AN10808

Thermal consideration of NXP FlatPower MEGA Schottky barrier rectifiers - Selection criteria

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Document information

Info	Content
Keywords	FlatPower MEGA Schottky barrier rectifiers, thermal consideration, selection criteria
Abstract	This application note describes how to select a medium power Schottky barrier rectifier from the NXP FlatPower package family.

Revision history

Rev	Date	Description
v.1	20100629	Initial version

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1. Introduction

NXP Semiconductors offers a wide variety of medium power Schottky barrier rectifiers in different packages and rated parameters like voltages, current and power capabilities.

This application note has the following purposes:

- Basics of NXP Semiconductors Schottky barrier rectifiers product range
- Review and explanation of the data sheet
- Design recommendation for the worst-case operating point

2. Description of NXP Semiconductors FlatPower Schottky barrier rectifiers

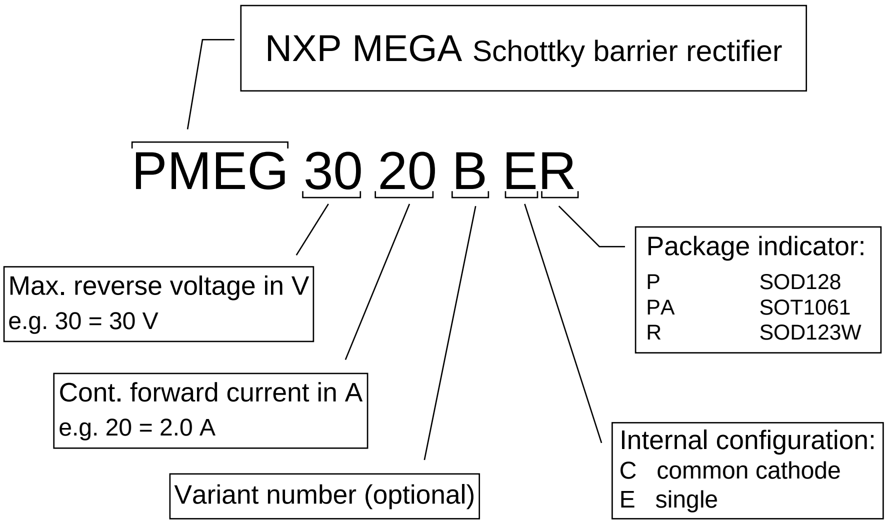


Fig 1. PMEG nomenclature

2.1 Data sheet parameters

In the data sheet different parameter values are given.

2.1.1 Limiting values

V_R = maximum reverse voltage

The maximum allowable reverse voltage, without exceeding the given reverse currents.

$I_{F(AV)}$ = maximum average forward current

The maximum allowable forward current, under a special condition.

I_{FSM} = maximum non-repetitive peak forward current

Single current pulse, from T_j = 25 °C prior to surge. After cooling down to T_j = 25 °C, the next event is allowed.

P_{tot} = total power dissipation

Maximum total power dissipation at 25 °C ambient temperature on different standard NXP conditions.

T_j = junction temperature

Maximum allowable junction temperature, usually 150 °C, for NXP discrete bipolar products.

T_{amb} = ambient temperature

Maximum allowable ambient temperature, usually 150 °C, for NXP discrete bipolar products.

T_{stg} = storage temperature

Maximum allowable storage temperature under MSL1 conditions.

2.1.2 Thermal characteristics

$R_{th(j\text{-}a)}$ = thermal resistance from junction to ambient

$R_{th(j\text{-}a)} = R_{th(j\text{-}sp)} + R_{th(sp–a)}$

The $R_{th(sp\text{-}a)}$ value depends on the Printed-Circuit Board (PCB) material and on the footprint, layout and surrounding environmental conditions.
Therefore, NXP Semiconductors gives you the information on which substrate the values were measured.

$R_{th(j\text{-}sp)}$ = thermal resistance from junction to solder point

The $R_{th(j\text{-}sp)}$ value is essentially independent of the external component, like PCB, footprint and solder.

It is sensitive to the die size, the leadframe, the die-bonding method and the mold compound of the package. The values of $R_{th(j\text{-}sp)}$ are measured from the cathode lead.

