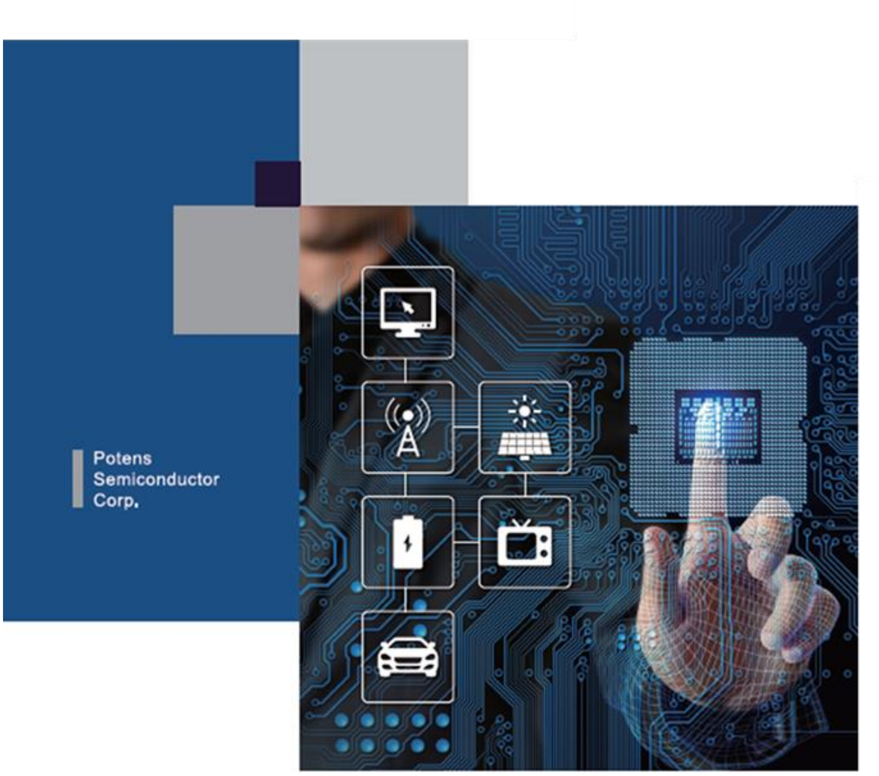
Application Information

Safe Operation for Driving Application



Enhancing everyday life

Safe Operating Area (SOA) is to mark the allowable operating area of the MOSFET in voltage, current, time duration and temperature of the component. It is established for the different operating conditions that the switching power supply works on its system load. The specifications of the MOSFET manufacturer will outline the specific limitations of the MOSFET. The purpose is to ensure that the MOSFET can meet the operating restrictions of the system application in different environments. Fig. 1 shows the SOA curves of Potens' Product PDC6986BZ-5 as the SOA example.

