SECTION 1

PRODUCT INTRODUCTION AND LOGISTICS

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1.1 Product History

ABB Semiconductors' present range of Gate Turn-Off Thyristors is based on three voltage grades and 5 wafer diameters, yielding a family of some 15 devices --- from 2500V to 6000V, with turn-off currents in the range 1500 A to 4000 A. There are several *types* of devices within this range, and these will be described later.
Salient features of the GTO range are:

- 4 inch wafer technology
- free-floating silicon for lowest possible losses
- negative angle junction bevelling for long-term stability
- cosmic ray withstand ratings for all devices

ABB Semiconductors was born from the merger of ASEA's and BBC's semiconductor facilities, which took place in 1991. During the 1970s, ASEA and BBC jointly developed a number of semiconductor technologies, one of the most significant being Free Floating Silicon. This technology was extensively exploited by both companies, even prior to creation of the present Company in Lenzburg, Switzerland. This allows ABB Semiconductors to boast over 20 years experience with Free Floating Silicon, having shipped over 100,000 thyristors in HVDC applications, over 80,000 GTOs in transportation and industrial, plus tens of thousands of diodes and other devices in miscellaneous industrial projects. Today's product range undergoes continuous improvement with respect to:

- production cycle-time, capacity, and process capability
- application support and calculation tools
- device-parameter data-bases
- production test capabilities
- new technologies, such as the transparent emitter and the snubberless GTO or IGCT

1.2 Product Matrix

All products are presently manufactured from 4 inch silicon, and each of the various device categories has a common process technology. Four basic processes and 5 housing sizes are currently used, and these can be identified in the part numbering system, an example of which is shown in Table I.

Table I illustrates the part numbering system.

Table I	Example of *Standard* Part N°											
Character	**5**	**S**	**G**	**A**		**3**	**0**	**J**	**4**	**5**	**0**	**2**
Position	1	2	3	4		5	6	7	8	9	10	11

Table II lists the housing codes. These appear in character position 7.

Table II	Standard Housing Codes				
Housing Letter Code:	**D**	**F**	**H**	**J**	**L**
Flange Diameter (mm) :	58.5	75	100/93	108	120
Housing Thickness (mm):	26	26	26	26	26

Table III represents the complete numbering system.

Table III	Part Numbering of Standard Products
Character Position	Character Meaning
1	**5** = “component”
2	**S** = “semiconductor”
3	**G** = “GTO” or “GCT”, **D** = “Diode”, **T** = “Thyristor”, **H** = “IGCT”
4	indicates *primary* technology: **A** = standard asymmetric (anode shorted), **R** = “reverse conducting”, **B** = reverse blocking, **F** = “fast”, (low loss, small snubber), **T** = “transparent emitter” (very low loss), **Y** = asymmetric snubberless, **X** = reverse conducting snubberless
5 & 6	turn-off current I_{TGQ} rating divided by 100 (i.e. “30” represents “3000 A”)
7	letter designating housing type per Table II
8 & 9	blocking voltage V_{DRM} divided by 100 i.e. (“45” represents “4500 V”)
10 & 11	indicates generation or *secondary* technology (running number)

Table IV summarises the product range

Table IV	Product Matrix GCTs, GTOs and Fast Diodes				
Voltage Class (V)	Wafer Diameter (mm)				
	38	51	68	85	91
2500	5SDF 05D2501 5SDF 05D2505	5SGA 15F2502 5SDF 11F2501	5SGA 20H2501 5SGA 25H2501	5SGA 30J2501	/
3300	/	/		/	5SGX…..(3Q97)
4500	*5SGX…..(4Q97)* 5SDF 03D4501	*5SGX…..(4Q97)* 5SDF 07F4501	5SGA 20H4502 *5SGX…..(4Q97)* 5SDF 07H4501 5SDF 13H4501 5SDF 14H4505	5SGA 30J4502 5SGA 30J4505 5SGT 30J4502 5SGF 30J4502	5SGA 40L4501 5SGF 40L4502 5SGR 30L4502 5SGY 35L4502 *5SGX ....(4Q97)*
6000	*5SGX…..(4Q97)* 5SDF 02D6002	*5SGX…..(4Q97)*	*5SGX…..(4Q97)* 5SDF 10H6004	5SGT 30J6004	5SGT…..(2Q97) *5SGX…..(4Q97)*

Note: dates in parentheses indicate sample introduction.

As shown in Table III, character position 4 identifies the key *primary* technologies. These are described in greater detail in Sections 2 and 5, but are also summarised here. Character positions 10 and 11 designate *secondary* technologies, such as process variations.

