Phase control and bi-directionally controlled thyristors

ABB Semiconductors' phase control thyristor has been the backbone of the high-power electronics industry since its introduction almost 50 years ago. Its field of application ranges from kW DC-drives and MW rated load commutated frequency converters to GW converters for HVDC transmission.

Due to the growing demand for energy efficiency, the thyristor remains at the heart of much of the equipment needed for energy transmission and distribution, as it allows the best performance in terms of cost, reliability and efficiency.

ABB was the first company to introduce 6" thyristor products for HVDC applications and offers the most complete range of high power thyristors. New thyristor products continue to be developed with focus on minimizing overall losses and maximizing the power rating of the device.

ABB's PCT product range (see table 1) includes press-pack devices with ratings of 1600 V – 8500 V and 350 A – 6100 A used in demanding applications such as HVDC, FACTS and DC-drives. These components have set benchmark reliability records over many years.

Product range for phase control thyristors

Part number ** = V_{RRM} / 100V	V_{DRM}, V_{RRM} T_{VJM}	I_{TAVM} T_C=70°C	I_{TSM} 10ms T_{VJM}	V_{T0} T_{VJM}	r_T T_{VJM}	T_{VJM}	R_{thJC}	R_{thCH}	F_m	Housing
	V	A	kA	V	mΩ	°C	K/kW	K/kW	kN	
5STP 06T1600	1600	641	9.9	0.99	0.503	125	44.0	12.0	9	T4
5STP 10D1601	1600	969	15.0	0.93	0.302	125	32.0	10.0	10	D
5STP 10T1600	1600	969	15.0	0.93	0.302	125	32.0	10.0	10	T1
5STP 20F1601	1600	1901	27.3	0.95	0.152	125	16.0	4.0	22	F
5STP 20T1600	1600	1956	27.3	0.95	0.152	125	15.5	4.0	22	T2
5STP 34H1601	1600	3370	49.0	0.94	0.066	125	10.0	3.0	50	H
5STP 34T1600	1600	3370	49.0	0.94	0.066	125	10.0	3.0	50	T3
5STP 07D1800	1800	730	9.0	0.80	0.540	125	36.0	7.5	10	D
5STP 09D1801	1800	932	13.7	0.94	0.341	125	32.0	10.0	10	D
5STP 18F1801	1800	1825	26.2	0.97	0.170	125	16.0	4.0	22	F
5STP 18T1800	1800	1870	26.2	0.96	0.170	125	15.5	4.0	22	T2
5STP 30H1801	1800	3108	47.0	0.98	0.081	125	10.0	3.0	50	H
5STP 30T1800	1800	3108	47.0	0.98	0.081	125	10.0	3.0	50	T3
5STP 42L1800	1800	4170	64.0	0.85	0.082	125	7.0	1.5	70	L
5STP 50Q1800	1800	6100	94.0	0.90	0.050	125	5.0	1.0	90	Q
5STP 09D2201	2200	863	12.0	0.98	0.414	125	32.0	10.0	10	D
5STP 17F2201	2200	1702	25.5	0.99	0.206	125	16.0	4.0	22	F
5STP 17T2200	2200	1743	25.5	0.99	0.206	125	15.5	4.0	22	T2
5STP 29H2201	2200	2855	45.0	1.00	0.107	125	10.0	3.0	50	H
5STP 29T2200	2200	2855	45.0	1.00	0.107	125	10.0	3.0	50	T3
5STP 06D2800	2800	620	8.0	0.92	0.780	125	36.0	7.5	10	D
5STP 08D2801	2800	792	10.6	1.06	0.492	125	32.0	10.0	10	D
5STP 08T2800	2800	792	10.6	1.06	0.492	125	32.0	10.0	10	T1
5STP 15T2800	2800	1589	23.6	1.02	0.265	125	15.5	4.0	22	T2
5STP 16F2800	2800	1400	18.0	0.82	0.370	125	17.0	4.0	22	F
5STP 16F2801	2800	1554	23.6	1.02	0.265	125	16.0	4.0	22	F
5STP 27H2801	2800	2670	43.0	1.04	0.127	125	10.0	3.0	50	H
5STP 27T2800	2800	2670	43.0	1.04	0.127	125	10.0	3.0	50	T3
5STP 33L2800	2800	3740	60.0	0.95	0.100	125	7.0	1.5	70	L
5STP 45N2800	2800	5080	75.0	0.86	0.070	125	5.7	1.0	90	N
5STP 45Q2800	2800	5490	75.0	0.86	0.070	125	5.0	1.0	90	Q
5STP 04D4200	4200	470	8.0	1.00	1.500	125	36.0	7.5	10	D
5STP 12F4200	4200	1150	19.0	0.95	0.575	125	17.0	4.0	22	F
5STP 21H4200	4200	2192	32.0	1.25	0.191	125	10.0	3.0	50	H
5STP 28L4200	4200	3170	52.0	0.97	0.158	125	7.0	1.5	70	L
5STP 38N4200	4200	3960	60.0	0.95	0.130	125	5.7	1.0	90	N
5STP 38Q4200	4200	4275	60.0	0.95	0.130	125	5.0	1.0	90	Q
5STP 04D5200	5200	440	5.0	1.20	1.600	125	36.0	7.5	10	D
5STP 17H5200	5200	1975	37.0	1.02	0.320	125	10.0	2.0	50	H
5STP 25L5200	5200	2760	55.0	1.00	0.225	125	7.0	1.5	70	L
5STP 25M5200	5200	2540	55.0	1.00	0.225	125	9.0	1.5	70	M
5STP 34N5200	5200	3600	55.0	1.03	0.160	125	5.7	1.0	90	N
5STP 34Q5200	5200	3875	55.0	1.03	0.160	125	5.0	1.0	90	Q
5STP 52U5200	5200	5120	85.2	1.04	0.115	125	4.0	0.8	135	U
5STP 03D6500	6500	380	4.5	1.20	2.300	125	36.0	7.5	10	D
5STP 03X6500	6500	350	4.5	1.20	2.300	125	45.0	7.5	10	X
5STP 08F6500	6500	830	16.0	1.24	1.015	125	17.0	4.0	22	F
5STP 08G6500	6500	720	16.0	1.24	1.015	125	22.0	4.0	22	G
5STP 12K6500	6500	1370	33.0	1.18	0.632	125	11.0	2.0	50	K
5STP 18M6500	6500	1800	50.0	1.20	0.430	125	9.0	1.5	70	M
5STP 26N6500	6500	2810	65.0	1.12	0.290	125	5.7	1.0	90	N
5STP 42U6500	6500	4250	80.0	1.24	0.162	125	4.0	0.8	135	U
5STP 20N8500	8000	2000	52.0	1.25	0.480	115	5.7	1.0	90	N
5STP 20Q8500	8000	2150	52.0	1.25	0.480	115	5.0	1.0	90	Q
5STP 37Y8500	8000	3720	90.0	1.22	0.220	110	3.0	0.6	190	Y

