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The PMEG1020EA and PMEG2010EA MEGA Schottky diodes-

a pair designed for high efficiency rectification

by Martin Lübbe

Introduction

Schottky diodes have found various applications in the fields of power supply and power management. Some characteristic examples are reverse polarity protection, OR'ing circuits and switch mode power supplies. These applications all exploit the reduced forward voltage V_F at a given forward current I_F as compared to standard pn-switching diodes.

With the MEGA type range Philips launched a whole portfolio of novel Schottky diodes designed especially to further improve the efficiency in the respective application.

The efficiency improvements are twofold: On the one hand the MEGA Schottkys are offered in small SMD packages like SOD323 (SC-76), SOD523 (SC-79) or the brand new, ultra flat SOT666, allowing a more efficient use of the available board space. On the other hand we developed novel production processes to further increase the electrical performance of MEGA Schottkys in the medium power range up to a few Amps.

In the following we will present two diodes, which very clearly illustrate the idea behind the MEGA portfolio, namely the PMEG1020EA and PMEG2010EA types. Both types are available in SOD323 (SC-76) and in the new ultra flat SOT666 (extension EV instead of EA).

Main features

The main parameters of both diodes are summarized in Table 1 and typical forward and reverse characteristics can be seen in Fig. 1.

Table 1: Electrical comparison of PMEG2010EA and PMEG1020EA MEGA Schottky diodes.

		Conditions	**PMEG2010EA**	**PMEG1020EA**	**Unit**
V_R	**Continuous reverse voltage**	-	20	10	V
I_F	**Continuous forward current**	-	1	2	A
V_{F1}	**Forward voltage**	$I_F = 1A$	480	280	mV
V_{F2}	**Forward voltage**	$I_F = 2A$	-	350	mV
I_{R1}	**Reverse current**	$V_R = 8V$	0.007	1	mA
I_{R2}	**Reverse current**	$V_R = 15V$	0.01	-	mA
C_D	**Diode capacitance**	$V_R = 5V$	19	37	pF

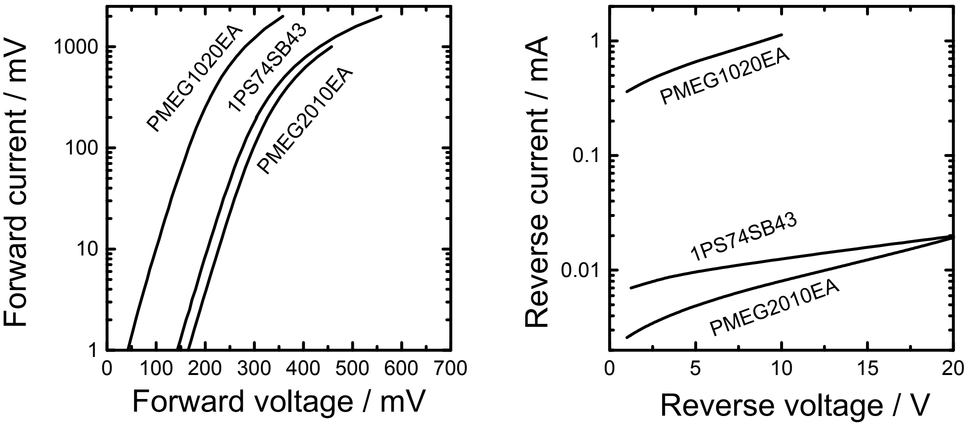

Fig. 1:Forward (left) and reverse (right) bias characteristics for the PMEG2010EA and PMEG1020EA MEGA Schottky diodes as compared to the 1PS74SB43 standard Schottky diode.

In Fig. 1 we also included the typical curves for the well-known 1PS74SB43 rectifier, which is available in the SC-74 package.

It can be clearly seen that the forward and reverse performances of the PMEG2010EA very closely match the performance of the 1PS74SB43 standard Schottky diode, which has twice the size of the PMEG2010EA. This example clearly illustrates the first branch of the MEGA Schottky innovation: Same performance on less required board space.

For a huge part of medium power applications with currents up to 1 A the PMEG2010EA will be the standard diode of choice. Especially for DC/DC converter applications this diode is also available in combination with NPN or PNP transistors in a single SOT457 (SC-74) package (typenames PMEM4010PD and PMEM4010ND).

However, especially in battery driven equipment the efficient use of the available power is of superior importance. For these cases we further extended the technologic limits and designed the PMEG1020EA.

Regarding Fig. 1 the differences of PMEG1020EA as compared to PMEG2010EA are obvious: The V_F and thus the forward power loss P_F is drastically reduced in the whole current range. At the same time due to a fundamental physical fact the reverse current I_R increases by a considerable amount. The consequences of this behavior are best illustrated by calculating an application example.

