High current rectifier Diodes

ABB Semiconductors AG

Rectifier diodes for medium frequency welding machines

Product Information

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1. Introduction

ABB Semiconductors AG has long experience in designing and manufacturing of rectifier diodes for high current resistance welding machines. Continuous improvements over the years have led to the design of the the producs available today. They are the diodes 5SDD 40B0200 and 5SDD 71B0200 using the same housing but with differences in the electrical parameters. Their very low forward voltage drop and thermal impedance in combination with good switching behaviour make them very appropriate for use in medium frequency welding equipment. They can operate with frequencies up to 1000 Hz with welding currents over 10 kA having a load cycle capability of millions of cycles corresponding to years of operation under very severe conditions.

2. Welding diode users guide

ABB Semiconductors AG has been cooperated with some of the largest welding equipment manufacturers for years. Through that cooperation ABB Semiconductors AG has gathered a lot of experience how to utilise the diode to reach optimum performance in terms of reliability and electrical characteristics, of which the welding current is the most important. In this product information we have tried to present our knowledge regarding the different issues that are of importance for designing a welding rectifier, to help the welding equipment manufacturer to design a reliable and powerful rectifier unit. We start by presenting the features of our diodes and explain how they affect the welding equipment performance. The installation and the mechanical considerations are then discussed and at the end we discuss reliability issues and the calculation of the welding current with consideration to the life time requirements of the equipment.

The welding diodes from ABB Semiconductors AG

ABB Semiconductors AG has 2 diodes in the product range which are specially designed for welding rectifiers. Both use the same housing size but they have some differences in the electrical performance as can be seen in table 1.

Type and ordering number	V_{RSM}	V_{RRM}	I_{FAVM}	I_{FSM}		V_{F0}	r_F	T_{VJM}	R_{thJC}	R_{thCH}	F_m
** = V_{RSM}/100 V		T_{VJM}	T_c = 85°C	8.3 ms T_{VJM}	10 ms T_{VJM}	T_{VJM}	T_{VJM}				
	V	V	A	kA		V	mΩ	°C	K/kW		kN
5SDD 40B0200	200	200	6130	50.0	45.0	0.80	0.030	170	10	5	22
5SDD 71B0200	200	200	7110	60.0	55.0	0.74	0.026	170	10	5	22

Table 1 The welding diodes from ABB Semiconductors AG.

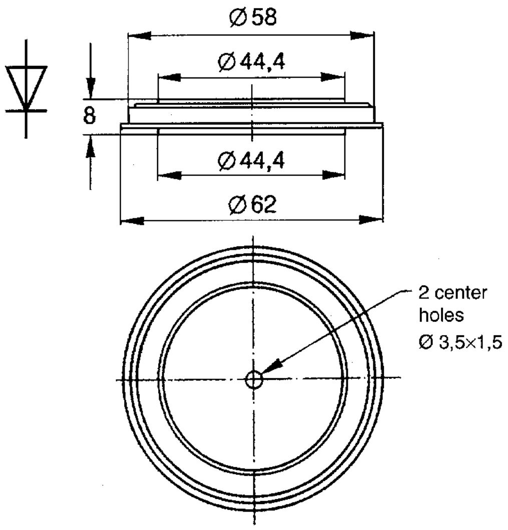


Figure 1 Outline drawing of the welding diode.

Symbol explanations and their relevance to the welding equipment.

V_{RSM}: The maximum surge peak reverse blocking voltage is the maximum single pulse voltage level that the devices can handle without the risk of destruction. If a voltage spike above this level is applied there is a risk of over voltage break down causing the diode to fail and becoming a short circuit.

V_{RRM}: The maximum repetitive peak reverse blocking voltage is the maximum repetitive voltage level that the devices can handle without the risk of destruction. If a repetitive voltage above this level is applied there is a risk of a break down, normally by thermal run-away, causing the diode to fail and becoming a short circuit.

I_{FAVM}: The maximum average forward current is calculated for current with 180 ° sine wave pulses at case temperature 85 °C. The parameter has not so much to do with the real application but it gives some idea about the capability of the device when comparing various devices.

I_{FSM}: The maximum surge peak forward current is defined with a 10 ms long 180 ° sine wave current pulse with no voltage reapplied after the surge and expresses the maximum current pulse the diode definitely can handle without malfunctioning. It is normally used for the design of the semiconductor protection, as specially designed fast fuses, but for welding equipment it is seldom of any significance since the transformer is often limiting the current well below this value.

V_{F0}: The threshold voltage is together with r_F: Slope resistance, a linear representation of the forward voltage drop for the diode and they are used to calculate the conduction losses. For a given current the conduction losses are calculated using formula 1. For the welding application V_{F0} and r_F should be as low as possible to keep the losses to a minimum.

$$P_{loss} = V_{F0} * I_{FAV} + r_F * I_{Frms}^2$$

Formula 1 where P_{loss} is the power loss, I_{FAV} is the average value of the current through the diode and I_{Frms} is the root mean square value of the current through the diode.

T_{VJM}: The maximum junction temperature is the maximum allowed calculated temperature for the silicon wafer. If it is exceeded the ratings for the device are no longer valid and there is a risk of destruction of the device.

R_{thJC}: The thermal resistance junction to case is together with R_{thCH}: Thermal resistance case to heat sink, a measure how good the power losses can be transferred to the cooling system. The temperature increase of the silicon wafer inside the diode and the heat sink is calculated using formula 2. R_{thJC} and R_{thCH} should be as low as possible since the temperature of the silicon wafer is the limiting factor regarding the current capability of the diode and as we later will see the temperature swing for the silicon wafer is determining the load cycling capability and through that the life time of the diode.

$$\Delta T_{JH} = \frac{P_{loss}}{R_{thJC} + R_{thCH}}$$

Formula 2 where ΔT_{JH} is the temperature difference between the silicon wafer and the heat sink.

F_m: The mounting force is the recommended force to be applied to get optimised performance from the device. Too low mounting force will increase the losses and worsen the thermal impedance thus leading to higher junction temperature swing causing a lower operating life time for the diode. Too high force may lead to local pressure spots causing the diode to break mechanically under load cycle conditions.

Customer specific devices.

