

Series, Inverse-Parallel and Turn-Off Connections for SCR Thyristor Devices

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APPLICATION NOTE

INTRODUCTION

In the big variety of the A.C. applications in which the thyristor technology is used, there are some cases in which high power loads must be controlled by solid state devices, but because of the high power, these big loads cannot be handled by only one TRIAC device, therefore, it is very common to connect two SCRs in inverse-parallel since this arrangement would allow to drive bigger levels of power since the control stand point.

In the case of the D.C. applications, there are also some cases in which the loads must be supplied with high levels of voltage (over than 1000 Volts), so for these kind of applications, it is needed to have a solid state device capable to sustain these high voltage levels, therefore in these cases, the most feasible solution is to connect two SCR (800 V) in series in order to generate a high voltage device (1600 V).

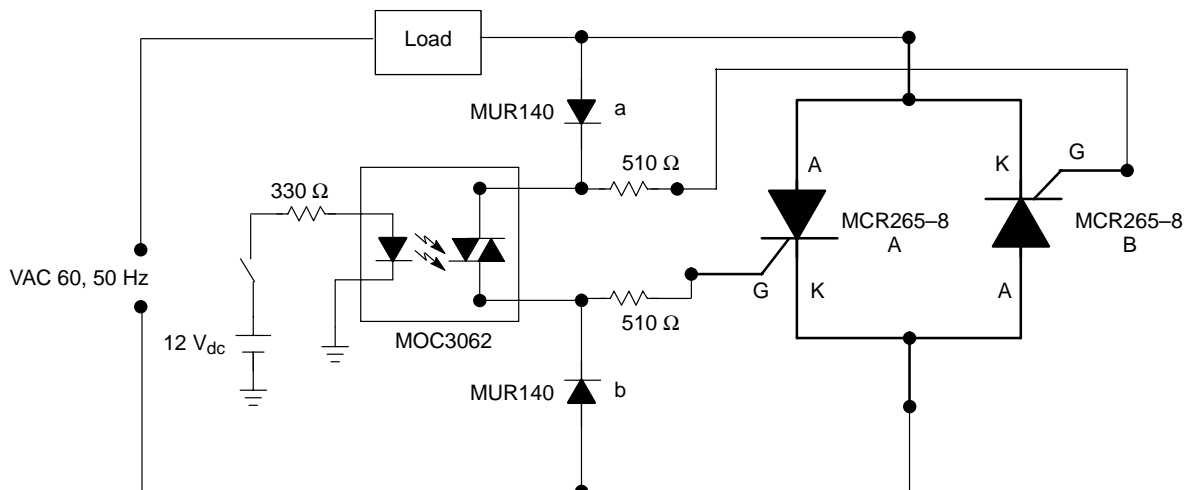
In addition to the previous cases, there are also some applications in which it is needed to make the turn-off of an SCR device when it is operating under D.C. current conditions, and this can be done through the forced commutation methods for SCRs.

The present application note is mainly focused in explaining some alternatives for making the control functions listed below:

- Inverse Parallel connection of two SCRs for driving high power loads.
- Series connection of two SCRs to generate a high voltage device.
- Forced commutation methods for turning-off the SCRs.

Inverse Parallel Connection of Two SCRs

As previously mentioned, there are some industrial applications in which it is needed to control big loads that can consume high amount of power, so due to this, sometimes it is not possible to control these loads through a single device (Triac) since their current rating may not be enough to cover the rating needed by the load. As an example of this, the biggest triac that Littelfuse is currently offering is the MAC224A series which is a triac for 40 Amp of $I_T(\text{RMS})$, therefore, if somebody wants to control a load that need to be supplied with 50 Amp of $I_T(\text{RMS})$, this triac would not be able to make the corresponding control function since its current rating is lower than the rating of the load, therefore in this case, it could be a good solution to use two SCRs (MCR265-8 series, 55 Amp of $I_T(\text{RMS})$) connected in inverse parallel in order to make the function of a bigger triac capable to control the 50 Amp of $I_T(\text{RMS})$ required by the load, the following figure shows the inverse parallel connection for two SCRs:



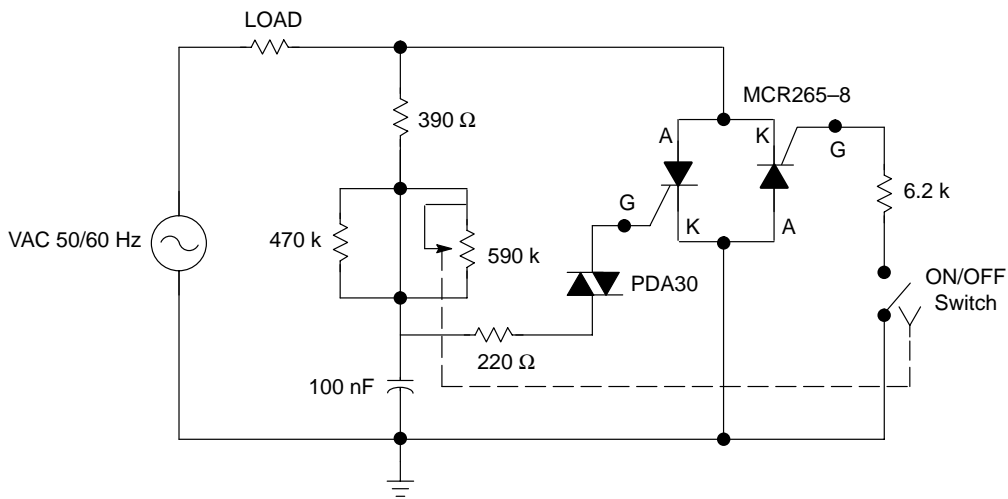
AND8030/D

When the led of the optocoupler MOC3062 is activated, it will cause the trigger of the diac and depending on the ac line polarity, one of the two SCRs (MCR265–8) will be triggered; in other words, if the half cycle of the ac line is positive, the **diode (a)** will be polarized in forward mode, so it will allow current flow through the diac of the optocoupler which will cause the trigger of the **SCR (A)**, this SCR (A) will be activated during the complete half positive cycle and will be deactivated as soon as a zero crossing condition occurs. Now, if the half cycle of the ac line is negative, the **diode (b)** will be polarized in forward mode, so it will allow current flow through the diac of the optocoupler which now will cause the trigger of the **SCR (B)** and this SCR (B) will be activated during the complete half negative cycle and will be turned-off as soon as a zero crossing condition occurs, the two SCRs will be

operating as previously explained whenever the led of the optocoupler is being activated. It is important to mention that in this case we are taking our MCR265–8 as an example, but in the real field of the applications the SCRs must be selected based in the applications requirements (VDRM, IT(RMS), etc).

The previous SCRs arrangement could be functional for another typical and useful applications related to the angle phase control which could be easily made by controlling the trigger of the SCRs as explained in the application note number AND8011/D named High Resolution Digital Dimmer.

On the other hand, this other schematic diagram shows a different alternative to control the phase angle of the inverse parallel arrangement of the two SCRs (MCR265–8):

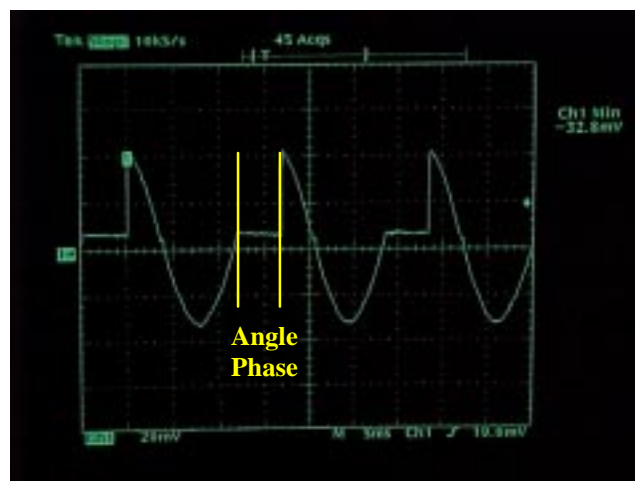


In a different way than in the application note number AND8011/D (High Resolution Digital Dimmer), this circuit is only controlling the angle phase of one half cycle of the ac line which is corresponding to the positive semi-cycle (SCR (A)), therefore, the SCR (B) will be conducting the complete negative semi-cycle of the ac line.