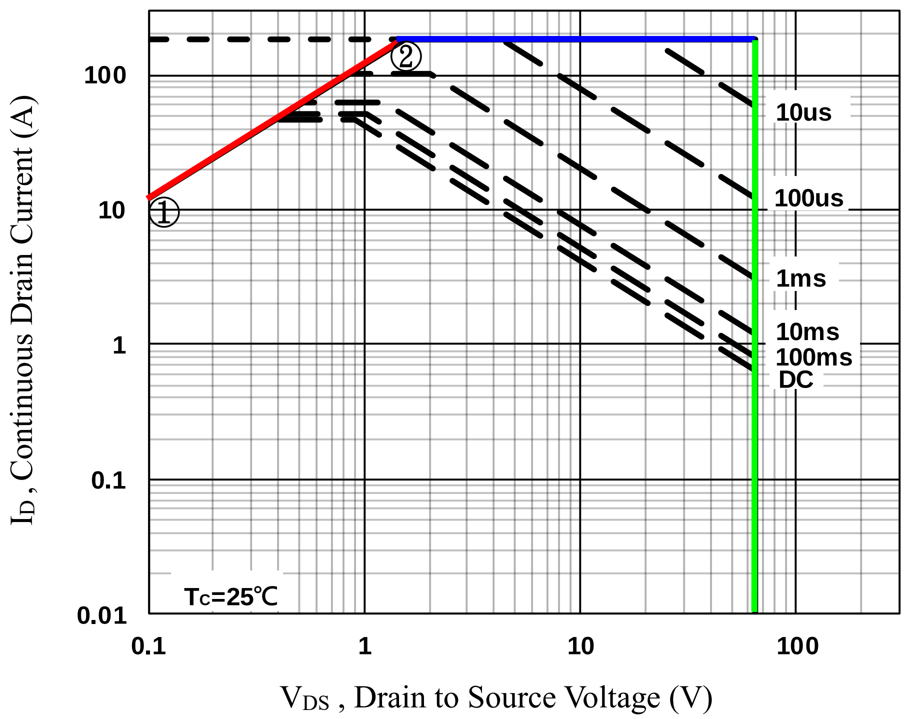


Fig. 1 The SOA of PDC6986BZ-5

The X-axis of the SOA curves is drain to source voltage (V_{DS}) and the Y-axis of the SOA is drain current (I_D). The major curves of the SOA are $R_{DS(ON)}$ limit (red line), pulse current limit (blue line) and breakdown voltage limit (green line). The following will explain how to draw these curves in the SOA figure.

1. $R_{DS(ON)}$ limit

The $R_{DS(ON)}$ limit curve is limited by the on-state resistance of the MOSFET. The maximum value of $R_{DS(ON)}$ is from the table I [1]. The relation of the point ① can be expressed as:

$$I_D = \frac{V_{DS}}{R_{DS(ON)}} = \frac{0.1}{0.0083} = 12A \tag{1}$$

The point ② is shown as

$$V_{DS} = I_{DM} \times R_{DS(ON)} = 184 \times 0.0083 = 1.523V \tag{2}$$

2. Pulse current limit

The pulse current limit curve is limited by the maximum drain current rating (I_{DM}=184A).

3. Breakdown voltage limit

The breakdown voltage limit curve is limited by the maximum drain to source voltage rating (BV_{DSS}=65V).

Table I. Electrical Characteristics of PDC6986BZ-5

On Characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$R_{DS(ON)}$	Static Drain-Source On-Resistance	V_{GS}=10V , I_D=15A	---	6.9	8.3	mΩ
		V_{GS}=4.5V , I_D=12A	---	10.5	13.6	mΩ

Absolute Maximum Ratings

Symbol	Parameter	Rating	Units
I_{DM}	Drain Current – Pulsed[1]	184	A

Off Characteristics

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS}=0V , I_D=250uA	65	---	---	V

The operation time duration while the MOSFET switching is also related to the SOA curves. Therefore, it need to consider the drain current I_D and the power dissipation P_D at the different time period of the MOSFET on/off switching operation. For the drain current and power dissipation calculation using thermal resistance relation by analogy to an electrical circuit, the equations can be derived as:

$$I_D = \sqrt{\frac{T_{J(max)} - T_C}{R_{\theta JC} \times Z_{\theta JC} \times R_{DS(ON)} \times K}} \quad (3)$$

$$P_D = V_{DS} \times I_D = \frac{T_{J(max)} - T_C}{R_{\theta JC} \times Z_{\theta JC}} \quad (4)$$

where $T_{J(max)}$ is the maximum operating junction temperature, T_C is the case temperature, $R_{\theta JC}$ is the junction-to-case thermal resistance, $Z_{\theta JC}$ is the normalized transient thermal resistance and K is the normalized on-state resistance. Fig. 2 shows the continuous current (DC) operation of SOA and the drain current and drain to source voltage of the point ③ are shown as

$$I_D = \sqrt{\frac{T_{J(max)} - T_C}{R_{\theta JC} \times Z_{\theta JC} \times R_{DS(ON)} \times K}} = \sqrt{\frac{150 - 25}{2.98 \times 1 \times 0.0083 \times 2.3}} = 46.9A \quad (5)$$

$$V_{DS} = \frac{T_{J(max)} - T_C}{R_{\theta JC} \times Z_{\theta JC}} \times \frac{1}{I_D} = \frac{150 - 25}{2.98 \times 1} \times \frac{1}{46.9} = 0.89V \quad (6)$$

At point ④, the relation of the drain current for V_{DS} = 65V is derived as

$$I_{DS} = \frac{T_{J(max)} - T_C}{R_{\theta JC} \times Z_{\theta JC}} \times \frac{1}{V_{DS}} = \frac{150 - 25}{2.98 \times 1} \times \frac{1}{65} = 0.65A \tag{7}$$

