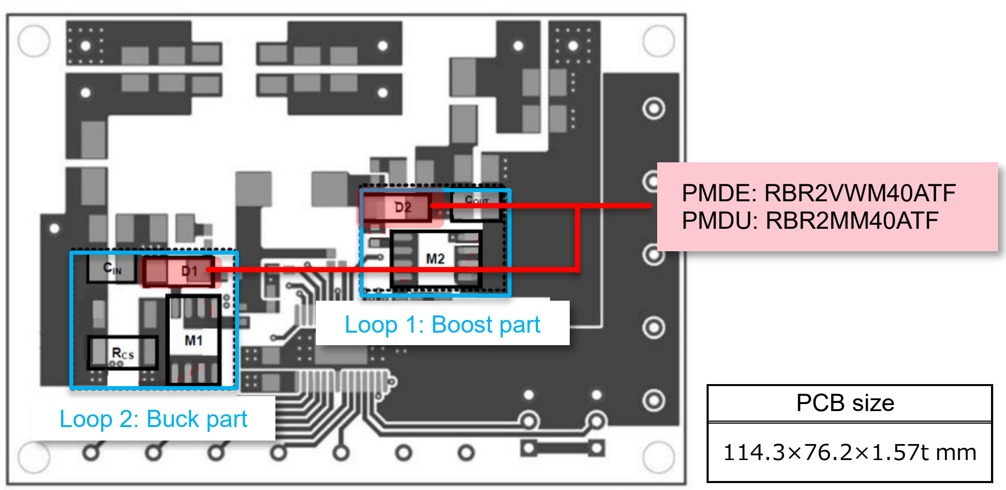


Figure 6. Circuit diagram (DC-DC part)

Figure 7 shows the PCB information on the evaluation board. The evaluation board is composed of a total of four layers. The copper foil thickness is 70um for the top and fourth (Bottom) layers, and 35um for the second and third layers. The first layer is patterned as shown in Figure 7, while the second, third, and fourth layers are patterned with a square of 74.2mm. The mounting positions of the diodes are D1 and D2 (displayed in pink). RBR2VWM40ATF (PMDE) or RBR2MM40ATF (PMDU) mounted on these positions and the comparative evaluation is performed.



Top		2 Internal Layers		Bottom	
Copper Pattern	Thickness	Copper Pattern	Thickness	Copper Pattern	Thickness
Footprints and Traces	70 µm	74.2 mm x 74.2 mm	35 µm	74.2 mm x 74.2 mm	70 µm

Figure 7. PCB information

3-2. Comparison of heating

Figure 8 shows the results of thermography measurement on PMDU and PMDE when the evaluation board is operated (package temperature “Tc”). The differences in Tc between PMDE and PMDU are very small. The temperature differences are ⊿Tc(D1)=1.7°C and ⊿Tc(D2) = 1.2°C on the buck and boost sides, respectively. Although PMDE is the compact package, an efficient heat dissipation to the board maintains its package temperature equivalent to that of PMDU.

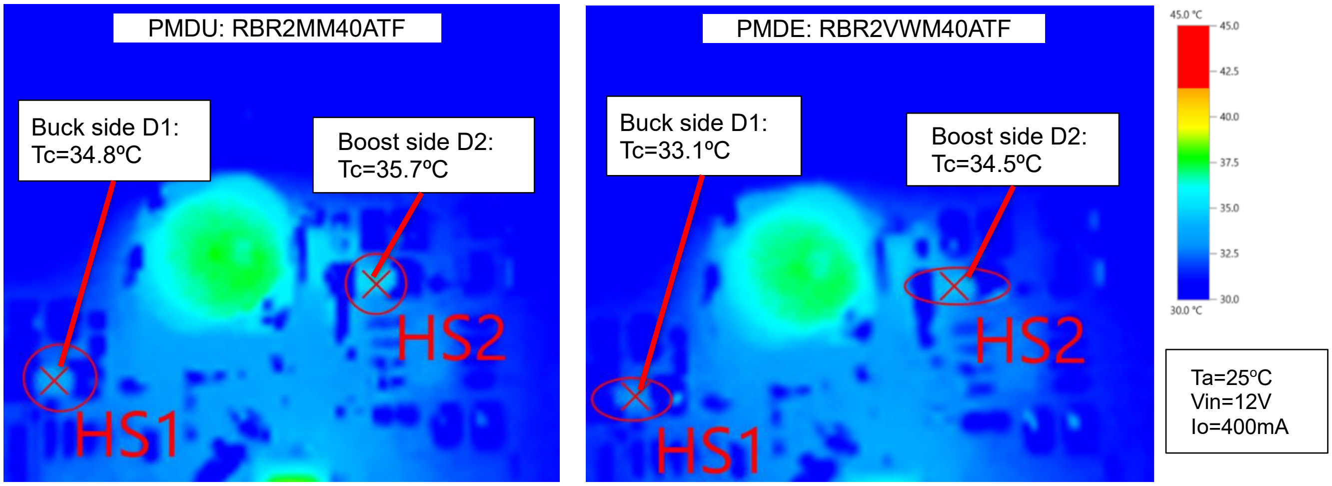


Figure 8. Comparison of thermographs

3-3. Comparison of efficiencies

Figure 9 shows the results of comparison of the efficiencies. The efficiency peak of PMDE is η_{peak}(PMDE)=88.6%, while that of PMDU is η_{peak}(PMDU)=88.7%, giving similar results. Since the dies are identical (the same temperature coefficients) for these samples, it is expected that the junction temperatures (Tj) are equivalent as well. Therefore, under these evaluation conditions, you can conclude that a heat dissipation performance equivalent to PMDU is achieved with PMDE and the risk of thermal runaway is contained at a similar level, although PMDE is more compact than the conventional PMDU package.