The 2 presented diodes are ABB Semiconductors AG standard devices. For specific needs we can also, within limits given by the design, adapt the devices according to customer specifications. Additional measurements, certain selection of electrical parameters and special coating are possible features that can be added to the standard diode. If such features are useful for improving the equipment performance please contact ABB Semiconductors AG for further information.

Consideration regarding correct installation of the diode

The mechanical design of the rectifier is crucial for its performance. Inhomogeneous pressure distribution is for instance one of the most common causes for diode failures in welding applications.

The cooling

Considering the size and weight demands for a welding rectifier combined with the high average power, water-cooling is in most cases the only alternative. This does normally not present a problem since other components in the welding systems, as the welding gun, are water-cooled. Regarding the design of the heat sink it must be remembered that the cooling should be homogeneous over the contact surface of the diode. To have just one water channel through the centre of the heat sink is for heavy-duty equipment not sufficient and loften leads to over heating of the diode rim. It is preferred to use water chzannels which give some turbulence to the water instead of straight paths.. For equipment with medium or low utilisation it may though be considered as an option to reduce cost.

The clamping

The clamping must be carefully designed to give a homogeneous pressure distribution over the whole contact surface of the diode. Uneven pressure will lead to deformation of the housing and internal stress between the different layers in the diode, causing the diode to fail after a much reduced number of load cycles compared to a diode with homogeneous pressure distribution. Practical experience shows that the design of the clamping must be carefully made to achieve sufficient pressure homogeneity. Simple solutions, as making a design by just pressing the diode between two rectangular heat sinks and making the clamping with screws in the corners of the heat sinks, have slim chances to reach an acceptable reliability. From mechanical theory the ideal case would be a mounting force applied from one point over the centre of the device and on a minimum distance of half the pole pieces diameter of the diode which would mean 22 mm. Due to the space requirements for the equipment this can be difficult to achieve but practice has shown that acceptable pressure homogeneity results can be achieved also with smaller distances, for example by using belleville springs.

For checking of the pressure distribution we recommend the use of Fuji Prescale film for pressure measurement or similar products from other vendors.

The surface treatment

To create optimum conditions for the heat and current transfer over the interfaces between the diode and the heat sink the surface treatment is important. The diode has a roughness of maximum Ra = 0.8 µm and a flatness of maximum 13 µm and we recommend that the heat sink surface have the same or better properties.

Before assembling the contact surfaces must be properly cleaned using ethanol or similar and lint-free cloth.

The question whether it is better to use some sort of grease, oil or similar solvents at diode assembly or not is not quite easy to answer. We give the following recommendations regarding the assembly of the diode without solvent:
The diode can be assembled without the use of contact grease or similar if the following conditions are fulfilled:
1) The heat sinks have a surface with equal or better roughness and flatness figures than the diode.
2) The heat sink should be galvanic plated with silver-nickel, pure silver, gold or soft Nickel.
3) The mounting pressure must be homogeneously applied over the whole diode surface.

This recommendation does though not exclude the use of very little contact grease or other solvents. The solvent must though be carefully selected so it has both good long-term thermal and electrical conductivity.

If a solvent is used it must be carefully checked that no emission of materials hazardous to the other parts of the equipment takes place.

Load cycling capability and the welding current

In order to specify the current capability of a welding machine for a given cooling system and a given load conditions, manufacturers of welding machines need more detailed information about the rectifier diodes than what is available in the standard specification. This paragraph shows the possible load cycling capability as a function of the junction temperature swing for the 5SDD 71B0200 welding diode of ABB Semiconductors based on experimental data measured in co-operation with some customers of ABB Semiconductors AG. Similar curves for the 5SDD 40B0200 can be supplied by ABB Semiconductors AG on request.

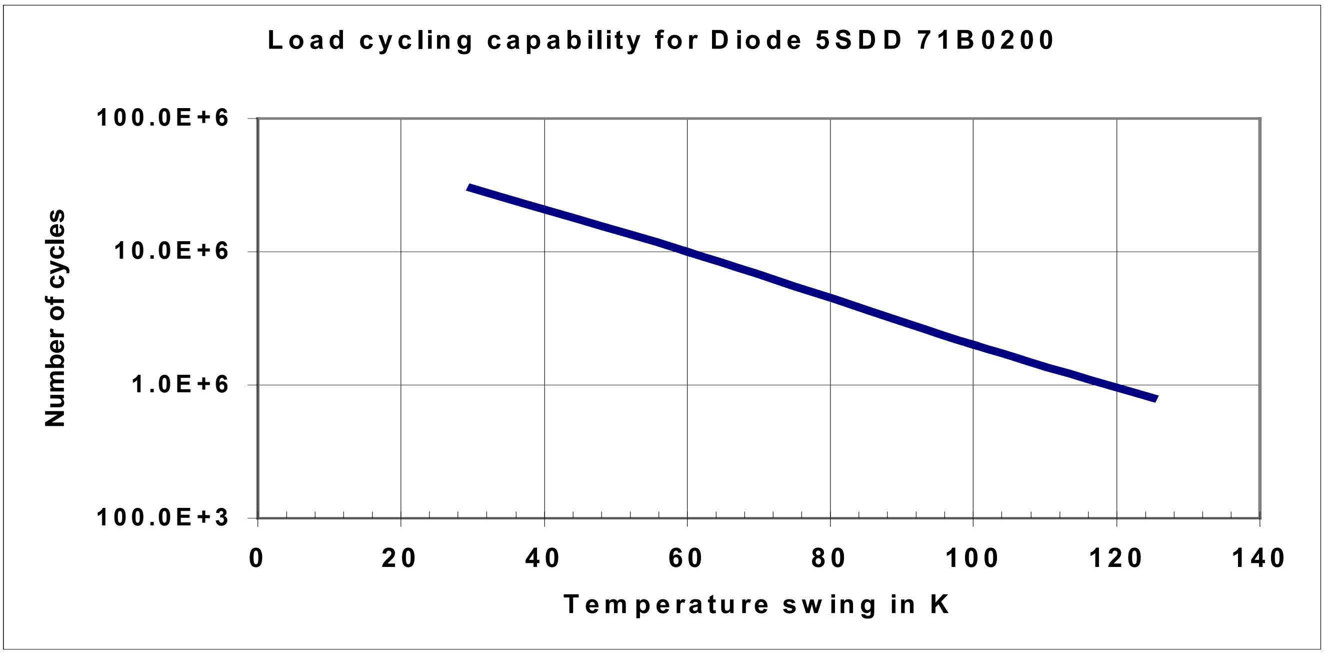


Figure 2 Load cycling capability as function of temperature swing for 5SDD 71B0200