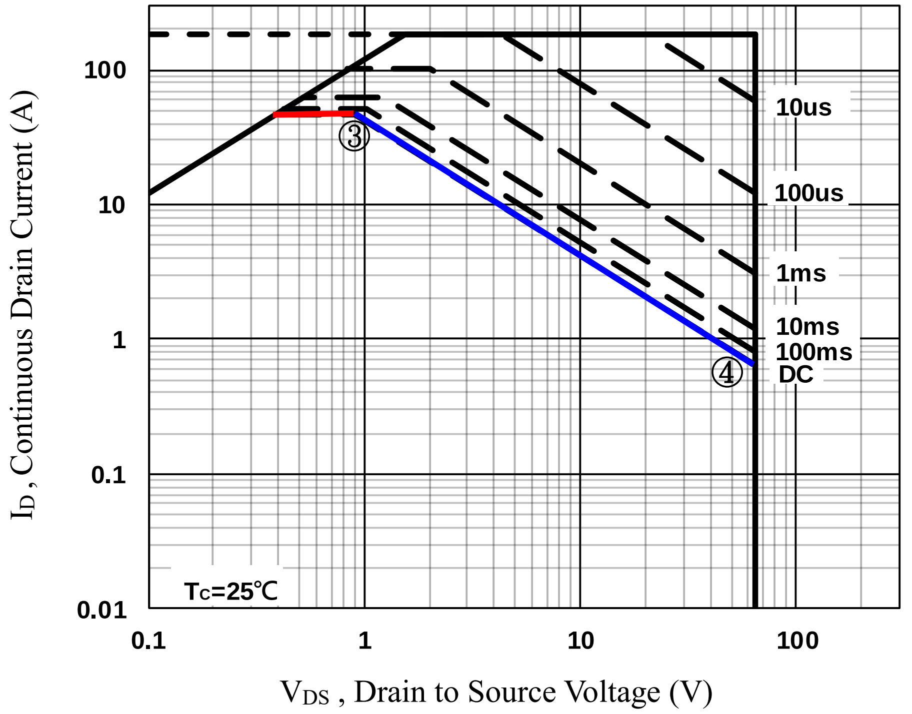


Fig. 2 The SOA of PDC6986BZ-5 for DC curve

Finally, one of the transient operation will be introduced as an example in Fig. 3. Fig. 3 shows the 1ms transient operation of SOA and the drain current and drain to source voltage of the point ⑤ (red line) are shown as

$$I_D = \sqrt{\frac{T_{J(max)} - T_C}{R_{\theta JC} \times Z_{\theta JC} \times R_{DS(ON)} \times K}} = \sqrt{\frac{150 - 25}{2.98 \times 0.2 \times 0.0083 \times 2.3}} = 104.8A \tag{8}$$

$$V_{DS} = \frac{T_{J(max)} - T_C}{R_{\theta JC} \times Z_{\theta JC}} \times \frac{1}{I_D} = \frac{150 - 25}{2.98 \times 0.2} \times \frac{1}{104.8} = 2V \tag{9}$$

At point ⑥ (blue line), the relation of the drain current for V_{DS} = 65V is derived as

$$I_{DS} = \frac{T_{J(max)} - T_C}{R_{\theta JC} \times Z_{\theta JC}} \times \frac{1}{V_{DS}} = \frac{150 - 25}{2.98 \times 0.2} \times \frac{1}{65} = 3.23A \tag{10}$$

