Email: powersolutions@dynexsemi.com
Main switchboard: +44 (0)1522 500 500
Website: www.dynexsemi.com

AN6175
Design of an RC Snubber Circuit for Dynex i² Thyristors

Application Note

Replaces AN6175-2
AN6175-3 October 2022 (LN42154)

There are many types of snubber that have been proposed to perform different duties in protecting a thyristor against overvoltage during the turn-off process; see for instance "Application note AN6144" chapter 8. The simplest snubber circuit consists of a resistor and capacitor in series connected across the thyristor. If the equipment requires series connected thyristors for high voltage then each device will have its own RC network connected across it.

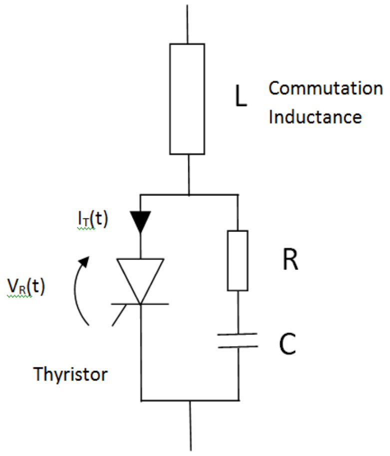


Fig. 1 Typical circuit with RC snubber and commutation inductance

The current and voltage transients typically seen during turn-off are shown in figure 2.

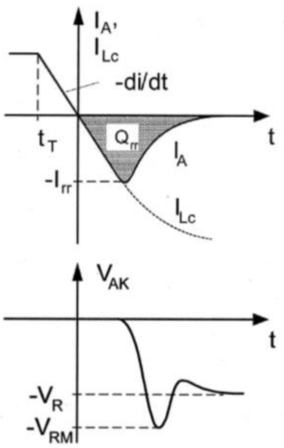


Fig. 2 Current through and voltage across thyristor during turn-off

V_R is the reverse voltage imposed on the thyristor by the circuit and V_{RM} is the peak of the transient over-voltage caused by the turn-off process. V_{RM} should be less than the repetitive voltage rating of the thyristor with a safety margin. The RC snubber is used to damp the oscillatory voltage to acceptable limits. The rigorous way to design the snubber is to employ a PSpice model of the circuit and adjust the values of R&C to achieve the desired effect. The method presented here is an engineering approximation, which is easy to apply.

For the investigation of the voltage overshoot during turn-off, it is necessary to analyse the circuit shown below.

