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AN10808

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

Rev. 3 — 29 April 2015 **Application note**

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
3	20150429	• Figure 1: updated • Figure 2: added • Table 1 and Table 2: updated • Section 7 "Legal information": updated
2	20130212	Section 4 "Product portfolio" added
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 with rated parameters like voltages, current and power capabilities.

This application note has the following purposes:

- Present the basics of NXP Semiconductors Schottky barrier rectifiers product range
- Review and explain the data sheet parameters
- Give design recommendation for the worst-case operating point

2. Description of NXP Semiconductors FlatPower Schottky barrier rectifiers

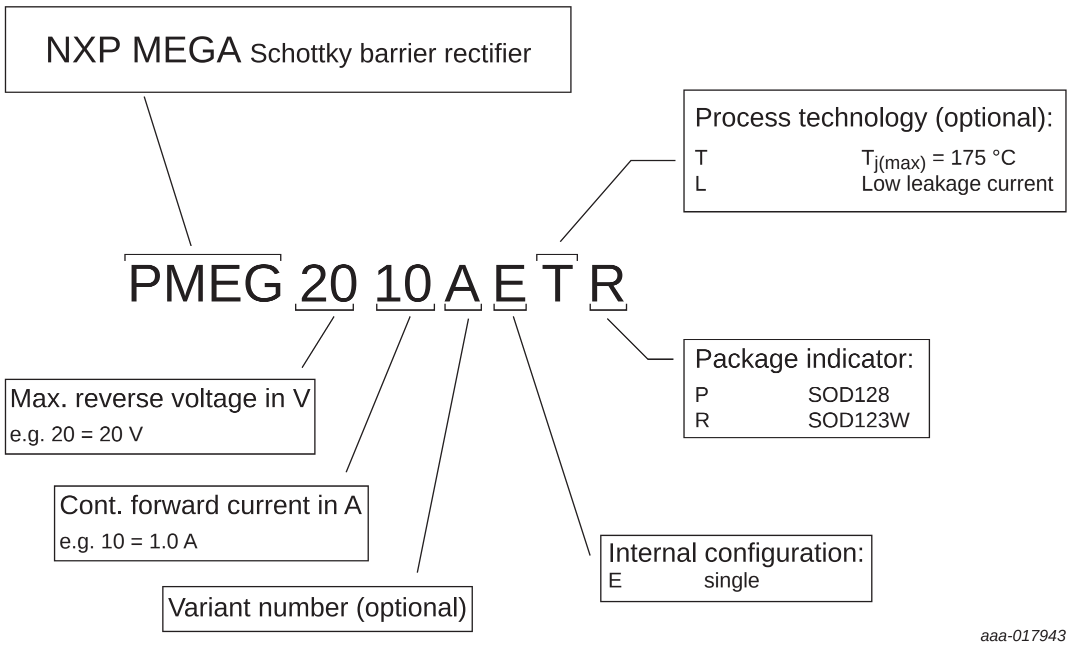


Fig 1. PMEG in SOD123W and SOD128: nomenclature

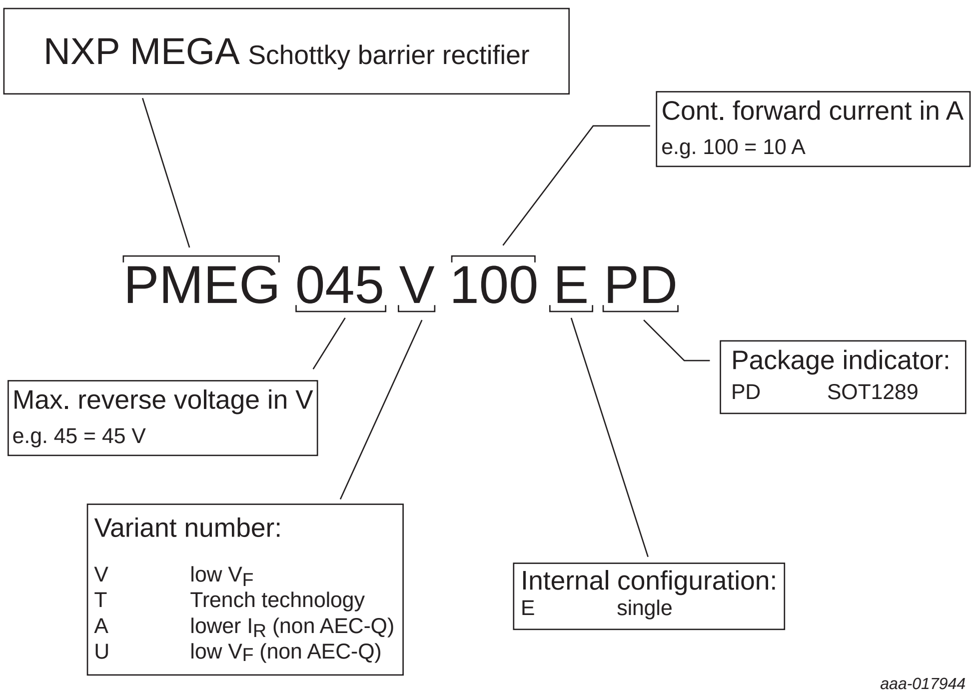


Fig 2. PMEG in SOT1289: nomenclature

2.1 Data sheet parameters

The data sheet gives different parameter values.

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 specific condition.

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

Single current pulse, from T_j = 25 °C before 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

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