Table 1

The bi-directionally controlled thyristor

Since many medium and high voltage applications use anti-parallel connected thyristors as AC controllers, ABB has introduced the bi-directionally controlled thyristor (BCT) which consists of two monolithically integrated anti-parallel thyristor functions on one silicon wafer. The two thyristor halves are individually triggered and have a separation region enabling the design of high voltage devices with the dynamic capability of discrete devices. Figure 1 shows a cross-section of the BCT's silicon wafer.

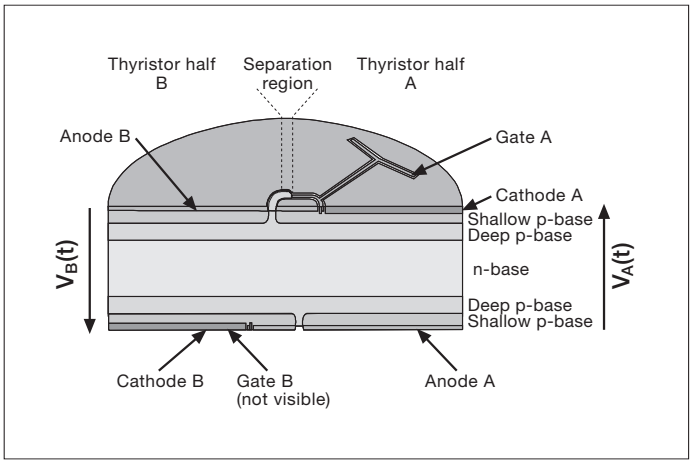

Fig. 1 Cross-section of a BCT

The BCT is designed, manufactured and tested using the same philosophy, technology and equipment as the well established PCT, thus reaching the same levels of performance and reliability. This enables manufacturers of equipment for applications such as

- SVC
- 4-quadrant DC-drives
- soft starters

to reduce part count and equipment size without jeopardizing reliability and performance by introducing the BCT instead of a conventional PCT. Examples show volume improvements and part count reductions for equipment with BCTs in the magnitude of 25 % compared with equally rated PCT-solutions.

The BCT product range includes 2 wafer sizes available in 3 different housings with ratings 2800 V – 6500 V and 3120 A – 5840 A (see table 2). The ratings I_{TSM}, and R_{thjc} are given for one "thyristor-half" of the device. I_{RMS} is the rms-current for a device operating in an AC-switch application.