The following ED-curves for 5SDD 71B0200 for different junction temperature swings (ΔTj) show the welding current as a function of the duty cycle. The duty cycle, normally referred to as ED from the German word EinschaltDauer, that normally is expressed in %, is defined as the ratio between welding time and total cycle time consisting of the sum of the welding time and the time between the welding intervals. For a typical welding sequence the definition of ED would be as follows as also is described in figure 3.
ED = Welding time / (Welding time + Holding time + Gun opening time + Time for moving gun to next welding spot + Gun closing time)

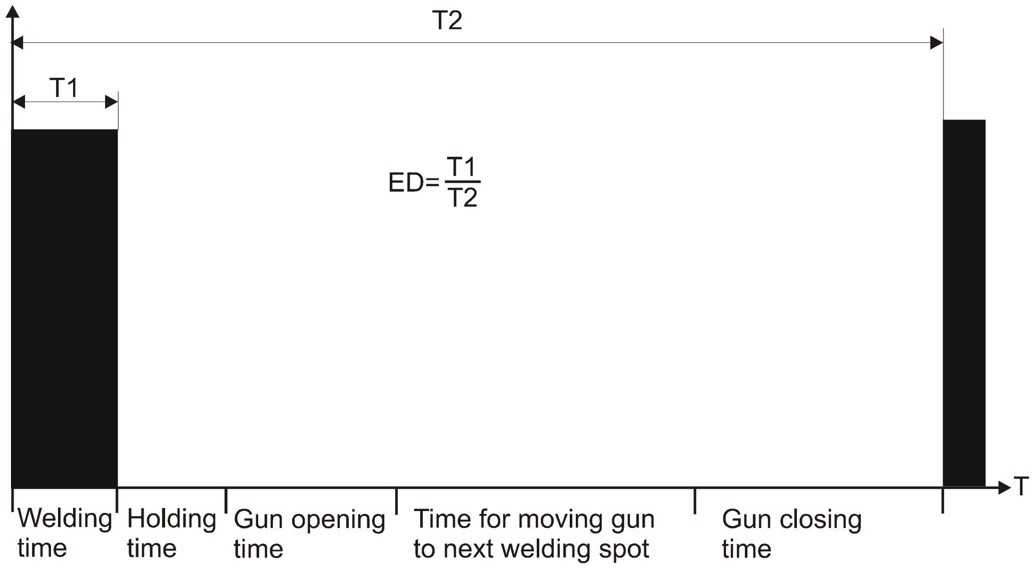


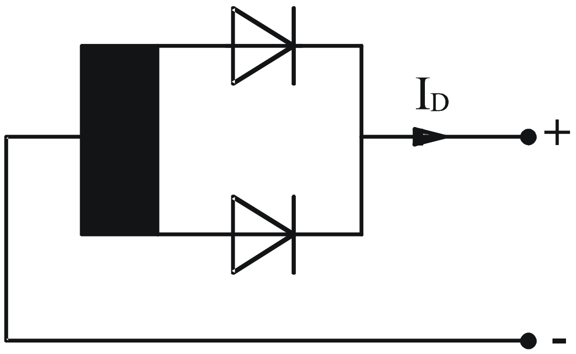
Figure 3 Definition of the duty cycle ED for a typical application.

For a specified temperature swing in each figure there are welding currents for several numbers of welding pulses. These welding pulses should not be mixed with the number of load cycles. One can read for a given number of welding pulses and a given duty cycle with a junction temperature difference, depending on the cooling.

For a desired load cycling capability (i.e. number of temperature cycles) one has to select the temperature swing out of figure 2. With that one can find the welding current in figure 4 to 12 for various duty cycles and numbers of welding pulses.
For example, if the application needs to reach close to 10 Mio cycles the max temperature swing is 60 K. If one is using 100 pulses with a duty cycle of 10 % one can read a welding current of 11 kA in figure 7.

In order to have the possibility to reach the load cycling capability as specified in the diagram above the considerations about the mechanical design earlier mentioned must be implemented.

Common data for the diagrams:



- Single phase centre tap connection (M2) as per the figure above.
- The current given is the output DC-current during the welding time that in the figure is called I_D.
- 1000 Hz square wave current.
- The curves are for (top to bottom) as per table 2.

Name in curve	Number of pulses	Welding time in ms
Id(0,ED)	20	20
Id(1,ED)	40	40
Id(2,ED)	100	100
Id(3,ED)	200	200
Id(4,ED)	300	300
Id(5,ED)	400	400
Id(6,ED)	600	600
Id(7,ED)	1000	1000

Table 2 Explanation to welding curves.