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, in the data sheets NXP Semiconductors indicates 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 source 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 as follows:

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

Heat transfer can occur 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 as follows:

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

Calculating the maximum power capability, the following temperatures must be taken 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 in the following sections.

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

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

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

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

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

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

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

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

This behavior is shown in Figure 9 and Figure 10 of the data sheet PMEG3020ER.

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

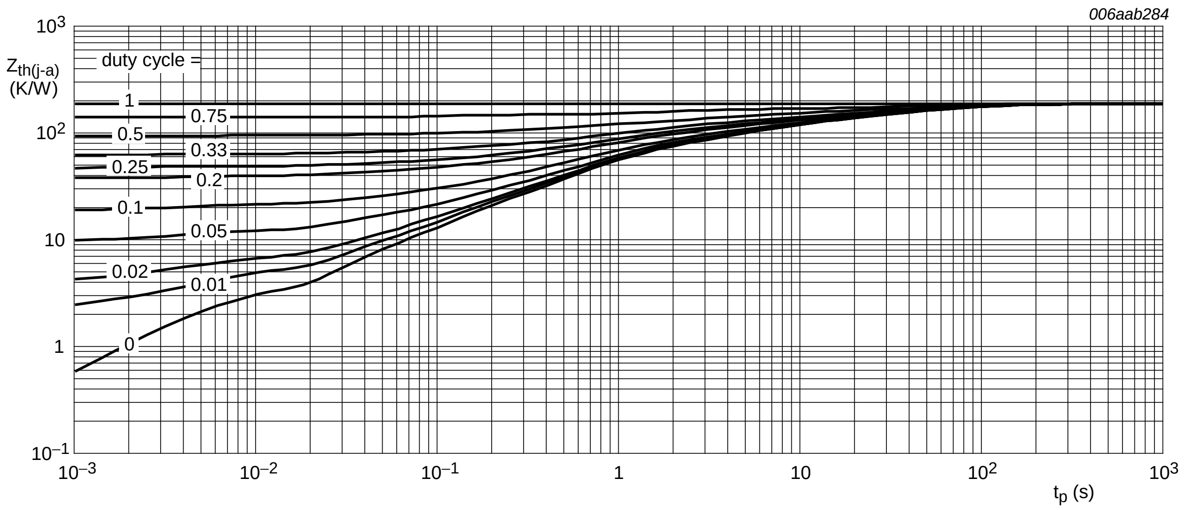
$T_{sp(max)} \leq 125$ °C

3.2 Pulse mode

In pulse mode, like in DC-to-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.