Product range for bi-directionally controlled thyristors

Part number	V_{RM}	I_{RMS} *	I_{TAVM}	I_{TSM}	V_{T0}	r_T	T_{VJM}	R_{thJC}	R_{thCH}	F_m
	T_{VJM}	T_C=70°C	T_C=70°C	10ms T_{VJM}	T_{VJM}					
	V	A	A	kA	V	mΩ	°C	K/kW	K/kW	kN
5STB 24N2800	2800	5400	2430	43.0	0.85	0.160	125	11.4	2.0	90
5STB 24Q2800	2800	5840	2630	43.0	0.85	0.160	125	10.0	2.0	90
5STB 18N4200	4200	4260	1920	32.0	0.96	0.285	125	11.4	2.0	90
5STB 17N5200	5200	4000	1800	29.0	1.02	0.320	125	11.4	2.0	90
5STB 25U5200	5200	4400	1980	42.0	1.06	0.219	110	8.5	1.6	135
5STB 13N6500	6500	3120	1405	22.0	1.20	0.600	125	11.4	2.0	90
5STB 18U6500	6500	3510	1580	29.7	1.20	0.458	110	8.5	1.6	135

* AC full-wave

Table 2

Voltage rating definitions

The development of high-voltage thyristors has lead to increased values of dissipated power in the off-state (due to higher voltages) even if the leakage currents themselves have remained at similar levels to devices with lower blocking capability. This can cause problems when such devices are characterised and measured in outgoing inspection at elevated temperature (eg 125 °C) because the *whole device* is heated to a constant temperature (not just the junction) and no temperature gradient exists to sink the generated heat away from the junction, resulting in thermal runaway during testing.

Here the applied voltage causes a leakage current and the product (V x I) heats the device. As the device gets hotter, leakage current increases exponentially and so does the heating. If the cooling of the device is not adequate, the device will get progressively hotter and will ultimately fail. This is in strong contrast to real-world applications where the junction temperature may indeed reach a maximum value of 125 °C but the case temperature never exceeds, say, 110 °C, allowing leakage current losses to be cooled away across the temperature gradient between junction and case.

A more realistic method of measuring power semiconductors is to have a sinusoidal 50 or 60 Hz wave of peak value V_{DWM}/V_{RWM} and to superimpose a narrow pulse of amplitude V_{DRM} as per figure 2. This pulse corresponds to repetitive voltage peaks as typically caused by commutation transients (though the RC-circuit limiting them should be designed to give a peak voltage below rated V_{DRM} and V_{RRM}).

By using this method, the voltage capability is tested at application-like conditions and in conformance with international standards, without thermal run-away. This method of rating is applied to ABB's high voltage thyristors, V_{DRM}/V_{RRM} > 4500 V. In the data sheets, the level for V_{DWM}/V_{RWM} is selected as the maximum expected working voltage for a device chosen according to the recommendations in Application Note 5SYA2051 "Voltage ratings for high power semiconductors".

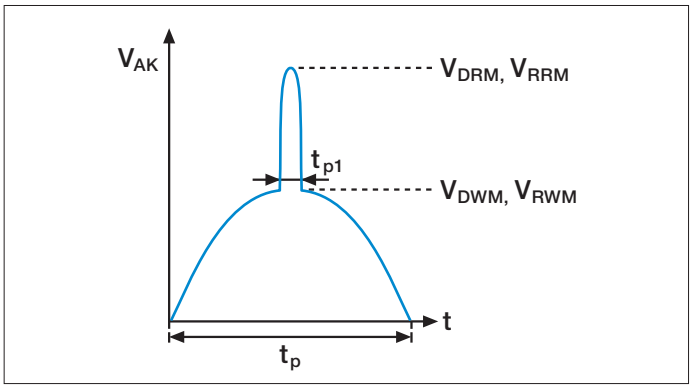

Fig. 2 Voltage definitions for high voltage PCTs and BCTs

Documentation

Device datasheets are available on the ABB website **www.abb.com/semiconductors**. Additional documentation required for the reliable application of phase control and bi-directionally controlled thyristors is also available on the website and is summarised in table 3.

Document title	Document number
Phase control thyristors, sections 1 - 5	
BCT application note	5SYA2006
Design of RC-snubbers for phase control applications	5SYA2020
Gate drive recommendations for phase control thyristors	5SYA2034
Recommendations regarding mechanical clamping of high power press pack semiconductors	5SYA2036
Field measurements on high power press pack semiconductors	5SYA2048
Voltage definitions for PCT and BCT	5SYA2049
Voltage ratings of high power semiconductors	5SYA2051
Surge current for PCTs	5SYA2102
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

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