

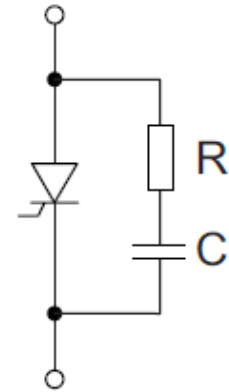
## Protection of diodes & thyristors

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### Voltage surge protection

The use of RC networks turns the inductors in the circuit to series resonant circuits, converting the steeply increasing voltage peaks into attenuated oscillations of low amplitude.



### *Uncontrolled rectifier circuits*

In uncontrolled bridge circuits, it is normally sufficient to include a snubber on the DC side only. It is often not needed to include any protection circuit as long as the maximum breaking voltage of the diodes is significantly higher than the operation voltage.

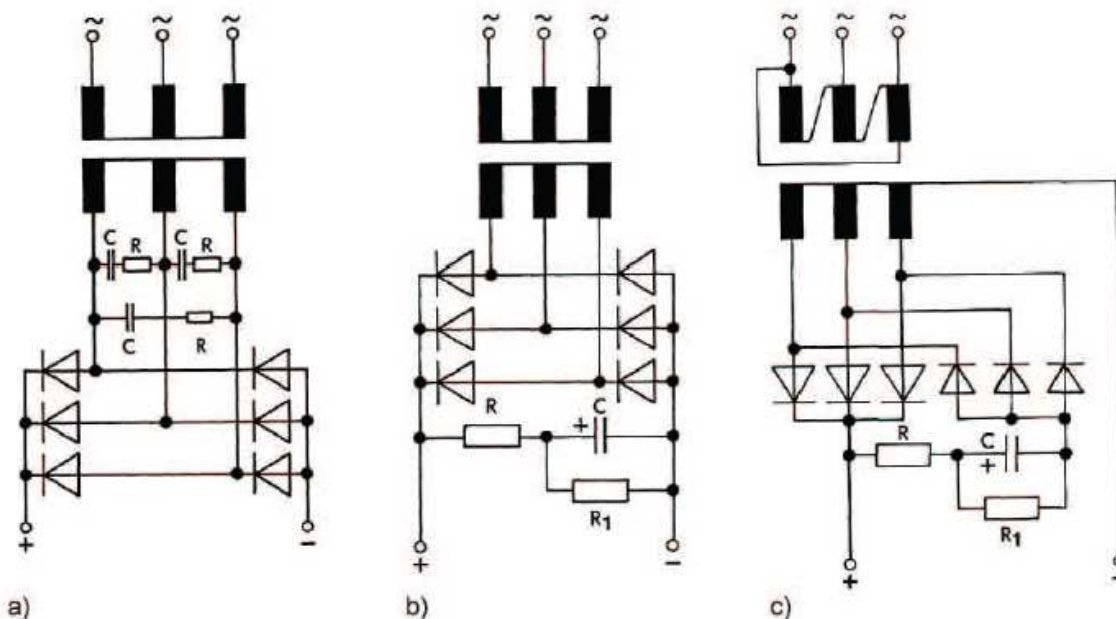


Figure 4.4.2 Snubber circuit for a diode assembly: a) on the AC side; b) on the DC side c) midpoint connection by adding auxiliary diodes to the bridge circuit

## Controllable switches (thyristors)

Thyristors have to be protected not only from excessive non-permissible surges, but also - and more importantly - from the steep rate of rise.

The use of a single-thyristor snubber is, however, limited because the capacitors discharge through these networks during triggering and thus cause undesired stress with a steep current rate of rise (di/dt stress).

In thyristor assemblies for low current densities and high voltages where relatively small capacitance and high-ohmic resistances are sufficient, this di/dt stress is still relatively low, meaning that here a single-switch snubber alone is often enough.

For higher current densities, however, the solution is to use an AC side snubber.

For very high power, in particular for parallel thyristor circuits, it can be of advantage to connect the RC circuit via an auxiliary bridge.

