Diodes for Switching Power Supplies

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1. Introduction

There has been remarkable progress in the application of switching power supplies to all types of electronic apparatuses in the consumer and industrial fields. This progress has been supported by improvements in power supply technology, which includes increased switching frequency and advanced circuit technology. This progress could also be expressed as the result of improvement in device level performance, new device development, and application technology. For example, in the area of applications, cooperation between placement equipment and device manufacturers has led to the creation of a new concept in switcing power supplies. Recently, under development is a switching power supply which seriously considers environmental impact as well as energy savings and countermeasures against the generation of higher harmonics. One of the fundamental factors of an environmentally friendly switching power supply is the power device technology.

Fuji Electric is developing and marketing products based on performance characteristics and device construction. These device include the fast recovery rectifier diode, one of the key devices for switching power supplies as well as the Schottky Barrier Diode (SBD), Low Loss Fast Recovery Diode (LLD), Fast Recovery Diode (FRD), and their respective Surface Mount Devices (SMD) packages.

2. Development of the Fast Recovery Rectifier Diode

2.1 Developmental trend

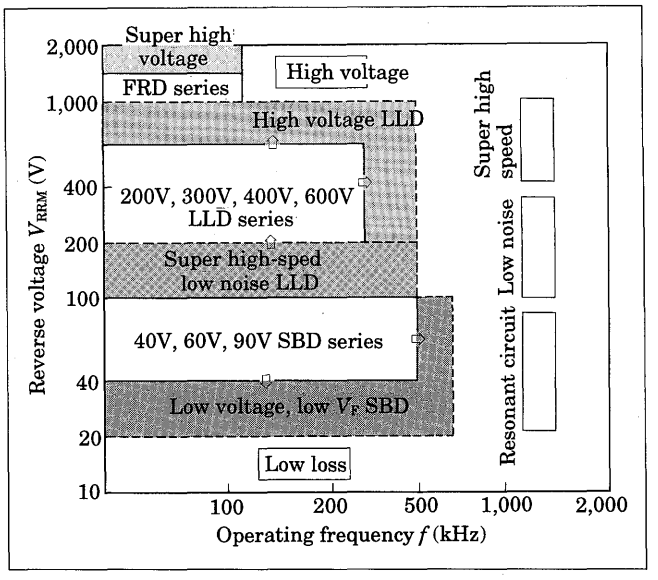
Market demands for a power supply include the following:

(1) Smaller size and lighter weight
(2) Higher efficiency
(3) Lower cost

The requirements for switching power supplies and the corresponding to the above needs are:

(1) An increase in switching frequency→Super high-speed, SMD
(2) A reduction in loss→Low V_F
(3) A reduction in the number of parts→Eliminating the snubber circuit

Fig. 1 Developmental trend of the fast recovery rectifier diode



As shown in Fig. 1, Fuji Electric has made progress in its product development in response to these various requirements. Regarding the LLD, we have introduced the 600V LLD series with a circuit that improves the power factor and has a higher breakdown voltage. Regarding the 200V group, we are also developing an LLD with low noise performance, a step towards facilitating circuit design. Also, an SBD of low V_F is being developed for devices with a low output voltage such as 3.3V or 2.2V.

2.2 Schottky barrier diode (SBD)

For the diodes of the secondary circuit rectifier in a switching power supply, SBDs are mainly applied in the low output voltage region. The SBD has a lower V_F (forward voltage drop) than a diode with a PN junction. Since the SBD is a unipolar device and has a short t_{rr} (revers recovery time), one of the factors which theoretically determines the switching characteristics, it can be driven at a high frequency. For example, it is presently used at a switching frequency of about 500kHz.