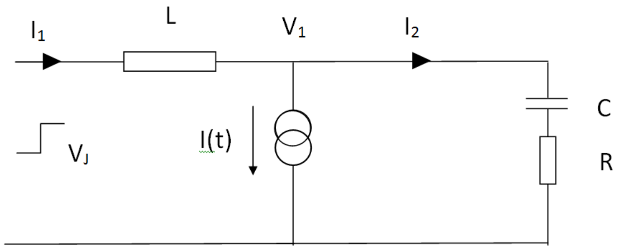
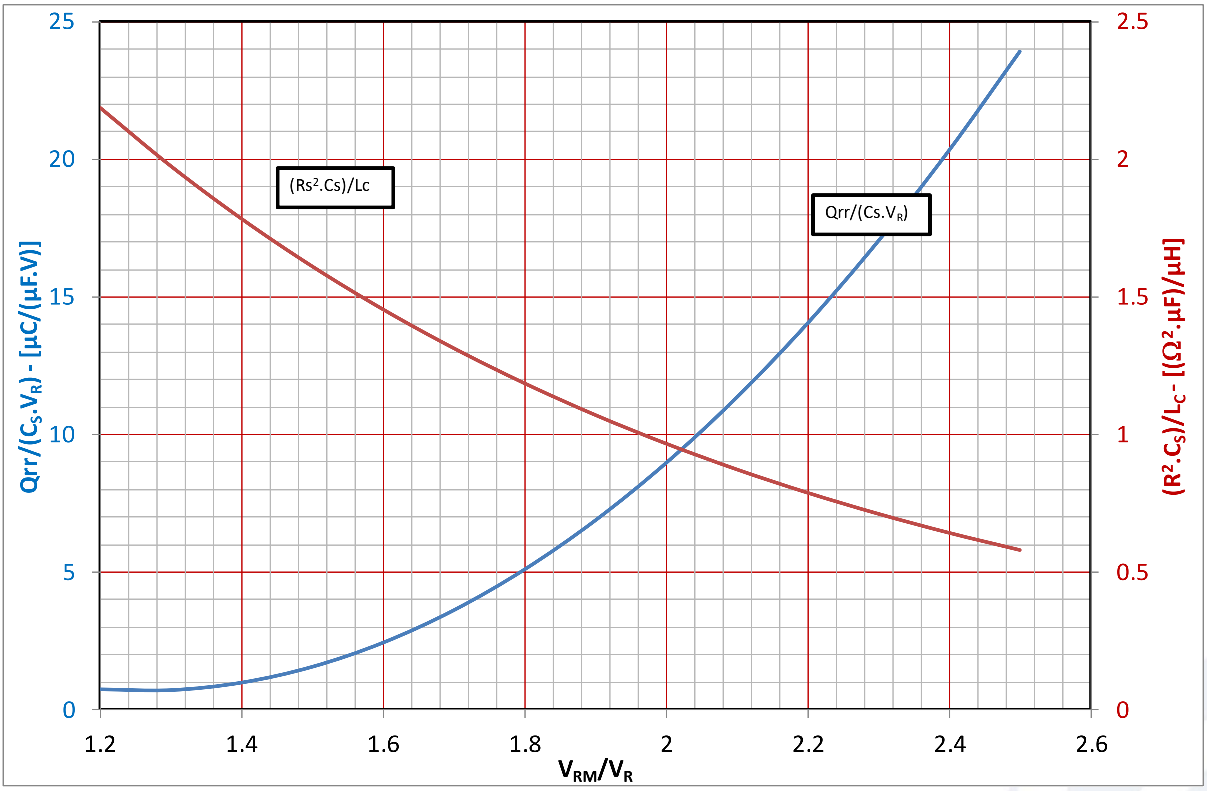


Fig. 3 Schematic of circuit for analysis of snubber design

The commutating inductance L and the RC snubber are shown. V_J is the commutation voltage jump. Analysis begins when the peak reverse current is reached in the device. $I(t) = I_R \exp(-t/\tau)$. By completing the analysis, it is possible to arrive at the following nomogram for a critically damped snubber.



Worked example: (Values chosen to illustrate the iterative nature of snubber choice.)

Consider the case where the stationary voltage V_R is 2000V and it is required to restrict V_{RM} to 3200V, i.e. $V_{RM}/V_R = 1.6$. The commutation inductance is 100µH, so the commutation di/dt is 2000/100 = 20A/µs. The thyristor being used is the DCR3030V42. Fig. 12 of the datasheet gives the stored charge against commutation di/dt and the value at 20A/µs can either be read from the graph to be 15,500µC or more accurately calculated from the formula as Qs(max) = 3397*20^0.5061 = 15,472µC.