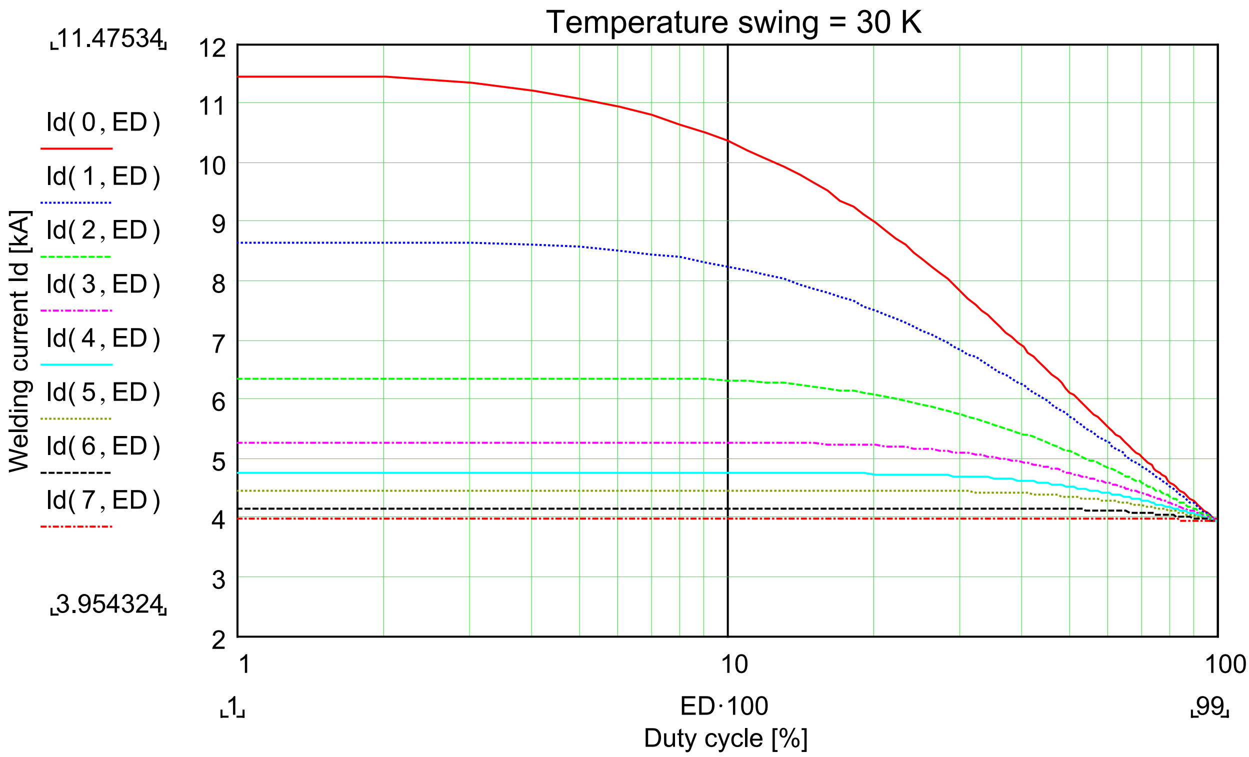


Figure 4 Welding current as function of ED with temperature swing 30 K.

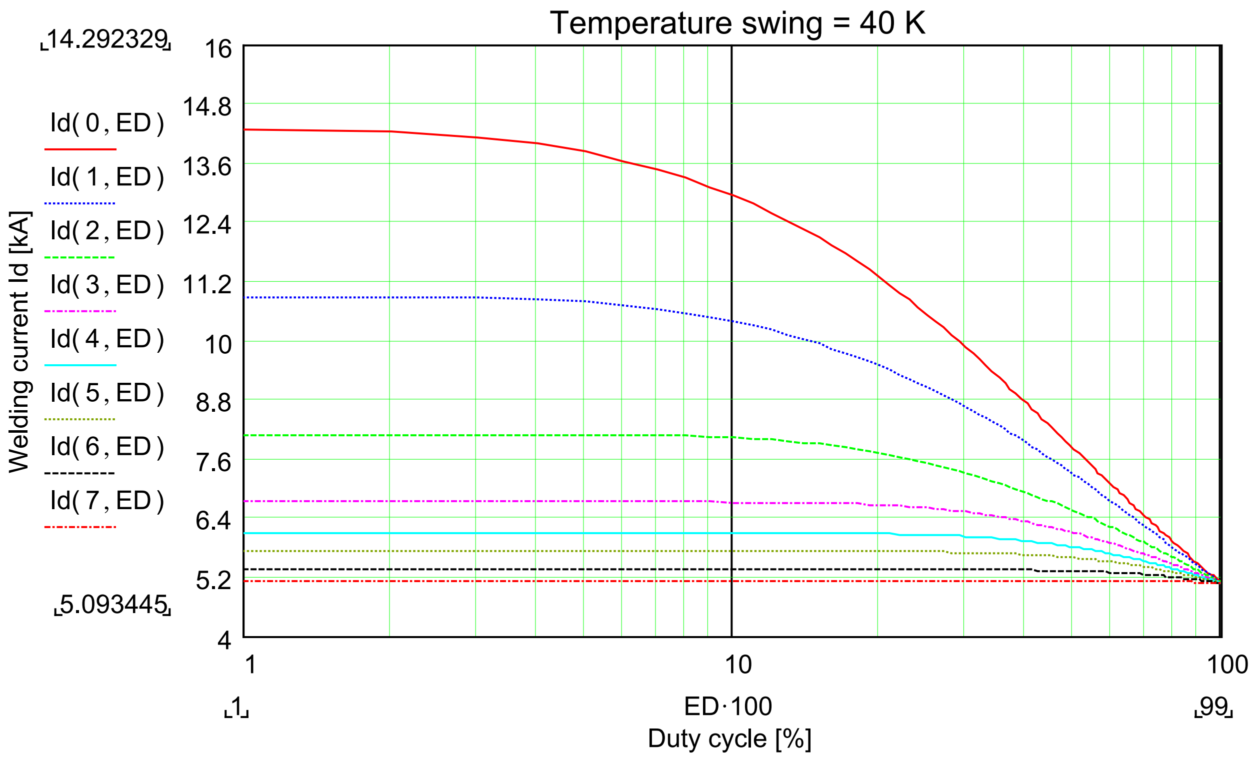


Figure 5 Welding current as function of ED with temperature swing 40 K.