The V_F of the SBD is determined by the barrier

Fig. 2 Correlations between barrier height and SBD characteristics

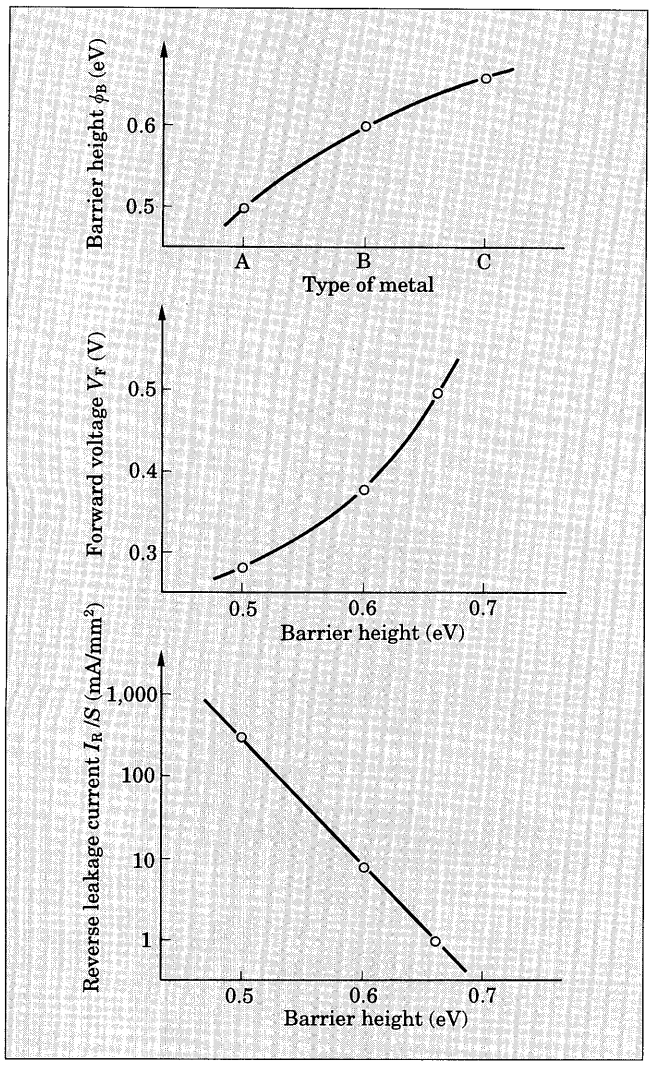


Fig. 3 Current-voltage diagram of the SBD series

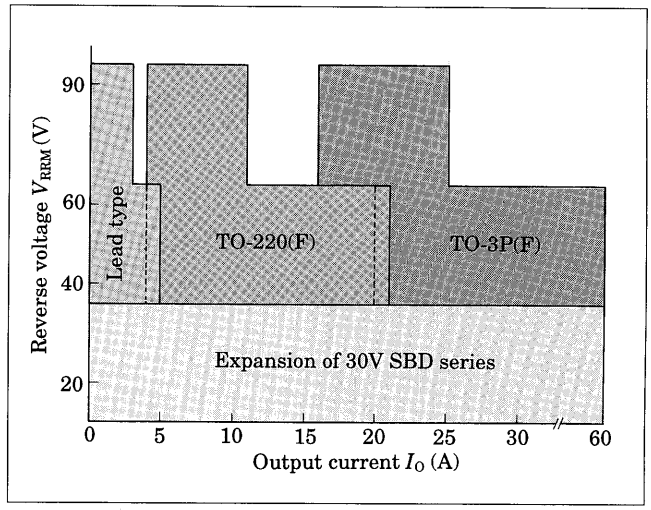
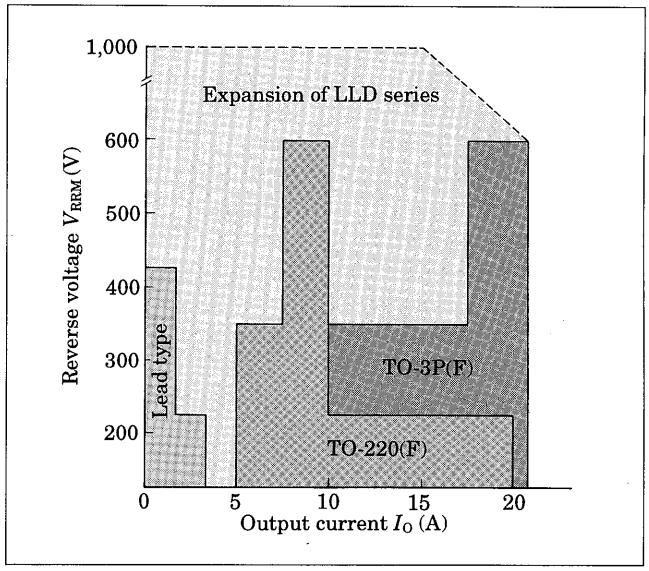