2.1.3 Electrical characteristics

V_F = forward voltage

Typical values under different forward current conditions.

I_R = reverse current

Typical values under different reverse voltage conditions.

C_d = diode capacitance

Typical diode capacitance under different reverse voltage conditions.

3. PMEG FlatPower Schottky barrier rectifier selection criteria

Circuit performance and long-term reliability are affected by the temperature of the die. Electrical power dissipated in any semiconductor device is a source of heat. This increases the temperature of the die above the reference point of 298.15 K | 25 °C | 77 °F.

3.1 Temperature limits

The increase in temperature depends on the power capability of the device and the thermal resistance of the complete system (SMD + PCB).

It can be described with the following formula:

$$P_{tot} = \frac{T_{j(max)} - T_{amb}}{R_{th(j-a)}} \tag{1}$$

Heat transfer can be occurring by radiation, conduction and convection.

Surface-Mounted Devices (SMD) loose most of their heat by conduction when mounted on a substrate. The heat conducts from the junction via the package leads and the soldering connections to the substrate. Some heat radiates from the package into the ambient, where it disappears by convection or by active cooling air. The heat from the substrate disappears in the same way.

The thermal resistance from junction to ambient can be described with the following formula:

$$R_{th(j-a)} = R_{th(j-sp)} + R_{th(sp-a)} \tag{2}$$

Calculating the maximum power capability, we must take the following temperatures into account:

- maximum junction temperature $T_{j(max)}$
- maximum solder point temperature $T_{sp(max)}$
- ambient temperature T_{amb}

As an example, the limiting factors of the SOD123W package are shown by the PMEG3020ER:

3.1.1 FR4 PCB, single-sided copper, tin-plated and standard footprint

- maximum junction temperature $T_{j(max)}$ = 150 °C | 423.15 K
- thermal resistance from junction to ambient $R_{th(j-a)}$ = 220 K/W
- thermal resistance from junction to solder point $R_{th(j-sp)}$ = 18 K/W

$$P_{tot(max)} = \frac{T_{j(max)} - T_{amb}}{R_{th(j-a)}} = \frac{423,15K - (298,15K)}{220\frac{K}{W}} = 0,57W \tag{3}$$

$$T_{sp} = T_{j(max)} - P_{tot(max)} \times R_{th(j-sp)} \tag{4}$$

$$T_{sp} = 423,15K - 0,57W \times 18\frac{K}{W} = 412,15K|139°C|(282,2°F) \tag{5}$$

To avoid issues, like solder cracks or degradation of the solder, NXP strongly recommends:

$T_{sp(max)} \leq 125$ °C

3.1.2 FR4 PCB, single-sided copper, tin-plated and mounting pad for cathode 1 cm^2

- maximum junction temperature $T_{j(max)}$ = 150 °C | 423.15 K
- thermal resistance from junction to ambient $R_{th(j-a)}$ = 130 K/W
- thermal resistance from junction to solder point $R_{th(j-sp)}$ = 18 K/W

$$P_{tot(max)} = \frac{T_{j(max)} - T_{amb}}{R_{th(j-a)}} = \frac{423,15K - (298,15K)}{130\frac{K}{W}} = 0,96W \tag{6}$$

$$T_{sp} = T_{j(max)} - P_{tot(max)} \times R_{th(j-sp)} \tag{7}$$

$$T_{sp} = 423,15K - 0,96W \times 18\frac{K}{W} = 405,87K|133°C|(271,4°F) \tag{8}$$

This behavior is shown in Figure 9 and Figure 10 of the data sheet.

To avoid issues, like solder cracks or degradation of the solder, NXP strongly recommends:

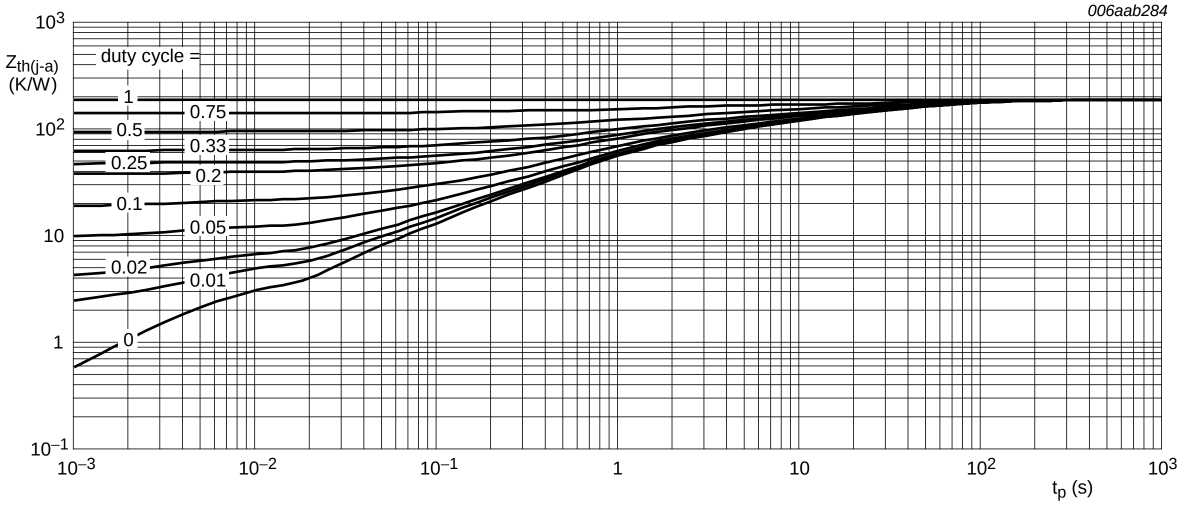
$T_{sp(max)} \leq 125$ °C

3.2 Pulse mode

In pulse mode, like in DC/DC converter, the thermal resistance from junction to ambient is a variable.

In order to give hardware designers the opportunity for best performance design, NXP's PMEG data sheets provide thermal impedance graphs at different footprint conditions.

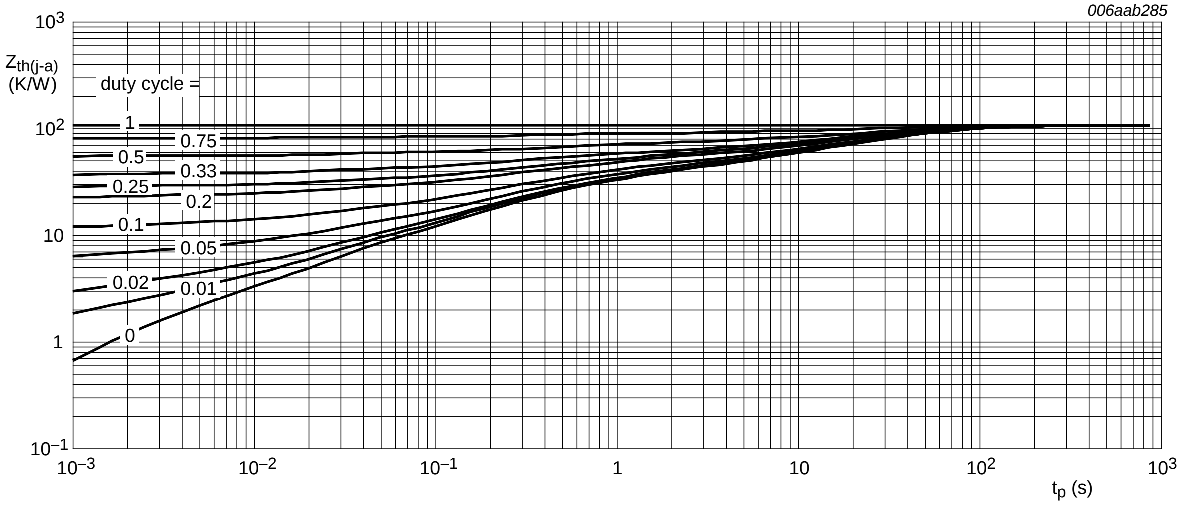
3.2.1 FR4 PCB, single-sided copper, tin-plated and standard footprint



FR4 PCB, standard footprint

Fig 2. **PMEG3020ER: Transient thermal impedance from junction to ambient as a function of pulse duration; typical values**