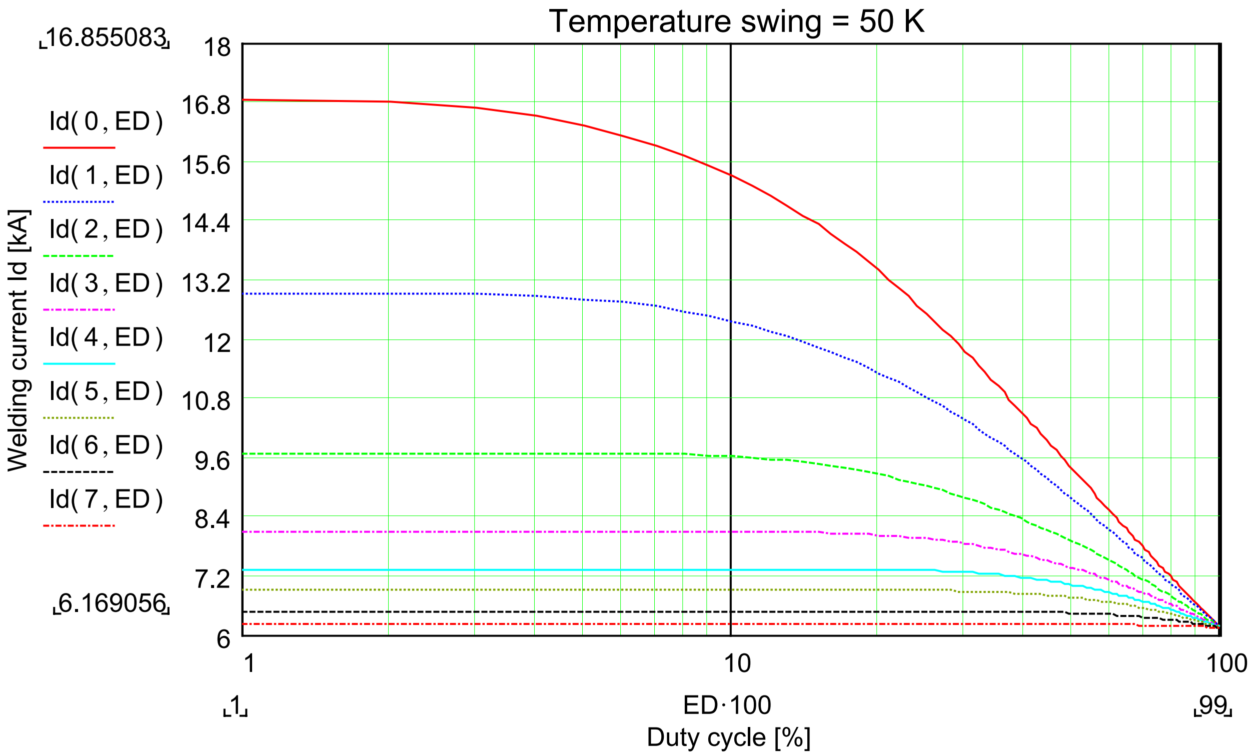


Figure 6 Welding current as function of ED with temperature swing 50 K.

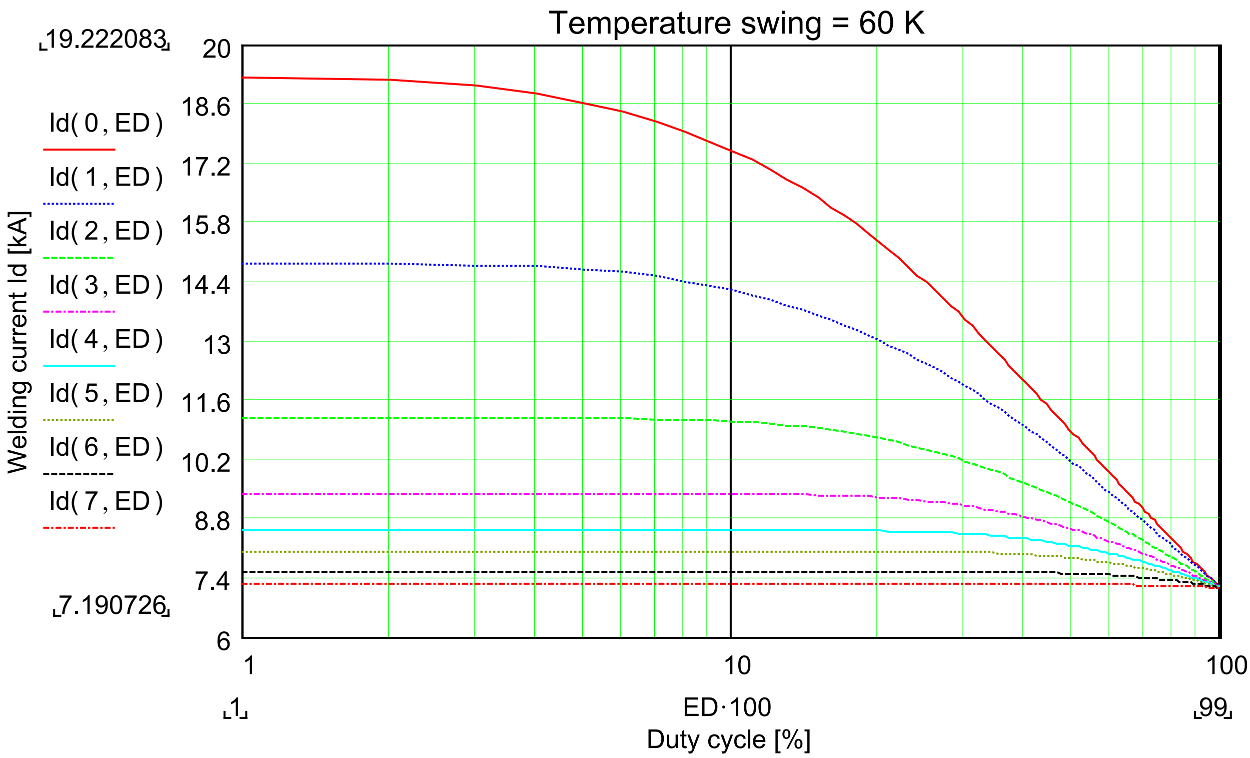


Figure 7 Welding current as function of ED with temperature swing 60 K.