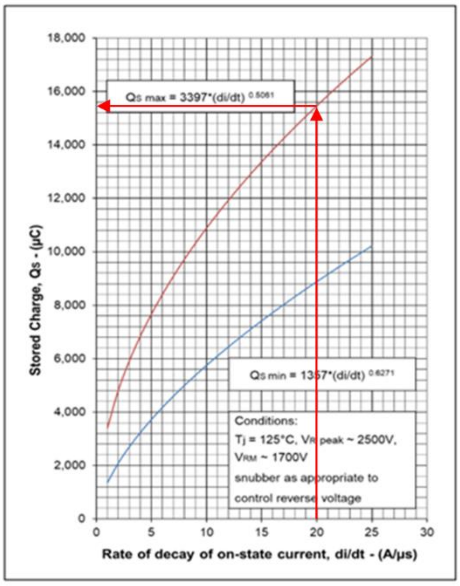
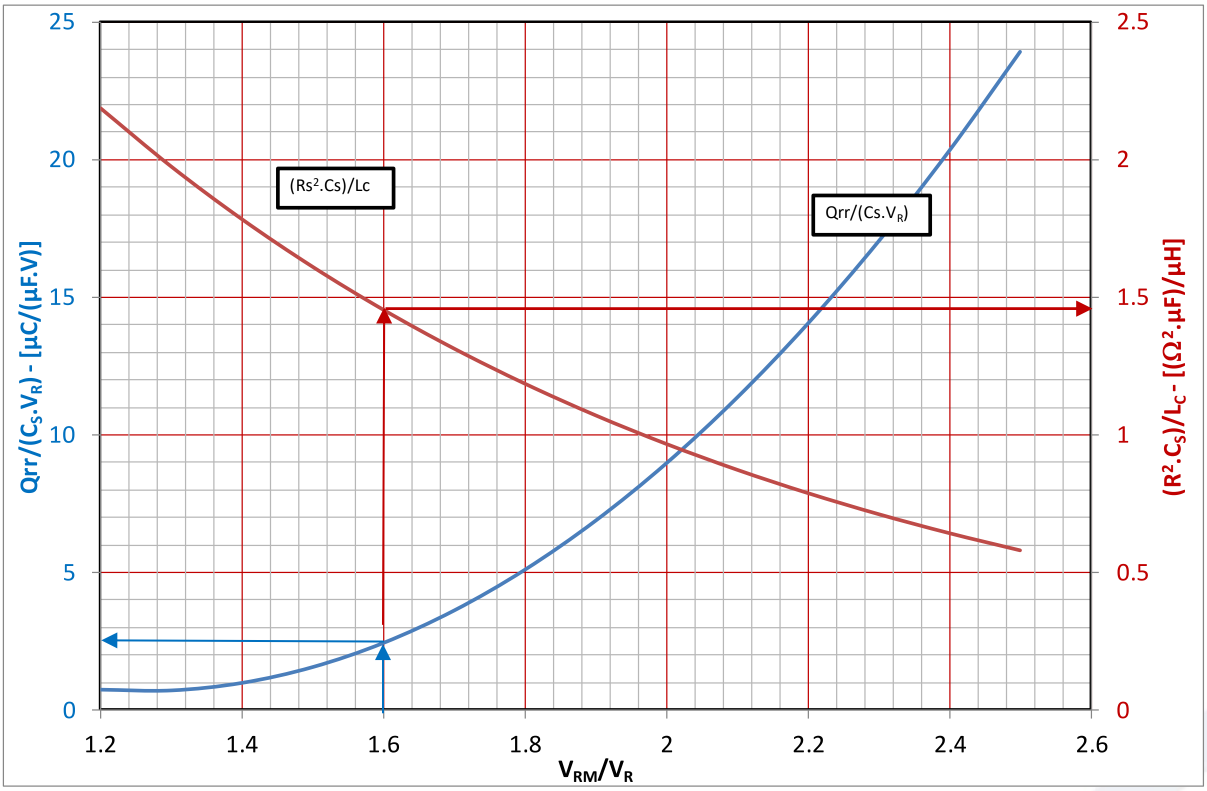


Fig. 12 Stored charge



For V_{RM}/V_R = 1.6 we can read off that $Q_{RR}/(C_S.V_R)$ = 2.5 where we know Q_{RR} = 15,500µC and V_R = 2000V. Hence C_S = 15500/(2.5 x 2000) = 3.1µF.

Similarly, we can also read that $(R^2.C_S)/L_C$ = 1.45 where C_S = 3.1µF and L_C = 100µH. Therefore, R = √(1.45 x 100/3.1) or √(46.77) = 6.84Ω.

Using standard values for capacitance and resistance we conclude the snubber to be 3.3µF and 6.8Ω.

