Thyristors

Module 6.0

What you'll learn in Module 6.0

After studying this section, you should be able to:

Recognise typical SCR packages:

Describe typical SCR construction:

Understand typical SCR characteristics diagrams:

Understand safety considerations for demonstrating SCRs.

Fig. 6.0.1 Typical SCR Packages

Thyristor (SCR) Packages

Thyristor is a general name for a number of high speed switching devices frequently used in AC power control and AC/DC switching, including triacs and SCRs (Silicon Controlled Rectifiers). The SCR is a very common type of thyristor and several examples of common SCR packages are shown in Figure 6.0.1. Many types are available that are able to switch loads from a few watts to tens of kilowatts. The circuit symbol for a SCR is shown in Figure 6.0.2 and suggests that the SCR acts basically as a **SILICON RECTIFIER** diode, with the usual anode and cathode connections, but with an additional **CONTROL** terminal, called the GATE, hence the name Silicon Controlled Rectifier.

A trigger voltage applied to the gate whilst the anode is more positive than the cathode will switch the SCR on to allow current to flow between anode and cathode. This current will continue to flow, even if the trigger voltage is removed, until anode to cathode current falls to very nearly zero due to external influences such as the circuit being switched off, or the AC current waveform passing through zero volts as part of its cycle.

The Silicon Controlled Rectifier (SCR)

SCRs, unlike normal two layer PN junction rectifiers, consist of four layers of silicon in a P-N-P-N structure, as can be seen in the cut-away view of a SCR in Fig 6.0.2. The addition of the gate connection to this structure enables the rectifier to be switched from a non-conducting 'forward blocking' state into a low resistance, 'forward conducting' state (see also Fig. 6.0.3). So a small current applied to the gate is able to switch on a very much larger current (also at a much higher voltage) applied between anode and cathode. Once the SCR is conducting, it behaves like a normal silicon rectifier; the gate current may be removed and the device will remain in a conducting state.

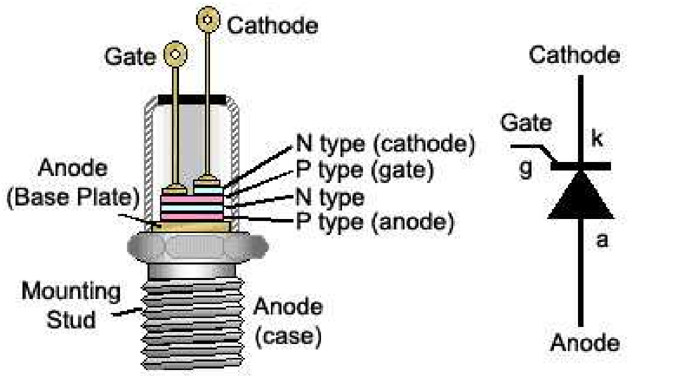


Fig. 6.0.2 Typical SCR Construction & Circuit Symbol

The SCR is made to conduct by applying the trigger pulse to the gate terminal while the main anode and cathode terminals are forward biased. When the device is reverse biased a gating pulse has no effect. To turn the SCR off, the anode to cathode current must be reduced below a certain critical "holding current" value, (near to zero).

A common application for SCRs is in the switching of high power loads. They are the switching element in many domestic light dimmers and are also used as control elements in variable or regulated power supplies.

SCR Characteristics

Fig. 6.0.3 shows a typical characteristic curve for a SCR. It can be seen that in the reverse blocking region it behaves in a similar way to a diode; all current, apart from a small leakage current is blocked until the reverse breakdown region is reached, at which point the insulation due to the depletion layers at the junctions breaks down. In most cases, reverse current flowing in the breakdown region would destroy the SCR.

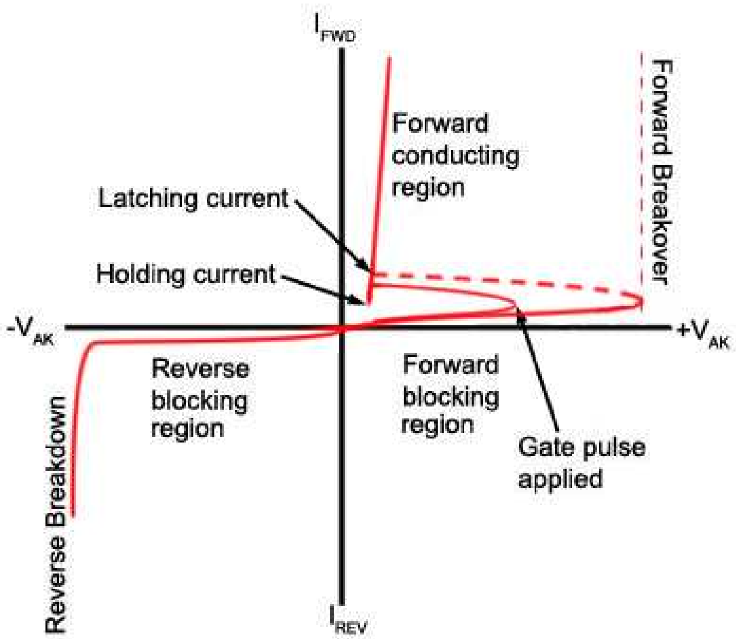


Fig. 6.0.3 SCR Characteristics

When the SCR is forward biased however, unlike a normal diode, rather than current beginning to flow when just over 0.6V is applied, no current apart from a small leakage current flows. This is called the forward blocking mode, which extends to a comparatively high voltage called the 'Forward Break over Voltage'. The SCR is normally operated at voltages considerably less than the forward break over voltage as any voltage higher than the forward break over voltage will cause the SCR to conduct in an uncontrolled manner; the SCR then suddenly exhibits a very low forward resistance, allowing a large current to flow. This current is 'latched' and will continue to flow until either the voltage across anode and cathode is reduced to zero, or the forward current is reduced to a very low value, less than the 'Holding Current' shown in Fig. 6.0.3. However the forward break over conduction may occur if the SCR is being used to control an AC (e.g. mains or line supply) voltage and a sudden voltage spike occurs, especially if it coincides with (or close to) the peak value of the AC. If the SCR is accidentally pushed into the forward break over condition, this can produce a sudden but short-lived surge of maximum current, which could prove disastrous to other components in the circuit. For this reason it is common to find that SCRs have some method of spike suppression included, either within the SCR construction or as external components usually called a 'snubber circuit'.

The correct way of triggering the switch on of the SCR is to apply a current to the gate of the SCR whilst it is operating in the ´forward blocking region´, the SCR is then ´triggered´ and its forward resistance falls to a very low value. This produces a ´latching current´, which, due to the low forward resistance of the SCR in this mode, allows very large (several amperes) currents to flow in the ´forward conducting region´ with hardly any change in the forward voltage (notice that the characteristic curve, once the SCR is triggered is practically vertical). In this region current will flow, and may vary, but if forward current falls below the ´holding current´ value or the anode to cathode voltage is reduced to very near 0V, the device will return to its forward blocking region, effectively turning the rectifier off until it is triggered once more. Using the gate to trigger conduction in this way allows conduction to be controlled, allowing the SCR to be used in many AC and DC control systems.

How the SCR Works

The SCR Two Transistor Model

The actual operation of the SCR can be described by referring to Fig. 6.0.4 (a) & (b), which shows simplified diagrams of the SCR structure with the P and N layers and junctions labelled. To understand the operation of a SCR, the four layers of the SCR can theoretically be thought of as a small circuit comprising two-transistors (one PNP and one NPN) as shown in Fig. 6.0.4 (b). Notice that layer P2 forms both the emitter of Tr1 and the base of Tr2, while layer N1 forms the base of Tr1 and the collector of Tr2.

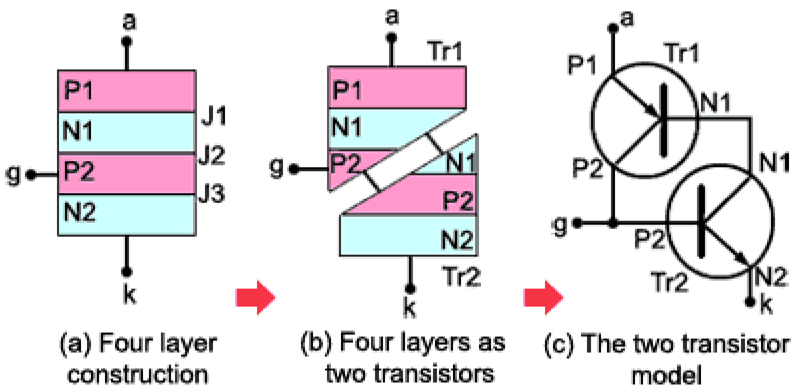


Fig. 6.0.4 The SCR 'Two Transistor Model'

The 'Off' Condition

Referring to the Fig. 6.0.4(c), with no gate signal applied and the gate (g) at the same potential as the cathode (k), any voltage (less than forward break over voltage) applied between the anode (a) and cathode (k) so that the anode is positive with respect to the cathode will not produce a current through the SCR. Tr2 (the NPN transistor) has 0v applied between base and emitter so will not be conducting, and as its collector voltage provides the base drive for Tr1 (the PNP transistor), its base/emitter junction will be reverse biased. Both transistors are therefore switched off and no current (apart from a tiny reverse leakage current) will be flowing between the SCR anode and cathode, and it is operating in its forward blocking region.

Triggering the SCR

When the SCR is operating in the forward blocking region (see the SCR characteristics in Fig. 6.0.3), if the gate and therefore the base of Tr2, see Fig 6.0.4(c) is made positive with respect to the cathode (also Tr2 emitter) by the application of a gating pulse so that a small current, typically a few µA to several mA depending on SCR type, is injected into Tr2 base, Tr2 will turn on and its collector voltage will fall. This will cause current to flow in the PNP transistor Tr1 and a rapid rise in voltage at Tr1 collector and therefore at Tr2 base. Tr2 base emitter junction will become even more forward biased, rapidly turning on Tr1. This increases the voltage applied to Tr2 base and keeps Tr2 and Tr1 conducting, even if the original gating pulse or voltage that started the switch on process is now removed. A large current will now be flowing between the P1 anode (a) and N2 cathode (k) layers.

The resistance between anode and cathode falls to near zero ohms so that the SCR current is now limited only by the resistance of any load circuit. The action described happens very quickly, as the switching on of Tr2 by Tr1 is a form of positive feedback with each transistor collector supplying large current changes to the base of the other.

As Tr1 collector is connected to Tr2 base, the action of switching on Tr1 virtually connects Tr2 base (the gate terminal) to the high positive voltage at the anode (a). This ensures that Tr2 and therefore Tr1 remain conducting, even when the gating pulse is removed. To turn the transistors off, the voltage across the anode (a) and cathode (k) must either have its polarity reversed, as would happen in an AC circuit at the time when the positive half cycle of the AC wave reached 0V before going negative for the second half of its cycle or, in a DC circuit the current flowing through the SCR is switched off. In either of these cases the current flowing through the SCR will be reduced to a very low level, below the holding current level (shown in Fig. 6.0.3), so the base emitter junctions no longer have sufficient forward voltage to maintain conduction.

Demonstrating SCR Operation

Because SCRs are normally used for controlling high power high voltage loads, this presents considerable risk of electric shock to users in any experimental or educational environments. The circuits described in the following web pages of Module 6 however, are designed to demonstrate the various control methods used with SCRs using low voltage ($12V_{RMS}$) AC as illustrated in Fig. 6.0.5 rather than exposing the user to the dangers of using mains (line) voltage. Note that the circuits shown in this module are intended as low voltage demonstrations only, not as working control circuits for mains (line) circuits. For real working examples you should consult application notes produced by SCR manufacturers.

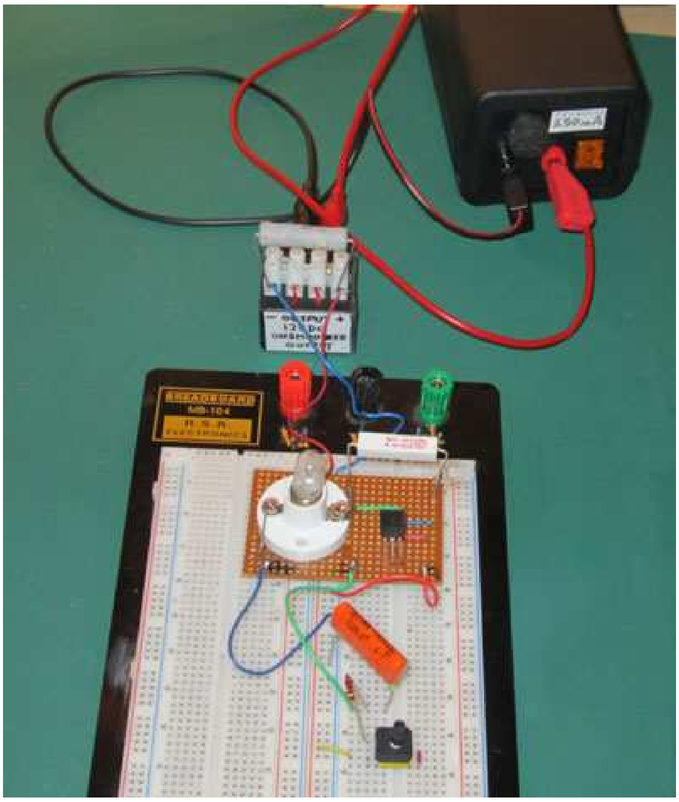


Fig. 6.0.5 Low Voltage SCR Supply

The section of the circuit containing the SCR (a C106M SCR), together with a 33R current limiting resistor and a 12V 100mA lamp is constructed on a small piece of Veroboard (protoboard), which can be easily attached to a breadboard using 'Blu Tack' or similar temporary adhesive, allowing various drive circuits to be constructed experimentally on the breadboard. The SCR is supplied with AC via a double pole switch and a 230V to 12V isolating transformer (a small medical isolation transformer is ideal) with a 250mA fuse in the secondary circuit, all housed in a double insulated box.

A bridge rectifier is contained within a separate insulated enclosure with a 1K8 wire wound resistor connected across the output to ensure there is always some load present. This ensures that output waveforms of the 12V full wave rectified output can be reliably displayed on an oscilloscope. These separate circuits, illustrated in Fig 6.0.6 are simply constructed and comprise a useful set for demonstrating and experimenting with different types of SCR or power supply operation at a low voltage.

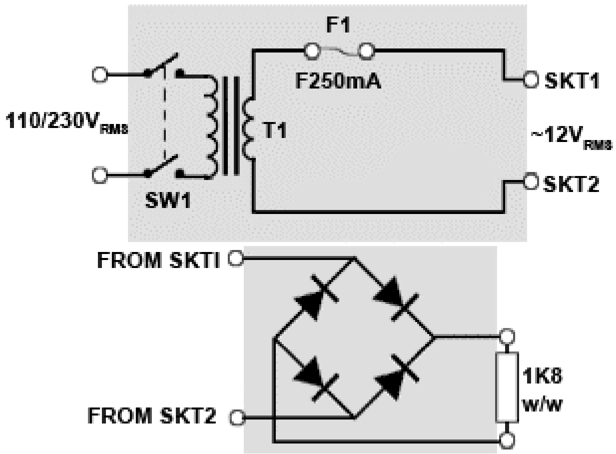


Fig. 6.0.6 Low Voltage SCR Supply Circuits

Module 6.1
Silicon Controlled Rectifiers (SCRs) in DC Circuits

What you'll learn in Module 6.1

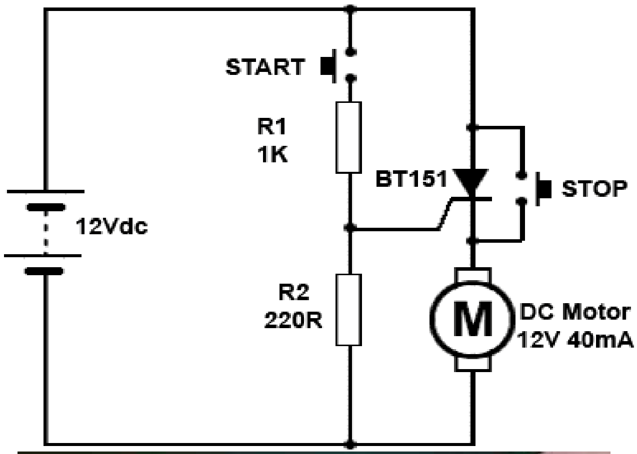
After studying this section, you should be able to:

Understand SCR operation in DC circuits:

- The SCR as a DC switch.
- The SCR as a Crowbar safety device.

DC Power Switching

Thyristors can be used to control either AC or DC loads and can be used to switch low voltage low current devices as well as very large currents at mains (line) voltages. A simple example of a thyristor controlling a DC load, such as a small DC motor is illustrated in Fig 6.1.1. The motor here is connected to a 12V DC supply via a BT151 thyristor, but will not run until the thyristor is made to conduct. This is achieved by momentarily closing the 'start' switch, which provides a pulse of current to the gate terminal of the thyristor. The motor now runs as the thyristor switches on and its resistance is now very low.



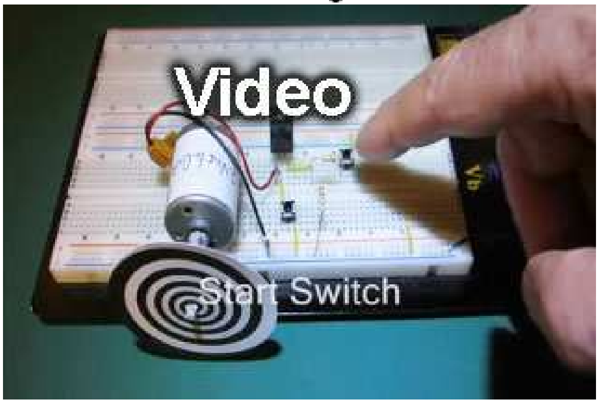


Fig. 6.1.1 DC Control Using a Thyristor
Video available on line

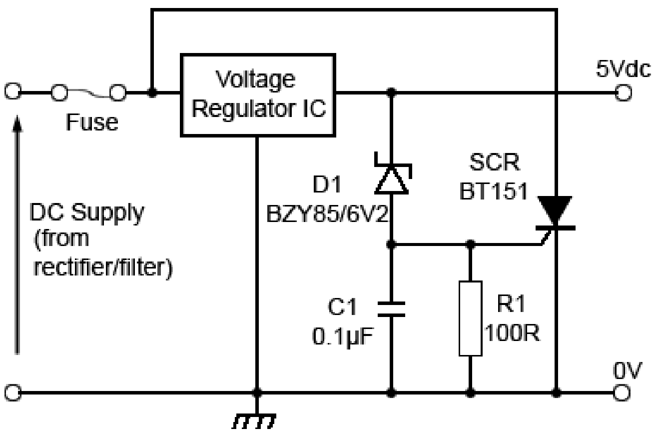
When the start switch returns to its normally open state, there is no longer any gate current but the thyristor continues to conduct, and in a DC circuit, current will continue to flow and the motor continues to run. Any further operations of the start switch now have no effect. The thyristor will only switch off if current flow reduces to a value below the thyristor's holding current threshold.

