Switching Regulator Series

Diode Selection Method for Asynchronous Converter

In the design of an asynchronous converter, the selection of the freewheeling diode affects the performance, such as the efficiency of the converter. It is also necessary to consider the risk of heat generation and breakdown. This application note explains the guidelines in selecting the freewheeling diode for asynchronous converters. We hope this will help you select the right components.

The role of the diode

Asynchronous rectification and synchronous rectification are compared using a buck converter as an example. Figure 1-a shows an asynchronous rectification circuit, and Figure 1-b shows a synchronous rectification circuit.

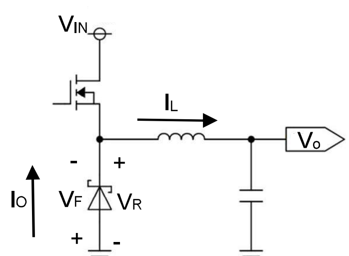

Figure 1-a. Asynchronous Buck Converter

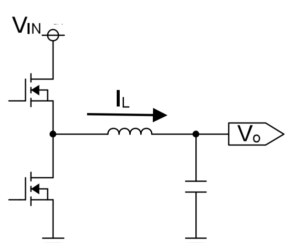

Figure 1-b. Synchronous Buck Converter

The difference between Figure 1-a and 1-b is that the low-side element is a diode for asynchronous rectification, and a MOSFET in synchronous rectification. Both low-side elements perform rectification by supplying the input energy stored in the inductor when the high-side switch is turned on, to the output side while the high-side switch is off. This output rectifier diode is called freewheeling diode or catch diode.

Effect of diode characteristics on converter

Since the output voltage increases when the inductor stores a lot of input energy, the ON time (On Duty) of the high-side switch is lengthened with respect to the switching period in order to increase the output voltage. Conversely, when the output voltage is low, the high-side On Duty is small and the low-side On Duty is larger.

At this time, the energy supplied by the inductor is {Output voltage (V_O) + Diode forward voltage (V_F)} x Coil current (I_L), but V_F is a loss. The loss increases as V_F becomes large, and as the output voltage becomes low, the percentage of loss due to V_F increases. On the other hand, while the high-side switch is on, it is wanted to store all the input energy in the inductor but at this time, the reverse current (I_R) flows through the diode, and the energy leaks. Therefore, low V_F and low I_R are ideal, but V_F and I_R are inversely proportional. The recommended diode of ROHM's asynchronous converter is the Schottky barrier diode, because of the importance of low V_F.

Also, from the viewpoint of component assurance of the diode, it is necessary to consider the reverse voltage (V_R) applied during the period when the high-side switch is ON and the forward current (I_O) that flows when inductor energy is transferred. (These will be explained in later chapters.)

View catalog values for diodes

Table 1 shows the parametric search result (by most relevant representative type name excerpt) of standard Schottky barrier diode in ROHM HP, $V_F \leqq 0.6$ [V], $I_O \leqq 10$ [A]. You can select from the devices in this table.

Here, we introduce a scheme for selecting parts from the items in Table 1. Figure 2-a/2-b shows the circuit characteristic constants of the buck/boost converter.

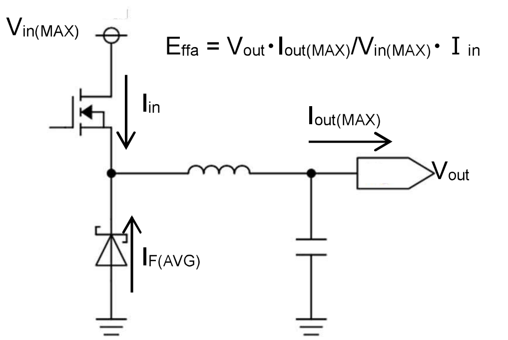

Figure 2-a. Buck Converter

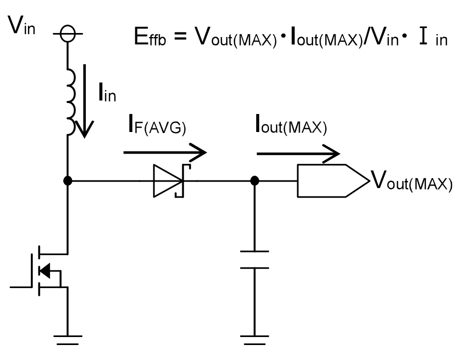

Figure 2-b. Boost Converter

Table 1. Candidates and Key Characteristics of ROHM Standard Schottky Barrier Diodes