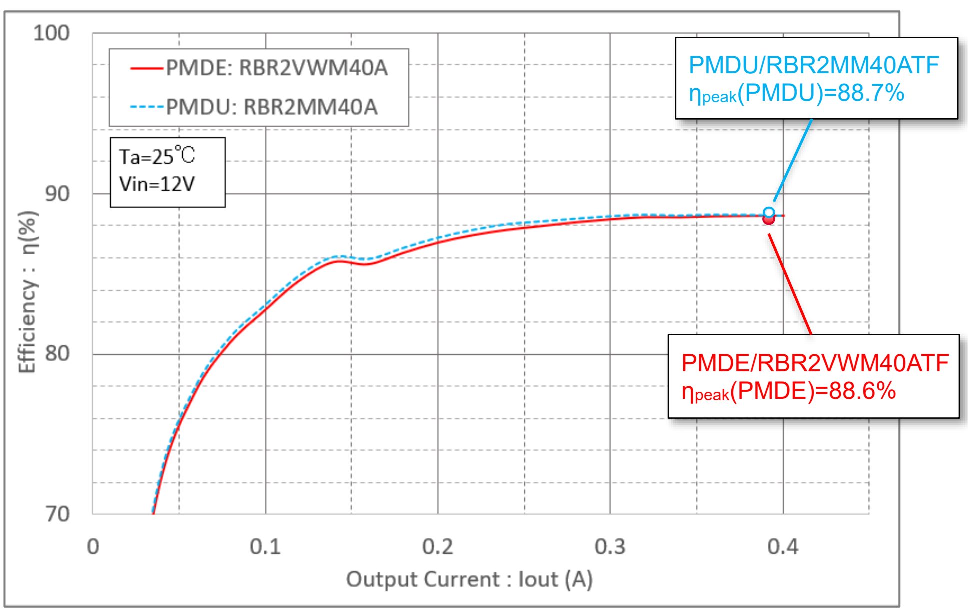


Figure 9. Comparison of efficiencies

4. Automotive PMDE package SBDs lineup

Figure 10 shows the SBDs lineup in the PMDE package (click the product names in blue to jump to the product pages).In addition to the RBR series featuring low V_F used for this evaluation on actual evaluations (in Chapter 3), a wide variety is offered including the RBxx8 series with ultra-low leakage current. Furthermore, in addition to SBDs, Fast Recovery Diodes (FRDs), Zener Diodes (ZDs), and Transient Voltage Suppressor (TVS) are also expected to be added to the lineup. Please feel free to contact us.

Series name	Part No.	Grade code *3	Absolute maximum ratings				Electrical Characteristics			
			V_{RM} (V)	Io (A)	I_{FSM} (A)	T_j max (°C)	V_F max (V)	Conditions	I_R max (uA)	Conditions
Low VF and high efficiency RBR series	RBR1VWM30A	TF	30	1	30	150	0.48	I_F=1A	50	V_R=30V
	RBR2VWM30A	TF		2	30		0.53	I_F=2A	50	
	RBR1VWM40A	TF	40	1	20		0.52	I_F=1A	50	V_R=40V
	RBR2VWM40A	TF		2	20		0.62	I_F=2A	50	
	RBR1VWM60A	TF	60	1	20		0.53	I_F=1A	75	V_R=60V
	RBR2VWM60A	TF		2	20		0.65	I_F=2A	75	
Ultra-low IR RBxx8 series *2	RB168VWM-30	TF	30	1	30	175	0.69	I_F=1A	0.6	V_R=30V
	RB068VWM-30	TF		2	30		0.75	I_F=2A	0.6	
	RB168VWM-40	TF	40	1	30		0.69	I_F=1A	0.5	V_R=40V
	RB068VWM-40	TF		2	30		0.79	I_F=2A	0.5	
	RB168VWM-60	TF	60	1	30		0.76	I_F=1A	0.5	V_R=60V
	RB068VWM-60	TF		2	30		0.84	I_F=2A	0.5	
	RB168VWM100	TF	100	1	30		0.84	I_F=1A	0.3	V_R=100V
	RB068VWM100	TF		2	30		0.94	I_F=2A	0.3	
	RB168VWM150	TF	150	1	30		0.89	I_F=1A	1	V_R=150V
	RB068VWM150	TF		2	30		0.96	I_F=2A	1	

*2: Under development   *3: The grade code "TF" represents compliance with AEC-Q101

Figure 10. PMDE SBDs lineup

5. Summary

- Compared with the conventional PMDU package, although the PMDE package is more compact (reduction in the mounting area by 40%), the heat dissipation performance from the back electrode is improved. This enables the allowable power dissipation equivalent to or greater than that of PMDU depending on the board conditions.
- To fully achieve the heat dissipation performance of PMDE within a limited space, the setting of the area and thickness of the mounting copper foil are very important.
- If the PCB is designed properly, the PMDE package can provide very significant advantages for automotive equipment that has stringent "space saving" and "low heating" requirements.

6. Reference

[1] 4ch White LED Driver Built-in Current Driver Buck-Boost and Boost DC/DC Converter for Automotive BD81A44EFV-M Data sheet (No. TSZ02201-0T3T0C600060-1-2 Rev.008) ROHM Co., Ltd., February 2021.

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