Asymmetric GTOs

At the time of writing, *all* ABB Semiconductor GTOs are asymmetric, that is: *non-reverse blocking*.
The "A" designation refers to the range of *conventional anode-shorted* GTOs for 2.5 and 4.5 kV.

Fast GTOs

These are designated by an "F". "Fast" GTOs can use smaller snubbers, and generate lower dynamic losses than their "A" counterparts. They are based on buffer layer technology, combined with anode transparency and anode shorts, and feature finer cathode structures. These devices are intended for new 4.5 kV designs, but because of specification compatibility with earlier GTOs, operating with either large or small snubbers in "high" or "low" dc-link circuits (see Product Design, Section 2), they are also ideal for retro-fitting older systems.

Transparent Emitter GTOs

TGTOs are optimised buffer layer devices, with transparent non-shorted anodes. They offer the lowest possible on-state and switching losses, but under *normal* gate drive conditions, require standard snubbers.

Reverse Conducting GTOs

RC-GTOs contain an integrated (monolithic) anti-parallel diode, which eliminates the need for a discrete free-wheel diode. The GTO technology is the same as that of fast GTOs.

Reverse Blocking GTOs

These devices are not presently offered.

Fast Diodes

Two types of fast diodes are available, “snubber diodes” and free-wheel diodes”, and both are designated by an “F”. The data sheets suggest appropriate applications for these products, which differ mainly in their life-time gradients and dc-link ratings. Diodes with similar voltage and current ratings are additionally differentiated by secondary technology considerations (character positions 10 & 11). See Section 2, *Product Design* , for an explanation of life-time gradients and their importance in an application.

1.3 Application References

ABB Semiconductors’ GTO range was first introduced in 1986. Because these products are based on the same wafer and encapsulation technologies as ABB *thyristor* products, much of the reliability data accumulated for these latter devices over many years, is entirely relevant. In particular, data related to such issues as *blocking voltage stability* (junction termination and passivation), *thermal cycling capability*, *on-state voltage* and *thermal resistance stability* (press-pack interface materials, specific loading), is directly applicable.

Field experience gathered over more than 20 years for thyristors, and 10 years for GTOs, has demonstrated the reliability of these products in the world’s most demanding applications. The number or devices in service for each application category is shown in Table V.

Table V	
Application	**N° of Devices**
GTOs for Traction	> 50 000
Thyristors for Traction	> 50 000
Diodes for Traction	> 20 000
GTOs for Industrial Applications	> 30 000
Thyristors for Industrial Applications	> 400 000
Diodes for Industrial Applications	> 15 000
Thyristors for Power Distribution and Transmission	> 150 000

1.4 Standard and Adapted Standard Products

A standard device is one defined by the published data sheet, manufactured and tested according to established routines. However, in order to accommodate certain customers' application-specific needs, ABB Semiconductors also offers *adapted standard products*. In this case, normal test limits, standard test conditions, or established measurement procedures, may be adapted to suit a particular need. In addition, irradiation levels (affecting V_T, E_{off}), gate lead length, device marking, or combinations of these and other parameters may also vary and these specifics are written into an *adapted standard* spec.

The kind of parametric changes or selections which may typically be requested for GTOs and diodes are:

- banding for stored charge, leakage current or switching times for the series connection of devices.
- banding for V_T or switching times for parallel connections
- V_T vs. E_{off} trade-offs for loss optimisation
- special marking and leading.

After agreement with the customer, the adapted standard device is assigned a special part number which differs from standard numbering practice, as shown in Table VI below:

Table VI	Example of *Adapted Standard* Part N°													
Character	5	S	G	A		4	0	**4**	**2**	**L**	**0**	**0**	**3**	**7**
Position	1	2	3	4		5	6	7	8	9	10	11	12	13

Table VII highlights the way in which *adapted standard* numbering differs from *standard* numbering, as defined by Table I.

Table VII	Part Numbering of Standard Products
Character Position	Character meaning
1 to 6	as for standard devices, see Table III
7 & 8	blocking voltage V_{DRM} divided by 100 i.e. ("42" represents "4200 V")
9	letter designating housing type per Table II
10 to 13	running numbers which identify the customers specification
Note: with adapted standard numbers, the two-digit current and voltage codes are sequential and not separated by the housing letter as in the case of a standard number.	

The advantage of this approach is that “front-end” wafer processing and bills-of-material are standard, with the device rendered customer-specific via “back-end processing” (irradiation, assembly and test). Nevertheless, it is usually more cost-effective in the case of small quantities, to use standard devices wherever possible.

1.5 Production Sequence

As described above, the production of ABB Semiconductors’ GTOs and Diodes is based on standardised raw materials and wafer processing, while allowing reasonable flexibility for adapted standards. Table VIII below depicts the main production steps, with corresponding cycle times.