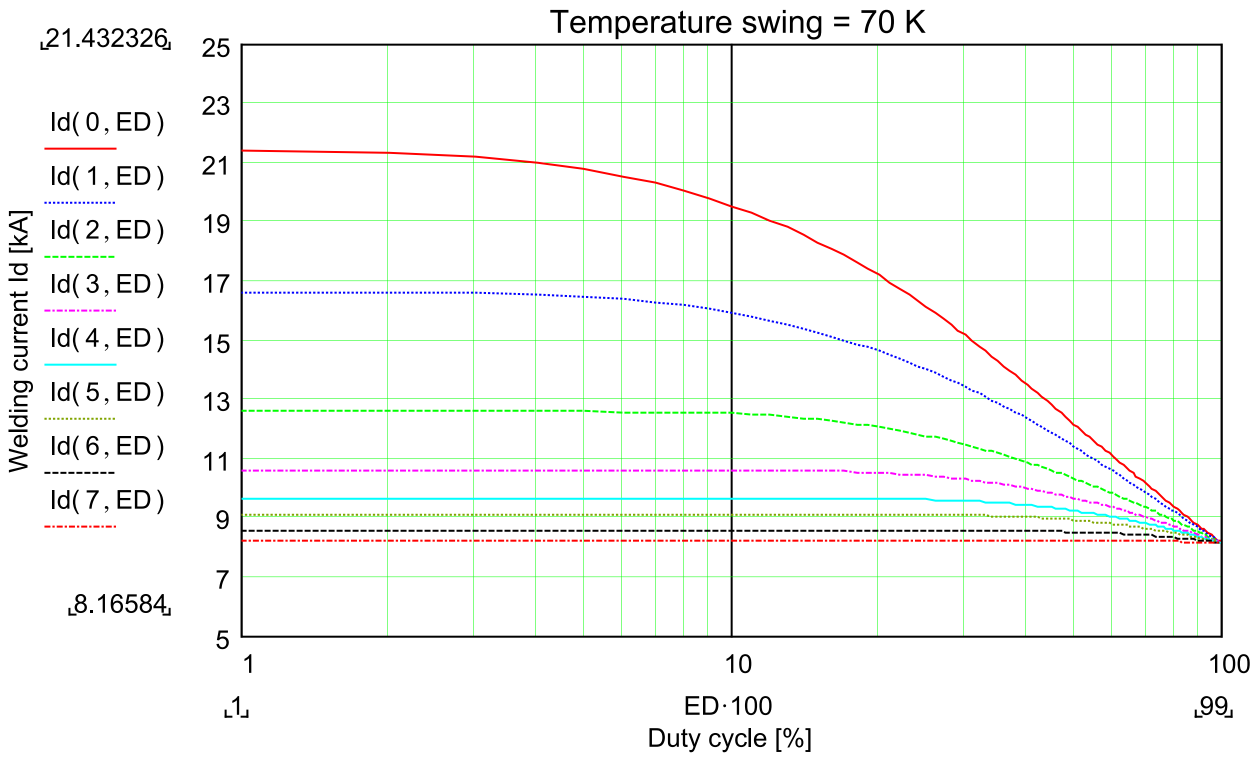


Figure 8 Welding current as function of ED with temperature swing 70 K.

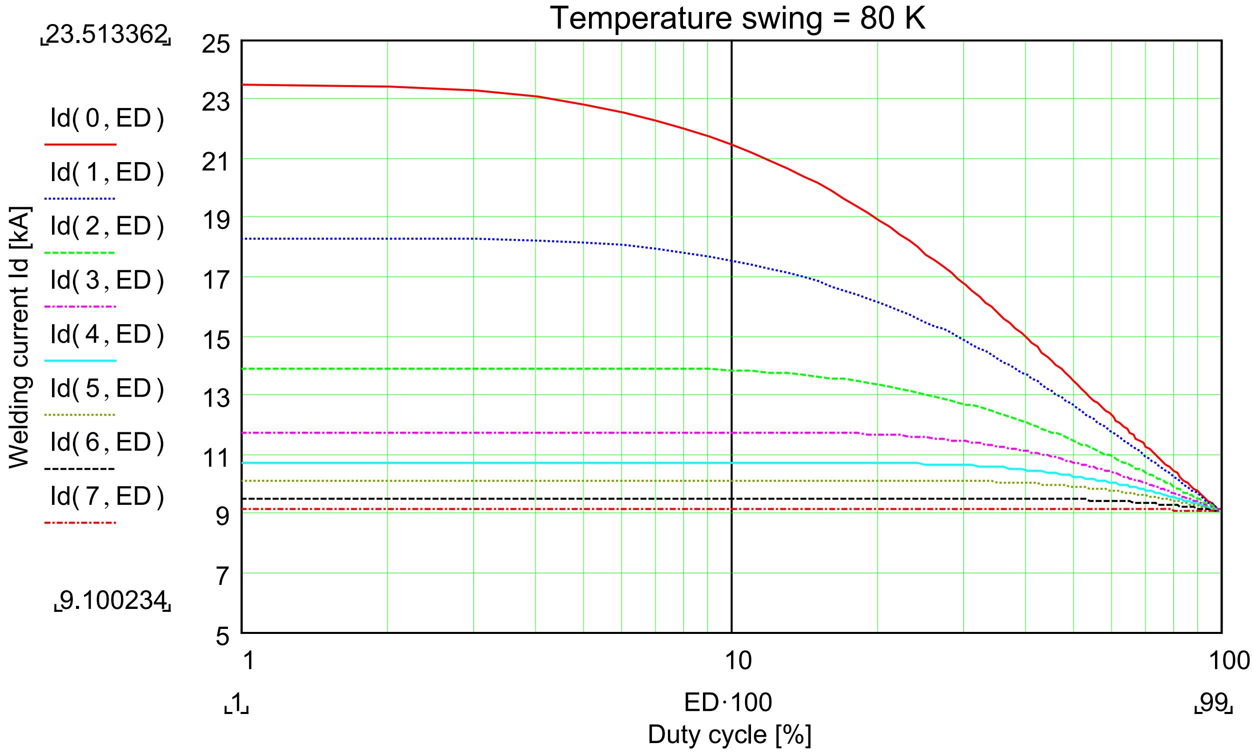


Figure 9 Welding current as function of ED with temperature swing 80 K.