This is achieved by shorting out the thyristor by momentarily closing the 'stop' switch. The circuit current now flows through the stop switch rather than through the thyristor, which instantly turns off, as the SCR current is now reduced to less than the holding current value. Stopping the motor could also be achieved by using a normally closed switch in series with the thyristor, which when pressed, would also temporarily prevent current flow through the thyristor long enough for the thyristor to turn off.

Although this simple circuit works, as can be seen in the video accompanying Fig. 6.1.1 it is not difficult to imagine simpler ways of switching a small motor on and off. However the principle is useful in situations such as using a computer to control a DC motor. The small current produced by the computer's output is used to trigger a thyristor (usually via an opto coupled device to provide electrical isolation). The thyristor can then supply the motor or other device with whatever higher value of current is required. The use of a thyristor could, with some appropriate extra circuitry, also allow for remote switching of a circuit or device, triggered for example by a radio signal.

Fig. SCR Crowbar Circuits

Another DC operation using thyristors is the 'Crowbar' circuit, used as an over voltage protection device. The circuit is called a crowbar, as its action is about as subtle as a swift blow with a crowbar. Such circuits may often be found preventing power supply circuits from outputting a higher than normal voltage under fault conditions.



6.1.2 Crowbar Over Voltage Protection

The basic idea is that if, for example a fault in a DC power supply line causes the output to rise above its specified voltage value, this 'over voltage' is sensed and causes a normally non conducting SCR connected between the power supply output and ground to switch on very rapidly. This can have different protective actions, the simplest of which, as illustrated in Fig. 6.1.2 is to blow a fuse and so switch off the power completely, requiring the attention of a service technician to get the circuit working again. This is often chosen as the safest option as the cause of the original over voltage should be examined and eliminated before the circuit is allowed to work again.

In Fig. 6.1.2 the output of a regulated 5V DC supply is sensed by D1, a 6.2V Zener diode, the anode of which is held at a voltage close to 0V by R1. This 100Ω resistor ensures that if the 5V supply line rises above its specified limit, sufficient current flows through the Zener diode to provide enough current at the SCR gate to switch on the SCR. Care must also be taken to ensure that the SCR is not triggered accidentally by any fast voltage spikes appearing on the 5V line, due for example to other switching devices in the circuit being supplied. C1 is therefore connected between the gate and cathode of the SCR to reduce the amplitude of any very short interference pulses, provided they do not exist long enough to charge C1 to a high enough level to trigger the SCR.

The reason for using a thyristor to blow the fuse is that fuses do not blow immediately; they operate by blowing when excessive current flows for long enough so that the fusible element heats up and melts. This may take long enough for the excessive voltage to have already destroyed a number of semiconductor components. The thyristor however has a very fast switch on time (about 2µs for the BT151) so that during the short time between the over voltage occurring and the fuse blowing, the entire power supply output current will be flowing through the thyristor, rather than through the circuit being supplied.

Although circuits similar to Fig. 6.1.2 are widely used, relying on fuses to protect complex low voltage semiconductor circuits may not provide suitable protection. However an improved circuit that can prevent over voltage situations without blowing fuses, and which depends only on the almost instant action of semiconductors is described in our Power Supplies Module 2.2 on Series Voltage Regulators.

Module 6.2
SCRs in AC Circuits

What you'll learn in Module 6.2

After studying this section, you should be able to:

Describe methods for AC power control using SCRs

- Half wave and full wave control
- Basic resistive control.
- Phase control.
- Level control.
- Pulse triggering.
- Synchronous or zero crossing switching.

Understand circuit operation for different methods of SCR triggering.

Describe safety isolation methods for medium and high voltage devices.

Basic Resistive Control

Thyristors are generally used in AC power control circuits such as lighting dimmers, AC motor speed controls, heaters etc. where mains (line) voltages are used for loads of many watts, or often kilowatts. The aim of AC Control is to trigger the SCR part way through each AC cycle so that the load current through the SCR is switched off for part of the AC cycle, so restricting the average current flowing through the SCR, and hence the average power delivered to the load.

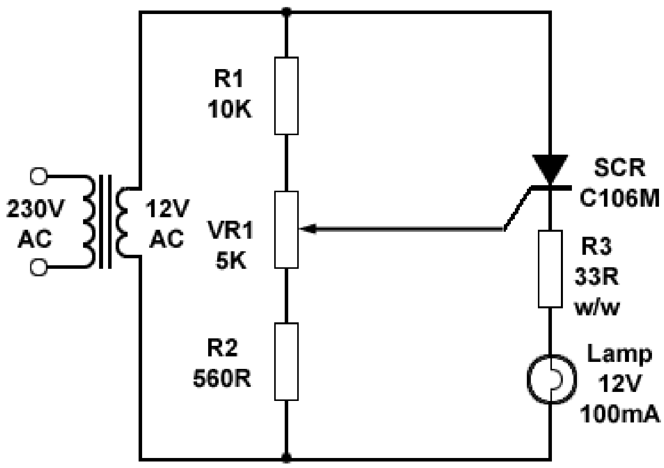


Fig. 6.2.1 Basic Resistive Control Circuit

The simplest way of achieving this is illustrated in Fig.6.2.1, where the thyristor is switched on by applying a low voltage sine wave (derived from the AC input by a simple resistor network containing a variable potentiometer) to the gate terminal of the SCR. Note that because the gate input wave is derived from the AC flowing through the SCR, it will consist only of rectified half wave pulses. The effect of this input wave is that the SCR will switch on only as the gate waveform reaches the SCR firing potential, which happens part way through each positive half cycle of the AC wave. Once the thyristor is switched on it continues to conduct until the AC wave reduces to just above zero volts, when the current flowing between anode and cathode falls to a value less than the 'holding current' threshold (shown in Thyristor Module 6.0 Fig. 6.0.3). The thyristor then remains in a non-conducting state during the negative half cycle of the AC wave as it is now reverse biased (in reverse blocking mode) during the remainder of the AC cycle. When the next positive half cycle starts the thyristor remains in a non-conducting state until the trigger waveform at the gate terminal reaches its firing potential once more.

The time or phase angle at which the SCR will be triggered can be varied by changing the amplitude of the gate waveform. As shown in Fig. 6.2.2. the smaller the gate signal amplitude, the later the SCR switches on. Changing the amplitude of the trigger waveform therefore controls the switch-on time of the SCR.

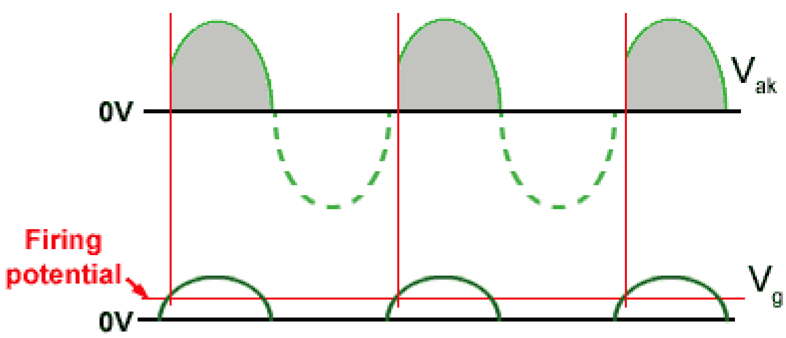


Fig. 6.2.2 SCR Resistive Triggering

Note however that as a thyristor is basically a rectifier diode it only conducts during half of the AC cycle, a single SCR can therefore only deliver 50% of the available AC power. Also, in using this very basic form of control, the current flow through the SCR is only controllable over half of the positive half cycle, that is a quarter of the full AC cycle. It can be seen that once the switch-on time reaches the peak amplitude of the AC wave it cannot be adjusted further, as the peak amplitude of the trigger waveform will no longer reach the SCR gate firing potential and so will not trigger the SCR after this point.

It can also be seen on line from both the animation, and the video in Fig 6.2.3, that when using the simple resistive method, control is not very linear; initially the current through the SCR changes only by a relatively small amount, but there is a more rapid change just before conduction ceases. Look carefully at the inset showing the lamp in the video; it only begins to visibly dim just as the switching time is close to the peak value of the AC wave.

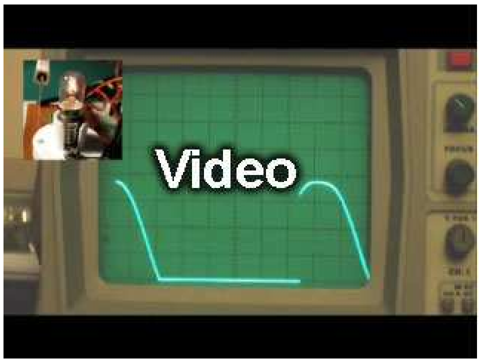


Fig. 6.2.3 AC Control Using Resistors Video Available on line

Full Wave SCR Control

The basic SCR operation described above can be considerably improved with some simple modifications. Perhaps the greatest drawback of the simple resistive control is that the range of adjustment could only cover 25% of the whole AC wave. This is due to the diode action of the SCR only conducting during the positive going half of the AC wave.

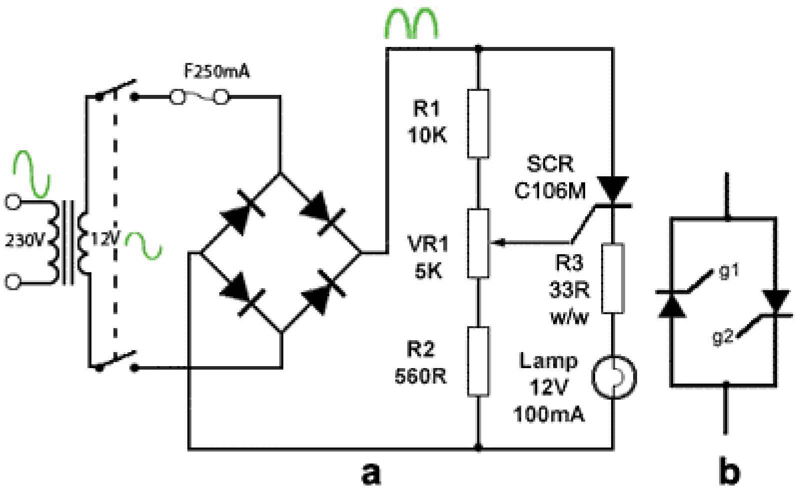


Fig. 6.2.4 Full Wave SCR Control Methods

To allow conduction during the negative going half of the AC wave, the AC can be rectified using a full wave rectifier, as shown in Fig. 6.2.4(a). As both halves of the AC wave will now be positive going, the range of adjustment is now improved to nearly 50%. An alternative is to use a second SCR connected in anti-parallel as shown in Fig. 6.2.4(b) so that one SCR conducts during positive half cycles, and the other SCR during negative half cycles. However this parallel arrangement of SCRs can also be obtained simply by using a single Triac instead of two SCRs.

SCR Phase Control

To achieve control over virtually 100% of the AC wave, phase control simply replaces one of the resistors in the resistive control circuit with a capacitor. This now converts the resistor network into a variable low pass filter that will shift the phase of the AC wave applied to the gate. Details of how a low pass filter works can be found here but basically, the values of C and R are chosen so that adjustment of R1 will provide a phase shift from 0° to nearly 90°. To be effective, the variation of R1 needs to give sufficient change in the behaviour of the load device (in this case a 12volt 100mA lamp).

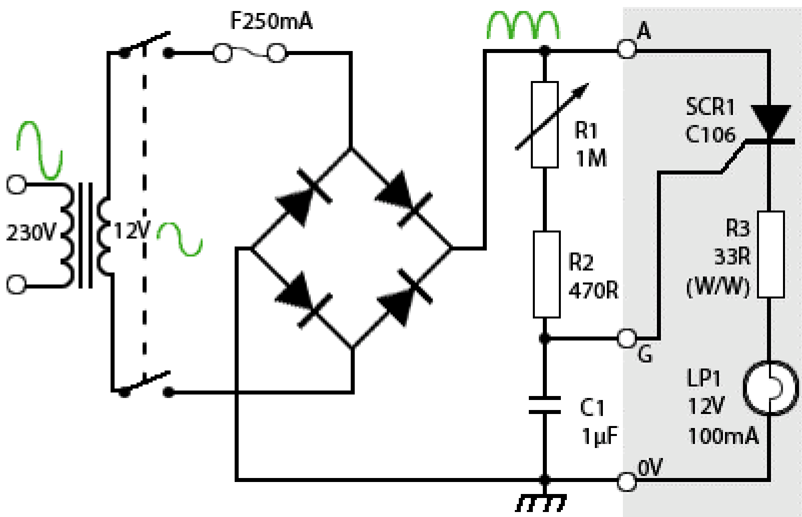


Fig. 6.2.5 SCR Phase Control Demo Circuit

As well as shifting the phase of the gate waveform however, the RC filter will also be altering the amplitude of the gate waveform, so the amplitude of the gate waveform also needs to be kept above the firing potential of the SCR type chosen, for switching to take place. From these conditions it can be seen that calculation of suitable values for R and C to provide appropriate control, depend on both phase and amplitude so can get quite complex. Therefore some practical experimentation with R and C values is also most likely to be necessary.

The video in Fig. 6.2.6 available on line shows a working circuit using the component values shown in Fig. 6.2.5. Watching the brightness of the lamp together with the changing waveform shown in the inset image, it can be seen that using phase control does give much improved control over almost the whole 180° of every half cycle, compared to the simple resistive control.

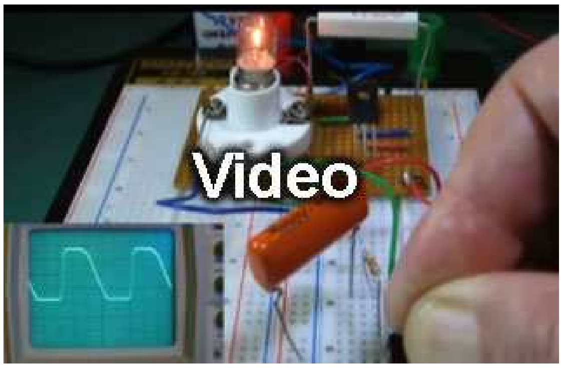


Fig. 6.2.6 SCR Phase Control Video available on line

SCR Level Control

Another way of switching on the SCR at the appropriate part of the AC cycle is to apply a DC voltage to the gate during the time the SCR is required to conduct. The DC applied to the gate will therefore be a variable width pulse having a voltage level sufficient to cause the SCR to conduct. These pulses must be synchronised with the rectified AC wave so that they always start and end at the correct time relative to the AC waveform.

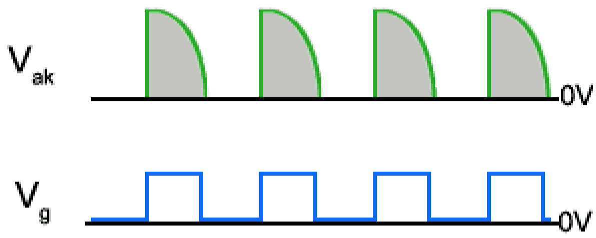


Fig. 6.2.7 SCR Level Control Animation available on line

The animation in Fig. 6.2.7 illustrates the basic method of triggering an SCR using level control. The SCR is triggered (switched on) for a period during each rectified AC half cycle by a voltage V_g applied to the SCR gate. The SCR turns off at the end of each half cycle as the voltage across the SCR falls to near zero, which also coincides with the end of the trigger pulse V_g. The DC pulses may be generated digitally, using a computer output or by using a discrete component circuit such as that shown below in Fig 6.2.8, which uses a 555 timer based monostable. This circuit offers a simple and inexpensive method of demonstrating SCR operation using only low voltages. Two power supplies are used, the shaded area of Fig. 6.2.8 is the AC demonstration power supply described in SCR Module 6.0, which isolates the demonstration circuit from the mains (line) supply. The control section of the circuit must be supplied with a DC voltage of between 5V and 12V. This can be from either a separate DC power supply (e.g. a 'Wall Wart'), a dedicated IC regulated supply, or a battery. The control section of the circuit (black) is also isolated from the AC section (red) by two optocouplers, IC1 and IC3. Because this circuit is already isolated from mains voltage by T1, it would seem unnecessary to use a second method of isolation in IC1, However the main function of IC1 is not isolation in this case, but to act as a zero crossing detector.