The final calculation is to determine what wattage of resistor is required to handle the repetitive charging and discharging of the snubber capacitor once every cycle.

Thus, $P = C_S \times V_R^2 \times f$. In the above, 3.3µF x 2000² x 50 = 660W

And the snubber discharge current $I_{DS} = V_R/R_S$ i.e. 294A

660W may be too much heat to dissipate from the resistor and it is wished to restrict the power to, say, 150W. Therefore, 150W = C_S x 2000² x 50, so C_S = 0.75µF.

Thus, $Q_{RR}/(C_S.V_R)$ = 15500/(0.75 x 2000) = 10.3

Reading 10.3 from the left-hand axis of the nomogram gives a V_{RM}/V_R of 2.06. Thus, V_{RM} = 4.12kV which is less than the voltage rating of the thyristor.

For V_{RM}/V_R = 2.06, $(R^2.C_S)/L_C$ = 0.9

Thus, R^2 = (100µH x 0.9)/0.75µF, so R = √(120) or 11Ω

and I_{DS} = 182A

The above illustrates the difficulty that arises at high di/dt rates, where large values of stored charge result and the desired value of voltage damping is impractical and the problem has to be re-worked to find a compromise between overshoot voltage and power dissipation in the resistor.

IMPORTANT INFORMATION:

This publication is provided for information only and not for resale.

The products and information in this publication are intended for use by appropriately trained technical personnel.

Due to the diversity of product applications, the information contained herein is provided as a general guide only and does not constitute any guarantee of suitability for use in a specific application. The user must evaluate the suitability of the product and the completeness of the product data for the application. The user is responsible for product selection and ensuring all safety and any warning requirements are met. Should additional product information be needed please contact Customer Service.

Although we have endeavoured to carefully compile the information in this publication it may contain inaccuracies or typographical errors. The information is provided without any warranty or guarantee of any kind.

This publication is an uncontrolled document and is subject to change without notice. When referring to it please ensure that it is the most up to date version and has not been superseded.

The products are not intended for use in applications where a failure or malfunction may cause loss of life, injury or damage to property. The user must ensure that appropriate safety precautions are taken to prevent or mitigate the consequences of a product failure or malfunction.

The products must not be touched when operating because there is a danger of electrocution or severe burning. Always use protective safety equipment such as appropriate shields for the product and wear safety glasses. Even when disconnected any electric charge remaining in the product must be discharged and allowed to cool before safe handling using protective gloves.

Extended exposure to conditions outside the product ratings may affect reliability leading to premature product failure. Use outside the product ratings is likely to cause permanent damage to the product. In extreme conditions, as with all semiconductors, this may include potentially hazardous rupture, a large current to flow or high voltage arcing, resulting in fire or explosion. Appropriate application design and safety precautions should always be followed to protect persons and property.

Product Status & Product Ordering:
We annotate datasheets in the top right-hand corner of the front page, to indicate product status if it is not yet fully approved for production. The annotations are as follows:

Target Information:	This is the most tentative form of information and represents a very preliminary specification. No actual design work on the product has been started.
Preliminary Information:	The product design is complete and final characterisation for volume production is in progress. The datasheet represents the product as it is now understood but details may change.
No Annotation:	The product has been approved for production and unless otherwise notified by Dynex any product ordered will be supplied to the **current version of the data sheet prevailing at the time of our order acknowledgement.**

All products and materials are sold and services provided subject to Dynex's conditions of sale, which are available on request.

Any brand names and product names used in this publication are trademarks, registered trademarks or trade names of their respective owners.

HEADQUARTERS OPERATIONS
DYNEX SEMICONDUCTOR LIMITED
Doddington Road, Lincoln, Lincolnshire, LN6 3LF
United Kingdom.
Phone: +44 (0) 1522 500500

Web: http://www.dynexsemi.com

CUSTOMER SERVICE
Phone: +44 (0) 1522 502753 / 502901

e-mail: powersolutions@dynexsemi.com