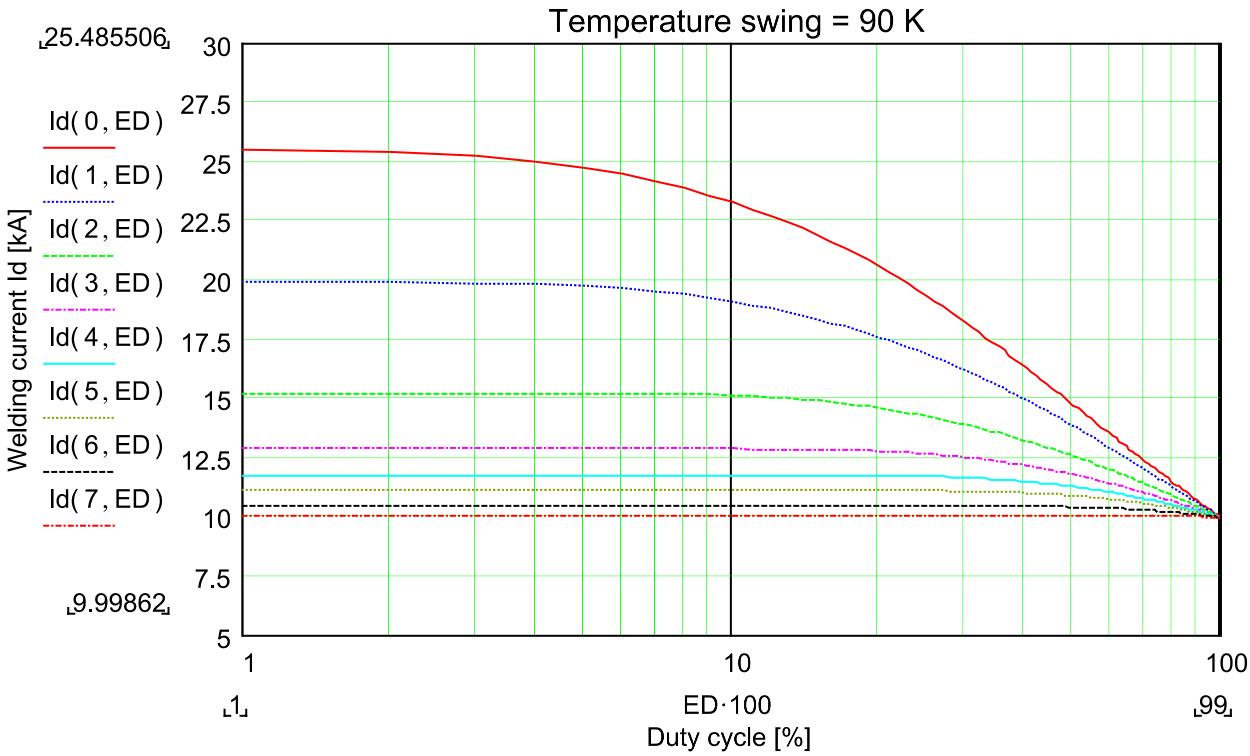


Figure 10 Welding current as function of ED with temperature swing 90 K.

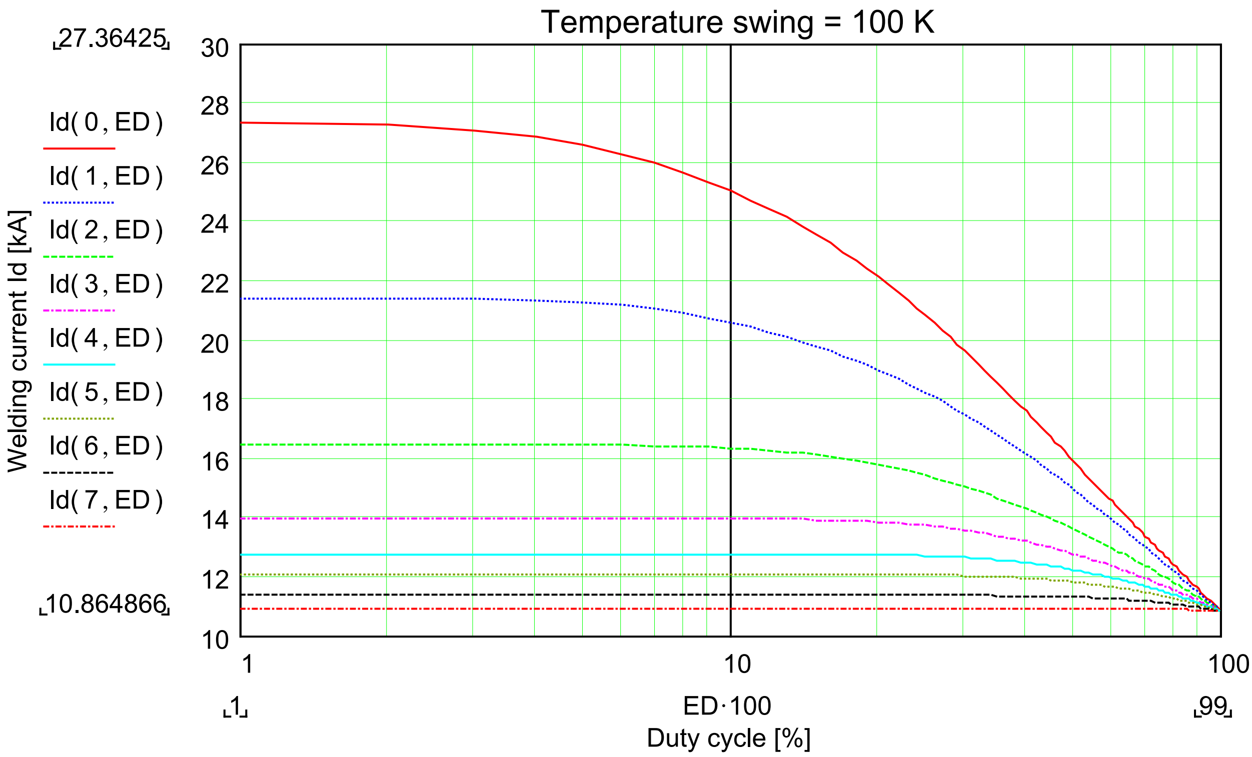


Figure 11 Welding current as function of ED with temperature swing 100 K.