Standard shotokky barrier diode product	Reverse Surge voltage V_{RM} [V]	DC reverse voltage V_R [V]	Average rectified current I_O[A]	Forward surge current I_{FSM} single [A]	Forward voltage V_F(Max.) [V]	I_F @ V_F[A]	Reverse current I_R(Max.) [mA]	V_R @ I_R [V]
RB050LAM-40	40	40	3	80	0.5	1.5	0.1	40
RB050LAM-60	60	60	3	80	0.52	2	0.1	60
RB051LAM-40	40	20	3	80	0.35	1	0.15	15
RB055LAM-40	40	40	3	70	0.55	1.5	0.1	40
RB056LAM-40	40	40	3	50	0.58	2	0.05	40
RB060LAM-40	40	40	2	80	0.45	1	0.1	40
RB060MM-60	60	60	2	30	0.52	1	0.05	60
RB070MM-30	30	30	1.5	30	0.43	0.5	0.05	30
RB080LAM-30	30	30	5	100	0.51	5	0.15	30
RB081LAM-20	25	20	5	80	0.45	5	0.7	20
RB160LAM-40	40	40	1	50	0.55	1	0.01	6
RB160MM-60	60	60	1	30	0.55	1	0.05	60
RB160VAM-60	60	60	1	3	0.43	0.1	0.04	60
RB161MM-20	25	20	1	30	0.32	0.5	0.7	20
RB162LAM-40	40	40	1	40	0.55	1	0.1	40
RB162MM-40	40	40	1	30	0.55	1	0.1	40
RB215T-60NZ	60	60	20	100	0.58	10	0.6	60
RB400VAM-50	50	40	0.5	3	0.55	0.5	0.03	10
RB411VAM-50	50	20	0.5	3	0.5	0.5	0.03	10
RB500VM-40	45	40	0.1	1	0.45	0.01	0.001	10
RB501VM-40	45	40	0.1	1	0.55	0.1	0.03	10
RB510VM-40	40	40	0.1	0.5	0.48	0.01	0.4	10
RB511VM-40	40	40	0.1	0.5	0.41	0.01	0.004	10
RB520CM-60	60	60	0.1	0.5	0.44	0.01	0.003	60
RB520SM-40	40	40	0.2	1	0.55	0.1	0.01	40
RB520VM-40	40	40	0.2	1	0.39	0.01	0.001	10
RB521SM-30	30	30	0.2	1	0.47	0.2	0.03	10
RB521SM-60	60	60	0.2	1	0.6	0.2	0.1	60
RB521VM-40	40	40	0.2	1	0.3	0.01	0.02	10
RB530CM-60	60	60	0.1	0.2	0.54	0.01	0.001	60
RB531CM-40	40	40	0.1	0.5	0.41	0.01	0.004	10
RB540VM-30	30	30	0.2	1	0.45	0.01	0.0005	10
RB541VM-30	30	30	0.2	1	0.35	0.01	0.01	10
RB550VM-40	40	40	0.2	1	0.51	0.2	0.012	10
RB551VM-40	40	40	0.2	1	0.43	0.2	0.08	10
RB751CM-40	40	30	0.03	0.2	0.37	0.001	0.0005	30
RB751SM-40	40	30	0.03	0.2	0.37	0.001	0.0005	30
RB751VM-40	40	30	0.03	0.2	0.37	0.001	0.0005	30
RBR3LAM30B	30	30	3	45	0.53	3	0.08	30
RBR3LAM40C	40	40	3	75	0.55	3	0.1	40
RBR3LAM60B	60	60	3	75	0.56	3	0.15	60
RBR3MM40B	40	40	3	30	0.58	3	0.1	40
RBR5LAM60A	60	60	5	100	0.55	5	0.25	60
RSX101VAM30	30	30	1	5	0.42	0.7	0.04	5
RSX201LAM30	30	30	2	60	0.44	2	0.15	30
RSX201VAM30	30	30	1.5	8	0.42	1	0.06	5
RSX205LAM30	30	30	2	60	0.49	2	0.2	30
RSX301LAM30	30	30	3	100	0.42	3	0.09	15
RSX501LAM20	25	20	5	100	0.39	3	0.5	20

Items 1) to 4) below are the key characteristics (V_R, I_O, V_F, I_R) of Schottky barrier diodes in Table 1 that should be considered in order of priority when choosing freewheeling diodes.