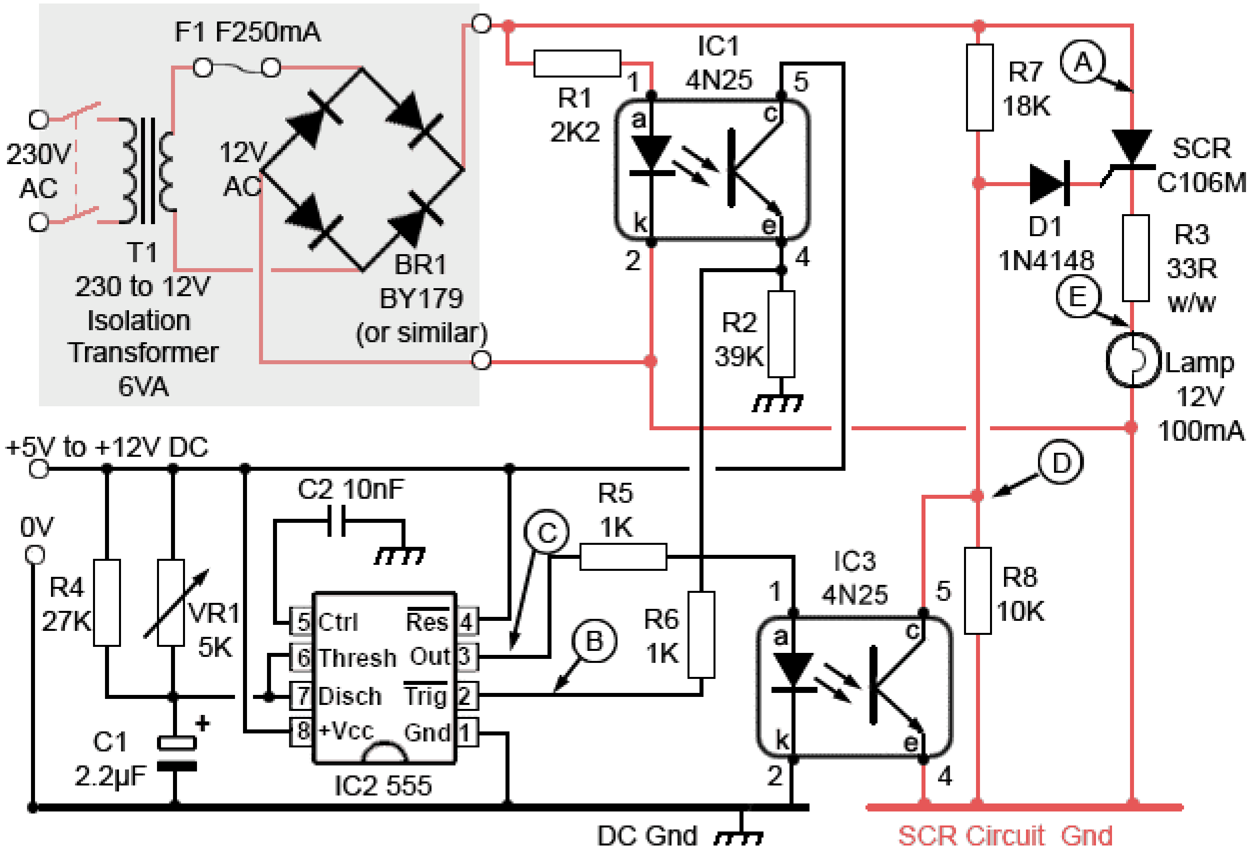


Fig. 6.2.8 SCR Level Triggering Circuit

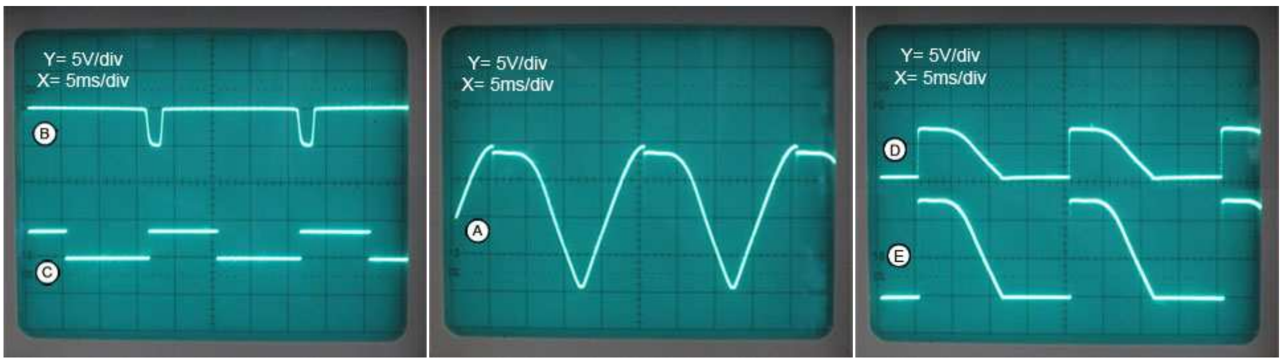


Fig. 6.2.9 SCR Level Triggering Waveforms

Level Triggering Demonstration Circuit

The circuit in Fig. 6.2.8 switches on the SCR at a time chosen by the setting of VR1 during each positive AC half cycle from the low voltage power supply (waveform A). The SCR switches off again as the rectified AC voltage reduces to near zero at the end of each half cycle. The control circuit is based around a 555 timer IC operating in monostable mode, and two 4N25 opto couplers.

As well as isolating the 555 circuitry from the incoming AC, IC1 (4N25) provides a synchronising pulse (waveform B in Fig. 6.2.9). This is achieved by biasing IC1 in common collector mode so that its output transistor conducts for most of the full wave AC input, producing a high (5V) voltage at pin 4, but turns off as the AC wave approaches 0V, producing a 0V output at pin 4 of IC1. These pulses are used to trigger the 555 monostable (IC2) at the start of each half cycle.

Each time IC2 is triggered its output on pin 3 goes high for a time set by the time constant created by variable resistor VR1 and the timing capacitor C1. Notice that VR1 is also connected in parallel with a 27K resistor R4. The purpose of this is to achieve a more accurate time constant than is possible using only the preferred values of VR1 and C1. It would also be possible to fit a preset resistor in place of R4 to obtain the exact duration for the high level trigger pulse produced by IC2.

Notice that the trigger pulse produced by IC2 (waveform C in Fig. 6.2.9) goes high immediately a synchronising pulse is received, which would turn the SCR on at the start of the half cycle. Also when the trigger pulse returns low this would not switch off the SCR, it would continue to conduct until the end of the half cycle; this is not what is needed. However, waveform C is inverted by the action of the optocoupler IC3, because its output transistor is connected in common emitter mode. Therefore the SCR is triggered during the latter period of the rectified AC half cycle, (waveform D in Fig. 6.2.9). Notice that waveform D does not look like the inverse of waveform C because, as soon as the SCR is triggered the gate input (together with the anode and cathode) follows the shape of the rectified AC wave from the moment of triggering to the time it reaches 0V.

Note that the level triggering circuit described here and shown in operation on line in the video in Fig. 6.2.10 is not particularly meant to represent a practical circuit for high voltage control, but as a demonstration piece allowing the control of an SCR to be studied. This module therefore provides the opportunity to study SCR triggering modes in more depth, using the low voltage AC power supply described in SCR Module 6.0 and constructing the trigger circuits on breadboard. In practice however, there are some drawbacks to level triggering, which can be overcome by using Pulse Triggering.

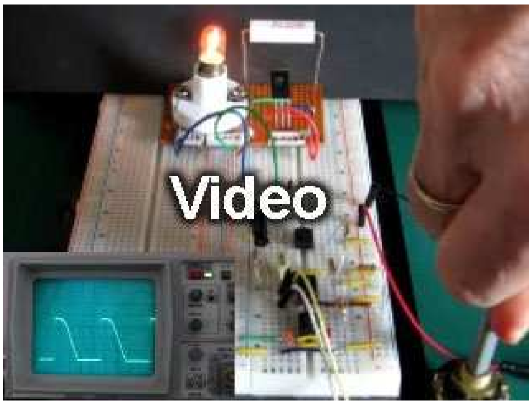


Fig. 6.2.10 SCR Level Triggering Video
Video Available on line

SCR Pulse Triggering

Using level triggering as described above has the drawback of creating gate current throughout the 'on' period of the SCR. This creates unnecessary gate current and in high power application can add to heat generated at junction 2 of the SCR, which in turn may reduce long term reliability.

A modification to the circuit shown in Fig. 6.2.8 is illustrated in Fig. 6.2.11. This circuit generates a single narrow pulse (about 4µs in duration) to trigger the SCR at the chosen firing angle, the SCR then continues to conduct until the forward current falls to less than the holding current value at around 0V so greatly reducing the average gate current.

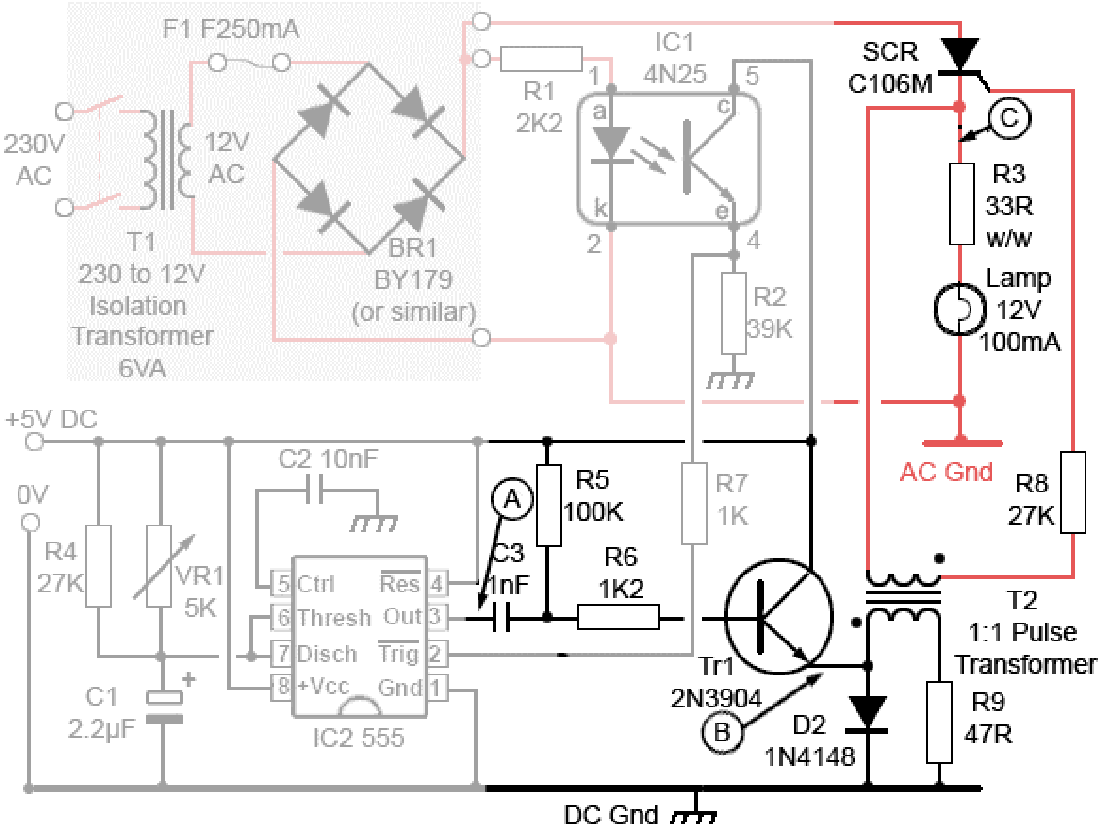


Fig. 6.2.11 SCR Pulse Triggering Circuit

How the Pulse Triggering Circuit Works

The portion of Fig. 6.2.11 shown in pale grey works in the same way as already described for Fig 6.2.8; the output of IC2 (the monostable) consists of variable width positive pulses (waveform A shown in Fig. 6.2.12) where the falling edge of each pulse defines the firing angle of the SCR. (Note that in the level triggering circuit this waveform is inverted before being applied to the gate, so that the falling edge becomes a rising edge to trigger the SCR). In Fig 6.2.11 before the output of IC2 is inverted, it is differentiated by C3 and R5 to produce a series of narrow 4μs positive and negative going pulses corresponding to the rising and falling edges of waveform A. These narrow pulses are fed to the common collector (emitter follower) driver transistor Tr1 via R6. Diode D2 at Tr1 emitter removes the positive going pulses (apart from a small residue due to the forward junction potential of the diode).

The negative going pulses (waveform B) at Tr1 emitter are inverted by the 1:1 pulse transformer T2 by connecting T2 secondary in anti-phase to the T2 primary (notice the phase indicator dots next to the primary and secondary windings) so producing positive going trigger pulses for the SCR. T2 also acts as the isolator between the low voltage DC control circuit and the higher voltage AC SCR.

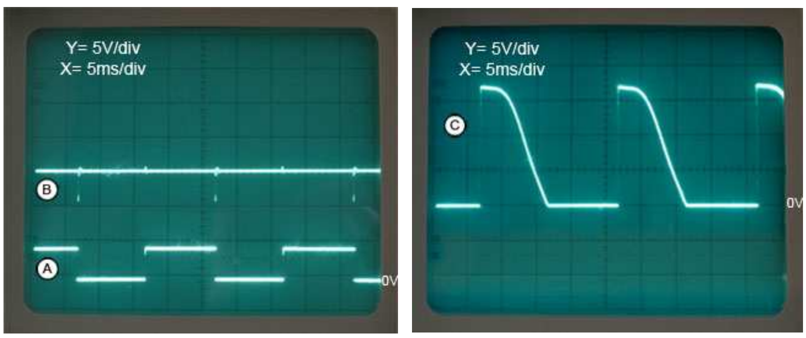


Fig. 6.2.12 SCR Pulse Triggering Waveforms

Fig. 6.2.12 waveform C shows the SCR cathode waveform, the fast rising edge corresponding to the timing of the trigger pulse delivered to the gate via R8 current limiting resistor; this reduces the current delivered by each trigger pulse to around 100μA.

Both the level triggering and pulse triggering circuits provide reliable triggering and adjustment over nearly the whole 360° of the 50Hz AC wave. Some adjustment of the monostable time constant may be necessary for 60Hz operation. The DC supply voltage level is not critical, between about 5V and 12V.

Synchronous (Zero Crossing) Switching

A problem exists however with all the control methods described above. The AC output waveform when the SCR is switched on during each positive half cycle of the AC wave, has a very fast rise time, as the current through the SCR suddenly switches from zero to the instantaneous value of the AC wave. When used with a 230V AC supply this sudden change can be around 325V (the peak value of the AC wave). The waveform may also be a sharp triangular spike if the SCR switches on after the peak value of the wave has occurred. In any case the AC voltage waveform produced by the SCR action will be rich in harmonics, that can generate a serious level of electromagnetic interference (e.m.i.) causing problems not only to other connected circuitry; the interference can also radiate to other nearby electronics as radio frequency interference (r.f.i.) as the harmonics produced can extend well into the radio frequency bands.

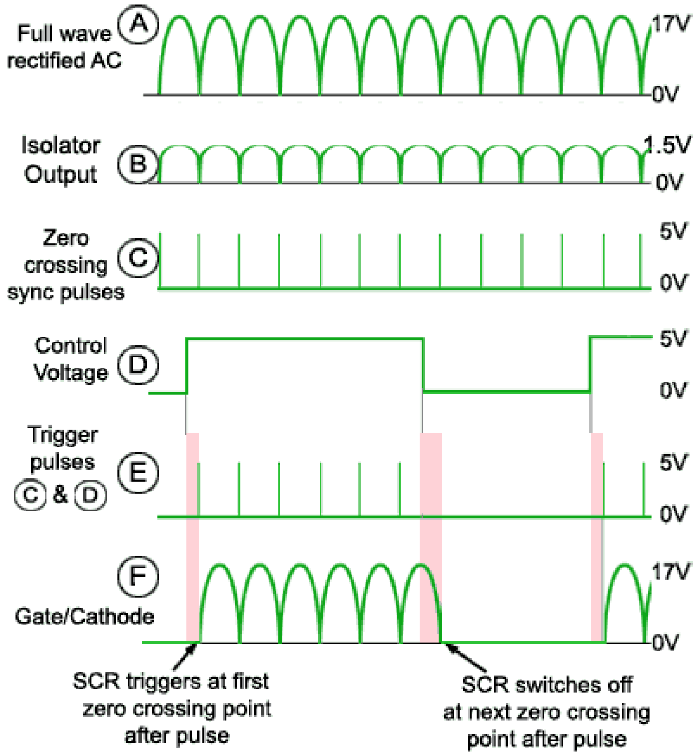


Fig. 6.2.13 SCR Zero Crossing Waveforms

To avoid these problems alternative control methods may be used. One such method, called 'Synchronous or Zero Crossing Switching' is to only allow thyristors to switch when the mains waveform is at, or very close to zero volts. The thyristor is then switched on for a number of cycles and then switched off again (as the AC voltage passes through 0V) for another number of cycles. The ratio of on to off cycles can then be altered to provide a variation of average power supplied to the load. Fig. 6.2.13 illustrates a theoretical method for achieving zero crossover switching. A practical demonstration circuit is shown in Fig. 6.2.14 and the actual waveforms obtained from the circuit are shown in Fig. 6.2.15.

Waveform A in Fig. 6.2.15 shows the 18Vpp 100Hz waveform applied to the zero crossing circuit from the full wave rectified AC power supply and bridge rectifier (shaded grey in Fig. 6.2.14).

Waveform B is a series of 5V pulses, derived from IC1 optocoupler. As the optocoupler transistor is turned on for most of the positive half cycle of the AC input, this makes the emitter high apart from a narrow pulse as the emitter falls from 5V to 0V each time the AC input falls to 0V. These pulses are therefore synchronised to the zero voltage point of waveform A.

However, as positive going trigger pulses are needed to trigger the SCR, the pulses at B are inverted by Tr1 to create waveform C.

Waveform D is the output of a free running 555 astable oscillator IC2, which produces square pulses at a pulse repetition frequency of about 7Hz and a variable duty cycle adjustable by VR1. This waveform is used to control the ratio of the on and off times of the SCR. As the SCR will be high (on) for a number of 100Hz half cycles, then low (off) for a number of half cycles. The mark to space ratio of the square wave produced by IC2 is adjustable by VR1 to produce an on time of between about 20% and 90% of the periodic time of the astable output. The operation of IC2 is described in more detail in Oscillators Module 4.4.

The outputs of Tr1 (waveform C) and IC2 (waveform D) are applied to the two inputs of the AND gate (IC3). The output of IC3 goes to logic 1 only when both inputs are at logic 1. This produces a series of narrow positive going trigger pulses (waveform E) to trigger the SCR only at the start of those half cycles whilst waveform D is high. The trigger pulses produced are applied to T2, a 1:1 isolating pulse transformer via the emitter follower driver transistor Tr2. The secondary winding of T2 applies the trigger pulses to the gate of the SCR via a current limiter resistor R11 and diode D3. The gate waveform (waveform F) is practically identical to the output waveform at the SCR cathode as there is only a small voltage difference between the gate and cathode of the SCR.