When the switch is turned-on, the SCR (B) is fully triggered while the SCR (A) will be allowing a certain conduction angle to the load which will be depending on the resistance value appearing in the variable resistor since this variable resistor is limiting the charge time of the capacitor, so as soon as the capacitor reaches the same level of voltage than the breakover voltage of the DIAC (PDA30), it will be triggered and due to this, the SCR (A) will be switched-on at certain angle phase of the positive semi-cycle of the ac line. The RC arrangement will be controlling the trigger of the SCR (A) which will be allowing an conduction angle dependable of the delay generated by the RC arrangement.

It is important to mention that in order to have a good control phase operation in the SCR (A), it is very important to keep its T_c within the rate of temperature

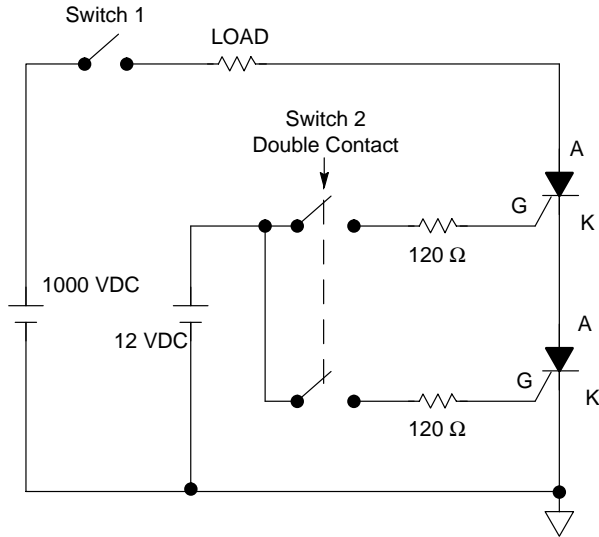
specified in its data sheet, otherwise, the SCR might not be operating properly.



This plot shows how the current waveform looks in the load when it is being controlled the angle phase only in the positive semi-cycle, so in this case it corresponds to the SCR (A).

Series Connection of SCRs

As also previously mentioned, there are some applications in which it is necessary to control high voltage levels (over than 800 V) through a solid state devices, but the main issue for these applications is related to the voltage rating of thyristors which commonly is for 800 V maximum which means that it is the level of voltage that one SCR would be able to sustain. Therefore, if there is an application that requires a blocking voltage of 1000 Volts, it could be a good solution to connect two SCRs in series in order to increase the blocking voltage and it could be made as shown in the following schematic diagram:



The above diagram can be operated very easily, first, it is needed to close the switch 1 and then, the two SCR can be activated by closing the switch 2; the current value that would be flowing through the SCRs would be the same since the devices are connected in series, nevertheless, the power dissipation in each device could be different since it depends of the V_{on} of each SCR.

The series connection of the SCRs devices can offer some benefits some of them are the following:

- Higher blocking voltage
- Reduce leakage current
- Better thermal stability
- Higher dV/dt static capability
- Reduce snubber cost or possible snubber-less operation