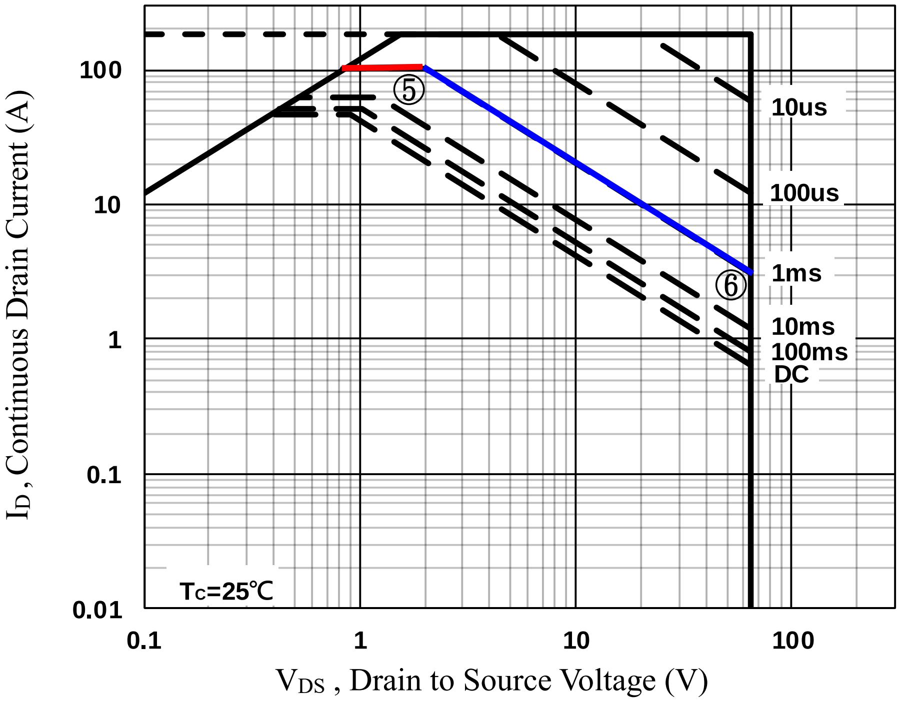


Fig. 3 The SOA of PDC6986BZ-5 for 1ms curve

The above results are under the condition that $R_{\theta JC}$ and $Z_{\theta JC}$ are measured by the part mounted on 0.66x0.66 in^2 FR4 PCB with 2oz copper shown as Fig. 4. In general, the 1x1 in^2 PCB shown as Fig. 5 is adopted in $R_{\theta JC}$ and $Z_{\theta JC}$ measurement. $Z_{\theta JC}$ is shown as Fig. 6. The product of $R_{\theta JC}$ and $Z_{\theta JC}$ for 1x1 in^2 PCB would be smaller than the product of $R_{\theta JC}$ and $Z_{\theta JC}$ for 0.66x0.66 in^2 PCB. Therefore, there is a certain margin for the SOA regions of Potens' parts. Potens keep this margin for allowable operating area.

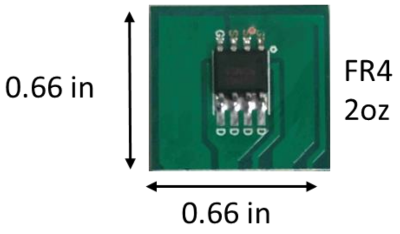


Fig. 4 0.66x0.66 in^2 PCB for $R_{\theta JC}$ and $Z_{\theta JC}$ measurement

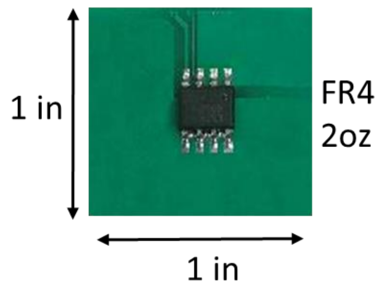


Fig. 5 1x1 in^2 PCB for $R_{\theta JC}$ and $Z_{\theta JC}$ measurement

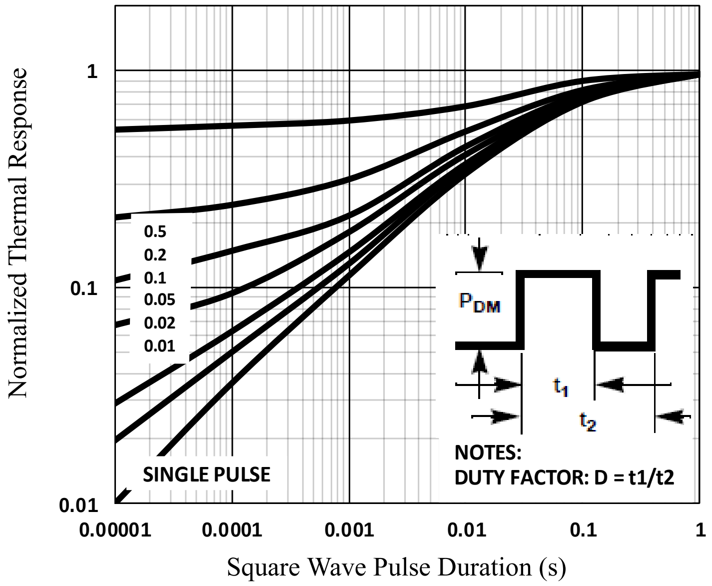


Fig. 6 The normalized transient thermal resistance

Reference

[1] Potens Semiconductor, “65V N-channel MOSFET,” PDC6986BZ-5 datasheet. https://www.potens-semi.com/upload/product/PDC6976BX-5.pdf.