MOSFET series

Temperature derating method for Safe Operating Area (SOA)

Generally, voltage, current and power applied to MOSFETs are limited by various conditions, and the limited area is called safe operating area (SOA). Although SOA has temperature dependence, SOA is usually specified at room temperature (25°C), so temperature derating is required when the device temperature rises. This application note describes temperature derating method for SOA. Note that the basic method is the same for bipolar junction transistors (BJTs).

1. Safe Operating Area (SOA)

The SOA of ROHM Super Junction MOSFET (SJMOS) "R6024KNX" is shown in Figure 1. As shown in (1) to (5) of Figure 1, SOA can be classified into the following five areas.

(1) Limited by on-resistance area

This area theoretically limited by the on-resistance “$R_{DS(on)}$”. The current in this area is shown as $I_D = V_{DS}/R_{DS(on)}$.

(2) Limited by maximum current rating area

This area is limited by the maximum rating of drain current “I_D(or I_{Dpulse})”.

(3) Thermal limited area *1 (*1: This area depends on the mounting conditions of the device.)

This is the area limited by the power dissipation “P_D”.

Since P_D is constant in this area, the slope is "-1" when plotted on a log-log graph.

(4) Secondary breakdown area*2 (*2: This area depends on the mounting conditions of the device.)

This is the area where operation is restricted due to local heat generation and current concentration in the device.

(5) Limited by maximum voltage rating area

This area is limited by the maximum rating of drain-source voltage “V_{DS}”.

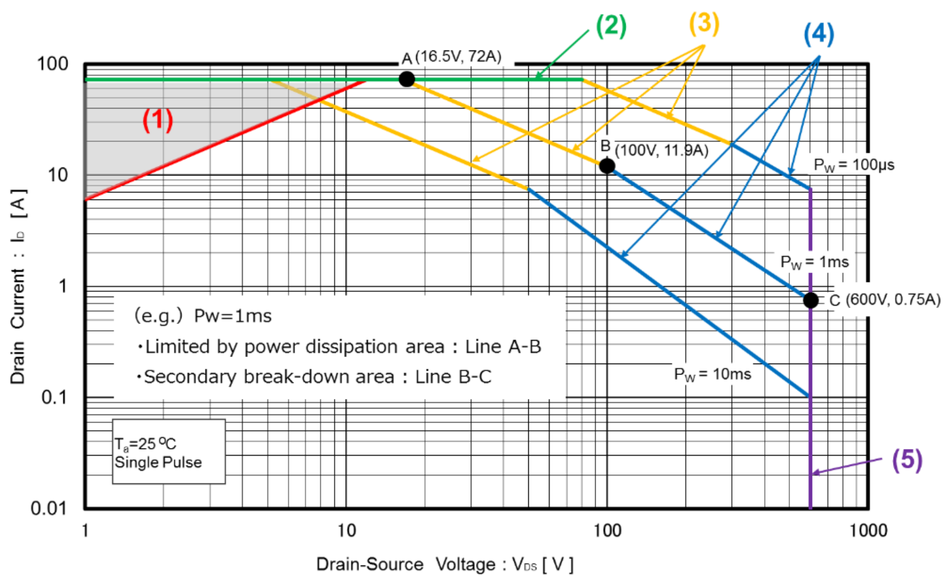


Figure 1. SOA of Super Junction MOSFET “R6024KNX”

2. Temperature derating for SOA

SOA described in the data sheet is generally specified under the condition that the ambient temperature Ta (or junction temperature Tj) is 25°C. Therefore, if Ta (or Tj) is higher than 25°C, temperature derating is needed. (However, note that SOA is normally not expanded even if Tj is below 25°C.)

Specifically, temperature derating is applied for the (3) thermal limiting area and (4) secondary breakdown area of Figure 1.

2-1. Derating for thermal limited area

For example, assume that a single pulse with a pulse width (Pw) of 1ms is applied when the ambient temperature Ta is 75°C.

The thermal limited area before derating (Ta=25°C) is defined by point A and B in Figure 1. From the voltage and current value at point B, the power dissipation at Ta=25°C is shown as:

$$P_D(1ms) = 100V \times 11.9A = 1{,}190W.$$

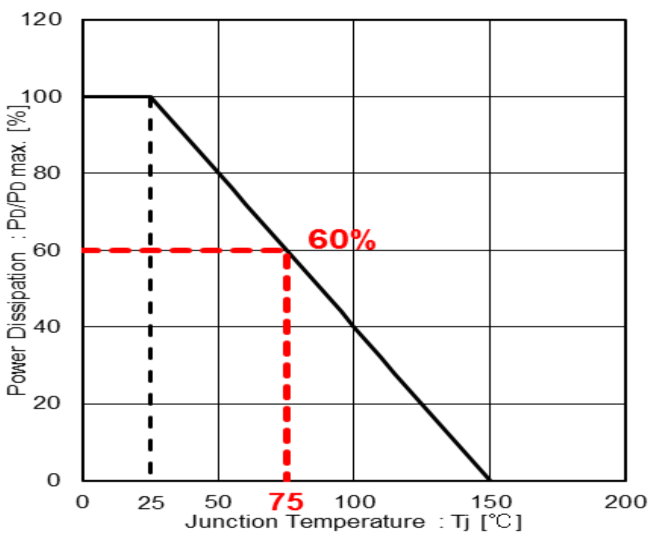
Also, from Figure 2, the power dissipation ratio $P_D/P_D max$ (75°C) at Ta=75℃ decreases to 60% compared to that at Ta=25°C. Therefore, when Ta=75°C, the power dissipation is shown as:

$$P_D(75°C) = 1{,}190W \times 60\% = 714W.$$

From the above, points A' and B' after derating can be calculated.

Voltage at point A' : $V_{DS\_A'} = 714W/72A \approx 9.91V.$ Therefore, the coordinates of point A' are (9.91V, 72A).

Current at point B' : $I_{D\_B'} = 714W/100V = 7.14A.$ Therefore, the coordinates of point B' are (100V, 7.14A).



$$P_D/P_{D\,max}(75°C) = 100 \times \{1 - (75-25)/(150-25)\} = 60\,[\%]$$

Figure 2. Power Dissipation Ratio vs. Junction Temperature

2-2. Derating for secondary breakdown area

Point C' after derating can be calculate as follows.

From Figure 2, the power dissipation ratio at Ta=75°C is 60%, the current at point C' is shown as:

$$I_{D\_C'} = 0.75A \times 60\% = 0.45A$$

Therefore, the coordinates of point C' are (600V, 0.45A).

From the calculation results of section 2-1. and 2-2., Figure 3 shows the SOA before and after derating.

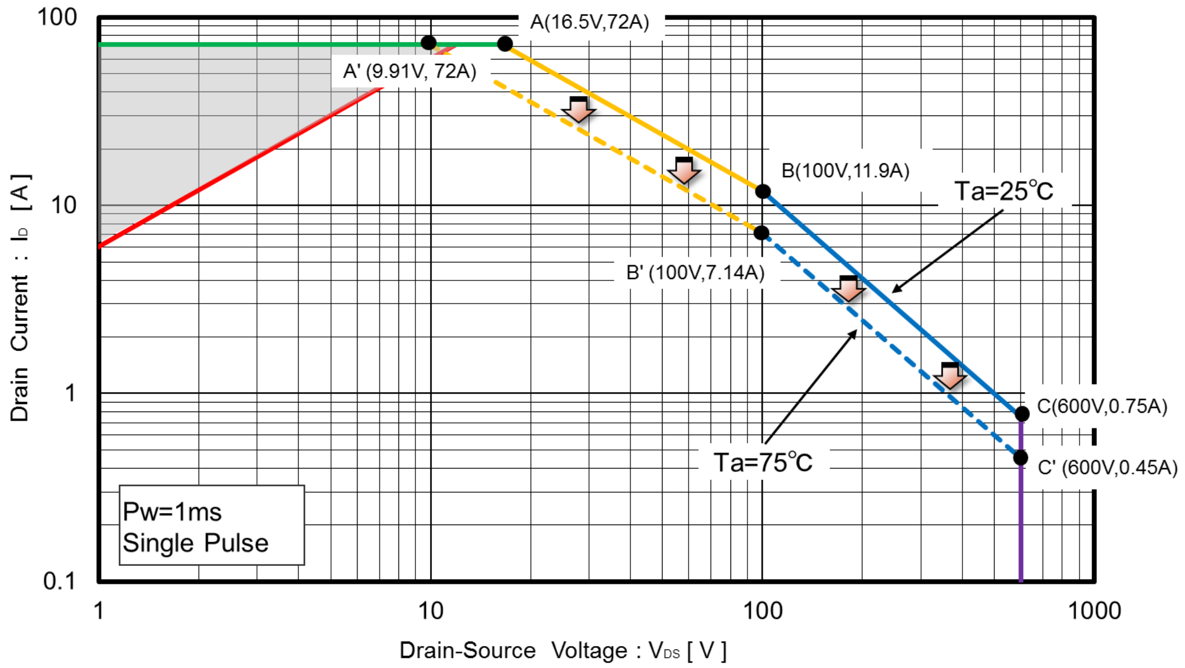


Figure 3. SOA before and after derating.

3. Summary

- The SOA needs to be derated with respect to the device temperature to see if the MOSFET can be used under certain pulse conditions.
- SOA temperature derating is applied for the thermal limited area and the secondary breakdown area.
- A graph of power dissipation ratio vs temperature is used to perform temperature derating.
- If the actual V_{DS} and I_D are out of the SOA after temperature derating, circuit conditions or devices have to be reviewed.

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