1) Forward voltage V_F

Unless individually recommended, normally select 0.6 [V] or less (Table 1 is already sorted below 0.6 [V]). If a larger voltage is used, the internal elements of the converter IC may be destroyed.

The data sheet of the Schottky barrier diode (SBD) is usually described as a condition of two types of forward current because V_F varies depending on the forward current. Table 1 shows the larger value (shown as V_{F2} etc. in the SBD data sheet). This is because the forward current condition of V_{F2} is often close to the I_O value of 2).

The above situation (in which the forward voltage increases depending on the forward current) also occurs in the protection element in the converter IC, and if the forward voltage of the freewheeling diode is greater than that of the protection element, current may flow and goes through the protection element, and the converter IC may be destroyed.

2) Average rectified current I_O

$$I_O > I_{F(AVG)} \times 1.2 \quad \cdots\cdot$$ 1.2 times or more of forward average current $I_{F(AVG)}$ flowing in diode

For buck converter, $I_{F(AVG)}$ is,

$$I_{F(AVG)} = Iout(MAX) - Iin = Iout(MAX) \times \frac{\left(Vin(MAX) - \left(Vout/_{Effa}\right)\right)}{Vin(MAX)}$$

For boost converter, $I_{F(AVG)}$ is,

$$I_{F(AVG)} = Iout(MAX) = Iin \times Effb \times \frac{Vin}{Vout(MAX)}$$

Keep the peak forward surge current I_{FSM} lower, including the ripple current . I_{FSM} is not particularly severe because it is often more than 5 times I_O. The ripple current is explained in Figure 3 using the symbols in Figure 2 using the buck converter as an example .

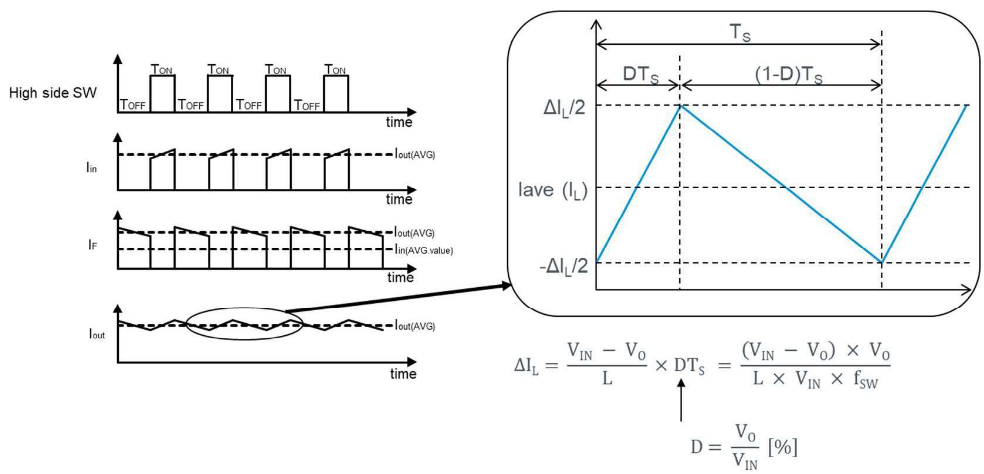

Figure 3. Illustration of Ripple Current

For buck converter, the forward loss P_F is,

$$P_F = I_{F(AVG)} \times V_F@Iout(MAX) = Iout(MAX) \times \frac{\left(Vin(MAX) - \left(Vout/_{Effa}\right)\right)}{Vin(MAX)} \times V_F@Iout(MAX)$$

Similarly, for a boost converter,

$$P_F = \mathrm{Iin} \times \mathrm{Effb} \times \frac{\mathrm{Vin}}{\mathrm{Vout(MAX)}} \times V_F@\mathrm{Iin}$$

In the case of SBD alone, looking at the data sheet of “RSX301LAW30” in the second row from the bottom of Table 1, there is the following forward characteristic curve.