Application example

To further compare the two MEGA diodes we calculate a practical example: It has been stated before that a main application for the PMEG1020EA is battery driven equipment. In many of these systems different supply voltages are needed for the various functional blocks. DC/DC converters mainly realize the required voltage conversion from the varying battery voltage to the different system voltages.

Let’s assume we have to convert the voltage of 3.6 V from a Li- ion battery to a voltage of 1.5 V, which is required by many modern ICs. For this purpose the buck converter topology is widely used (see Fig. 2). The duty cycle of the converter is determined by the ratio of the input and the output voltage. For the voltage conversion of 3.6 V down to 1.5 V we get a duty cycle of approx. 40 % for the transistor and 60 % for the diode. During the on- state of the

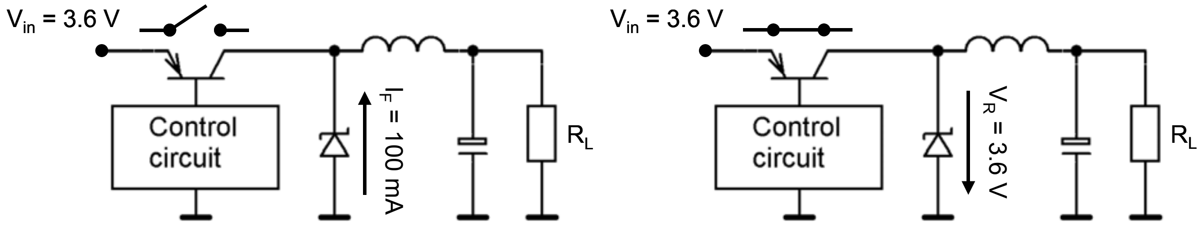

Fig. 2: Schematics a buck converter as calculated in the text. Left hand side: Diode on- state, transistor switch is open. Right hand side: Diode off- state, transistor switch is closed.

diode the output current I_{out} is flowing through the diode (see Fig. 2, left) while during the off- state the diode is reverse biased with the whole input voltage V_{in} (see Fig. 2, right).For an output current of 100 mA and a Schottky junction temperature T_j of 25 °C the calculation of the power loss can be found in Table 2.

Table 2: PMEG2010EA and PMEG1020EA efficiency calculation for the presented Buck converter application example.

		PMEG2010EA	**PMEG1020EA**	**Unit**
Forward voltage at I_{out} = 100mA	**V_F (see Fig. 1)**	300	170	mV
Power loss in forward bias	**$P_F = V_F \times 100$ mA**	30	17	mW
Reverse current at V_{in} = 3.6 V	**I_R (see Fig. 1)**	0.004	0.6	mA
Power loss in reverse bias	**$P_R = I_R \times 3.6$ V**	<0.1	2.2	mW
Mean power loss in cycle for 60% diode duty factor	**P_{tot}= $0.6 \times P_F + 0.4 \times P_R$**	18	11	mW
P_{tot} in percentage of P_{out} **P_{out} = 1.5 V x 100 mA = 150 mW**	**P_{tot}/ P_{out}**	12	7.3	%

Comparing the PMEG2010EA and the PMEG1020EA the power loss in percentage of the output power is reduced from 12 % to 7.3 %, which is a reduction by 40 %. If we assume that the diode accounts for half of the total power dissipation we get an overall efficiency improvement from 76 % (100 % - 12 % - 12 %) to 80.7 % (100 % - 12 % - 7.3%). At higher diode duty cycles or lower input voltages V_{in} the improvement will be even more pronounced.

For the following part it is important to note that in case of the highly efficient PMEG1020EA the reverse power loss P_R is a significant part of the total power loss. In our exemplary buck converter application this fact limits the operating range of the PMEG1020EA towards high temperatures as the reverse current increases with rising temperature. In the calculation of Table 2 we were also able to neglect the self- heating of the diode due to the very limited dissipated power. At high ambient temperatures T_a we will have to include the influence of the rising junction temperature T_j.

Temperature dependence

Fig. 3 shows the variation of the main parameters V_F and I_R for different junction temperatures. The forward voltage at a given current is reduced by approximately 1 mV for a temperature rise of 1 °C while the reverse current doubles each 15 °C.