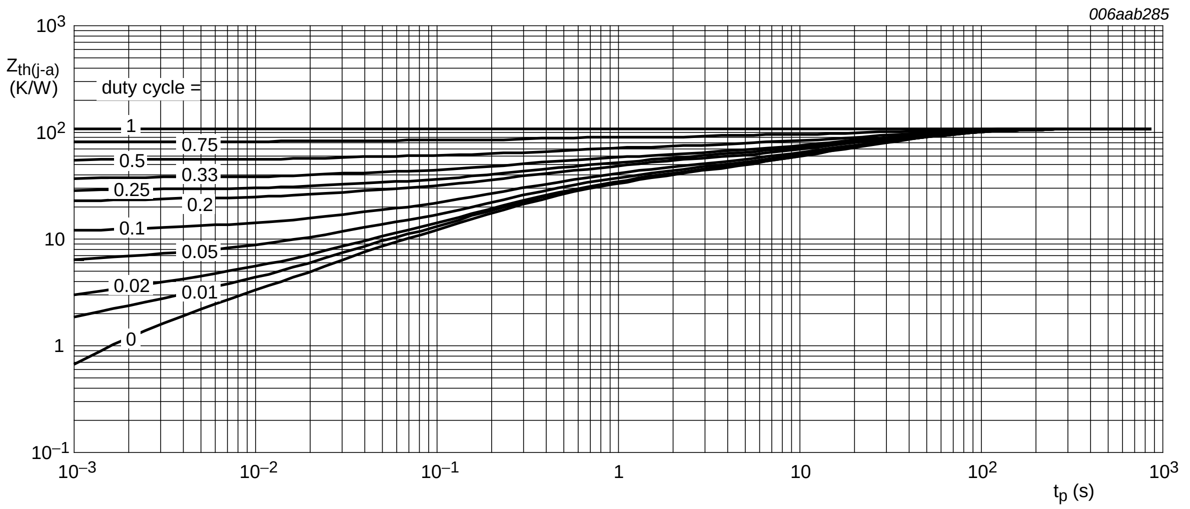
3.2.1 FR4 PCB, single-sided copper, tin-plated and standard footprint



FR4 PCB, standard footprint

Fig 3. 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 cm² cathode mounting pad



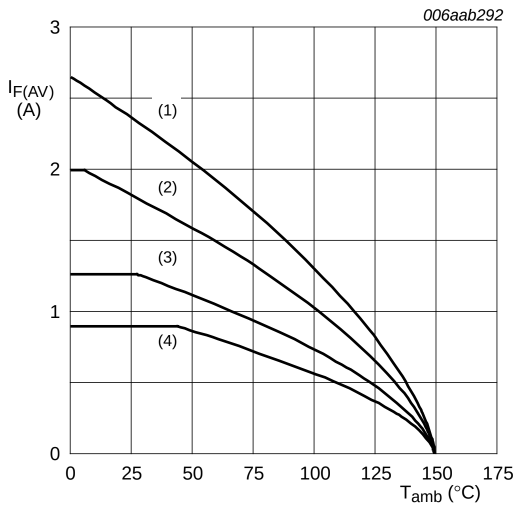
FR4 PCB, mounting pad for cathode 1 cm²

Fig 4. 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 5) is verified.



FR4 PCB, standard footprint

T_j = 150 °C

(1) δ = 1; DC

(2) δ = 0.5; f = 20 kHz

(3) δ = 0.2; f = 20 kHz

(4) δ = 0.1; f = 20 kHz

Fig 5. 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

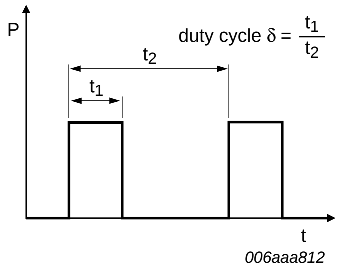
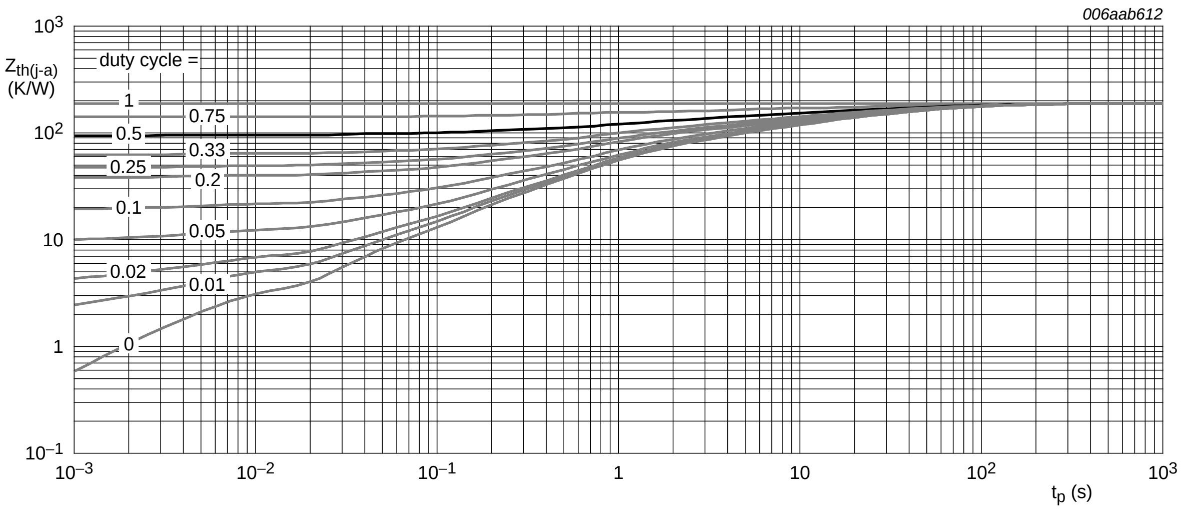