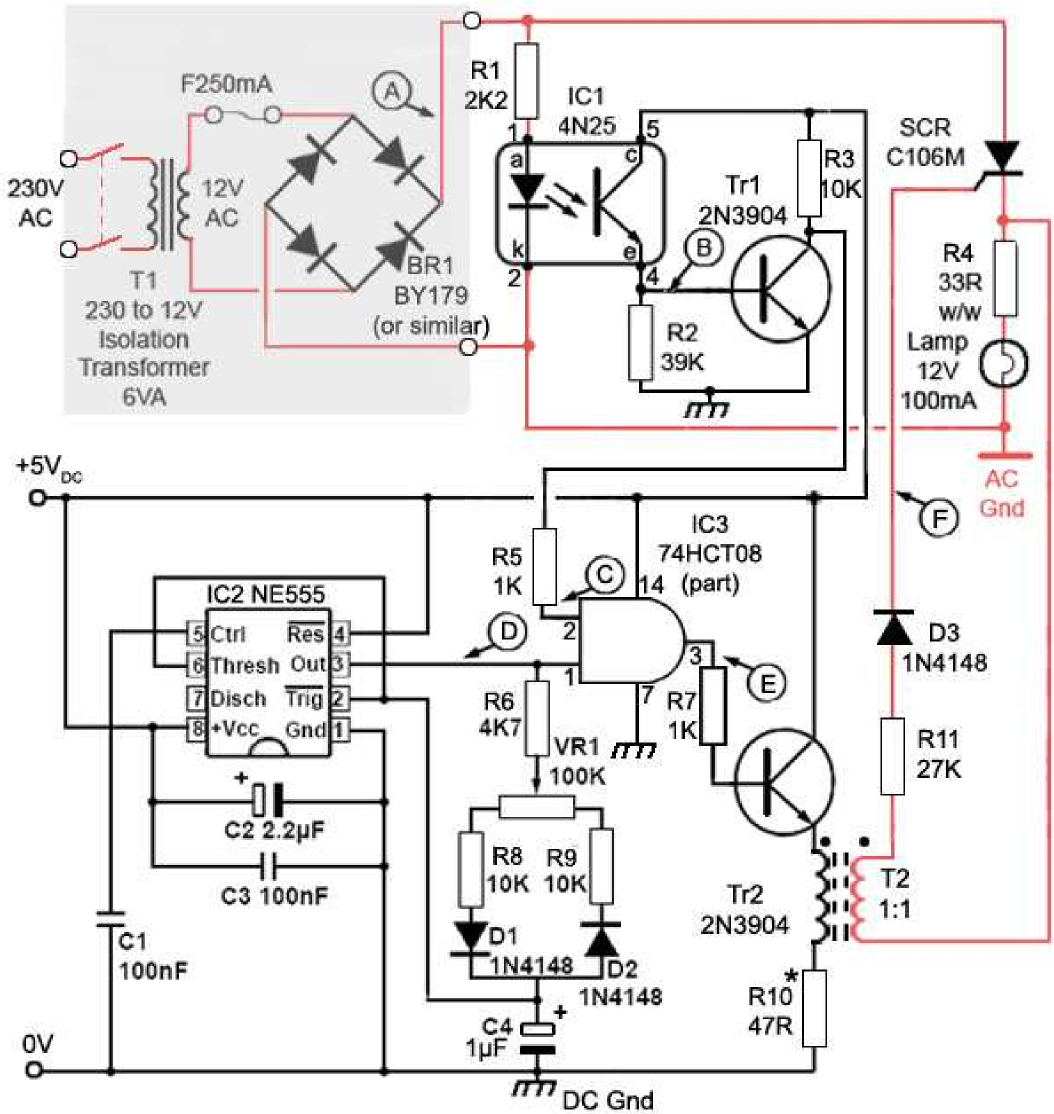


Fig. 6.2.14 SCR Zero Crossing Control Circuit

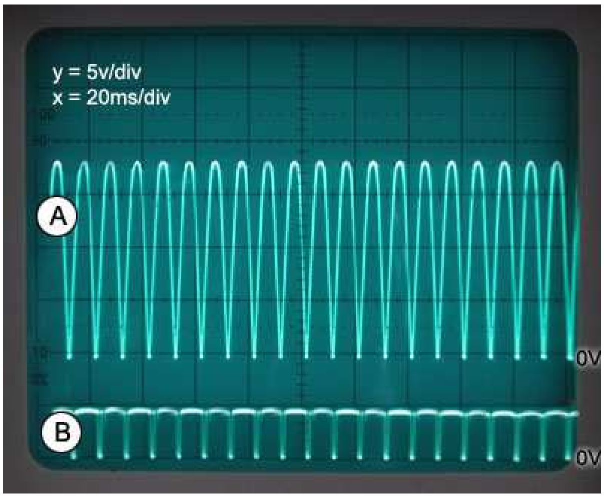
Safety Note:

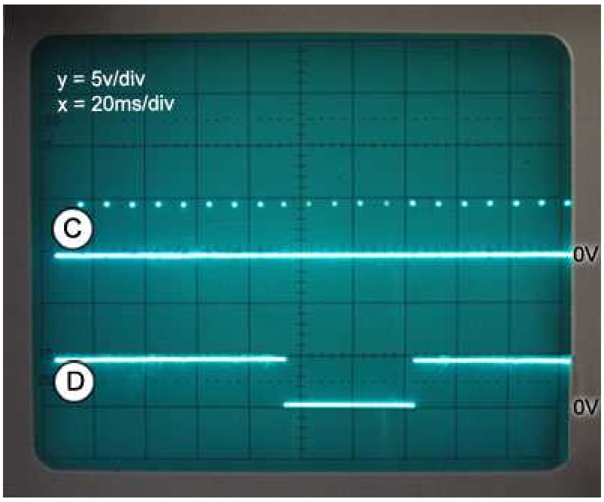
Generally 0.25watt resistors are OK for this design, but if the circuit is operated for a prolonged time with no AC supply but with the DC supply still on, there is a possibility that R11 (47R 0.25W) can overheat, as under these conditions it will be passing increased current due to waveform E being a higher current version of the astable output (waveform D). To avoid overheating, R5 could be replaced by a higher wattage version, or preferably both AC and DC supplies should always be turned off when the circuit is not operating!

SCR Zero Crossing Circuit Operation

This demonstration circuit again uses the low voltage ($12V_{RMS}$) full wave rectified AC supply described in Thyristors Module 6.0 and shaded grey in Fig. 6.2.14.

Fig. 6.2.14. uses two different methods of isolation and demonstrates how the zero crossing control method may be achieved using standard components. It is not meant to represent any particular commercially available solution, nor is it meant to represent the best available method. The purpose of the SCR gate drive circuits discussed in this module is to provide useful demonstrations of commonly used drive techniques and a low voltage environment for relevant experimentation.





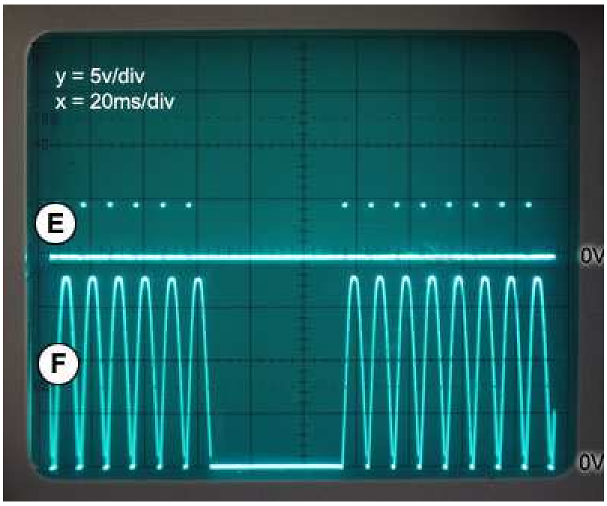


Fig. 6.2.15 Waveforms for Fig. 6.2.14 Circuit

They can be inexpensively built on standard breadboard or strip board as shown in Fig. 6.2.16 to serve as useful demonstrations, or as student projects. Low voltages are used in these projects to maintain a safer environment, but learnabout-electronics.org does not claim or suggest that any electronic circuit is totally safe, choosing to build and/or use the circuits and methods described on this site is done entirely at your own risk.

The video in Fig 6.2.17 shows the effect of zero crossing control when used to dim a lamp. Notice the pronounced flicker produced as the SCR switches on and off at low frequencies, showing that this solution, whilst removing one problem of SCR control (interference) produces another - the low switching speed and associated flicker. However while this may be a problem for lighting applications, it is not a problem for applications with slowly changing values such as heating control. Zero crossing can therefore be effective in controlling temperature by varying the average power supplied to a heating element. Also, because of the absence of fast changing voltage spikes in zero crossing control, it is more suited to use with inductive loads than drive circuits that switch during the AC cycle.

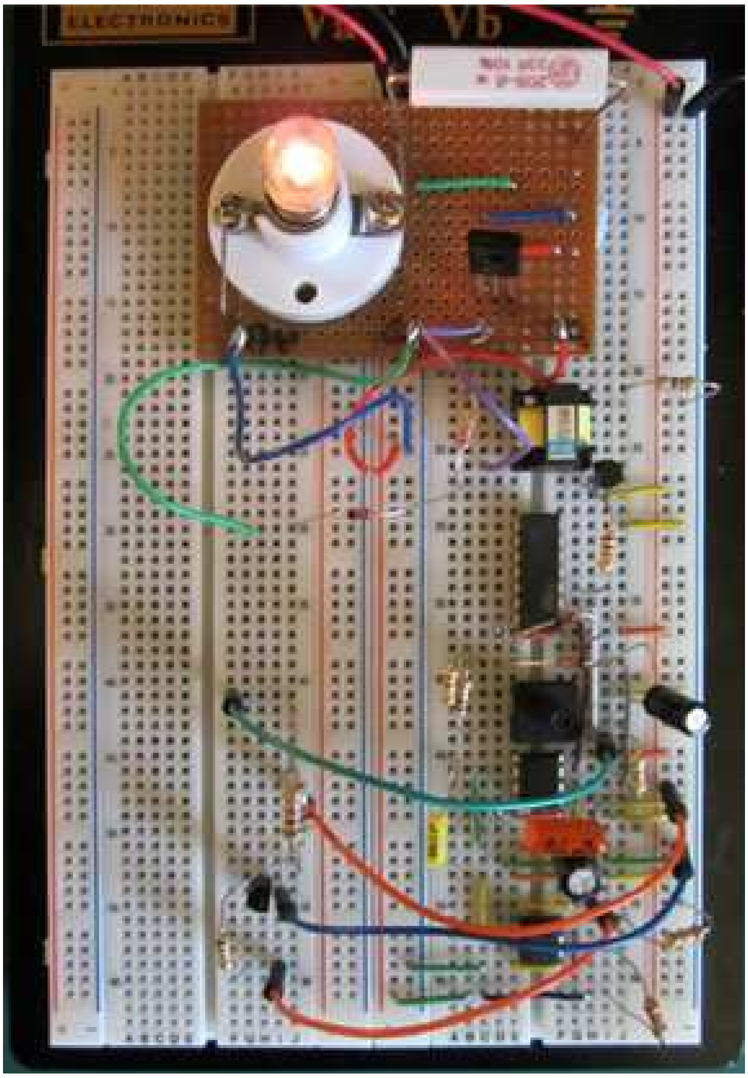


Fig. 6.2.16 SCR Zero Crossing Breadboard Circuit

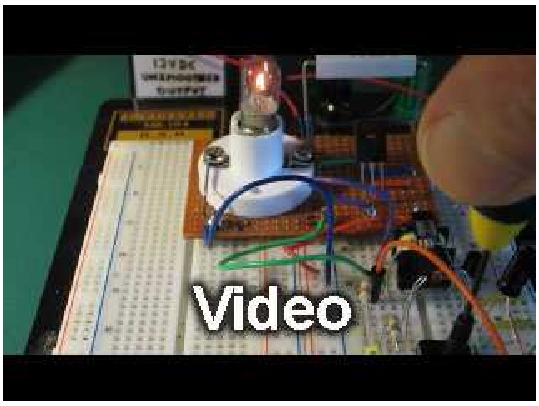


Fig. 6.2.17 Zero Crossing Dimmer Video Available on line

Module 6.3
Triacs & Diacs

What you'll learn in Module 6.3

After studying this section, you should be able to:

Recognise typical triac packages:

Understand a typical triac characteristics diagram.

Understand the function of quadrants in triggering triacs:

Understand the basic principles of opto triacs.

Understand the operation of diacs.

Understand methods and limitations for out of circuit testing of thyristors.

Safety considerations for using medium and high voltage devices.

Fig. 6.3.1 Triac Packages

The Triac

Fig. 6.3.1 shows some typical triac packages together with the circuit symbol for a triac. The triac is a bi-directional thyristor, similar in operation to two SCRs connected in reverse parallel but using a common gate connection. Therefore the triac can conduct and be controlled during both positive and negative half cycles of the mains waveform. Instead of having positive anode and negative cathode connections however, the triac's main current carrying connections are normally labelled MT1 and MT2 signifying Main Terminals 1 and 2 (although other letters may be used) as either terminal can be positive or negative. The triac can be triggered into conduction by a pulse of current applied to the gate terminal (G). Once triggered the triac will continue to conduct until the main current reduces below the current holding threshold close to zero.

Fig. 6.3.2 illustrates the main characteristics of the triac.

V_{BO} is the maximum forward or reverse voltage that the triac can tolerate before it breaks over into uncontrolled conduction.

V_{DRM} is the maximum repetitive peak voltage (usually the maximum peak voltage of the applied AC wave) that can be reliably tolerated.

V_{GT} is a range of gate voltages that will trigger conduction.

I_L is the minimum current that will cause the triac to latch and continue conducting after the gate triggering voltage is removed.

I_H is the minimum holding current below which a conducting triac will cease conduction.

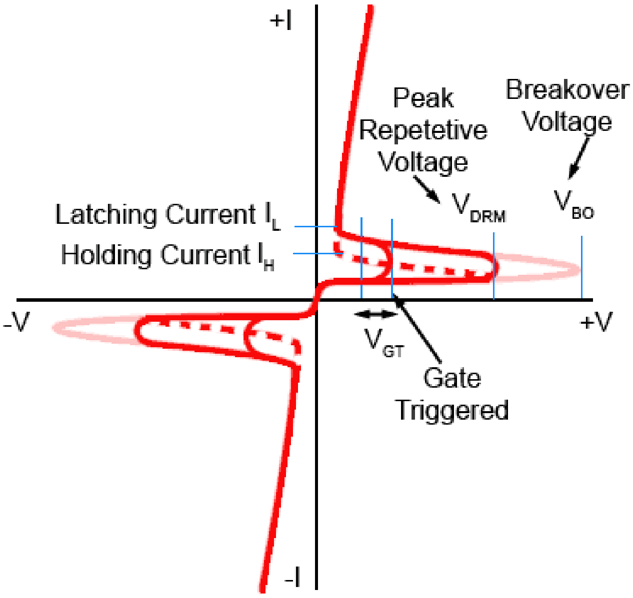


Fig. 6.3.2 Triac Characteristics

Triac Quadrants

Because the gating current or pulse used to trigger the triac may be applied whilst the MT2 terminal is either positive or negative, and the gating current or pulse may also be either positive or negative, there are four different ways to trigger the triac. These are usually described as ´Quadrants´ as shown in Fig. 6.3.3

Most triacs can be triggered in any of the four quadrants, and two of the four possible quadrants are needed to trigger conduction during the two (positive and negative) half cycles of the AC wave. Quadrants I, and III or quadrants II, and III are the favoured methods of triggering, as quadrant IV is much less sensitive to triggering because of the way the diac is constructed.

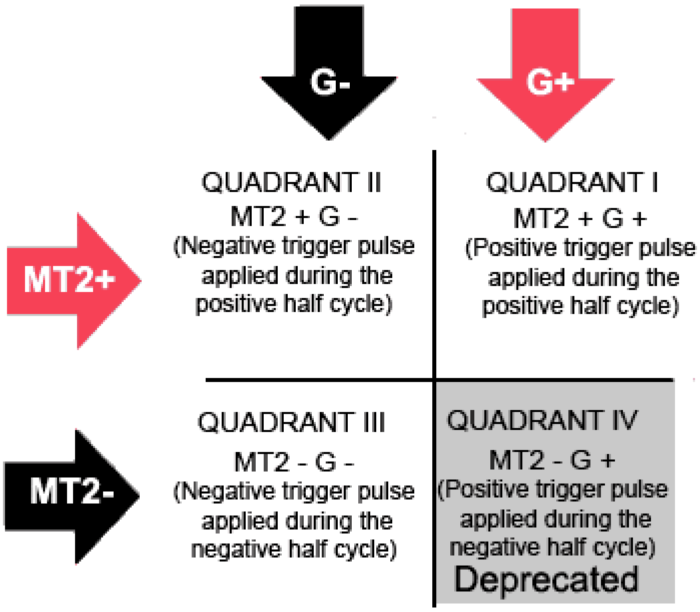


Fig. 6.3.3 Triac Quadrants

So if quadrant IV is used with any of the other three quadrants, the positive and negative half cycles would need different values of trigger current, creating an unnecessary complication. Also if a triac is triggered in quadrant IV, its capability of handling any fast current changes (δI/δt) is reduced, making the triac more susceptible to damage from events such as random high current spikes and the inevitable high inrush currents when filament lamps are switched on.

An important aim in many modern designs is to combat potentially damaging over voltage spikes, and to reduce the tendency for the triac to re-trigger during the switched off portion of a cycle. This happens during each AC cycle between the time when the current drops below the holding current of the thyristor and before the next trigger pulse. Although not normally a problem when the triac is driving a resistive load such as an incandescent lamp, when used with inductive loads such as motors the load voltage and load current will quite likely not be ´in phase´ with each other, so the voltage can actually be near its peak value when the current drops to zero, (as described here) causing a large and rapid change in voltage across the triac that may cause the triac to instantly re-trigger and so switch on again so that control is lost.

Standard triacs have been used for AC control for many years, but over that time the range of different triac designs has increased enormously. Modern triac designs such as 3Q HIGH-COM (3 quadrant, high commutation) triacs from NXP/WeEn and Snubberless$_{TM}$ triacs from ST Microelectronics have many advantages such as improved performance, less false triggering, usability with both resistive and inductive loads and improved switch off capabilities without the need for additional circuitry such as snubbers. Additional input conditioning is also a feature of some designs, including gate pulse conditioning such as zero crossing detectors and logic level inputs etc.

