Fast Recovery Diodes
ABB Switzerland Ltd, Semiconductors

To enable the full utilisation of the performance of their IGCTs and GTOs, ABB has an accompanying range of fast recovery diodes for the use as snubber, clamping and free-wheeling diodes in various configurations and 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 converter design, traditionally take a ”back seat” both at the device and equipment design levels where attention tends to focus on the Turn-Off Devices (TODs) such as IGBTs, IGCTs or GTOs. As a result, Snubber, Clamp, Neutral-Point Clamping (NPC) and Free-Wheel Diodes (FWDs) have traditionally been a limiting device for 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 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 the cost-effective delivery of robust and reliable components. In contrast to TODs, thyristors and diodes have traditionally been production-tested for their *characteristics* only and classified accordingly. New generations of high-performance fast diodes 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. These modes are described overleaf along with a brief overview of the selection criteria and available fast diodes from ABB.

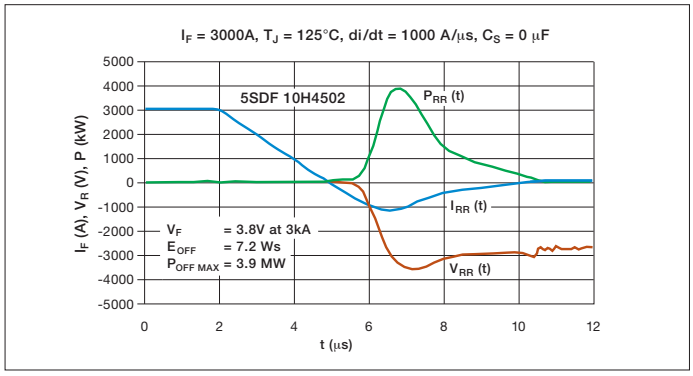

Fig. 1 Snubberless, clamped, FWD commutation showing high SOA and soft recovery

Benefits:

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

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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.

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

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

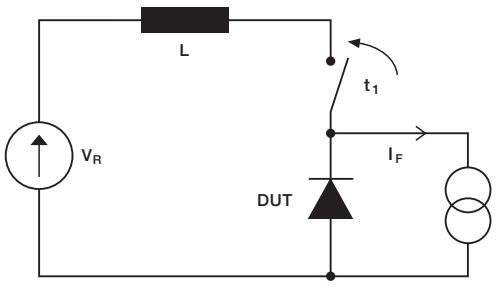


Fig. 2a Inductive commutation

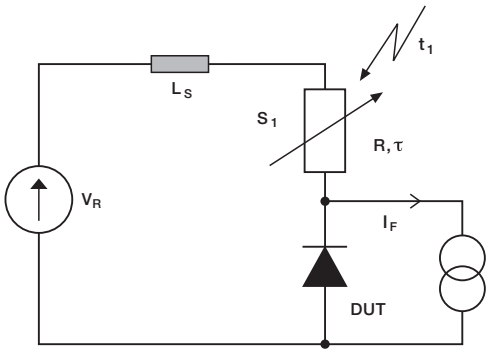


Fig. 2b Resistive commutation

Category	Application	Snubber Type	Commutation Characteristics	Required Diode Characteristics
I	FWD and NPC diodes for GTOs and IGCTs in LF VSIs	RCD	- inductive - unclamped - snubbered - low dv/dt	- uniform lifetime - high cosmic ray withstand 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 - HF Series-connected IGCTs	RC	- inductive - unclamped - snubbered	- profiled lifetime - medium cosmic ray withstand capability
V	FWD and NPC diodes in snubberless HF 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 Withstand 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 roughly 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, freewheel diodes, snubber diodes and clamp diodes operating from a 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, say, 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 each allocated to its intended application category. Note that categories III, IV and V are all covered by the high dV/dt-diodes referred to as IGCT 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_{RRM} (V)**	**I** (GTO Freewheeling Diodes)	**II** (Snubber Diodes)	**III, IV, V** (IGCT Diodes)
	2500	5SDF 05D2505	5SDF 05D2501	/
38	4500	/	5SDF 03D4501	5SDF 03D4502
	6000	/	5SDF 02D6002	5SDF 02D6002
	2500	5SDF 11F2501	/	/
51	4500	5SDF 07F4501	/	5SDF 05F4502
	6000	/	/	5SDF 04F6004
	2500	/	/	/
68	4500	5SDF 13H4501	5SDF 07H4501	5SDF 10H4502, 10H4503 and 10H4520
	6000	5SDF 10H6004	/	5SDF 08H6005
	2500	/	/	/
91	4500	/	/	5SDF 16L4503
	6000	/		/