Fig 6. Duty cycle definition

For $\delta = 0.5$ and f = 20 kHz:

- $t_1 = 25\ \mu s$ (pulse duration) = t_p (s)
- $t_2 = 50\ \mu s$ (cycle duration)



FR4 PCB, standard footprint

Fig 7. 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 $\delta = 0.5$ and calculate the maximum power dissipation with the formula:

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

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

From this, $I_{F(AV)}$ can be calculated with the Equation 11 and the typical V_F value taken from the data sheet:

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

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

This result fits with the graphic $I_{F(AV)}$ vs T_{amb} (see Figure 5).

So thermal and electrical parameters are essential factors for the selection of the right PMEG Schottky barrier rectifier under considerations.

Changing the package (bigger package size, bigger silicon die, better thermal performance) fulfill easier the requirements than increasing the cooling pad area.

3.3 Conclusion

The characteristics given in the data sheet, help choosing the right PMEG Schottky barrier rectifier. The most critical question in hardware design is the maximum allowable P_{tot} capability.

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

The worst-case scenario of an application can be calculated from the Z_{th} graphs and $R_{th(j-a)}$ values. After that the right NXP PMEG Schottky barrier rectifier for design can be selected.

4. Product portfolio

Table 1. Product portfolio with T_j = 150 °C

Type number	V_R	I_F	$I_{FSM(max)}$	$V_{F(max)}$ at I_F	$I_{R(max)}$ at V_R	Package	AEC-Q101
PMEG2010ER	20 V	1 A	50 A	340 mV	1.00 mA	SOD123W	YES
PMEG2010BER	20 V	1 A	50 A	450 mV	0.05 mA	SOD123W	YES
PMEG3010ER	30 V	1 A	50 A	360 mV	1.50 mA	SOD123W	YES
PMEG3010BER	30 V	1 A	50 A	450 mV	0.05 mA	SOD123W	YES
PMEG3010EP	30 V	1 A	50 A	360 mV	1.50 mA	SOD128	YES
PMEG3010BEP	30 V	1 A	50 A	450 mV	0.05 mA	SOD128	YES
PMEG3020ER	30 V	2 A	50 A	420 mV	1.50 mA	SOD123W	YES
PMEG3020BER	30 V	2 A	50 A	520 mV	0.05 mA	SOD123W	YES
PMEG3020EP	30 V	2 A	50 A	360 mV	3.00 mA	SOD128	YES
PMEG3020BEP	30 V	2 A	50 A	450 mV	0.10 mA	SOD128	YES
PMEG3020CEP	30 V	2 A	50 A	420 mV	1.50 mA	SOD128	YES
PMEG3020DEP	30 V	2 A	50 A	520 mV	0.05 mA	SOD128	YES
PMEG3030EP	30 V	3 A	50 A	360 mV	5.00 mA	SOD128	YES
PMEG3030BEP	30 V	3 A	50 A	450 mV	0.15 mA	SOD128	YES
PMEG3050EP	30 V	5 A	70 A	360 mV	8.00 mA	SOD128	YES
PMEG3050BEP	30 V	5 A	70 A	450 mV	0.25 mA	SOD128	YES
PMEG4010ER	40 V	1 A	50 A	490 mV	0.05 mA	SOD123W	YES
PMEG4010EP	40 V	1 A	50 A	490 mV	0.05 mA	SOD128	YES
PMEG4020ER	40 V	2 A	50 A	490 mV	0.10 mA	SOD123W	YES
PMEG4020EP	40 V	2 A	50 A	490 mV	0.10 mA	SOD128	YES
PMEG4030ER	40 V	3 A	50 A	540 mV	0.10 mA	SOD123W	YES
PMEG4030EP	40 V	3 A	50 A	490 mV	0.20 mA	SOD128	YES
PMEG4050EP	40 V	5 A	70 A	490 mV	0.30 mA	SOD128	YES
PMEG45U10EPD	45 V	10 A	180 A	490 mV	0.60 mA	SOT1289	NO
PMEG45A10EPD	45 V	10 A	170 A	540 mV	0.50 mA	SOT1289	NO
PMEG45T15EPD	45 V	15 A	210 A	580 mV	0.10 mA	SOT1289	NO
PMEG6010ER	60 V	1 A	50 A	530 mV	0.06 mA	SOD123W	YES
PMEG6010EP	60 V	1 A	50 A	530 mV	0.06 mA	SOD128	YES
PMEG6020ER	60 V	2 A	50 A	530 mV	0.15 mA	SOD123W	YES
PMEG6020EP	60 V	2 A	50 A	530 mV	0.15 mA	SOD128	YES
PMEG6030EP	60 V	3 A	50 A	530 mV	0.20 mA	SOD128	YES