Fig. 4 Current-voltage diagram of the LLD series



height, which is dependent upon the type of metal that comprises the Schottky junction. Therefore, in order to achieve low V_F, a metal with low barrier height is first selected . Then, the size of the chip is enlarged in order to reduce current density. In Fig. 2, the relationships between metal and barrier height, barrier height and V_F and barrier height and reverse leakage current (I_R) are shown. As seen in these relationships, the selection of a metal that results in low barrier height enables the reduction in the V_F. But on the other hand, I_R increases exponentially. This increase of I_R together with the increase in loss during reverse bias could result in an increase in the overall loss. Therefore, the barrier metal is selected by also taking into consideration the portion of loss in the SBD's reverse bias.

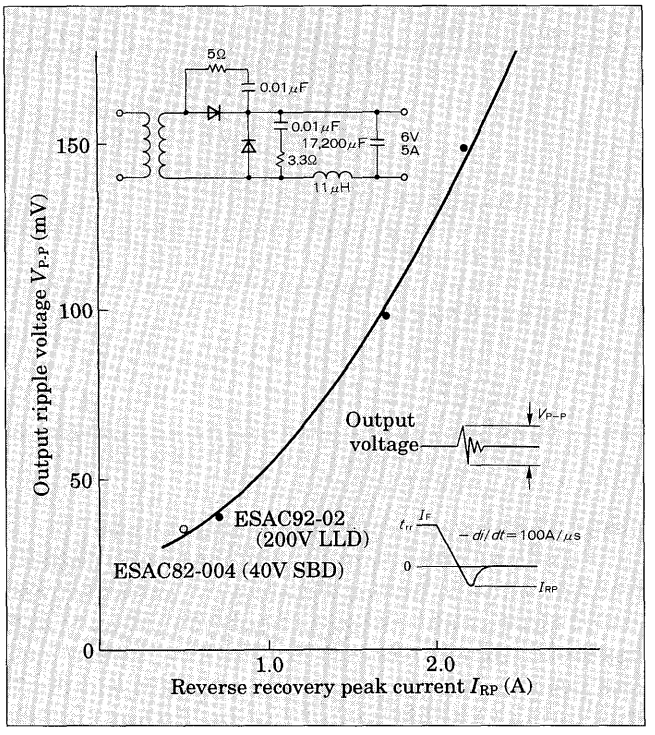
Fuji Electric's SBD has been introduced as a series with the current and voltage regions shown in Fig. 3. The SBD is applied to various switching power supplies.

2.3 Low loss fast recovery diode (LLD)

FRDs with a PN junction structure have been applied to switching power supplies for high output voltage region. The LLD has been developed in order to attain an FRD with lower loss and higher speed. Since in the LLD the thickness and specific resistance of the epitaxial layer, which is a high resistance layer, can be precisely controlled, it is possible to decrease the design margin of the reverse breakdown voltage and to reduce V_F.

At present, the LLD product line has expanded to include the area conventionally covered by the FRD, as shown in Fig. 4. As seen from the recent trends in switching power supply technology, demands on the design requirements of power supplies have been increased. One of these requirements includes a low noise diode, the performance of which complies with high frequency noise regulations. Figure 5 shows the relationship between output ripple noise and the recovery characteristic (reverse recovery peak current: I_{RP}). The diode's recovery characteristic is cited as one of the source of noise generation in switching power supplies.

Fig. 5 Relationship between output ripple noise and recovery characteristics



Therefore, it is necessary that the recovery characteristic has a soft recovery in order to achieve low noise performance.

Furthermore, if the snubber circuit that is conventionally provided for noise absorption can be eliminated due to the soft recovery of the diode, positive results can be expected. Such results include a reduction in the number of components and improved efficiency of the power supply.

Fuji Electric has developed the new LLD with a breakdown voltage of 600V and expanded its application area to that of the conventional FRD. In addition, we are promoting the development of the low noise LLD as the next generation LLD.