Forced Commutation Methods for Turning-Off the SCRs

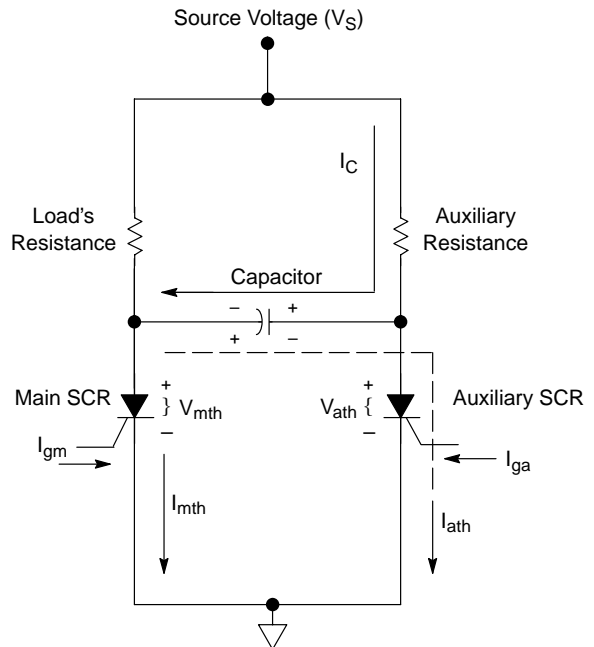
As known, when a SCR device is used in D.C. applications, once it is triggered, it is going to be latched no matter its I_{gt} signal is taken off from its gate terminal and it will remain its on-state whenever the current flowing through its main terminals is higher than its I_H (holding current), so in order to experiment a successful turning-off condition, it is necessary to eliminate the gate current and then reduces the current flowing through the anode and cathode terminals until the current level drops lower than the SCR's holding current, so based in this, it would be required to have either an extra circuit or method capable to cut down the main current flowing through the main terminals of the SCR until it is turned-off. Actually, some of the most common methods for the forced commutation are listed below:

1. Forced commutation method by voltage and current.
2. Forced commutation method of blocking by an external source.
3. Forced commutation method by static blocking.
4. Forced commutation method type E or complementary commutation.

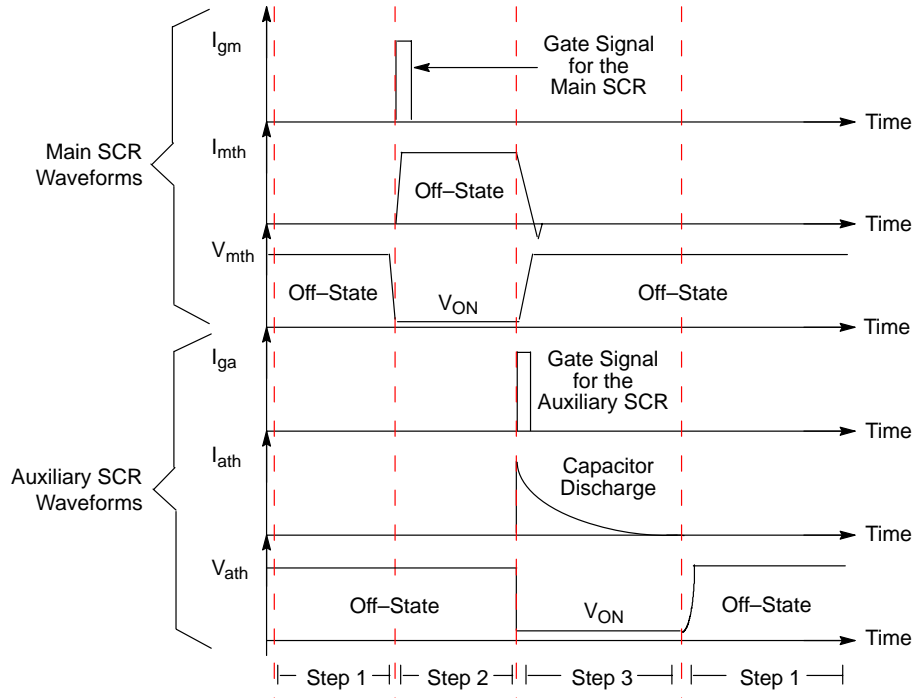
Nevertheless, it will be explained only the method 4 in this application note since it is the option that is more useful in industrial applications.

Forced Commutation Method Type E or Complementary Commutation

The figure below shows the circuit diagram for this method and its corresponding operating sequence:



Operating Sequence Diagram



The steps of the operating sequence are explained below:

Step 1. At the first time, the capacitor is not charged and it is not being applied any trigger signal to the gate terminals of both SCRs, therefore, there is no current flow in the circuit.

Step 2. As soon as current pulse is applied to the gate terminal (I_{gm}) of the main SCR, it will be triggered allowing current flow through the load, and at the same time, the capacitor will start to be charged and once it has reached its maximum charge voltage level ($\tau = R_{aux} C$), it will act as an open element while the main SCR will remain its on-state no matter the current signal has been taken-off from its gate terminal.