Table 2. Product portfolio with T_j = 175 °C

Type number	V_R	I_F	$I_{FSM(max)}$	$V_{F(max)}$ at I_F	$I_{R(max)}$ at V_R	Package	AEC-Q101
PMEG4010ETR	40 V	1 A	50 A	490 mV	0.05 mA	SOD123W	YES
PMEG4010ETP	40 V	1 A	50 A	490 mV	0.05 mA	SOD128	YES
PMEG4020ETR	40 V	2 A	50 A	490 mV	0.10 mA	SOD123W	YES
PMEG4020ETP	40 V	2 A	50 A	490 mV	0.10 mA	SOD128	YES
PMEG4030ETP	40 V	3 A	70 A	490 mV	0.20 mA	SOD128	YES

Table 2. Product portfolio with T_j = 175 °C *…continued*

Type number	V_R	I_F	$I_{FSM(max)}$	$V_{F(max)}$ at I_F	$I_{R(max)}$ at V_R	Package	AEC-Q101
PMEG4050ETP	40 V	5 A	50 A	530 mV	0.30 mA	SOD128	YES
PEMG045V050EPD	45 V	5 A	160 A	490 mV	0.30 mA	SOT1289	YES
PMEG045V100EPD	45 V	10 A	210 A	490 mV	0.60 mA	SOT1289	YES
PMEG045V150EPD	45 V	15 A	270 A	490 mV	0.90 mA	SOT1289	YES
PMEG045T150EPD	45 V	15 A	210 A	580 mV	0.10 mA	SOT1289	YES
PMEG050V150EPD	50 V	15 A	240 A	500 mV	1.0 mA	SOT1289	YES
PMEG6010ELR	60 V	1 A	50 A	660 mV	300 nA	SOD123W	YES
PMEG6010ETR	60 V	1 A	50 A	530 mV	0.15 mA	SOD123W	YES
PMEG6020ELR	60 V	2 A	50 A	760 mV	300 nA	SOD123W	YES
PMEG6020ETR	60 V	2 A	50 A	530 mV	0.15 mA	SOD123W	YES
PMEG6020ETP	60 V	2 A	50 A	530 mV	0.15 mA	SOD128	YES
PMEG6030ETP	60 V	3 A	50 A	530 mV	0.20 mA	SOD128	YES
PMEG6045ETP	60 V	4.5 A	70 A	530 mV	0.40 mA	SOD128	YES
PMEG060V050EPD	60 V	5 A	160 A	560 mV	0.40 mA	SOT1289	YES
PMEG060V100EPD	60 V	10 A	210 A	560 mV	0.70 mA	SOT1289	YES
PMEG10020AELR	100 V	2 A	50 A	770 mV	300 nA	SOD123W	YES

5. Appendix

5.1 Average value

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

For the given square-wave signal:

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

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

In general, for square wave as simplification:

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

In general, for full-wave sinusoidal signal as simplification:

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

In general, for triangle signal as simplification:

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

5.2 Root Mean Square value

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

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^T i(t)^2 dt} \quad (21)$$

For the given square wave:

$$I_{RMS} = \sqrt{\frac{1}{T}\int_0^{T/2} (i(t)^2 dt + 0)} \quad (22)$$

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

$$I_{RMS} = I_M\sqrt{0,5} \quad (24)$$

In general, for square waves:

$$I_{RMS} = I_M \times \sqrt{\delta} \quad (25)$$

In general, for full-wave sinusoidal signal as simplification:

$$I_{RMS} = \frac{I_M}{\sqrt{2}} \quad (26)$$

In general, for triangle signal as simplification:

$$I_{RMS} = I_M \times \sqrt{\frac{\delta}{3}} \quad (27)$$

6. 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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