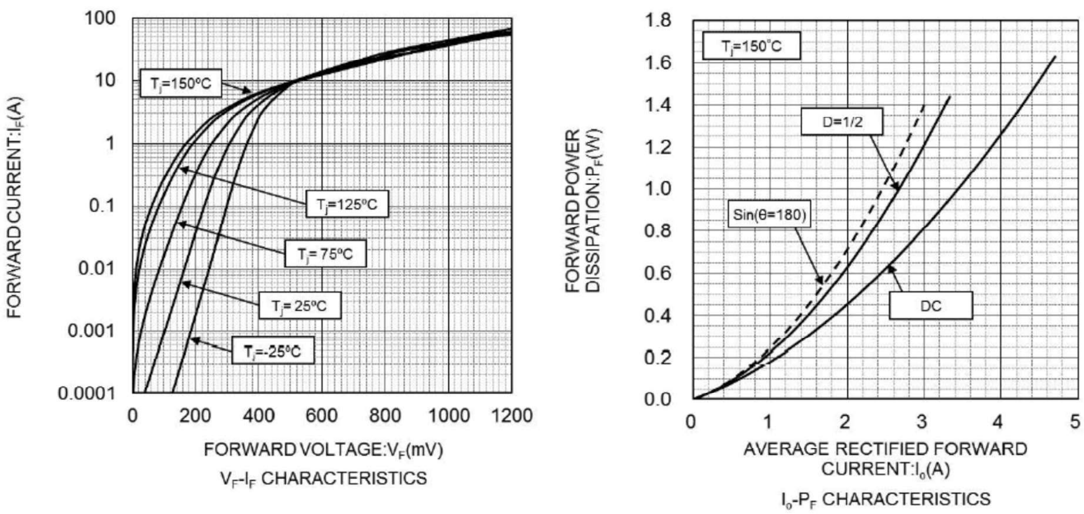

Figure 4. Rohm Schottky Barrier Diode RSX301LAW30 Characteristic Curve for Forward Loss

In 4 Figure, T_j = 0.99 [°C], under conditions of DC, I_F = 3 [A] is a loss,

3 [A] x Approx. 270 [mV] (Figure 4 left figure) = 0.8 [W] (Figure 4 right figure)

Interpolate T_j and Duty conditions (DC: Duty = 100% in the above calculation example) from Figure 4 according to the usage conditions.

3) DC reverse voltage V_R

It must be at least 1.2 times the maximum voltage used in the converter.

For a buck converter,

$$V_R > V_{in(MAX)} \times 1.2$$

For boost converter,

$$V_R > V_{out(MAX)} \times 1.2$$

Keep the peak reverse voltage V_{RM} lower, including switching spikes. When $V_{RM} = V_R$, the peak reverse voltage V_{RM} must be kept below V_R, including spike noise.

4) Reverse current I_R

Choose the smallest possible item from those that have cleared items 1) to 3) above. However, SBD with small V_F tend to have large I_R. Since I_R vary drastically with respect to the temperature, care must be taken in the design of the equipment which high-temperature operation is required. The reverse characteristic curve of " RSX301LAM30" is as follows.

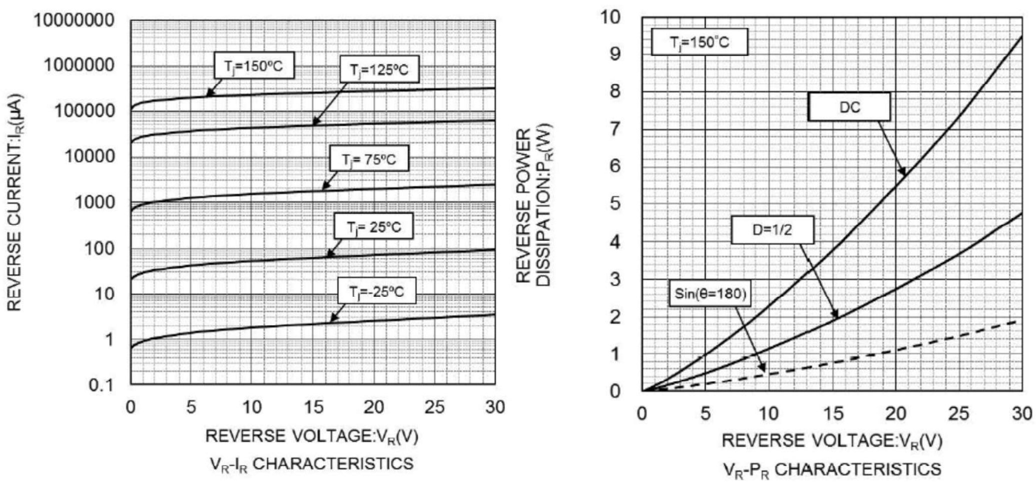

Figure 5. Rohm Schottky Barrier Diode RSX301LAW30 Characteristic Curve for Reverse Loss

Similarly, in Figure 5, T_j = 150 [°C], under the conditions of DC, P_R is about 9 [W], and P_F is equivalent to 10 times. For the loss of free-wheeling diode, P_F and P_R must be estimated in consideration of the operating temperature, along with the consideration of the Duty ratio.