3. Package Development

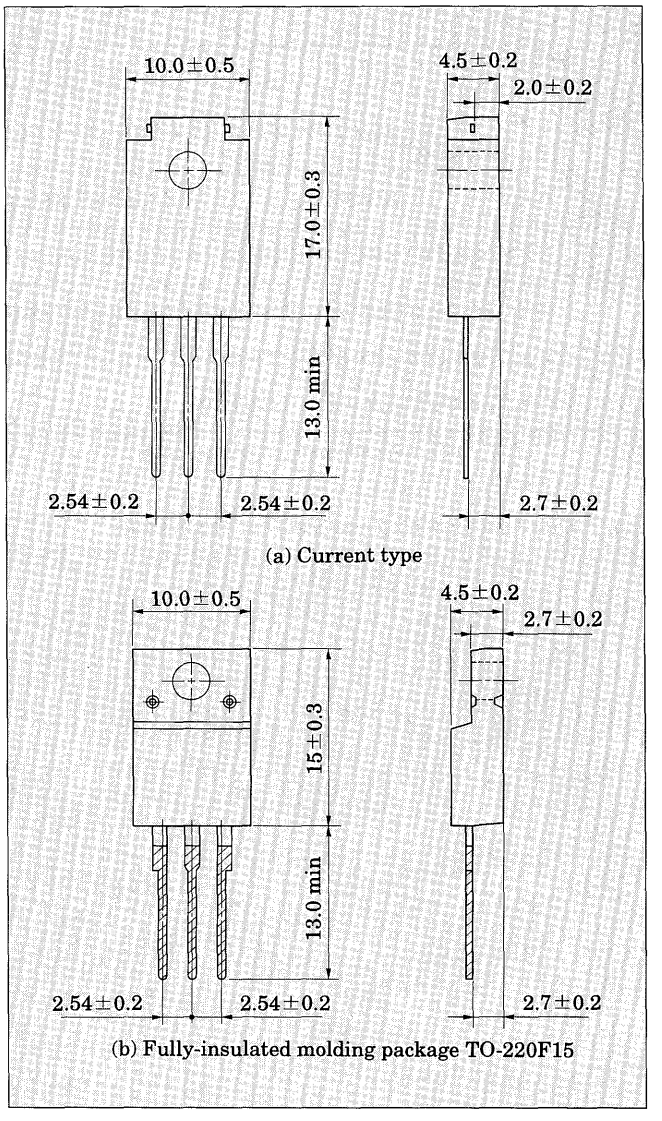
3.1 Fully-insulated molding package

Packages for switching power supplies show a tendency toward an SMD and full molding together with smaller size, lighter weight, and reduced thickness. In particular, improvement in the insulation by full molding, safety standards, reducing the number of parts, and reducing human labor are all being demanded..

However, the conventional, full mold products have an installation fin that is covered with mold resin. There is an exposed part on either the upper part or surface of the frame, as a result, they are not a completely molded construction.

Fuji Electric has developed and marketed two packages with a fully-insulated molding: the TO-220F15 and the TO-3PF. Figure 6 shows a comparison

Fig. 6 Comparison of the current and the new TO-220 fully-insulated molding package



between the TO-220F15 package and the conventional package.

The features of the fully-insulated molding package TO-220F15 are as follows:

(1) There is no exposed metal except for the outer leads
(2) Length of the molded part is 15mm, shorter than the conventional package between such advantages as a height limit.
(3) Heat radiation is improved by adoption of a mold resin with good heat conductivity.