## Circuits

- **Dimensioning guidelines for single-switch snubbers**

Assumption: around half of the energy represented by the recovered charge  $Q_{rr}$  is transferred to the circuit in the form of an overvoltage.

$$C = \frac{Q_{rr}}{V_v \cdot \sqrt{2}}$$

$$R = \sqrt{\frac{L_s}{C}}$$

C: Capacitance (in  $\mu\text{F}$ );  
R: Resistance (in  $\Omega$ );  
 $Q_{rr}$ : Recovered charge (in  $\mu\text{C}$ ).

$L_s$ : Total inductance in the circuit (in  $\mu\text{H}$ );  
 $V_v$ : Effective terminal voltage (in V);

The table below features typical RC values for SEMIPACK modules:

SEMIPACK®	$V_{VRMS} \leq 250 \text{ V}$		$V_{VRMS} \leq 400 \text{ V}$		$V_{VRMS} \leq 500 \text{ V}$		$V_{VRMS} \leq 660 \text{ V}$	
	C	R	C	R	C	R	C	R
SKKT 15, 19, 20, 26, 27 SKKH 15, 26, 27 SKKD 15, 26                      SKKE 15	0,22 $\mu\text{F}$	68 $\Omega$	0,22 $\mu\text{F}$	68 $\Omega$	0,1 $\mu\text{F}$	100 $\Omega$	-	-
		6 W				6 W		10 W
SKKT 41, 42, 56, 57, 71, 72, 91, 92, 105, 106 SKKH 41, 42, 56, 57, 71, 72, 91, 92, 105, 106 SKKD 46, 81, 100                      SKKE 81	0,22 $\mu\text{F}$	33 $\Omega$	0,22 $\mu\text{F}$	47 $\Omega$	0,1 $\mu\text{F}$	68 $\Omega$	0,1 $\mu\text{F}$	100 $\Omega$
		10 W				10 W		10 W
SKKT 122, 131, 132, 161, 162, 210, 213, 250, 253 SKKH 122, 131, 132, 161, 162, 210, 213, 250, 253 SKKD 162, 201, 260                      SKKE 162, 201, 260	0,22 $\mu\text{F}^{1)}$	33 $\Omega^{1)}$	0,22 $\mu\text{F}^{1)}$	47 $\Omega^{1)}$	0,1 $\mu\text{F}^{1)}$	68 $\Omega^{1)}$	0,1 $\mu\text{F}^{1)}$	100 $\Omega^{1)}$
		10 W				10 W		10 W
SKKT 122, 131, 132, 161, 162, 210, 213, 250, 253, 500 SKKH 122, 131, 132, 161, 162, 210, 213, 250, 253, 500 SKKD 162, 201, 260                      SKKE 162, 201, 260 SKET 330, 400	0,47 $\mu\text{F}$	33 $\Omega$	0,47 $\mu\text{F}$	33 $\Omega$	0,22 $\mu\text{F}$	47 $\Omega$	0,22 $\mu\text{F}$	68 $\Omega$
		25 W				25 W		25 W

<sup>1)</sup> Only with heatsink P3

- **Snubbers for AC voltage converters (W1C)**

W1C circuits comprise two antiparallel thyristors; the following, however, applies to a circuit comprising one thyristor with antiparallel diode. This is always equipped with a snubber circuit, in the simplest case comprising one common RC element (Figure 4.4.10). If each of the antiparallel components has its own fuse protection, then each must also be equipped with its own RC element.