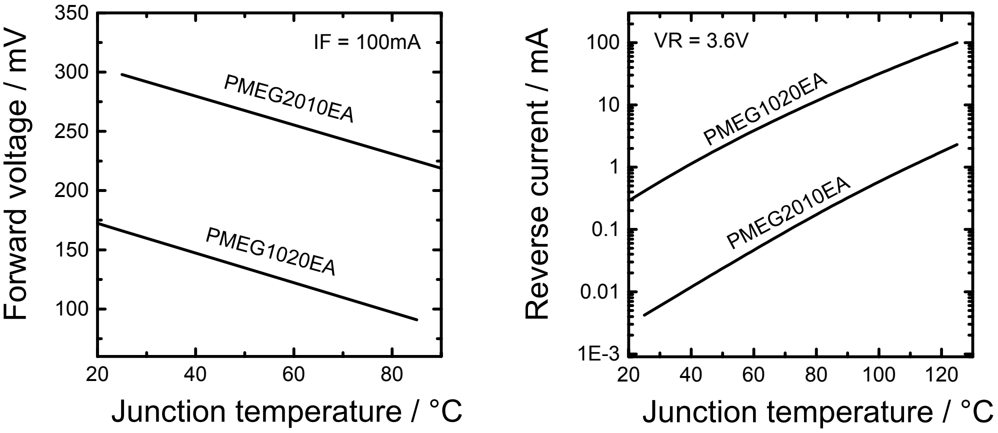

Fig. 3: Temperature dependence of the forward voltage (left hand side) and the reverse current (right hand side) for the PMEG2010EA and PMEG1020EA MEGA Schottky diodes.

The junction temperature, which is reached in the application, depends on the ambient temperature, the dissipated power and the thermal resistance $R_{th(j-a)}$ from junction to ambient. The calculation of the junction temperature T_j is a complicated task, which we will skip in this paper. Just the result for different ambient temperatures is shown in Table 3. The table is very similar to Table 2, only two rows were added for the ambient temperature T_a and the junction temperature T_j, respectively.

Table 3: Ambient temperature dependence of efficiency improvement using PMEG1020EA instead of PMEG2010EA.

	PMEG2010EA					**PMEG1020EA**					**Unit**
Ambient temperature T_a	25	35	45	55	65	25	35	45	55	65	°C
Junction temperature T_j	32.8	42.5	52.2	61.9	71.6	29.7	39.7	49.9	60.5	72.0	°C
V_F (see Fig. 3)	290	278	265	253	241	159	146	133	120	106	mV
$P_F = V_F$ x 100 mA	29.0	27.8	26.6	25.3	24.1	15.9	14.6	13.3	12.0	10.6	mW
I_R (see Fig. 3)	0.02	0.03	0.05	0.08	0.14	0.69	1.17	2.00	3.50	6.42	mA
$P_R = I_R$ x 3.6 V	0.07	0.11	0.18	0.30	0.50	2.49	4.22	7.21	12.6	23.1	mW
P_{tot}= 0.6 x P_F + 0.4 x P_R	17.4	16.7	16.0	15.3	14.7	10.5	10.4	10.9	12.2	15.6	mW
P_{tot}/ P_{out}	12	11	11	10	10	7	7	7	8	10	%

The calculation bases on two assumptions: First we assumed the devices to be placed on standard footprint without extra cooling areas. In this case we get an $R_{th(j-a)}$ value of 450 K/W. The second assumption is an operating frequency, which is high enough to get an almost constant temperature during the diodes on and off cycle. As in DC/DC converters normally the operating frequency is above 50 kHz to keep the size and the costs of the passive components small this assumption is fulfilled.

Regarding Table 3 the main difference is obvious: While the efficiency of the PMEG2010EA diode increases with rising ambient temperature, the effect is the other direction for the PMEG1020EA. The reason is the higher power loss under reverse bias for the PMEG1020EA.

At an ambient temperature of 65 °C (149 °F) the power losses are comparable for both diodes. For even higher ambient temperatures the results very much depend on the exact nature of the mounting and the cooling conditions including the amount of air circulation. We therefore did not perform the calculation. In these cases the usability of the PMEG1020EA has to be thoroughly investigated which exceeds the scope of the present paper.

Conclusion

We presented two diodes of the new Philips MEGA Schottky typerange: The PMEG2010EA and the PMEG1020EA. We illustrated how these diodes can yield an electrical performance comparable to standard Schottky diodes in considerably larger packages. For an exemplary DC/DC conversion application we have shown how using the PMEG1020EA can boost the diode efficiency.

Further we investigated the temperature dependence of the derived efficiency and found that at an ambient temperature of 65 °C (149 °F) the efficiencies for both diodes are aligning.

In conclusion, the PMEG2010EA is a standard diode for medium power applications, which yields top class performance in a very small package.

The PMEG1020EA on the other hand is the diode of choice if efficient use of the available power is extremely important. Due to the increasing losses at higher temperatures this diode is most suitable in applications with limited temperature ranges like handheld devices, laptops or temperature controlled circuit boards.

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