

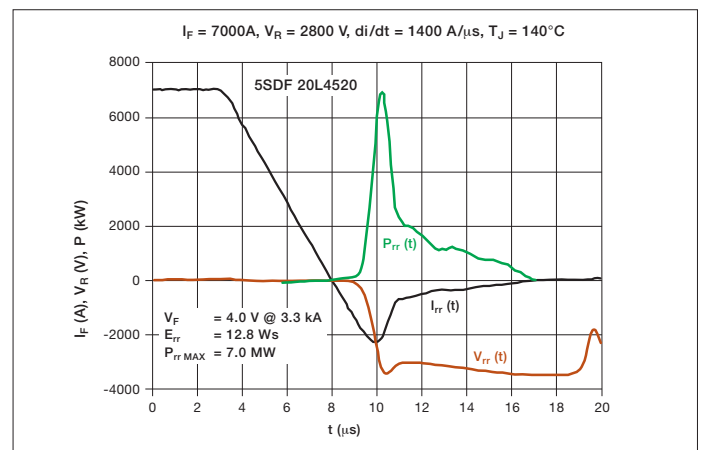
# Fast recovery diodes

ABB Semiconductors offers a wide range of fast recovery, low loss diodes such as snubber, clamping and free-wheeling diodes in various configurations to enable full performance of the IGCTs, IGBTs and GTOs in demanding applications.



A comprehensive family of fast recovery diodes allows a wide choice of recovery characteristics suited to all converter applications.

Fast recovery diodes, though an integral part of inverter design, have seldom received the same attention as turn-off devices (TODs) such as IGBTs, IGCTs or GTOs. As a result, snubber, clamp, neutral-point clamping (NPC) and free-wheeling diodes (FWDs) have too often limited optimal equipment design. Recognising this and the growing trend to eliminate voltage snubbers on semiconductors, ABB has developed a full range of fast diodes offering enhanced Safe Operating Areas (SOA) and controlled (soft) recovery at very high  $di/dt$  and  $dv/dt$  levels. The growing demand for switching capability (*ratings*) and not just recovery charge or losses (*characteristics*) imposes new constraints on diode design and production test equipment to ensure cost-effective delivery of robust and reliable components. In contrast to TODs, thyristors and diodes have traditionally been tested for their *characteristics* only and classified accordingly. New generations of high-performance fast diodes, as 5SDF 11H4505, 20L4520 / 21 and 28L4520 / 21, are now tested for their dynamic characteristics and ratings on production test equipment that accurately reproduces the main commutation modes required of today's fast diodes. The fast diodes 5SDF 20L4521 and 28L4521 have been developed to operate safely in power electronic circuits employing IGBT and IEGT press-packs, where  $di/dts$  up to 5 kA/ $\mu$ s are especially required.



## Benefits:

- Free-wheeling diodes
- Clamp and snubber diodes
- Snubbered types
- Unsnubbered types
- Soft recovery
- High SOA
- Cosmic ray resistance capability

## Applications

Fast diodes of a given blocking voltage and silicon wafer diameter are designed using five basic variables: resistivity, thickness, uniform lifetime control, profiled lifetime control and emitter efficiency. Combining these variables allows diodes to meet the requirements of five different commutation modes encountered in voltage source and current source inverters (VSIs and CSIs). These are defined in table 1.

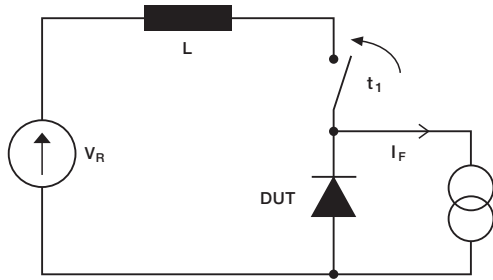


Fig. 2a Inductive commutation

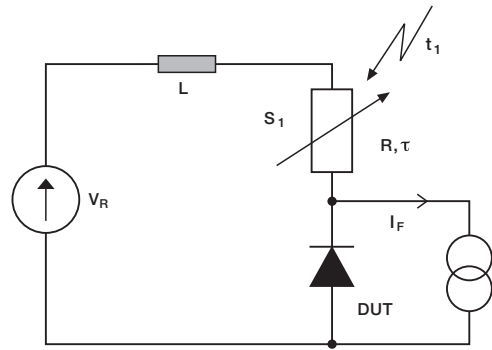


Fig. 2b Resistive commutation

Category	Application	Snubber type	Commutation characteristics	Required diode characteristics
I	FWD and NPC diodes for GTOs and IGCTs in low frequency VSIs	RCD	- inductive - unclamped - snubbered - low dv/dt	- uniform lifetime - high cosmic ray resistance capability - low $V_{FM}$
II	Snubber diode in RCD circuits	R	- inductive - unclamped - snubbered	- profiled lifetime - soft recovery at low $I_F$
III	- Snubber diodes in Undeland, Marquardt and McMurray VSIs - Clamp diodes	none	- resistive - unclamped - unsnubbered	- profiled lifetime - soft recovery at low $I_F$
IV	- Commutation diodes in CSIs - High frequency series-connected IGCTs	RC	- inductive - unclamped - snubbered	- profiled lifetime - medium cosmic ray resistance capability
V	FWD and NPC diodes in snubberless high frequency VSIs	none	- inductive - clamped - high dv/dt	- profiled lifetime - high cosmic ray withstand capability - high SOA - soft recovery at low $I_F$