Table VIII	Production Steps and Cycle Times		
Product Category	**Un-irradiated Wafer**	**Classified Wafer**	**End-product**
Product Status or Feature	a finished wafer that has not yet been subjected to carrier life-time control	an irradiated and tested wafer	a fully tested device with marking and gate-lead, ready to ship
Production Step	full processing from raw silicon to wafer, testing before irradiation	irradiation, test and classification of water	assembly, testing, marking, gate-leading and packing
Cycle Time	8 weeks	2 weeks	1 week

The basic production sequence is explained by the following process-flow. **Production Sequence of GTOs and Fast Diodes** (product structure showing 1 *standard* and 2 *adapted-standard devices).*

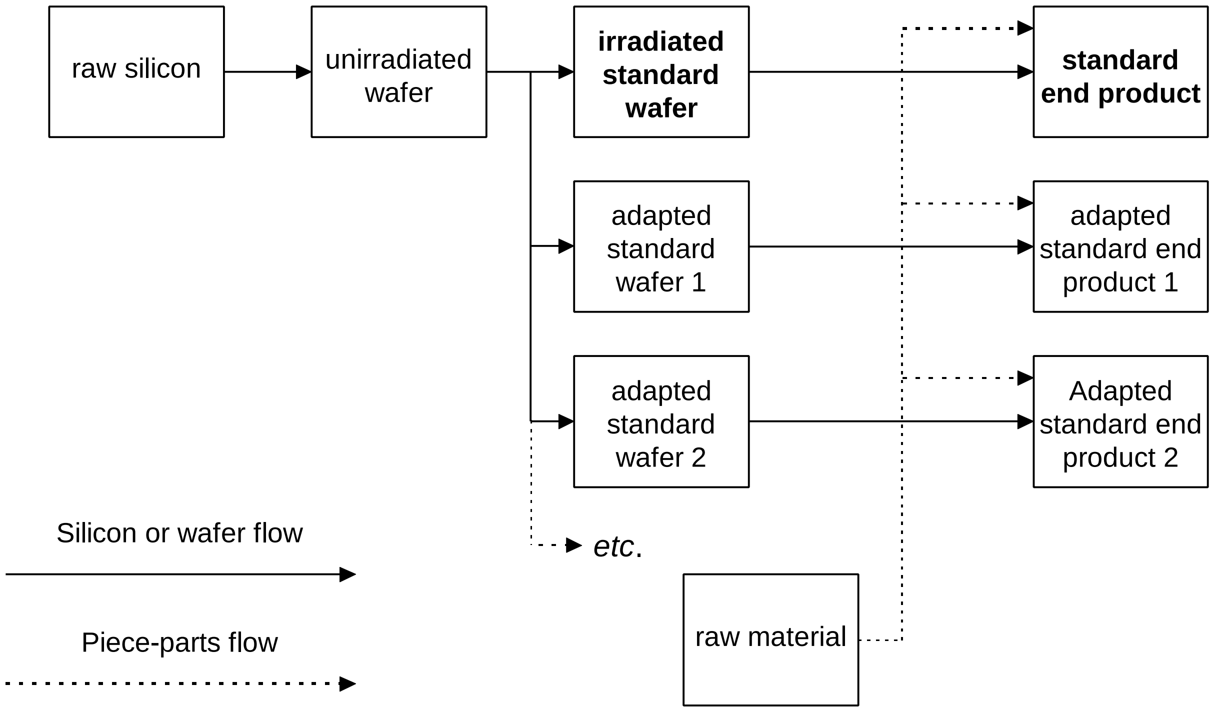

Fig. 1 The Production and Planning Process Flow

Salient features of this processes are:

- *raw material*: purchases of silicon and housing parts are based on the total backlog and forecasts for related end-products
- *un-irradiated wafer*: planning and corresponding wafer-starts are based on the total backlog and forecasts of all dependent end-products
- *wafer*: wafers are irradiated, tested and classified according to backlog
- *end product:* assembly and test of end-products is order-driven, based on standard parts, and exploits the short assembly and test cycles common to both standard and adapted standard devices.

Fast Deliveries

The key to short delivery times lies, firstly, in the standardisation of un-irradiated wafers and other “piece-parts” (constituent housing components), and secondly, in accurate forecasting by product groups. These two criteria drive piece-part purchasing and wafer diffusion starts, as these represent the longest production times. Under these conditions, ABB Semiconductors’ lead times are normally only a few weeks. Even adapted standards can be quickly implemented; modern and flexible test equipment allows accurate measurement of GTOs and fast diodes under most application conditions up to, currently, 6 kV and 6 kA. Such a tester for GTOs is shown in Fig. 2.