Main target products and recommended diodes

Table 2 lists the major asynchronous converters from ROHM HP and lists the recommended diodes listed in the converter IC datasheet. Many of the recommended diodes listed in the converter IC datasheet are “not recommended for new design”. As of '19/8, recommended products and their key characteristics are added. Although the model name of the datasheet recommended product and the current recommended product are different, the element characteristics remain unchanged.

Table 2. Targeted Asynchronous Converters in this Document and Recommended SBD (as of '19/ 8)

Converter products	Grade	Recommended Di in data sheet	New recommended Di ('19/8 current)	V_{RM}[V]	V_R[V]	I_O[A]	I_{FSM}[A]	V_F(Max)[V]	I_R(Max)[uA]
BD8152FVM	Standard	RB161M-20	RB161MM-20	25	20	1	30	0.32	700
BD8158FVM	Standard	RB161M-20	RB161MM-20	25	20	1	30	0.35	700
BD8311NUV	Standard	RSX201L-30	RSX201LAM30	30	30	2	60	0.44	150
BD8314NUV	Standard	RSX201L-30	RSX201LAM30	30	30	2	60	0.44	150
BD8316GWL	Standard	RSX101VA-30	RSX101VAM30	30	30	1	5	0.42	40
BD8317GWL	Standard	RB521S-30	RB521SM-30	-	30	0.2	1	0.47	30
BD9035AEFV-C	Automotive	RB225NS-40	RB225NS-40XX	40	40	30	100	0.63	50
BD9060F-C	Automotive	RB095B-40	RB095BM-40XX	45	40	6	45	0.55	100
BD9060HFP-C	Automotive	RB095B-40	RB095BM-40XX	45	40	6	45	0.55	100
BD90610EFJ-C	Automotive	RB055L-40TF	RB055LAM-40XX	40	40	3	70	0.55	100
BD90620EFJ-C	Automotive	RB095BM-40FH	RB095BM-40XX	45	40	6	50	0.55	100
BD90620HFP-C	Automotive	RB095BM-40FH	RB095BM-40XX	45	40	6	50	0.55	100
BD90640EFJ-C	Automotive	RB095BM-40FH	RB095BM-40XX	45	40	6	50	0.55	100
BD90640HFP-C	Automotive	RB095BM-40FH	RB095BM-40XX	45	40	6	50	0.55	100
BD9227F	Standard	RB060MM-30	RB060MM-30	30	30	2	55	0.45	50
BD9701CP-V5	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9701FP	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9701T	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9701T-V5	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9702CP-V5	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9702T	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9702T-V5	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9703CP-V5	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9703FP	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9703T	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9703T-V5	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9778F	Automotive	RB050L-40	RBR3LAM40CXX	40	40	3	75	0.55	1000
BD9778HFP	Automotive	RB050L-40	RBR3LAM40CXX	40	40	3	75	0.55	1000
BD9859EFJ	Standard	RSX301LA-30	RSX301LAM30	30	30	3	100	0.42	90
BD9870FPS	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9873CP-V5	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9874CP-V5	Standard	RB050LA-40	RBR3LAM40C	40	40	3	75	0.55	100
BD9E151NUX	Standard	RSX101VA-30	RSX101VAM30	30	30	1	5	0.42	40
BD9G101G	Standard	RB060M-60	RB060MM-60	60	60	2	30	0.52	50
BD9G102G-LB	Industrial	RB060MM-60	RB060MM-60	60	60	2	30	0.52	50
BD9G201EFJ-LB	Industrial	RB050LAM-60TFTR	RB050LAM-60TFTR	60	60	3	80	0.56	100
BD9G201EFJ-M	Automotive	RB050LAM-60TFTR	RB050LAM-60TFTR	60	60	3	80	0.56	100
BD9G341AEFJ	Standard	RB095B-90	RB095BGE-90	90	90	6	45	0.75	150
BD9G341AEFJ-LB	Industrial	RB095B-90	RB095BGE-90	90	90	6	45	0.75	150
BD9G401EFJ-M	Automotive	RB050L-60	RBR3LAM60BXX	60	60	2	75	0.56	150

In the table, “XX ” at the end of the model name in the “Recommended Di” column is described as a symbol indicating the name of an on-vehicle product, and contains two or more letters (example: TF).

History

Date	Revision	Changes
2019.11.20	001	New Release

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