As many control functions are now carried out using microprocessors and/or logic circuits, there are also many triacs that accept logic signals for triggering rather than relying solely on traditional phase control techniques. One such triac is the 6073A Sensitive Gate triac from ON Semiconductor, which is used in the low voltage demonstration circuit in Thyristors Module 6.4.

Opto Triacs

The materials used in the manufacture of Triacs and SCRs, like any semiconductor device, are light sensitive. Their conduction is changed by the presence of light; that's why they are normally packaged in little chunks of black plastic. However, if an LED is included within the package, it can turn on the high voltage device output in response to a very small input current through the LED.

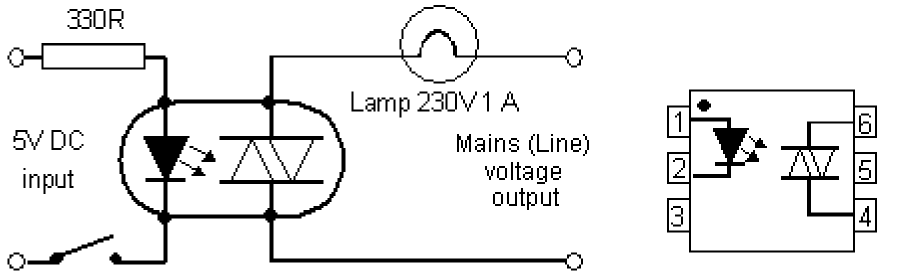


Fig 6.3.4. The Opto Triac

This is the principle used in Opto-Triacs and Opto-SCRs, illustrated in Fig. 6.3.4, which are readily available in integrated circuit (IC) form and do not need very complex circuitry to make them work. Simply provide a small pulse at the right time to illuminate the built in LED and the power is switched on. The main advantage of these optically activated devices is the excellent insulation (typically several thousand volts) between the low power and high power circuits. This provides safe isolation between a low voltage control circuit and high voltage high current output. Although the output current of opto triacs is usually limited to tens of milliamps, they provide useful interface when the output is used to trigger a high power triac from a low voltage opto triac.

The Diac

Fig. 6.3.5 DB3 Diac & Circuit Symbol

The diac is a bi-directional trigger diode (see Fig.6.3.5) that has been used for many years as the main triggering component for standard triacs. It blocks current flow when a voltage applied across it is less than its break over potential V_{BO} (see Fig.6.3.6), but conducts heavily when the applied voltage is equal to V_{BO}. However, unlike other diodes that conduct in one direction only, the diac has similar break over voltage in both positive or negative directions. Once the AC voltage applied to the diac reaches either $+V_{BO}$ or $-V_{BO}$, a positive or negative current pulse is produced. The break over potential for diacs is typically around 30 to 40 volts. This action makes diacs particularly useful in triggering triacs in AC control circuits because of its ability to trigger the triac during either the positive or the negative half cycle of the mains (line) waveform. Its circuit symbol (shown in Fig. 6.3.5) is similar to that of a Triac, but without the gate terminal.

The Diac characteristics illustrated in Fig. 6.3.6 show that at voltages below V_{BO} the diac has a high resistance, (the characteristic curve is nearly horizontal indicating that there is only a small leakage current of a few µA flowing, but once $+V_{BO}$ or $-V_{BO}$ is reached, the diac exhibits a negative resistance. Normally, Ohm's law states that an increase in current through a component with a fixed value of resistance, causes an increase in voltage across that component; however the opposite effect is happening here, the diac is exhibiting negative resistance at break-over, where the current increases sharply, although the voltage is actually reducing.

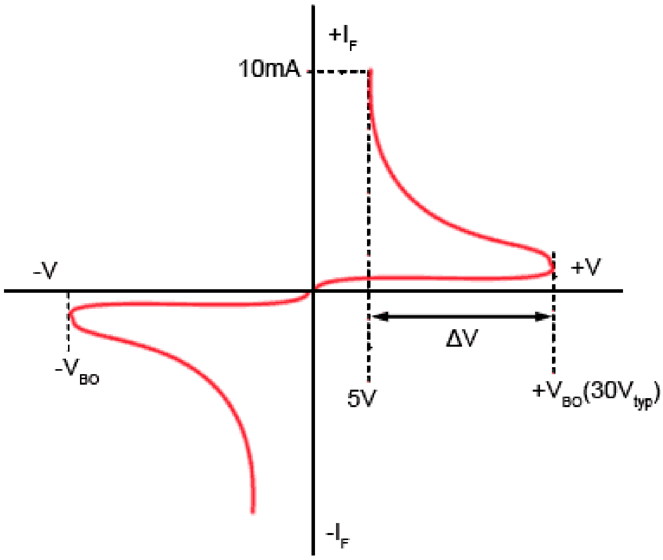


Fig. 6.3.6 Typical Diac Characteristics.

The negative resistance mode lasts for a period of about 2µs, by which time the forward voltage has dropped to about 5V and the diac is passing a current of 10mA. This action is fairly (though not exactly) symmetrical in either the positive (+V) or negative regions of the characteristics.

Internally Triggered Triac (Quadrac)

There are far fewer types of diac available from component suppliers than there are triacs. Also it is easier to select the ideal diac for triggering a particular triac when it is already built in to the package. Such is the case with the ´Quadrac´ or Internally Triggered Triac illustrated in Fig. 6.3.7. These devices also reduce component count and PCB space.

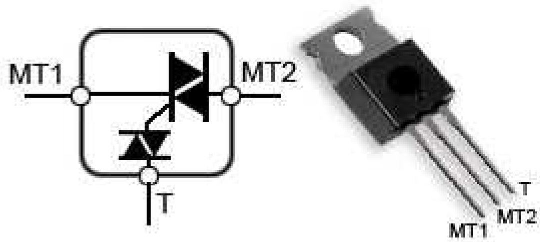


Fig 6.3.7. The Internally Triggered Triac (Quadrac)

Sensitive Gate Triacs

Triacs that depend on a diac for triggering have a drawback for many modern low voltage applications. The voltage required for the diac to produce a trigger pulse must be at least as equal to, or greater than it's break over potential (V_{BO}) and this is about 30V or more. However there are triacs available - Sensitive Gate Triacs - that can be triggered by much lower voltages, within the range of TTL, HTL, CMOS and OP AMP devices as well as microprocessor outputs. A demonstration circuit for driving a sensitive gate triac is shown in Thyristor Module 6.4.

Testing Thyristors, Triacs and Diacs.

There are many pages on the Internet that offer methods for testing SCRs and triacs using a multi meter. They basically involve checking the resistance of the device being tested to ascertain whether or not it is open circuit. Measuring the resistance between anode and cathode of a SCR or between the two main terminals of a triac, should indicate a very high resistance when measured in either direction by swapping round the meter probes.

In both tests the meter should register out of range resistances (usually indicated by the display showing ´1´ or ´OL´) also called infinity or infinite resistance. Similar resistance tests can be carried out by measuring the resistance, again in both directions, between the gate of an SCR and its cathode, or the gate and MT1 on a triac, and should indicate a much lower resistance, but not zero ohms.

If any of these four tests produce a reading of zero ohms it may be assumed that the component is faulty; however if the results show no faults this only means the component is PROBABLY OK. Resistance tests on these high voltage components are only of limited use and can only be relied on as a simple guide; they do not show that the device will be triggered at the correct voltage, or that the holding current is correct. SCRs and Triacs usually operate at mains (line) voltage and when they fail the results can be dramatic. At least the violent blowing of a fuse will be the usual result of a short circuit SCR or triac. It is quite possible however, for these devices to be faulty and not show any fault symptoms on an ohmmeter test. They may seem OK at the low voltages used in test meters, but still fail under mains voltage conditions. High voltage components such as SCRs and triacs may also be damaged by unseen voltage spikes or over current events.

The normal method of testing in equipment using SCRs or triacs would be the checking of voltages and waveforms if the circuit was operating, or substitution of a suspect part when damage (e.g. blown fuses) is apparent. In many cases components in power supplies or high voltage control circuitry of manufactured equipment will be designated "safety critical components" and must only be replaced using manufacturers recommended methods and components. It is common for manufacturers to specify complete "service kits" of several semiconductor devices and possibly other associated components, all of which must be replaced, since the failure of one power control device can easily damage other components in a way that is not always obvious at the time of repair.

ANY WORK ON MAINS POWERED CIRCUITS MUST BE DONE WITH THE MAINS SUPPLY FULLY DISCONNECTED. ALSO ANY CHARGE STORING COMPONENTS (e.g. CAPACITORS) SHOULD BE DISCHARGED UNLESS THIS IS ABSOLUTELY UNAVOIDABLE.

If you have not been trained in the safe working practices that are essential for work on these types of circuit DON'T DO IT! These circuits can kill!

Module 6.4
Triac Circuits

What you'll learn in Module 6.4

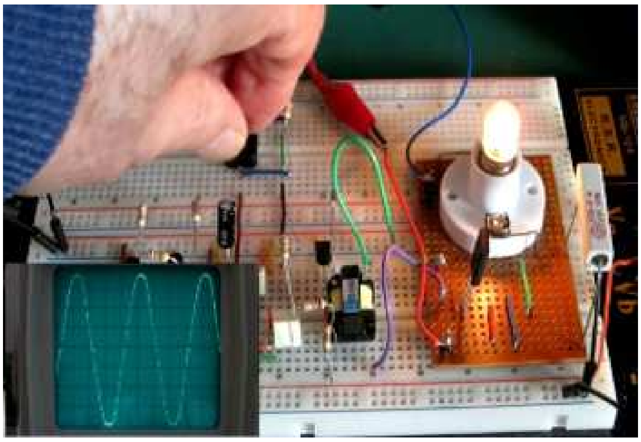
After studying this section, you should be able to:

Describe Phase Control in triac circuits:

Describe Hysteresis in basic triac control circuits:

Understand how hysteresis may be minimised in triac circuits:

Understand timer-based circuits for triggering sensitive gate triacs.



Basic Diac-Triac Dimmer Circuit

A basic power control circuit using a triac and diac is shown in Fig. 6.4.1. The capacitor C1 is charged via the variable resistance comprising R1 and R2, in either a positive or negative direction alternately by the AC input voltage. Current pulses created by the diac each time the capacitor voltage (V_C) reaches either the positive or negative break over potential of the diac (+/-V_{BO}) are used to trigger a triac.

The time (or phase angle) at which this happens will depend on how quickly the voltage across the charging capacitor C1 in Fig. 6.4.1 charges up. This is controlled by the variable resistor R2 and creates a variable 'Phase Control' method similar to that described in SCR Module 6.2 for SCR triggering. The AC mains waveform is effectively delayed or phase shifted by the RC circuit so that the diac is triggered by a discharge of current from the capacitor C1 into the triac gate. The triac then conducts for the remainder of the mains half cycle, and when the mains voltage passes through zero it turns off. Some time into the next (negative) half cycle, the voltage on C1 reaches break over voltage in the opposite polarity and the diac again conducts, providing an appropriate trigger pulse to turn on the triac. By varying the point in the waveform at which the triac is triggered in this way, the amount of power delivered to the load can be varied.

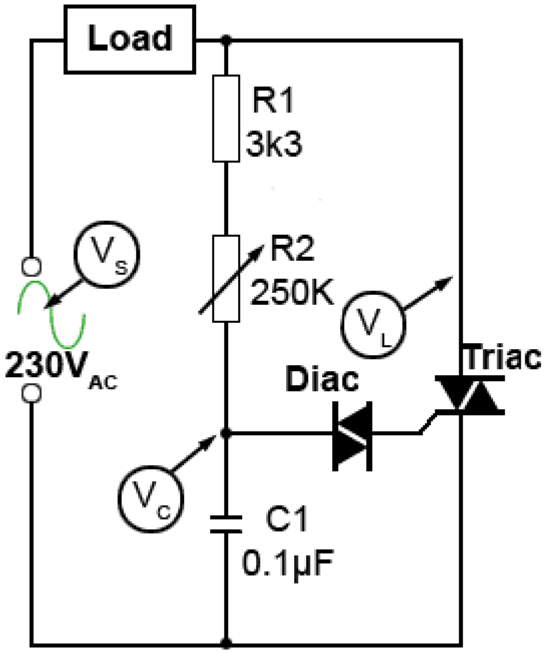


Fig.6.4.1 Basic Triac Phase Control Circuit

Phase Shift Control

Using a basic design such as that shown in Fig 6.4.1, adjustment of the power output is possible by varying the amount of phase shift produced by the RC phase shift network R (comprising R1 and R2) and C1. As R2 is adjusted the total resistance (R) will vary between 3.3K ohms when R2 is at zero ohms, and 253.3K when R2 is at maximum resistance and producing a phase shift of almost 90°.

The value of C1 is chosen so that when it is charged up to at least the break over voltage of the diac (V_{BO}) it can supply enough current for the diac to trigger the triac without being totally discharged. However, as the phase shift of the AC waveform across C1 increases towards 90°, the amplitude of the phase shifted wave will decrease, (as can be seen by comparing Figs. 6.4.2. and 6.4.3) but its minimum amplitude must still be equal to or greater than V_{BO}.

The value of R1 is chosen to give only a few degrees of phase shift when R2 is adjusted to its minimum resistance (zero ohms), and the maximum value of R2 is selected so that together with R1, the amount of phase shift produced is as close to 90° as possible without letting the peak to peak voltage of the waveform V_C fall below $+V_{BO}$ and $-V_{BO}$.

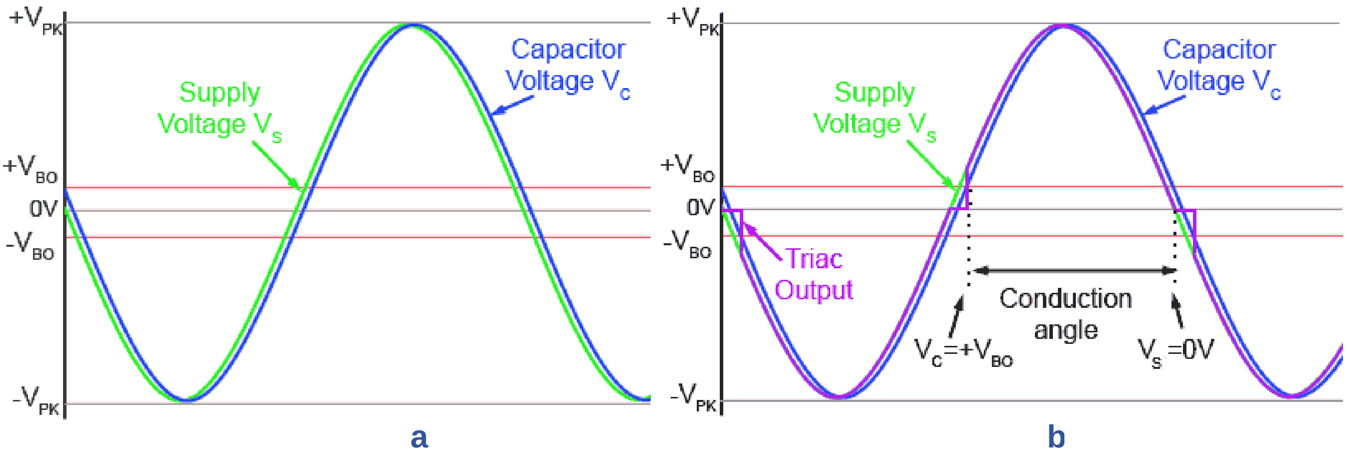


Fig.6.4.2 Waveforms at Maximum Power (R_2 at Minimum Resistance)

Typical waveforms for the triac phase control circuit in Fig.6.4.1 are shown in Fig. 6.4.2 and Fig. 6.4.3. Figure 6.4.2 shows the supply voltage (V_S) and the phase shifted voltage (V_C) appearing across the capacitor C1 when R2 is set at minimum resistance. Note that there is very little difference between V_S and V_C. The blue waveform (V_C) is approximately the same amplitude as V_S (shown in green), and the phase shift is not much greater than 0°. Hover the PC mouse over Fig 6.4.2a (or ´touch´ on a touch screen) to view the effect on the output waveform.

In Fig. 6.4.2b the triac output waveform (purple) is added and shows that the triac is triggered early in the positive half cycle at the point where $V_C = +V_{BO}$ (the diac positive break over voltage,) which will be approximately +30V, depending on the diac used. At this point capacitor C will discharge current into the diac, causing a positive trigger pulse at the triac gate. The triac switches on and the output waveform is then practically identical to the supply voltage V_S (apart from the very small voltage drop across the triac) until V_S returns to 0V at the end of the positive half cycle when, because the current through the triac is now less than the triac´s holding current, the triac switches off.

A short time later, the triac switches on again when $V_C = -V_{BO}$ (the diac negative break over voltage,) at about -30V, C discharges current into diac and the triac switches on once more. The result is that the output waveform is practically the same as the input waveform apart from two short periods of time around the time the waveform passes through zero volts. This therefore applies maximum power to the load, which will be indistinguishable to applying full mains (line) potential to the load.