Table 1

## Cosmic ray resistance capability

An important parameter for the rating of any semiconductor in a converter is the voltage to which it is exposed. This has two reasons: the stability of the leakage current at rated temperature and the potential failures provoked by ionising cosmic particles – events whose probability of occurrence increases exponentially with field strength but only linearly with voltage duty cycle. The various functions within power conversion equipment may be exposed to different voltages and duty cycles even though the peak voltages might be the same. Thus, an inverter containing 4.5 kV GTOs, free-wheeling diodes, snubber diodes and clamp diodes operating from a

One of the basic principles influencing the nature of a commutation is the origin of the  $di/dt$ . Figure 2 illustrates this and defines two types:

- *inductive commutation* in figure 2a whereby the active switch is considered "perfect" (e.g. a thyristor) and an inductance determines  $di/dt$
- *resistive commutation* in figure 2b whereby the active switch is considered as a time-dependant resistor (e.g. a transistor) and this controls  $di/dt$ .

2.8 kV DC link, would require that the GTOs and snubber diodes have a 2.8 kV DC rating.

The snubber and clamp diodes however, due to their infrequent exposure to the DC link (duty cycle of approx. 5 %), would be better served with diodes of lower DC rating (thinner silicon), thus endowing them with superior dynamic properties (fast forward and reverse recovery, low losses, no snap-off). These requirements, coupled with the various commutation modes, necessitate the comprehensive diode range shown in table 2. For further information see application note 5SYA2061 "Failure Rates of Fast Recovery Diodes due to Cosmic Rays".

## Product range

Table 2 shows the diode types currently available from ABB in its intended application category. Note that categories III, IV and V are all covered by the high dV/dt-diodes referred to as IGCT / IGBT / IEGT diodes. Table 4 in the appendix shows the

equivalent commutation circuits and the resulting voltage and current waveforms. Combining the data of tables 1, 2 and 4 allows an optimal diode selection.

## Application category

Wafer Ø mm	V <sub>RRM</sub> (V)	I (GTO Freewheeling diodes)	II (Snubber diodes)	III, IV, V (IGCT / IGBT / IEGT diodes)
38	2500	5SDF 06D2504, 06T2504	5SDF 05D2501	/
	4500	5SDF 04D4504, 04T4504	5SDF 03D4501	5SDF 03D4502
	6000	/	5SDF 02D6002	5SDF 02D6004
51	2500	/	/	/
	3000	5SDF 12F2505, 12T2505	/	/
	4500	5SDF 08F4505, 08T4505	/	5SDF 05F4502
	6000	/	/	5SDF 04F6004
68	2500	/	/	/
	4500	5SDF 13H4501	5SDF 07H4501	5SDF 10H4503, 13H4505
	6000	5SDF 10H6004	/	5SDF 08H6005
91	2500	/	/	/
	4500	/	/	5SDF 20L4520, 28L4520, 5SDF 20L4521, 28L4521
	6000	/	/	/

Table 2

## Application documents

Table 3 summarises the essential documents relating to the application of fast recovery diodes.

Document title	Document number
Recommendations regarding mechanical clamping of press-pack high power semiconductors	5SYA2036
Field measurements on high power press-pack semiconductors	5SYA2048
Voltage ratings of high power semiconductors	5SYA2051
Failure rates of fast recovery diodes due to cosmic rays	5SYA2061
Applying fast recovery diodes	5SYA2064
Specification of environmental class for pressure contact diodes, PCTs and GTO, STORAGE	5SZK9104
Specification of environmental class for pressure contact diodes, PCTs and GTO, TRANSPORTATION	5SZK9105
Specification of environmental class for pressure contact diodes, PCTs and GTO, OPERATION Industry	5SZK9115
Specification of environmental class for pressure contact diodes, PCTs and GTO, OPERATION Traction	5SZK9116

Table 3 Principal applications documents

Appendix

Table 4. Equivalent circuits and stylised voltage and current waveforms of the five commutation categories.

		<p><b>Category I</b> RCD-snubber for FWD, inductive switching</p>
		<p><b>Category II</b> R-snubber for RCD, snubberdiode, inductive switching</p>
		<p><b>Category III</b> Snubberless Undeland/McMurray snubber-diode, resistive switching</p>
		<p><b>Category IV</b> RC-snubber, inductive switching</p>
		<p><b>Category V</b> Snubberless, clamped inductive switching</p>

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