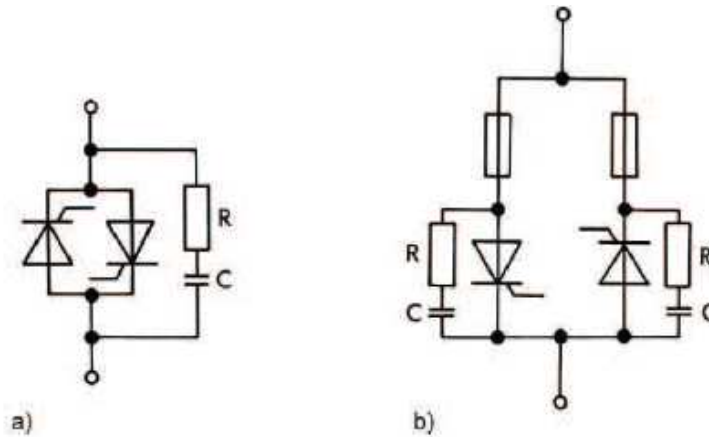


Figure 4.4.10 Snubber for AC controller; right: with individual fuses

The values for capacitor C ( $\mu\text{F}$ ) and resistor R ( $\Omega$ ) can be determined using the following formulae:

$$C \approx 700 \cdot \frac{I_V}{V_V^2} \qquad R \approx \frac{9000}{C \cdot V_V}$$

### ***Overvoltage protection using varistors***

The resistance of a varistor decreases as the voltage increases. Varistors can be used to attenuate overvoltage on the AC or on the DC side, or even as single-switch snubbers.

One shortcoming of varistors is that they do not attenuate the voltage  $dv/dt$ . Thus, in thyristors with low  $dv/dt$  values, an additional RC snubber is needed.

### ***Snubber circuits based on silicon avalanche diodes***

Also known as clamping diodes (transient voltage suppressors), they have the advantage over RC snubbers of being small in size and having lower energy consumption.

## Overcurrent protection

### ***Bimetal thermostats***

Bimetal thermostats contain bimetal discs which, at a certain factory-set temperature, snap from one position to the next, opening or closing a contact in the process.

### ***Temperature-dependent resistors***

Temperature-dependent resistors have the advantage over bimetal thermostats that they respond to temperature changes more quickly. An additional electronic circuit is needed to convert the change in resistance into a signal that can, for example, trigger a protective device.

### ***Fuses***

In bridge circuits, two power semiconductors each have a common AC terminal. For this reason they can be protected by a common fuse in the AC supply line. This is known as a phase or AC side fuse.

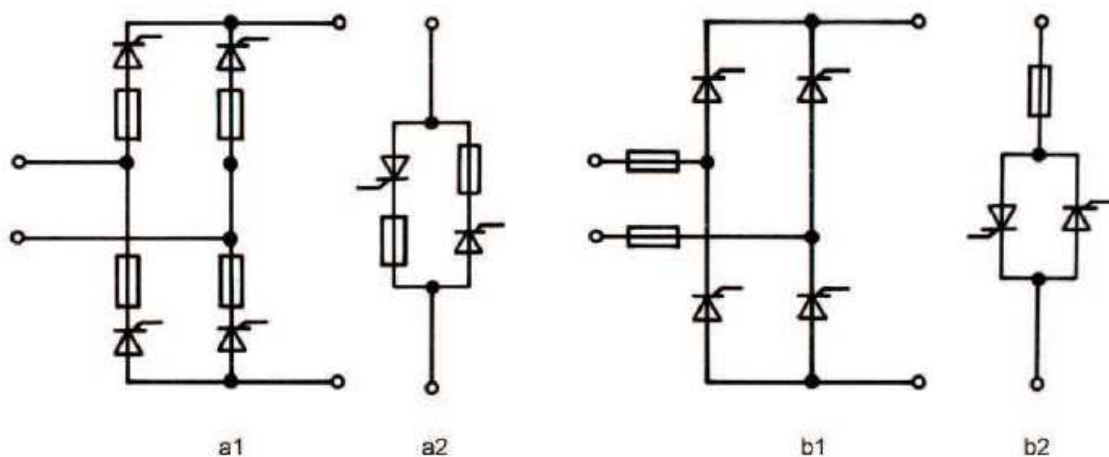


Figure 4.4.15 Possible arrangements for semiconductor fuses in a converter bridge (a1 and b1) and for an AC controllers (a2 und b2); a) Arm fuse or b) Phase fuse

If rectifier diodes or thyristors are connected in parallel for high power densities, each semiconductor component is equipped with a fuse. Short circuits shall only occur very seldom.