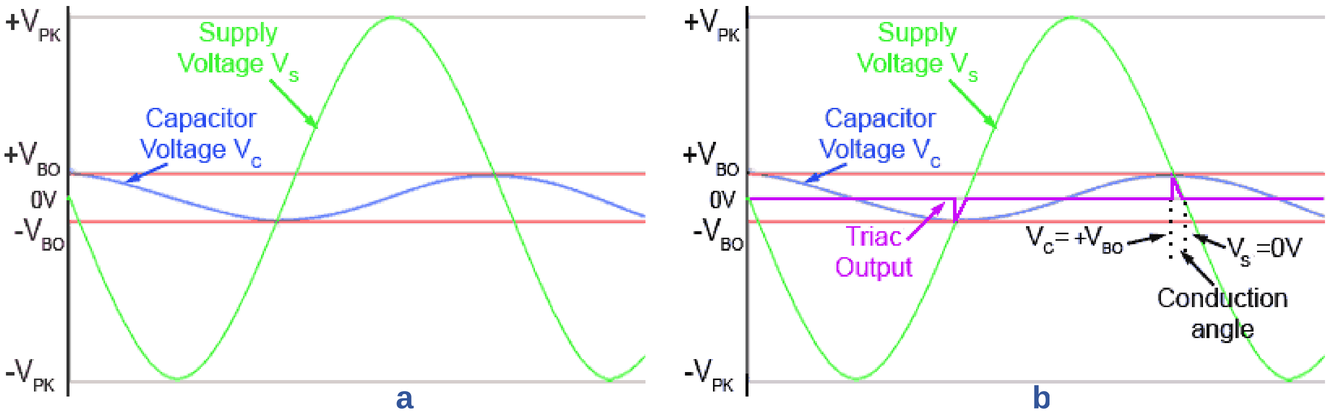
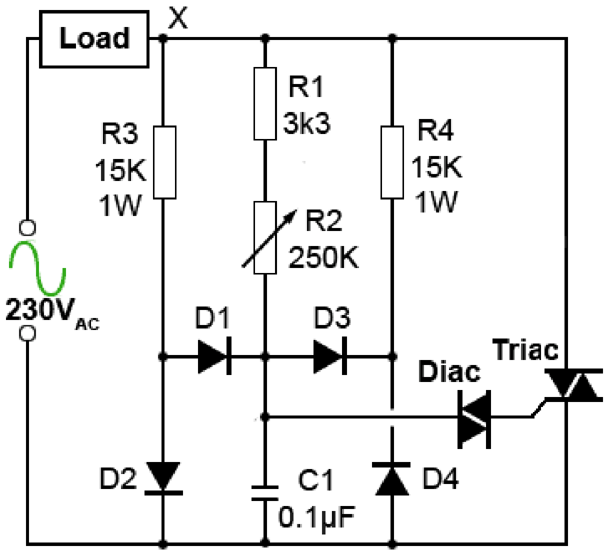


Fig.6.4.3 Waveforms at Minimum Power (R_2 at Maximum Resistance)

Fig. 6.4.3 shows the phase control waveforms relating to Fig. 6.4.1 with R2 at maximum resistance (250KΩ). Here the RC network (R1+R2)C has caused a phase shift of nearly 90° but reduced the amplitude of Vc so that it is still just enough to cause the peaks of the wave to reach VBO so that the triac can still be triggered. Looking at the output wave (Fig. 6.4.3 b) it can be seen that when the capacitor voltage VC coincides with -VBO close to the end of a negative half cycle of VS the triac is triggered and the triac output voltage takes up the instantaneous value of VS. As VS is already close to zero volts, the triac switches off again as its current drops below the holding current (IH) to zero. The triac remains in its off condition until it is triggered once more as VC coincides with +VBO, so starting another very short, but this time positive pulse at the end of the positive half cycle. The triac output is therefore at its minimum condition.

Hysteresis Problems

There is however a problem with this basic triggering circuit, although it is widely used in many domestic lamp dimmers. The problem occurs because when C1 is partially discharged into the diac there will be some charge remaining on C1 and when V_S passes through zero and begins to charge C1 in the opposite polarity, this remaining charge will oppose the build up of the opposite polarity charge on C1. Therefore triggering during the next half cycle will be delayed, causing unequal conduction angles, especially during the initial turn on cycles of the mains waveform. This hysteresis effect causes a difference between the amount of conduction occurring in the positive and negative half cycles, which also means that the AC wave at the triac output will not be centred on zero volts, but will effectively have a varying and unwanted DC component.



Note: C1 and Diodes D1 to D4 should be rated at 400V or more

Fig 6.4.4. Eliminating Hysteresis in Triac Dimmers

This hysteresis effect can be eliminated however, using the circuit from a detailed application note from Littelfuse shown in Fig. 6.4.4. Here the capacitor C1 is fully discharged every time V_S passes through zero. If the charge on the top plate of C1 is positive and point X is at zero volts, C1 will discharge to 0V via D3 and R4. If the charge on C1 is negative when X = 0V, C1 will be discharged via D1 and R3.

When point X is either positive or negative C1 cannot be charged via D1 or D3 as the voltages at the bottom of R3 and R4 will be held within about +/-0.6V of zero due to the forward conducting voltage of either D2 (during the positive half cycle) or D4 (during the negative half cycle). C1 is therefore always charged via R1 and R2.

Note that in practical control circuits using Thyristors, Triacs and Diacs, large voltages are switched very rapidly. This can give rise to serious RF interference, and steps must be taken in circuit design to minimise this. Also as mains (line) voltage is present in the circuit there must be some form of safe isolation between the low voltage control components (e.g. the Diac and phase shift circuits) and the mains ´live´ components, e.g. the triac and load. This can easily be achieved by "Opto-coupling" a low voltage control circuit to the high voltage power control part of the circuit, and/or using isolating components such specially designed pulse transformers as described in SCR Module 6.2

Triggering a Sensitive Gate Triac

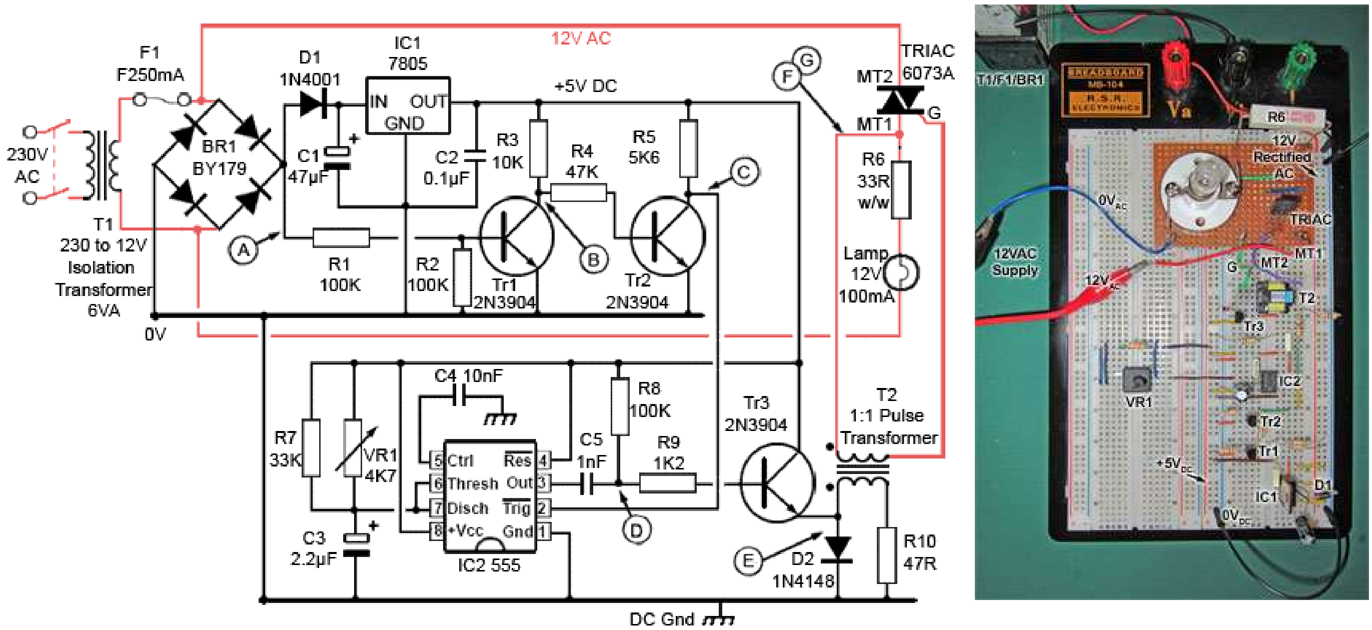


Fig. 6.4.5 Triggering a Sensitive Gate Triac

The circuit in Fig. 6.4.5 demonstrates a low voltage dimmer control by triggering a SN6073A sensitive gate triac in quadrants II and III. Control is achieved over practically 180° of both positive and negative half cycles of the wave as shown in the circuit waveforms F and G in Fig. 6.4.7.

Fig. 6.4.5 uses a variation on the low voltage triggering techniques demonstrated for SCR triggering in Thyristor Module 6.2 but this time driving a sensitive gate triac, which is triggered from a low voltage analogue circuit comprising a transistor zero crossing detector (Tr1), which switches off each time waveform A falls close to 0V, producing a series of positive pulses at its collector (waveform B), coinciding with the AC wave zero crossing points.

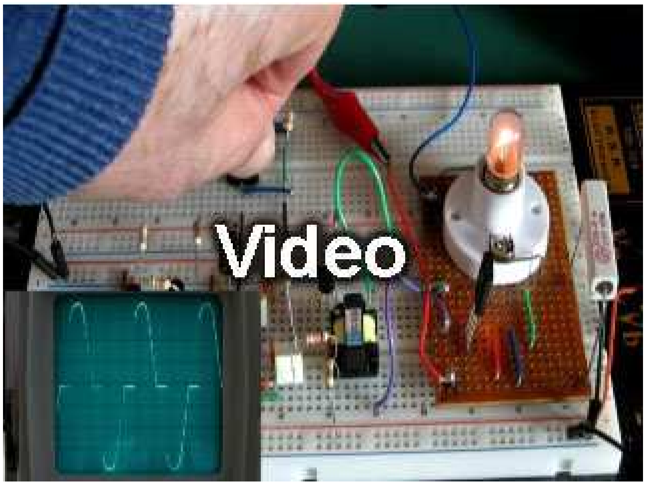
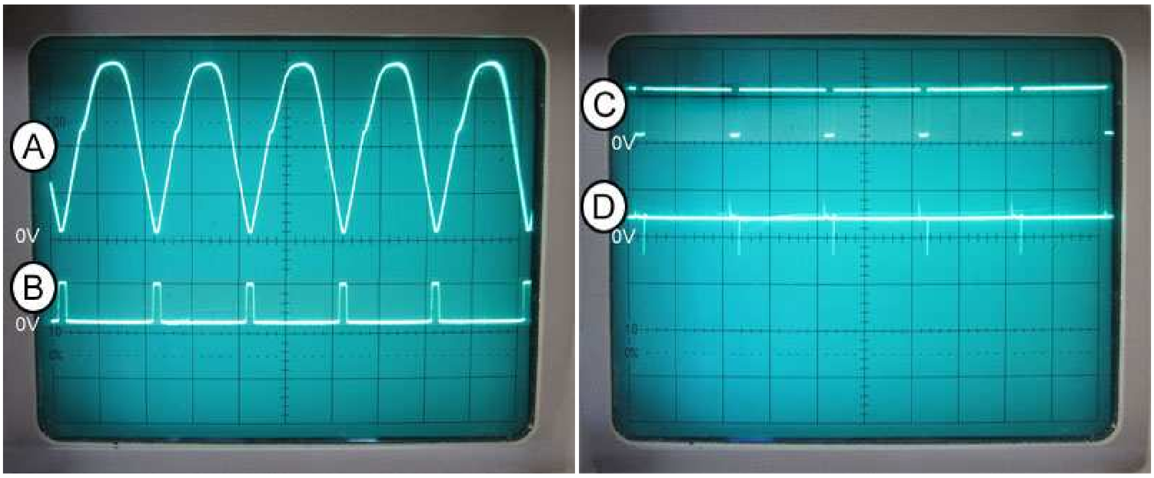


Fig. 6.4.6 Triggering a Sensitive Gate Triac Video available on line

These pulses are then inverted by an inverting amplifier (Tr2) to produce negative going synchronising pulses (waveform C) are used to trigger a variable delay monostable (555 timer IC1) to produce variable width square pulses having a width (and therefore time delay) controlled by VR1. The square pulses produced by IC2 are conditioned by a differentiator C5/R8 to produce narrow positive and negative going pulses (waveform D).

These pulses are amplified by a current amplifier (emitter follower) Tr3 and the unwanted positive part of the waveform is removed by D2. The resulting negative going pulses drive the triac gate via an isolating pulse transformer T2 (waveform E). The whole trigger circuit is fed from a 12V AC source derived from an isolating transformer T1. The bridge rectifier BR1 supplies a 100Hz half wave waveform for the zero crossover detector, and a 5V DC stabilised supply via D1 and IC1, eliminating the need for a second low voltage DC supply. Fig 6.4.7 also shows the triac output waveforms at maximum power (F) and minimum power (G).



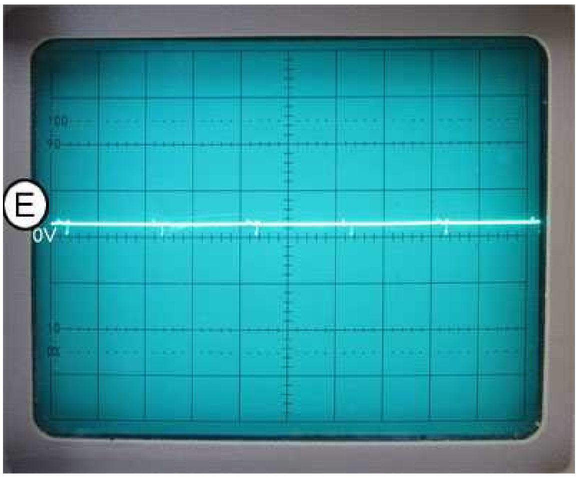
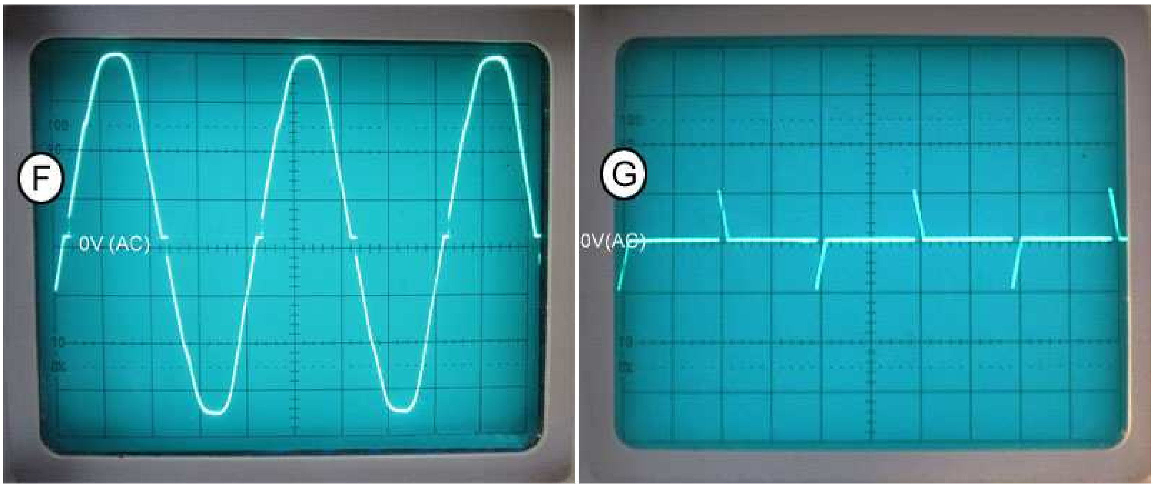


Fig. 6.4.7 Sensitive Gate Triac Triggering and Output Waveforms



Module 6.5
Thyristor Protection

What you'll learn in Module 6.5

After studying this section, you should be able to:

Recognise over voltage & over current conditions in SCRs:

- High voltage spikes.
- Voltage surges.
- Causes of high current.

Identify typical components for preventing over voltage and over current.

Understand potential hazards in protection methods

Describe methods for improving safety in protection methods.

Thyristor Protection

Thyristors usually operate in high voltage, high current conditions. In controlling AC supplies the SCRs or triacs may be affected by, and damaged by a variety of randomly occurring over voltage and/or over current conditions. Therefore circuits using thyristors will normally use a variety of safety devices to protect circuits being controlled by a SCR or triac from damage. In addition, as thyristor action can also cause electrical interference, measures may also need to be taken to minimise this.

A number of these safety features are described in Semiconductors Module 5.5, in addition to these, two more commonly used components, the MOV (metal oxide varistor) and the PPTC (polymer positive temperature coefficient) resistor are described below.

Over Voltage

The mains (line) supply can cause a number of over voltage conditions; these may be sudden voltage spikes, as shown in waveform (a) in Fig. 6.5.1. which although they may be very short in duration can comprise very high voltages and large amounts of electrical energy. These voltage spikes may be due to natural causes such as lightning discharges, or locally sourced events such as the switching of inductive loads e.g. electric motors. Voltage spikes can be many times a thyristor's maximum peak voltage and so potentially damage the thyristor. Even when the voltage spike is not large enough to cause permanent damage, if it exceeds the break-over voltage of the thyristor, this could cause it to switch on prematurely.

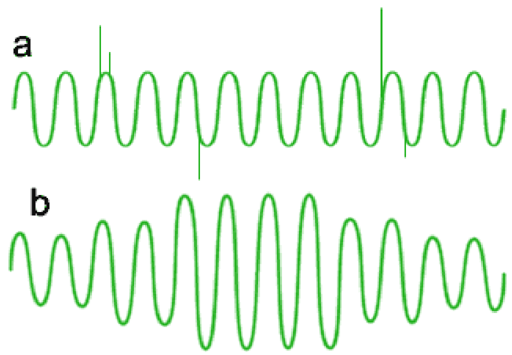


Fig. 6.5.1 Over Voltage Spikes and Surge

Another type of over voltage event that could happen is a voltage surge, see waveform (b) in Fig. 6.5.1 when a higher than normal voltage lasts longer than a voltage spike, and can be caused by faults on the supply grid.

The Metal Oxide Varistor (MOV)

A common safety component used to protect mains (line) driven thyristor circuits from either of these over voltage conditions is a resistive voltage-clamping device such as the MOV (Metal Oxide Varistor), illustrated along with its circuit symbol in Fig. 6.5.2, which acts as a non-linear resistor, meaning that the relationship between current and voltage in the MOV is not linear, but changes at different applied voltages.

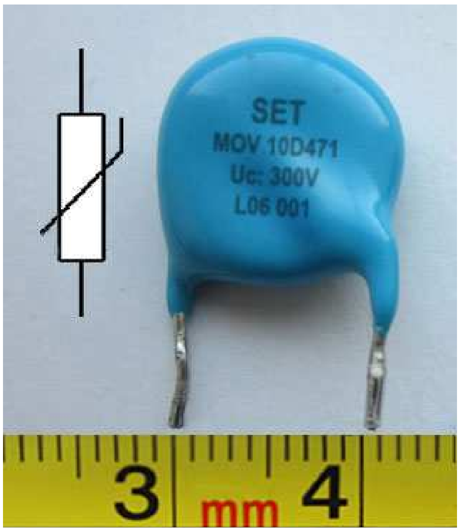


Fig. 6.5.2 Metal Oxide Varistor

As shown in Fig. 6.5.3, a MOV looks very similar to a ceramic disc capacitor, and has some similarities in construction. The MOV has two parallel disc shaped plates just like a small ceramic capacitor, but the ceramic material between the plates of a MOV is impregnated with tiny grains of a metal oxide such as zinc oxide (ZnO) and (in much smaller amounts) another metallic oxide such as either cobalt oxide (CoO) or manganese oxide (MnO).