3.2 Surface mount device (SMD)

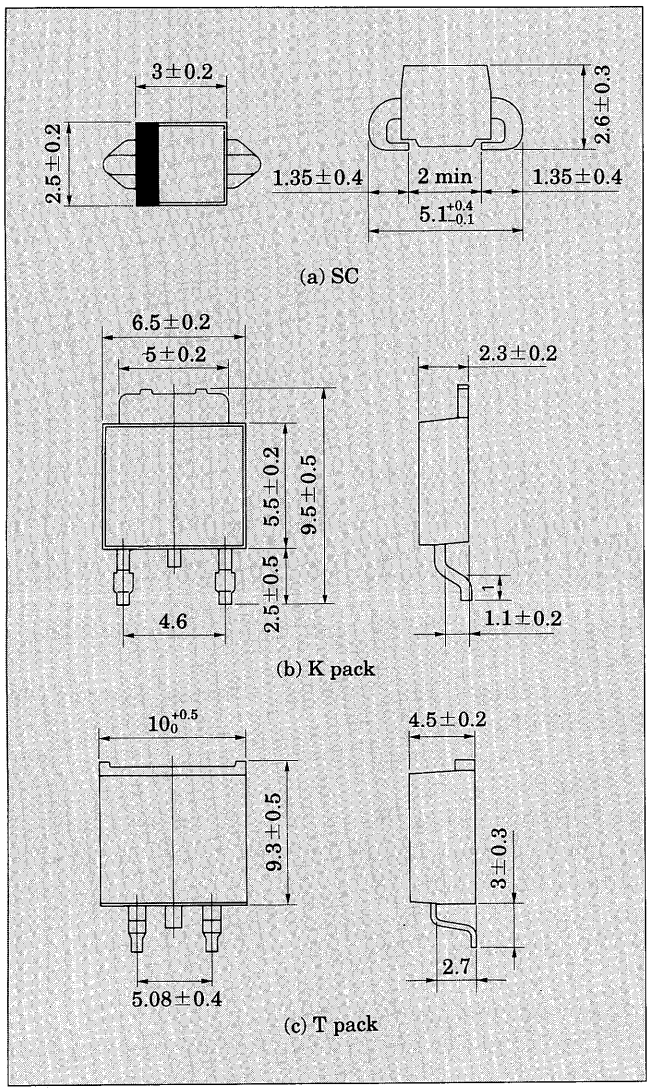
The packages for switching power supplies are changing over to SMDs, which result in smaller size and high-density mounting. From small components such as chip capacitors and resistors to power devices, this changeover to SMD is a remarkable occurrence. This is supported by not only the effort of device manufacturers, but also the improvement in mounting tech-

Table 1 Fuji Electric's SMD series

package \ division			SBD				LLD				FRD	General
			30V	40V	60V	90V	200V	300V	400V	600V	200 to 600V	200 to 600V
SC	Single	0.5A 0.5A 0.8A 1 A 1.5A	 △ SC802-03	 SC802-04	 SC802-06	 SC802-09	 SC902-2	 	 	 	SC201-2, 4, 6 0.4 μs SC311-4, 6 0.05 μs SC211-2, 4 0.4 μs SC321-2 0.1 μs	 SC016-2, 4, 6 SC017-2, 4
K pack	Single	5 A		KS826S04		☆ KS826S09	KS926S2	☆ KS926S3	△ KS926S4	△ KS926S6		
	Dual	5 A	☆ KS823C03	KS823C04	☆ KS823C06	KS823C09	KS923C2		△ KS923C4	△ KS923C6		
T pack	Dual	10A	☆ TS802C03	TS802C04	TS802C06	TS802C09	TS902C2	TS902C3	△ TS902C4	△ TS902C6		
		20A	☆ TS805C03	TS805C04	TS805C06		TS906C2					
		30A	☆ TS808C03	TS808C04	TS808C06							

☆: Under development △: planned

Fig. 7 Outer dimensions of the SMD series package



nology by placement equipment manufacturers.

Fuji Electric has developed and marketed the SMD package to match market demands. In particular, the 1A SC model is an original design by Fuji Electric and has been favorably received. Furthermore, to meet various demands, the K pack which covers 5A and the T pack covers 10 to 30A (both the K and T packs are Fuji Electric's own designations). A list of the various SMD series is shown in Table 1, and outer dimensions of each package are shown in Fig. 7.

4. Conclusion

In this paper fast recovery rectifier primarily used for switching power supplies were introduced. Both the SBD and LLD are indispensable power devices for switching power supplies, and further improvement in their performance is required. In the future, we will promote the development of new, timely products, and activity research, develop, and market the following diodes:

(1) An SBD with low V_F for an output of 2 to 3V
(2) A low noise LLD