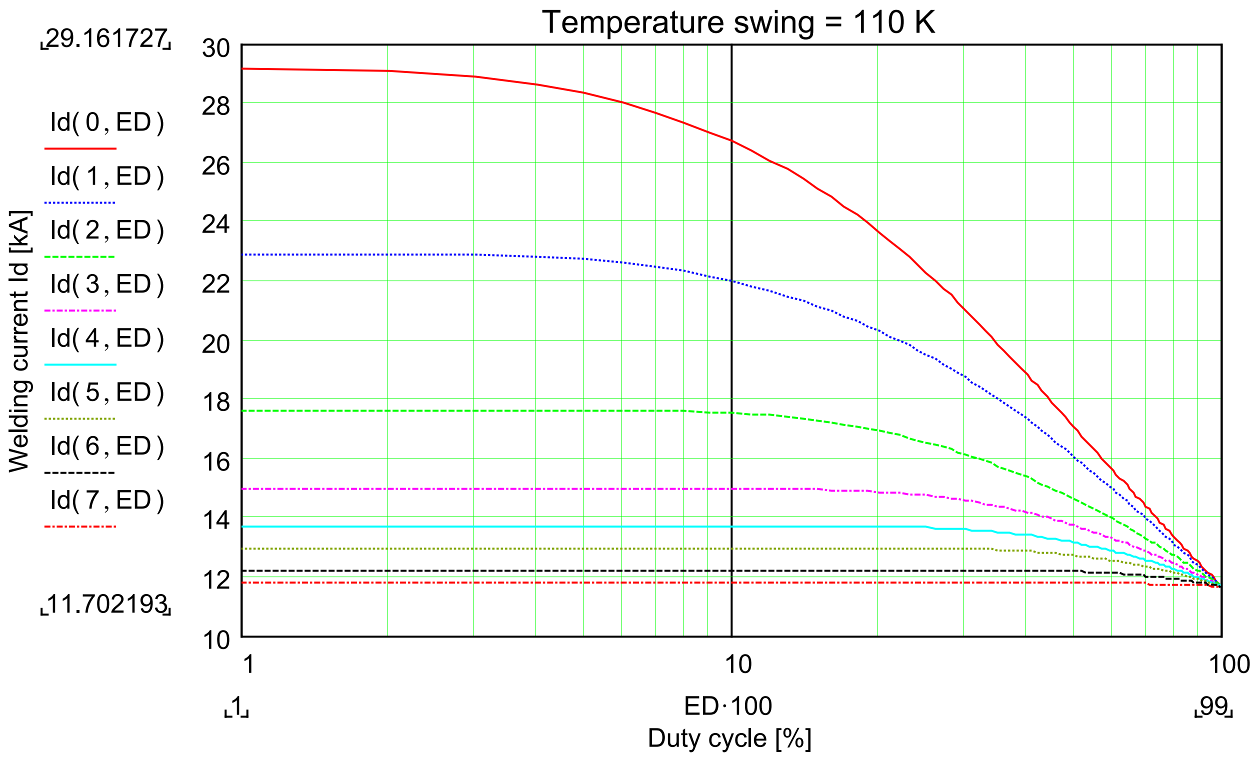


Figure 12 Welding current as function of ED with temperature swing 110 K.

Parallel connection.

The diodes from ABB Semiconductors AG can be parallel connected without any special means. We recommend though that the diodes are only utilised up to 90 % of their capability as single diode since, even if the VF-spread is quite small, there is some spread between the devices that, together with some possible small unbalances caused by the connections to the transformer, will make that the current is not exactly equal shared between the devices. This will lead to different losses in the diodes which can lead to over heating, or at least a higher temperature swing, of one diode causing the equipment to have lower reliability than expected.

If we use the earlier example: The application needs to reach close to 10 Mio cycles the max temperature swing is 60 K. If one is using 100 pulses with a duty cycle of 10 % one can read a welding current of 11 kA. If using two diodes in parallel and we want to have the same probability of reaching 10 Mio cycles at the same conditions as for the single diode the equipment can maximum be loaded with 2 * 0.9 * 11 kA = 19.8 kA.

Turn-off behaviour, worst case.

The turn-off behaviour of the diode is of relevance in the welding equipment even the supply voltage is in the range of 6 – 20 V. Since the diodes are used without any voltage limitation, as an RC-circuit connected in parallel to the diode, a diode with a snappy turn-off behaviour can generate itself a voltage spike that destroys the component.

The diodes from ABB Semiconductors AG are designed to have a soft turn-off that does no generate voltage spikes of a magnitude that is of danger to the device. The robustness of the device has been tested at conditions much more severe than what the device sees in the application. In figure 6 we see the result of a turn-off test with forced turn-off by an external circuit with a di/dt of –30 A/µs at Tj = 170 °C and with a commutation voltage of 100 V. At these very severe conditions the diode is generating an over voltage spike of about 600 V but due to the short duration and the robustness of the device it is not damaged. At normal conditions the turn-off generated over voltage spike is by far less than 200 V.

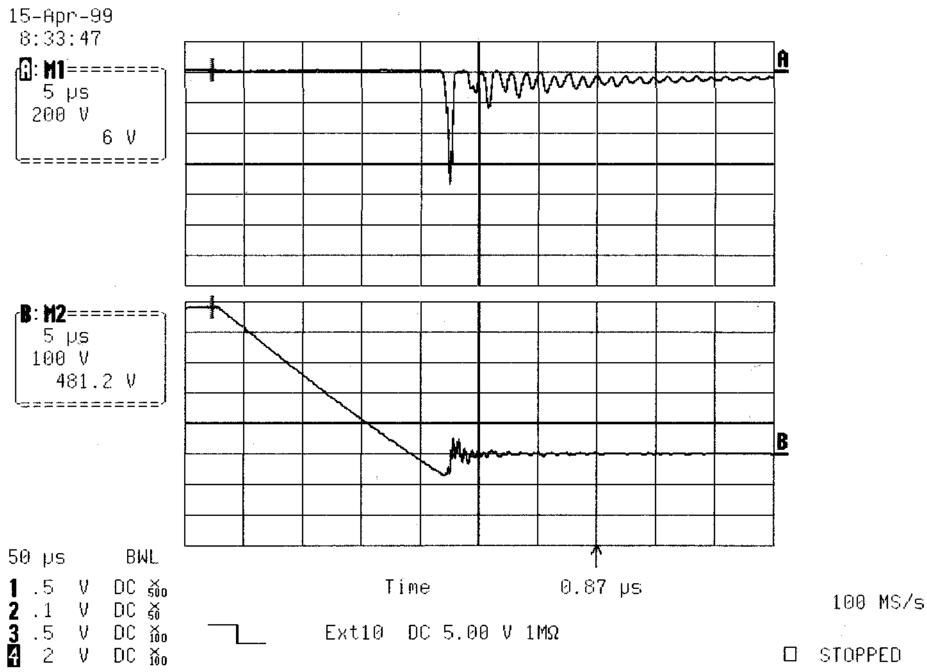


Figure 13 Turn-off worst case of a 5SDD 71B0200 at di/dt = -30 A/µs, Tc = 170 °C.

3. Application support

For further information please contact:

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