This has the effect that the junctions between the two types of metal oxide grains used produce many tiny diodes that are randomly oriented and so combine to form many series and parallel forward and reverse biased diode networks. Therefore when a low voltage is applied to the conducting plates, only a very small current (the reverse leakage current of the diodes) flows, but above a certain critical voltage, called the Varistor Voltage, the diode junctions within the ceramic material break down allowing a large current to flow.

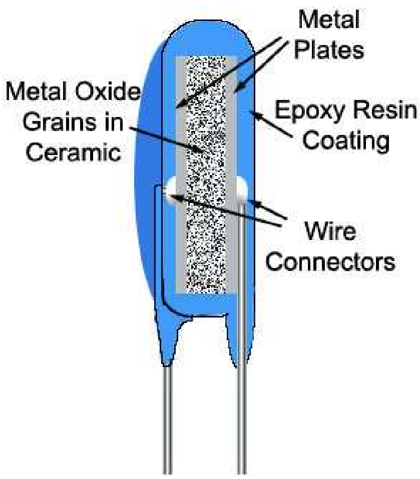


Fig. 6.5.3 MOV Construction

Therefore the MOV has a very high resistance below the varistor voltage and a very low resistance above it. This voltage is specified for any particular MOV as the voltage at which a current of 1mA flows through the MOV.

Typical voltage/current characteristics for a MOV are shown in Fig. 6.5.4 where the MOV described by these characteristics has a varistor voltage of 300V. Therefore between -300V and +300V there is no perceptible change in current, indicating that the MOV has a resistance approaching infinity, but at higher voltages (in either polarity) than the 'Varistor Voltage' specification, a large current flows with hardly any further change in voltage. The MOV in this region therefore has a very low resistance.

To protect a thyristor, a MOV would be chosen with a varistor voltage higher than the maximum operating voltage, but lower than the break-over voltage of the thyristor.

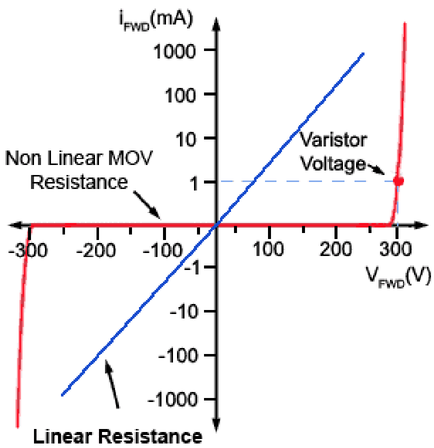


Fig. 6.5.4 MOV Characteristics

MOV Capacitance

Because the structure of a MOV is similar to that of a ceramic capacitor, the capacitance of a MOV has a significant effect in slowing the response time of its operation. It has more capacitance than a zener diode for example, which can be an advantage or disadvantage. In protecting DC circuits the capacitance of the slower response time of a MOV can be useful in reducing the amplitude of short duration over voltage spikes. In high frequency applications such as data line protection, the extra capacitance of a MOV across the lines could severely limit its ability to pass high frequency data.

MOV Hazards

However, although MOVs are useful in controlling over voltage events, their use does have some problems. When a voltage spike or surge occurs, the high voltage will also produce a high current through the temporarily low (but not quite zero) resistance MOV for the time that the over voltage condition exists. This means that during that time, there will also be a high current through the MOV. Therefore voltage current and time are all involved, so the spike could more properly be described as an energy spike, with the amount of energy involved measured in joules rather than simply in volts, so MOVs are rated in joules as well as in volts.

Fig. 6.5.5 MOV Destroyed by Fire

In protecting against these high-energy events the MOV must dissipate a large amount of energy in a very short time. This causes a large amount of heat to be generated in the MOV, and if this heat cannot be dissipated quickly enough, or the over voltage continues for more than a very short time, the MOV can go into thermal runaway, where the increase in temperature causes an increase in current, which in turn causes a further increase in temperature, leading to so much current that the MOV is rapidly destroyed, creating a fire risk, see Fig. 6.5.5. Even supposing the MOV is totally destroyed without catching fire, but becomes open circuit, there is then the situation that the circuit it was protecting is now unprotected against the next over voltage event.

A MOV is very effective in eliminating short spikes in voltage, provided that the voltage does not go too high or last too long, but cannot be expected to deal with events such as direct or nearby lightning strikes, nor will they survive prolonged over voltage conditions due to power surges.

Extra Protection for MOVs

To minimise the fire risk in MOVs, they must in turn be protected by at least a second safety device. This may be a fuse, which will blow to cut off current to the circuit in the event of too much current flowing. Fuses can either act immediately in the case of fast blow fuses, typically marked F250mA for example on a 250mA fast blow fuse, see example (a) in Fig. 6.5.6 or after a short time of over current, often necessary to avoid the fuse blowing due to normal current surges at switch on of the equipment. Anti-surge fuses can vary in construction, but a typical anti-surge fuse is shown in example b in Fig. 6.5.6. Note the spring device inside the fuse and the letter 'T' before the indicated current rating embossed on one of the end terminals, denoting 'time delay'.

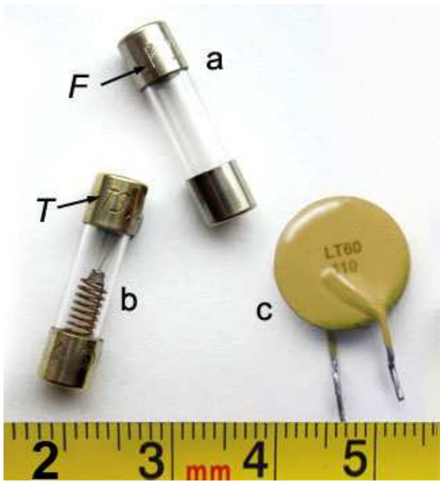


Fig. 6.5.6 MOV Protection

Fuses are a simple 'one off' over-current protection device; once a fuse inside a piece of electronic equipment fails, it generally requires the attention of a service technician, not just to replace the fuse but to diagnose the fault that caused the over-current. This human intervention provides an extra layer of protection in what could be a dangerous condition.

Polymer based positive temperature coefficient (PPTC) resistors (example c in Fig. 6.5.6) are also available to provide over-current protection, these components act thermally in rapid response to the extra heat caused by the over current, but instead of failing permanently like ordinary fuses, they can reset themselves after the over-current situation has ended.

These devices, also called Multifuses or Polyfuses (Manufacturers names), are basically resistors made by using a polymer material impregnated with carbon granules. In PPTCs their resistance remains low at normal temperatures, as the carbon granules in contact with each other form low resistance chains across the device, but when a specified high temperature is reached, due to high current flow, the polymer expands to a point where, the carbon granules are separated and the resistance though the device rapidly increases to a very much higher value, cutting off current flow almost completely until the PPTC is allowed to cool once more.

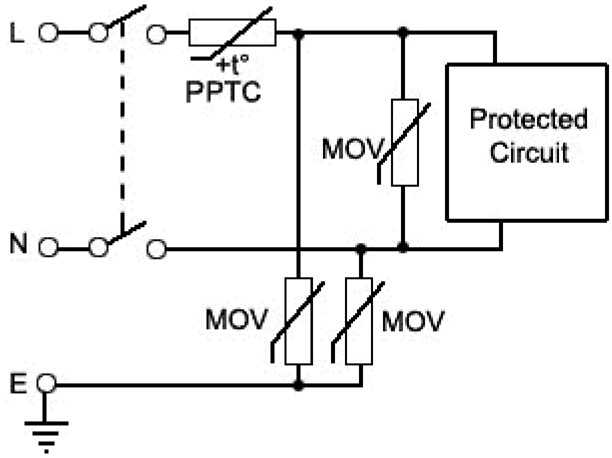


Fig. 6.5.7 PPTC Over Current Protection

Then the carbon granules reconnect and the low resistance pathways return once more. These thermal cut off devices may be used in series with the supply, to protect the whole circuit, as shown in Fig. 6.5.7 or may be combined within the MOV (called a TMOV or thermally protected MOV) in which case the thermal protection only applies to the MOV itself. The time to trip (TtT) taken for the PPTC resistor to 'trip' into its high resistance state will typically be in a range from one millisecond to around 10 seconds. The trip time for any given device will be approximate, as it will also depend on external factors such as fault current and ambient temperature.

Gas Discharge Tubes (GDTs)

MOVs are efficient at suppressing voltage spikes up to a few hundred volts but for over voltage spikes and surges induced by distant lightning strikes it is necessary to use devices such as Gas Discharge Tubes (GDTs). These surge arresters (illustrated in Fig. 6.5.8) are small ceramic or glass tubes filled with an inert gas between two electrodes, which has an almost infinite resistance up to its particular breakdown or spark-over voltage, but above this limit will conduct heavily.

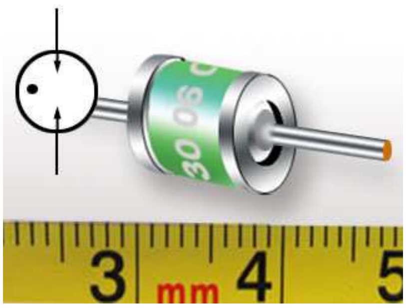


Fig. 6.5.8 Gas Discharge Tube (GDT)

GDTs are available over a range of breakdown voltages from around 75volts up to several thousands of volts, depending on the gas used, its pressure and the physical dimensions of the tube.

Snubber Circuits

Another method for reducing the impact of voltage spikes on SCR operation is to use a RC snubber circuit across the SCR or triac as shown in Fig. 6.5.9. In this simple circuit the correct choice of RC time constant can reduce the amplitude of voltage spikes by diverting the energy produced by the high voltage and current into charging the capacitor over the time duration of the over voltage, by partly charging the capacitor (and therefore reducing the amplitude of the voltage across the circuit during the charge) then releasing the stored energy back to the circuit at a controlled rate via the resistor.

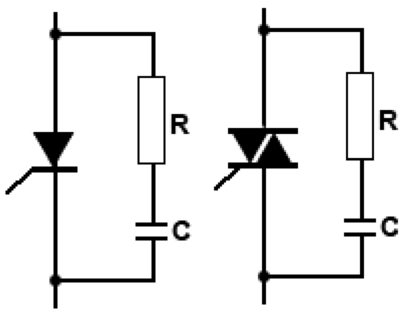


Fig. 6.5.9 SCR Snubber

The overall effect being to substantially reduce the amplitude of any random over voltage spikes. More information on snubber circuits is available in Thyristor Module 6.6 RC Snubber Circuits.

Module 6.6
Opto Coupled Devices

What you'll learn in Module 6.6

After studying this section, you should be able to:

Describe typical uses for Opto Triacs:

- Electrical isolation.
- Switching capability.
- Typical construction.

Describe typical features of Solid State Relays:

- Electrical isolation.
- Switching AC and DC loads.
- Typical parameters.

Describe typical safety features used in solid state relays (SSRs):

- Reverse Polarity Protection.
- Over Voltage Protection.
- Transient Voltage Suppression.
- Snubber circuits.
- Zero voltage crossing.

Describe Basic measures for testing IC based Optocoupled devices.

- Basic tests.
- Safety considerations for medium and high voltage devices.

Opto Triacs and Solid State Relays.

Devices that are used in the control of high voltage/high power equipment need to have good electrical insulation between their high voltage output and low voltage input. Relying on a layer of silicon oxide, a few atoms thick to provide the required insulation is not really an option in such conditions. When faults occur (and they are more likely to do so in high power circuits) the results can be catastrophic, not only to the circuit components but also to the users of such equipment. Physical isolation (meaning that there is no **electrical** connection at all between the input and output) is what is needed. Fortunately there are readily available solutions to this problem. Many high power circuits today are controlled by low voltage, low current circuits such as microprocessors, using opto electronic devices such as Opto−Triacs, Opto−Thyristors and Solid State Relays to isolate the low and high power circuits.

The control device must be able to handle the high voltages, including very high voltage spikes that may occur in either AC or DC output circuits due to back emf from inductive loads and voltage spikes that may be randomly present on the mains (line) power supply. Also high values of surge current (much higher than the normal 'running current') that occur for example when loads such as motors or incandescent lamps are switched on, can require that the control device must be rated to handle surge currents up to 40 or 50 times higher than normal ´running´ current. The control device chosen must also ensure electrical isolation between the input and output circuits. In addition to these criteria, the circuit around the control device must also provide safeguards against dangerous situations. For example, adequate heat sinks for the solid-state devices used. Also special very fast acting fuses or circuit breakers are needed to prevent damage to the semiconductors due to current overloads.

In this group of optocouplers, photo-triacs, photo-SCRs or photo-diode/MOSFET combinations replace the photodiodes and phototransistors described in Opto Coupled Devices Module 5, and are also readily available in integrated circuit (I.C.) form for switching relatively low power AC or DC loads. High power solid state relays (SSRs) illustrated in Fig. 6.6.2 use ICs such as those shown in Fig. 6.6.1 with extra ´built in´ circuitry to handle high voltage, high current loads safely and reliably.

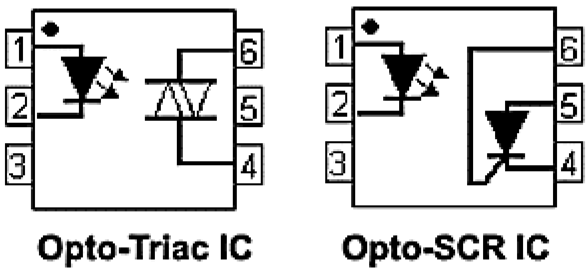


Fig. 6.6.1 Opto Triac & Opto SCR

Solid State Relays

Opto triacs and Opto SCRs are used for switching AC loads but solid state relays using power MOSFET transistors that can switch AC or DC are also available. Low power solid state relays, consisting basically of an opto triac circuit, such as the type illustrated in Fig. 6.6.1 can be used as conventional integrated circuits, mounted on a printed circuit board. Alternatively these low power optocouplers can be enclosed within an insulated case along with high power triacs or SCRs and extra safety components, such as heat sinks and pulse suppression components, in larger rack mounted Solid State Relays (SSRs) with just four or five screw type heavy duty terminals that can be treated as mains (line) power switches and can replace many types of electromechanical relays.

Fig. 6.6.2 Typical High Power SSR

One of the most important features of SSRs is for the optocoupling to provide complete electrical isolation between its low power input circuit and its high power output circuit. When the output switch is 'open' (i.e. the MOSFETs are turned off) the SSR has a **nearly** infinite resistance across its output terminals, and an **almost** zero resistance when 'closed' (i.e. MOSFETs conducting heavily).

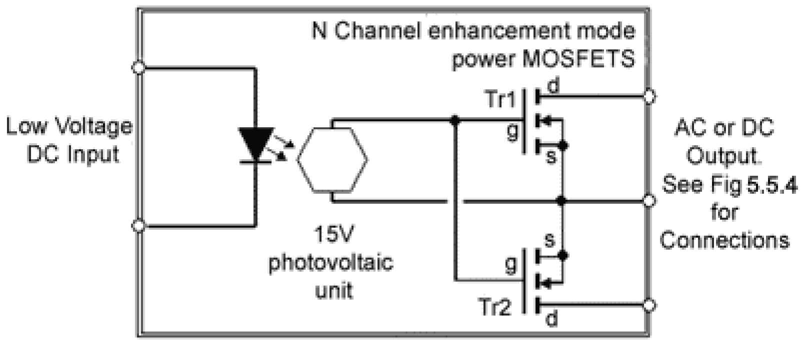


Fig. 6.6.3 MOSFET Solid State Relay

Even so, some power will be dissipated by the semiconductor switch when in either 'on' or 'off' state with either AC or DC currents. For this reason adequate heat sinks are required to prevent overheating.

A typical circuit of a basic MOSFET SSR is shown in Figure 6.6.3. A current of about 20mA through the LED is sufficient to activate the MOSFETs that take the place of mechanical relay contacts. The (infra red) light from the LED falls on the Photovoltaic unit that comprises a number of photodiodes. Because a single photodiode will only produce a very low voltage, the diodes in the photovoltaic unit are arranged in a series/parallel array to produce sufficient voltage to turn on the MOSFETS.

Figure 6.6.4 represents a basic example of a MOSFET SSR, showing how the outputs can be arranged to allow the SSR to switch either AC or DC loads. A number of similar SSRs are available to meet different AC and DC output voltage and current requirements, a typical example is the PVT412 SSR from International Rectifier (now part of Infineon Technologies) manufactured in several versions as a 6 pin DIL package and

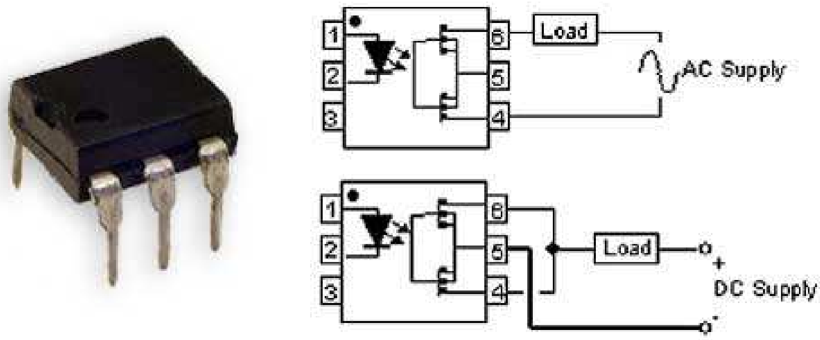


Fig. 6.6.4 Using a MOSFET Relay chip for switching A.C. or D.C.

capable of replacing a single pole mechanical relay to switch AC or DC voltages up to 400V (peak) with currents up to 140mA AC or 210mA DC. Other chips are available that act as double pole, Normally Closed (NC), Normally Open (NO), and Changeover relays with a wide variety of extra facilities. SSRs are also manufactured in a range of output voltages and current ratings, with a range of package types ranging from small surface mount components through complex multi pin chips and large heavy current examples for rack mounting in electrical control cabinets. More information on SSRs can be found by searching for Solid State Relays on manufacturers websites such as Infineon Technologies or at semiconductor suppliers such as RS Components

SSR Safety Features

SSRs consist basically of an optocoupler driving some high power switching device such as a power triac, MOSFETS or a SCR, but as their purpose is to switch high power electrical loads, often in safety critical situations SSRs are manufactured with a wide variety of features, designed to allow for safe and reliable operation. Some of these are illustrated in the circuit shown in Fig 6.6.5:

Reverse Polarity Protection. If the input terminals are connected in the wrong polarity, diode D1 conducts and reduces the voltage at the bottom of R1 to about 0.7V, thereby saving the optocoupler LED from damage. Note that the diode and the current limiting resistor R1 power ratings must be able to withstand the reverse polarity current at maximum input voltage without damage, otherwise a suitably rated input fuse may be inserted between the input positive terminal and the current limiting resistor.