3.2.2 FR4 PCB, single-sided copper, tin-plated, 1 cm^2 cathode mounting pad



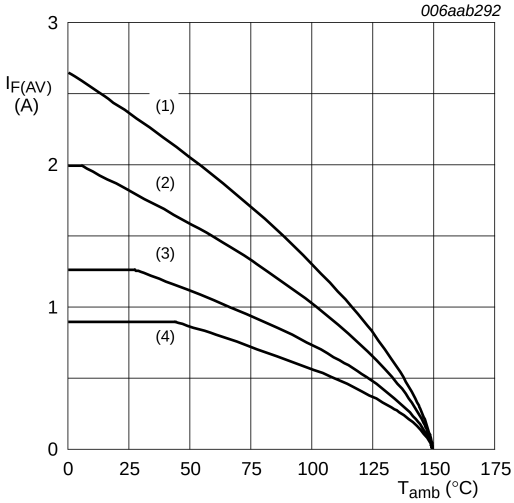
FR4 PCB, mounting pad for cathode 1 cm^2

Fig 3. **PMEG3020ER:**
Transient thermal impedance from junction to ambient as a function of pulse duration; typical values

3.2.3 Example

The correct use of the thermal impedance graphics is very important.

In order to show how to use the Z_{th} graph the right way, the $I_{F(AV)}$ value from the corresponding graphic $I_{F(AV)}$ vs T_{amb} (see Figure 4) is verified.



FR4 PCB, standard footprint

T_j = 150 °C

(1) $\delta = 1$; DC

(2) $\delta = 0.5$; f = 20 kHz

(3) $\delta = 0.2$; f = 20 kHz

(4) $\delta = 0.1$; f = 20 kHz

Fig 4. PMEG3020ER: Average forward current as a function of ambient temperature; typical values

$I_{F(AV)}$ is calculated as follows:

$$I_{F(AV))} = I_M \times \delta \quad (9)$$

I_M = peak current

δ = duty cycle

$$\delta = \frac{t_1}{t_2} \quad (10)$$

t_1 = pulse duration

t_2 = cycle duration

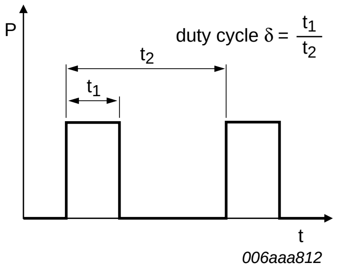
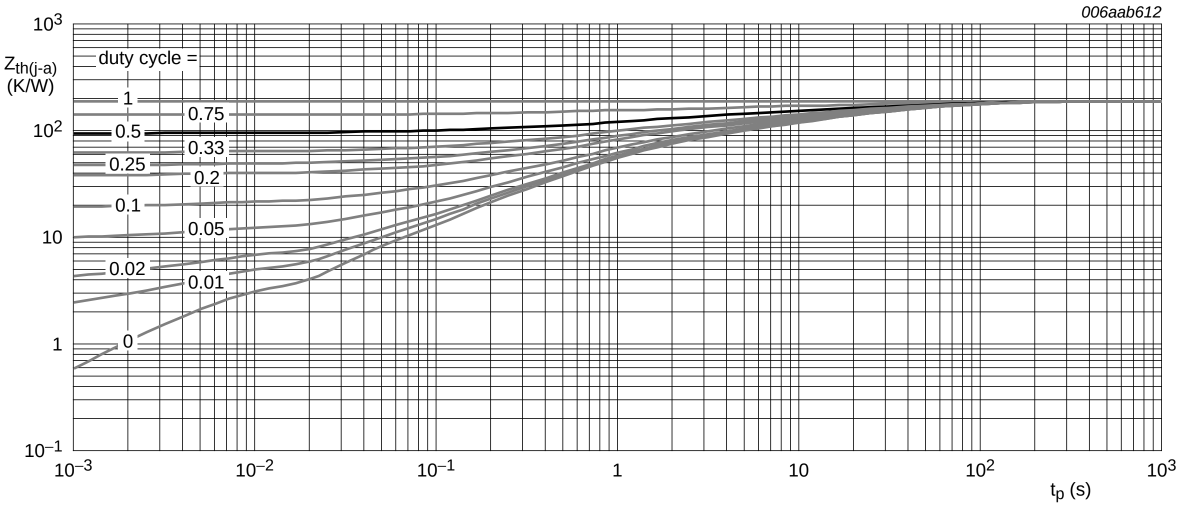