Table 2

Application documents

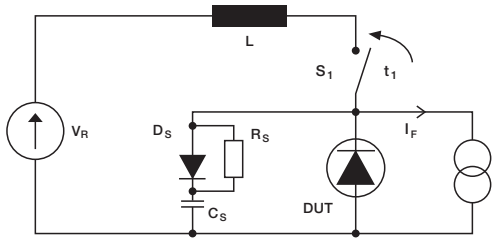
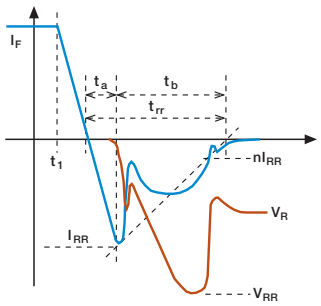
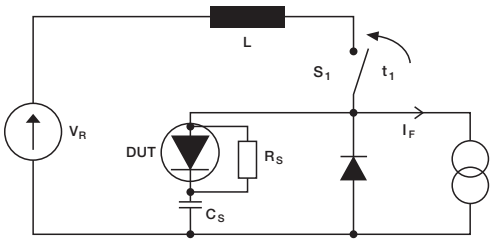
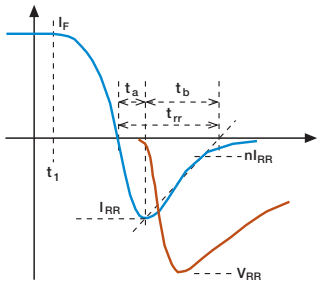
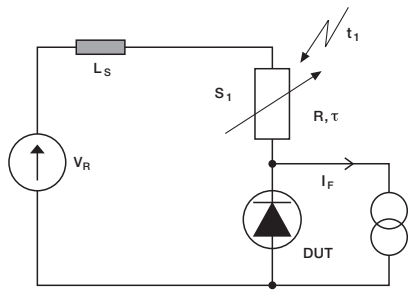
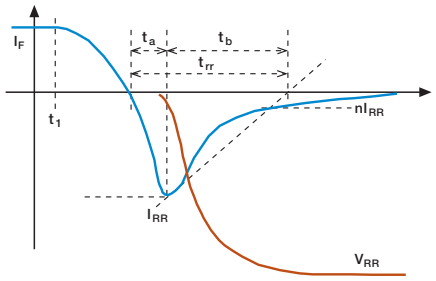
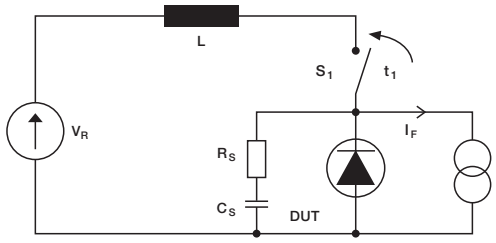
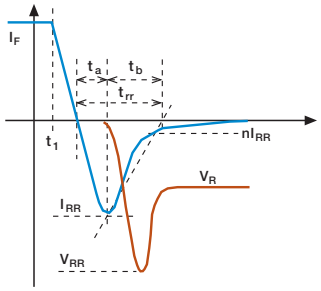
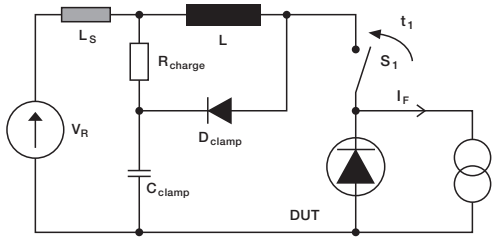
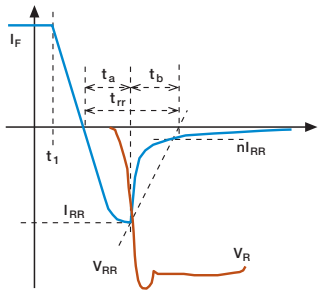
Table 3 summarises the essential documents relating to the application of Fast Recovery Diodes.

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

Table 3 Principal applications documents

Appendix

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

		**Category I** RCD-snubber for FWD, inductive switching
		**Category II** R-snubber for RCD, snubberdiode, inductive switching
		**Category III** Fig. 2c) Snubberless Undeland/McMurray snubber-diode, resistive switching
		**Category IV** RC-snubber, inductive switching
		**Category V** Snubberless, clamped inductive switching

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