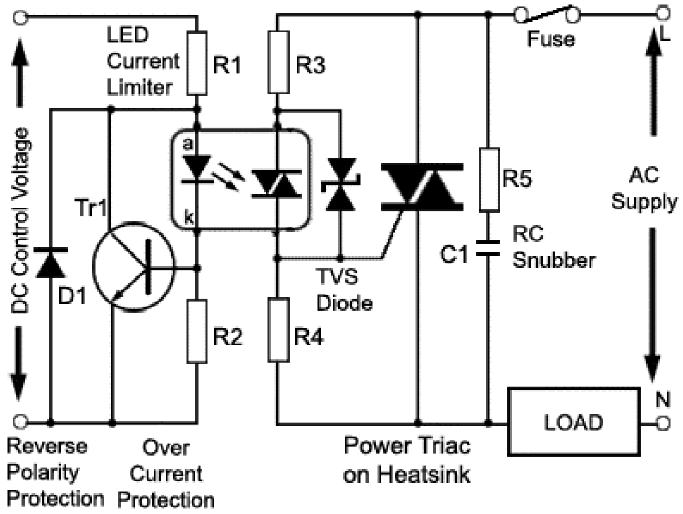


Fig. 6.6.5 Solid State Relay Safety Features

Over Current Protection. It is common for SSRs to be able to work from a range of DC input voltages, for example 5v to 24V. These higher voltages can cause the current through the optocoupler LED to rise higher than its required maximum, in this case the over current protection circuit operates to maintain a suitable current level through the LED. R2 is a low value resistor for current sensing; it's value is chosen so that under normal operating conditions Tr1 is biased just below its cut-off threshold, but if the current through the optocoupler input LED increases due to an excessive input voltage, the extra current through R2 will cause Tr1 to conduct, diverting some of the LED current through Tr1 reducing the voltage at the bottom of R1 and the current though the LED to a safe level.

Transient Voltage Suppression (TVS) Diode. SSRs used in control situations can be liable to damage caused by sudden and short lived (i.e. transient) voltage spikes, which can be caused by external events such as back emf pulses when switching inductive loads; also remote lightning discharges and other electromagnetic or electrostatic discharges are high risk occurrences for semiconductor devices. Such voltage spikes may be very short in duration but can be hundreds or thousands of volts in amplitude, and although the current they create may be very small, the stress caused by such voltages can cause total failure in the semiconductor devices used in SSRs. One way to reduce these dangerous events is the use of a transient voltage suppressor (TVS) diode connected in parallel with sensitive devices such as the optocoupler as shown in Fig. 6.6.5.

Fig. 6.6.6 illustrates the action of the TVS diode, and shows a sine wave output superimposed on the TVS diode characteristics. The bi-directional TVS diode works rather like two back to back Zener diodes, where above a certain reverse voltage, current breakdown occurs and the diode conducts heavily. As the TVS diode in this case is bi-directional, breakdown occurs in both forward and reverse conditions.

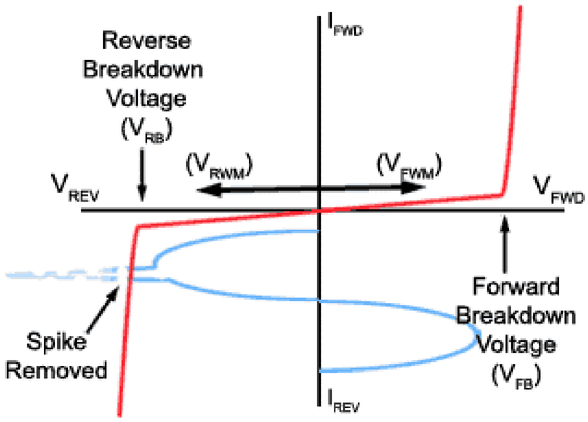


Fig. 6.6.6 Transient Voltage Suppression

In use, a TVS diode must have a breakdown voltage higher than the peak voltage of the AC wave, which is 1.414 x V_{RMS} so a TVS diode with a breakdown voltage about 1.5 times greater than the RMS voltage of the sine wave is normally used.

A voltage spike exceeding this limit causes the diode to conduct heavily, limiting its voltage to the breakdown voltage of the diode. A notable difference between a Zener and a TVS diode is that the TVS diode has a more rugged junction area, to cope with the sudden heavy current rush during spike events. Once the spike is over however, the diode stops conducting (apart from a small reverse leakage current) and has no further effect on the output wave until any further spikes occur. TVS diodes are also available in single directional types that may also be used in the input side of the optocoupler in SSRs using a DC input if there is high risk of spikes occurring. However, because the DC input is usually fed from a smoothed DC power supply, this would normally be expected to minimise the risk, therefore the use of TVS diodes across the input components is rarely considered necessary.

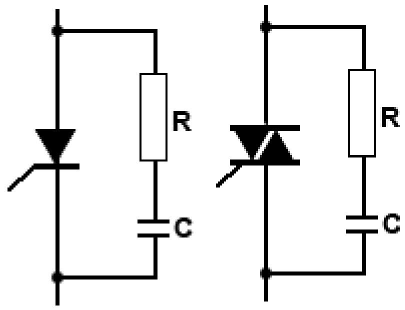


Fig.6.6.7 RC Snubber Circuits

RC Snubber Circuits. These circuits provide a method of reducing the damaging effect of spikes occurring on the AC mains supply, or the very large and fast voltage changes that can occur when an inductive load is switched on or off (Commutated). With older types of triacs or SCRs this RC network (R5 and C1) is connected across the output triac or SCR as shown in Fig. 6.6.5 and Fig 6.6.7. Its effect is to slow the rapid increase or decrease of voltage during the spike. The use of a snubber circuit can also reduce the radio interference caused by the triac or SCR switching. By choosing a suitable time constant for R5/C1 the capacitor will not have time to charge as the spike voltage rises, before the voltage is reducing once more and discharging the capacitor. In this way the amplitude of any fast voltage spikes is reduced. Typical values for R would be about 39 to 100Ω for R5 and 22 to 47nF for C1. The capacitor would also need to be a pulse type having a very high maximum working voltage, much higher than the peak value of the output wave, to allow for the added stress caused by any voltage spikes. The design of snubber circuits is more complex however, than simply choosing typical R and C values, and must take into account a number of factors that will be unique to the circuit or component the snubber is protecting and to the loads the circuit may be driving. A useful application note on snubber design and component calculator is provided on line by HIQUEL (High Quality Electronics).

Alternistors

Alternatively there are modern Triacs available, which can also be called ´Alternistors´ or ´Alternistor Triacs´ that are much less prone to damage or random false triggering caused by fast transient voltages. Several semiconductor manufacturers have their own range of devices, such as the ´Snubberless$_{TM}$´ range from ST Microelectronics or the ´Hi-Com$_{TM}$´ range from WeEn Semiconductors that are able to handle the voltage spikes as well as the fast dV/dt events encountered during commutation (switch off) with inductive loads. The internal design of these triacs is different to the original types, making them much better at handling the fast high voltage changes that can happen as inductive loads are switched off, due to the phase difference between current and voltage in inductors. In this case it is possible that when the triac switches off as the mains (line) current passes through zero volts, the mains voltage across the triac can be at its maximum value. While such events in original triac designs could cause problems with uncontrolled re-triggering, this has been greatly reduced in modern designs.

Zero Voltage Crossing. Some SSRs include 'Zero Crossing' or 'Synchronous Switching' circuits, which reduce the possibility of introducing fast changing 'spikes' onto the mains (line) supply by ensuring that their output will only switch on as the mains voltage cycle passes through zero volts. As shown in Fig. 6.6.8 if the control voltage requests a switch on at a time during the voltage cycle when the AC voltage is not passing through 0V, the switching action is delayed until the voltage next crosses 0V at end of the present half cycle. The zero voltage crossing circuit does not play any part in switching the output off however; this is controlled by the action of the triac or SCR, which once turned on will only turn off when the output load current falls below the triac or SCR's specified holding current, which it will do as the current waveform passes through zero.

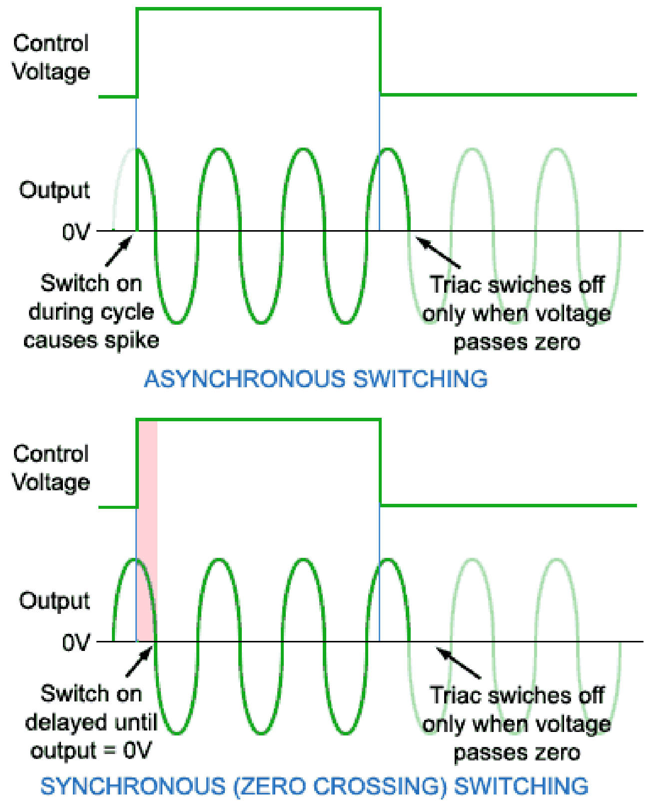


Fig. 6.6.8 SSR Zero Crossing Action

The above descriptions of safety features are intended to introduce users of SSRs to some of the necessary safety constraints when choosing the right SSR for any particular operation. However this list is not offered as a comprehensive guide, the importance or non-importance of any of these factors will depend very much on the intended use of the SSR. It is advisable therefore, especially when considering the safe operation of circuits, to obtain advice specific to the intended project, many manufacturers or national and international safety agencies can readily give qualified advice on the suitability of SSRs for particular uses. You are also encouraged to further study by following some of the recommended links at the bottom of page 37.

Solid State and Mechanical Switching Compared

Solid State Relays (SSRs) have a number of advantages over electromechanical relays, some of which are obvious advantages and some that would be disputed by adherents to (and manufacturers of) electromechanical relays. Which type of relay is better for a particular application however, depends more on the application rather than the type of relay. This should therefore be carefully considered when reading the following lists.

Advantages of SSRs against electromechanical relays.

1. Because SSRs have no inductive coils or moving contacts they do not generate electromagnetic interference.
2. SSRs do not cause any potentially dangerous arcing.
3. SSRs are silent in operation.
4. SSRs are not subject to mechanical wear, so will potentially perform many more switching operations than electromechanical relays (however either type may be designed to perform more operations than is required during the lifetime of the equipment they are used in).
5. SSRs do not suffer from contact bounce.
6. SSRs have a faster switching time than electromechanical relays.
7. For switching AC, Zero Crossing SSRs are available that only switch on at, or close to the time when the AC waveform passes through zero volts, so reducing the occurrence of voltage spikes that occur if a circuit is switched on when the AC voltage is at a maximum.
8. SSRs can be physically smaller than comparable types of electromechanical relays.

Disadvantages of SSRs against electromechanical relays.

1. When SSRs are switched on there is a measurable resistance between the output terminals, therefore SSRs produce some heat as well as a voltage drop in their ‘on’ condition.
2. When SSRs are in their ‘off’ state, there is still a small reverse leakage current flowing in the output. Unlike electromechanical relays, SSRs are therefore neither totally ‘on’ or ‘off’. Therefore they may not be permitted for use under some safety regulations.
3. Because SSRs are able to switch on very quickly (in milliseconds) random interference spikes in their input circuits or sudden fast voltage changes at their outputs can cause unwanted switching of some SCRs or triacs.
4. Failure of an SSR will usually cause a short circuit (switch on) whereas failure in an electromechanical relay will usually cause an open circuit (switch off). Because of this, using SSRs may cause some concern in safety critical systems.

Further information

Solid State Relays vs Electromechanical Relays - Application Notes Solid State Patronise USA

How to choose the right relay - National Instruments

Tech tips on relays-Crydom Inc.

Module 6.7
Thyristor Quiz

Try this quiz based on thyristors. Hopefully it'll be easy. Submit your answers but don't be disappointed if you get answers wrong. All the information you need is in Module 6 on the learnabout-electronics website. Find the right answer and learn about thyristors as you go.

1.

What is the value indicated by point X in Fig. 6.7.1?

a) The holding current I_H.

b) The break over current I_{BO}.

c) The latching current I_L.

d) The forward conducting current I_{FB}.

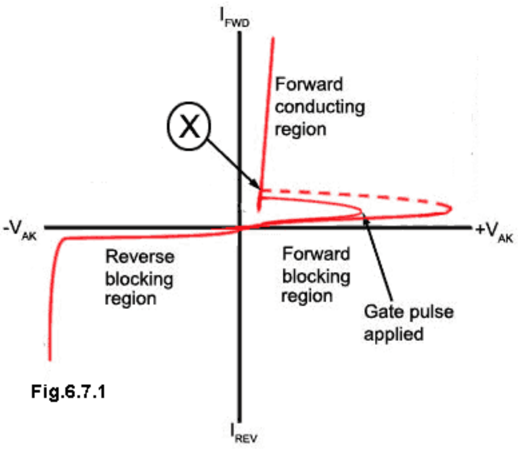


Fig.6.7.1

2.

What is the function of a crowbar protection circuit?

a) To provide over voltage protection.

b) To isolate a high voltage triac from a low voltage control circuit.

c) To prevent thermal runaway.

d) To prevent a power supply output short circuit.

3.

Referring to Fig. 6.7.2, what is the maximum achievable conduction angle using this circuit?

a) 90 degrees.

b) 180 degrees.

c) 270 degrees.

d) 360 degrees.

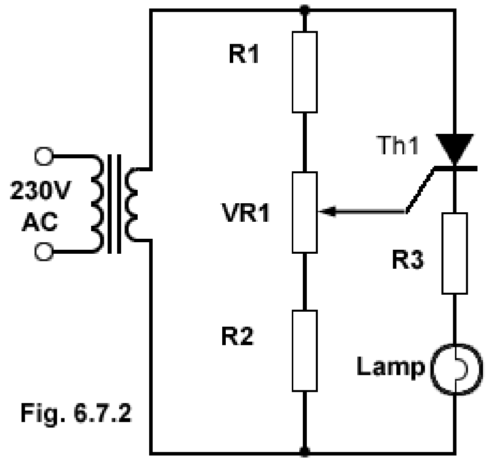


Fig. 6.7.2

4.

Which of the following advantages and disadvantages describes a zero crossing SCR circuit?

a) Usable with AC motors but unsuitable for heaters.

b) Reduces low frequency flicker but increases RF interference.

c) Suitable for incandescent lamps but not for inductive loads.

d) Produces low frequency flicker but reduces RF interference.

5.

Which quadrants are used when triggering a triac with a negative going trigger pulse in both the positive and negative half cycles of the AC wave?

a) I and II

b) II and III

c) III and IV

d) I and IV

6.

Referring to Fig. 6.7.3, what is the purpose of diodes D1 to D4 in this circuit?

a) A Bridge rectifier to provide a DC voltage to drive the diac.

b) Transient pulse suppression diodes to protect the triac.

c) Steering diodes to eliminate hysteresis.

d) A bridge rectifier to enable the circuit to trigger during both AC half cycles.

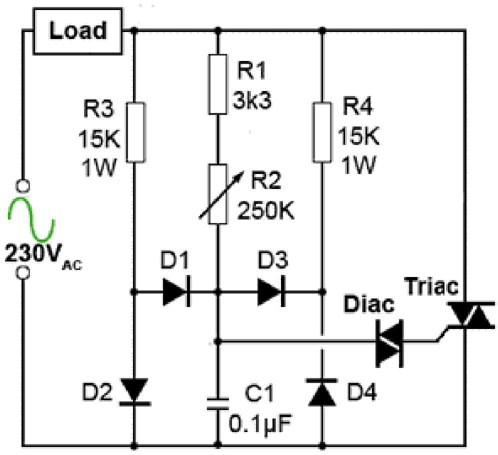


Fig. 6.7.3

7.

What is the function of a Metal Oxide Varistor (MOV) in the protection of thyristor power supplies?

a) Protection against voltage spikes.

b) Protection against high current surges.

c) Protection against high inrush currents.

d) Protection against thermal runaway.

8.

Under which of the following conditions will a triac cease conducting?

a) When IGT falls to zero.

b) When the current between MT2 and MT1 falls below IL

c) When the current between MT2 and MT1 falls below IH

d) When VDRM falls below VBO

9.

Which of the following statements is untrue?

a) Solid State Relays are likely to be safer in failure mode than Electromagnetic Relays.

b) Solid State Relays can switch faster than Electromagnetic Relays.

c) Solid State Relays have a higher 'ON' resistance than Electromagnetic Relays.

d) Solid State Relays have a lower 'OFF' resistance than Electromagnetic Relays.

10.

What is the function of a TVS diode when used in a high power SSR?

a) To trigger the power Triac.

b) To clip interference spikes.

c) To counteract CTR variations.

d) To provide over current protection.