Fig 5. Duty cycle definition

For δ = 0.5 and f = 20 kHz:

- t_1 = 25 μs (pulse duration) = t_p (s)
- t_2 = 50 μs (cycle duration)



FR4 PCB, standard footprint

Fig 6. Transient thermal impedance from junction to ambient as a function of pulse duration; typical values

Approximate the $Z_{th(j-a)}$ value from the graph at δ = 0.5 and calculate the maximum power dissipation with the below formula:

$$P_{tot(max)} = \frac{T_{j(max)} - T_{amb}}{Z_{th(j-a)}} = \frac{423,15K - (298,15K)}{100\frac{K}{W}} = 1,25W \tag{11}$$

So, there is an “improvement” in P_{tot} by factor 2 under pulsed condition.

From this you can calculate $I_{F(AV)}$ with the formula given above and the typical V_F value taken from the data sheet:

$$I_M = \frac{P_{tot(max)}}{V_F} = \frac{1,25W}{0,365V} = 3,4A \tag{12}$$

$$I_{F(AV)} = I_M \times \delta = 1,7A \tag{13}$$

This result fits with the graphic $I_{F(AV)}$ vs T_{amb} (see Figure 4)!

Now you are able to choose the right PMEG Schottky barrier rectifier under thermal and electrical considerations.

Our experience shows that changing the package (bigger package size, bigger silicon die, better thermal performance) will easier fulfill your requirements than increase the cooling pad area!

3.3 Conclusion

From the characteristics given in the data sheet, you are now able to choose the right PMEG Schottky barrier rectifier! The most critical question in your hardware design is the maximum allowable P_{tot} capability at your requirements, not only at data sheet parameters!

Data sheet parameters are a good instrument to compare different products under standard conditions!

By means of the Z_{th} graphs and $R_{th(j-a)}$ values you are able to calculate the worst-case scenario of your application, and after that you are able to choose the right NXP PMEG Schottky barrier rectifier for your design.

4. Appendix

4.1 Average value

$$I_{F(AV)} = \frac{1}{T}\int_{0}^{T} i(t)dt \tag{14}$$

For the given square-wave signal:

$$I_{F(AV)} = \frac{1}{T}\int_{0}^{T/2} (i(t)dt + 0) \tag{15}$$

$$I_{F(AV)} = I \times 0,5 \tag{16}$$

In general for square wave as simplification:

$$I_{F(AV)} = I_M \times \delta \tag{17}$$

In general for full-wave sinusoidal signal as simplification:

$$I_{F(AV)} = \frac{2 \times I_M}{\Pi} \tag{18}$$

In general for triangle signal as simplification:

$$I_{F(AV)} = I_M \times \frac{\delta}{2} \tag{19}$$

4.2 Root Mean Square value

$$I_{RMS} = \sqrt{I_{F(AV)}^{2}} \qquad (20)$$

$$I_{RMS} = \sqrt{\frac{1}{T}\int_{0}^{T} i(t)^{2}dt} \qquad (21)$$

For the given square wave:

$$I_{RMS} = \sqrt{\frac{1}{T}\int_{0}^{T/2} (i(t)^{2}dt + 0)} \qquad (22)$$

$$I_{RMS} = \sqrt{I_{M}^{2} \times \frac{T}{2T}} \qquad (23)$$

$$I_{RMS} = I_{M}\sqrt{0, 5} \qquad (24)$$

In general for square waves:

$$I_{RMS} = I_{M} \times \sqrt{\delta} \qquad (25)$$

In general for full-wave sinusoidal signal as simplification:

$$I_{RMS} = \frac{I_{M}}{\sqrt{2}} \qquad (26)$$

In general for triangle signal as simplification:

$$I_{RMS} = I_{M} \times \sqrt{\frac{\delta}{3}} \qquad (27)$$

5. References

[1] **Philips Semiconductors —** Power Semiconductors, Applications Handbook 1995

[2] **NXP Semiconductors —** Product data sheet PMEG3020ER, Rev. 01, 29 December 2008

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