Fig. 2 A 6 kV/6 kA GTO Production Tester

1.6 The Specification Review Process and Creating Adapted Standards

So as to provide our customers with the adapted-standard products they require, a *specification review process* is followed (Fig. 3). This ensures that the customer's true needs are captured and that these are correctly translated into ABB Semiconductors' product structure and testing specifications. The spec review is the customer's assurance that the correct product will be supplied. The procedure is as follows:

1) The customer requirement is reviewed and compared to ABB Semiconductors' standard data-sheet and device parameter data-base. If needed, supplemental device evaluation is carried out.
2) The request for quotation is reviewed by Sales and Product Management.
3) The technical content is reviewed by both product engineers and production engineering. A preliminary testing specification is prepared and conformance to the customer's specification verified. If the demand cannot be met, an alternative is proposed.
4) The technical review is returned to Sales, with the newly created "adapted standard" part number. Sales then issues a quotation to the customer.
5) If accepted by the customer, a definitive specification is drawn up and returned by Sales to Product Management, who then establish a Bill of Material. The final Test Specification is vetted by Quality & Reliability, then released to Production for manufacturing.

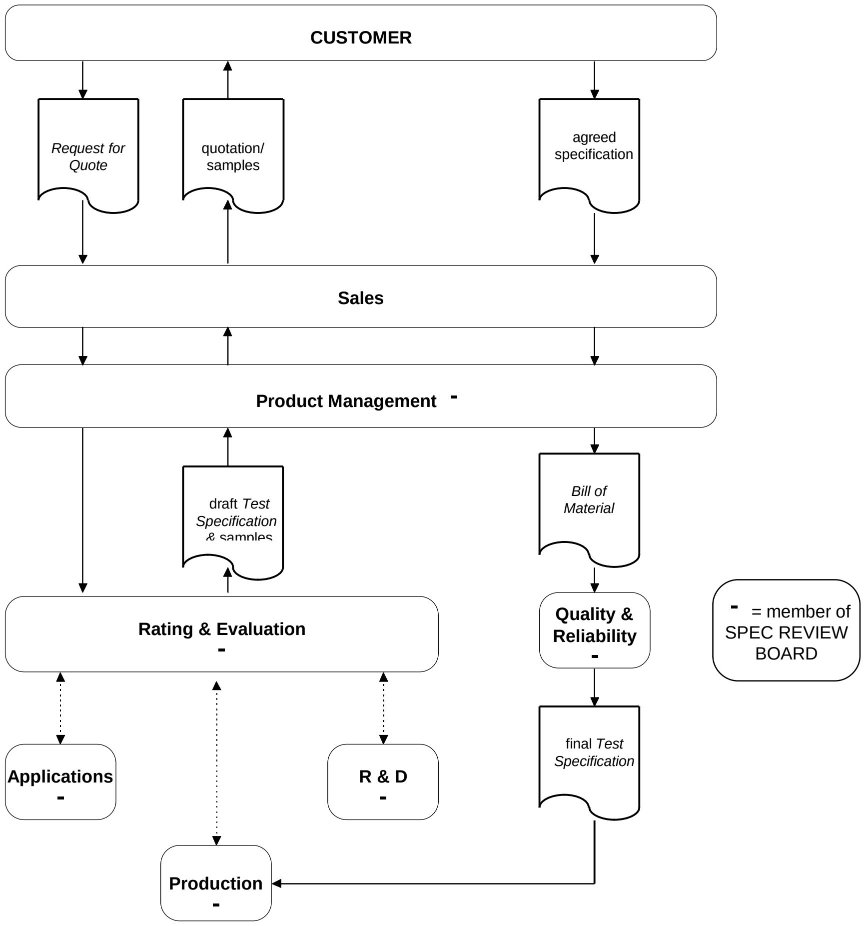

Fig. 3
The *Spec Review* Process Flow

1.7 Old and New Part Numbers

Following the fusion of ASEA and BBC, a unified part-numbering system was created. The following table shows equivalents and replacements resulting from this and subsequent changes.

Table IX Equivalents and Replacement Part Numbers

Old Number	New Number	Comments
CRG 2003-45A01	5SGR 30L4502	replacement
CRG 2501-25A01	5SGR 30L4502	replacement
CSG 1501-25A01	5SGA 15F2502	same part
CSG 2001-25A01	5SGA 20H2501	“
CSG 2501-25A01	5SGA 25H2501	“
CSG 2003-45A01	5SGA 20H4502	“
CSG 3001-25A01	5SGA 30J2501	“
CSG 3003-45A01	5SGA 30J4502	“
5SGA 30**L**2501	5SGA 30**J**2501	same wafer, new housing
5SGA 30**L**4502	5SGA 30**J**4502	“