Step 3. Now, when a current pulse is applied to the gate terminal (I_{ga}) of the auxiliary SCR, it will be triggered causing the discharge of the capacitor through itself (I_{ath}), this auxiliary SCR will be turned-off as soon as the current level of the capacitor's pulse discharge has dropped below than its holding current (I_H) since the auxiliary resistance will not be allowing enough current flow through the device to keep itself in the on-state. Once the capacitor has been totally discharged, it will act as a short circuit thereby

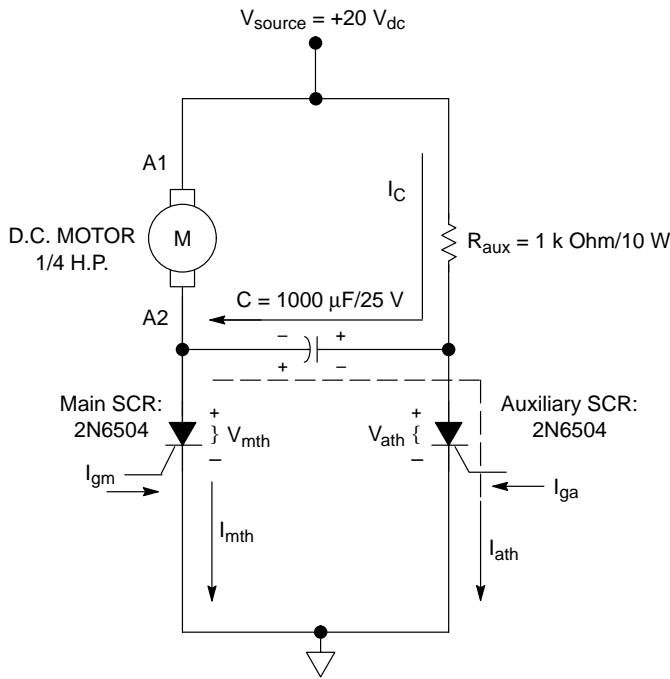
it will start to be charged through the load resistance but now in inverse polarity, this action will cause the elimination of the current flow through the main SCR which will be turned-off. After the main SCR has been turned-off, it could be activated again by supplying another current pulse to its gate terminal and can be deactivated in the same way than previously explained.

It is important to mention that there are some points that must be taken into consideration in order to ensure the properly operation of this commutation method, these points are described below:

- The source voltage must be minor than the V_{DRM} and V_{RRM} of the main and auxiliary SCRs.
- The operating condition for the commutation is:
 - R_{aux} is the auxiliary resistance (Ohms)
 - C is the capacitor to be used (Faraday)
 - T_q is the turn-off time of the main and auxiliary SCRs

The following schematic diagram shows a real application circuit in which it is used this commutation method already explained:

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Note:

When the main SCR is turned-off and the capacitor has been fully discharged, the current through the auxiliary SCR (I_{ath}) will be 20 mA ($20 \text{ V}/1 \text{ KW}$) which is a lower current value than the holding current of the 2N6504 device, so due to this, the auxiliary SCR will be turned-off.

Through this circuit, it is possible to switch-on and switch-off the dc motor through the SCRs and also it could be possible to control the speed of the motor by applying an angle phase control to the main SCR. This circuit basically operates in the same way than previously explained. As soon as a pulse current is applied to the main SCR, it will be activated thereby the motor will start to operate which will be stopped whenever the auxiliary SCR is activated. It is important to mention that the auxiliary resistance was calculated taking into consideration the holding current value of the SCR since this resistance is the one that limits

the current through the auxiliary SCR (see note in the diagram).

In summary the present application note was focused in showing some of the most popular configurations for applications circuits using SCR devices, nevertheless, it is important to mention that all these concepts were only tested into our Lab environment, therefore, if any of these concepts may be used in the real field, it would be necessary to take into consideration the real field conditions (environment temperature, voltage variations, etc.) in order to avoid bad operation from the circuits.

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