Driving Triacs with Phototriacs

Modern applications use complex controls to enhance safety, implement convenient features, and save energy. Control units use switches to control the sensors and actuators in a system. Since most applications are powered from the AC mains network, several AC voltage loads have to be controlled, e.g. heaters, lamps, motors, fans or valves. Switching used to be realized with electromechanical relays but have been recently replaced with triacs because of their smaller size, longer lifetime, better switching speed, and lower power consumption. If galvanic isolation of control and load circuit should be realized with triacs, optically isolated triac drivers can be used.

These phototriac devices consist of an LED and a triac device detector chip. If current flows through the LED, it emits infrared light which is detected by the detector chip. The detector chip triggers the small triac device making, the driver's output conductible. The output is triggered in one of two ways: zero-crossing and non zero-crossing.

Zero-crossing: When the input signal is activated, the internal zero-crossing detector circuit triggers the output as the AC load voltage crosses zero. To be more precise, the internal zero-crossing detector circuit monitors the output voltage and allows turn-on only if its value is below a certain level, which is close to zero. Since the output is only activated at low load voltages, zero-crossing limits high inrush currents, consequently minimizing EMC effects and stress for the electrical load and the SSR.

Non zero-crossing: When the input signal is activated, the output immediately turns on, since there is no zero-crossing detector circuit. As the output turns on immediately, a phase angle control circuit can be realized by controlling the effective voltage for a load.

In both operation modes, the output can be used to drive a larger triac's gate as shown in Figure 1. Since the output of the phototriac introduces a gate current to the main triac, it will proceed to on state and carry the load current. As soon as the main triac is triggered, the voltage across the driver drops and therefore load current of the driver drops. Even though a typical forward current I_{FT} of 10 mA is still applied to the input side, the triac driver will proceed to the off state when the load current drops below the holding current I_H (typically 0.3 mA).

This will happen every half cycle of the load voltage as long as a forward current I_{FT} is applied. As long as the output of the phototriac coupler APT1221 is conductible, it can carry a continuous current of up to 100 mA with a voltage drop of V_{TM} = 2.5 V across its output.

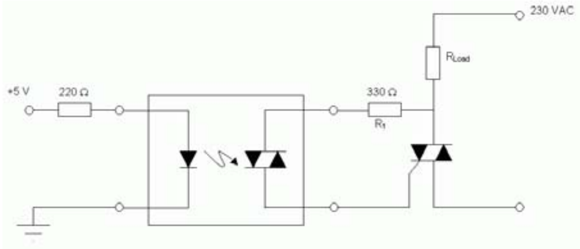

Figure 1: Simple Triac driving circuit

Figure 1 shows a simple circuit for driving a triac with a phototriac, e.g. APT1221. The maximum surge current through the phototriac is determined by the maximum load voltage and the value of the resistor R_1. If the maximum surge current of the phototriac I_{FP} is 1 A and we assume a 230 VAC line, the value of R_1 can be determined as follows:

$$R_1 = \frac{V_{in\max}}{I_{FP}} = \frac{325V}{1A} = 325\Omega \approx 330\Omega$$

Since the main triac requires a gate current and voltage, a certain load voltage value results, which is necessary to trigger the triac. If the main triac's electrical characteristics are I_{GT} = 50 mA and V_{GT} = 1.5 V, then:

$$V_{inT} = R_1 \cdot I_{GT} + V_{TM} + V_{GT} =$$
$$= 330\Omega \cdot 50mA + 2.5V + 1.5V = 20.5V$$

But the phototriac may also be triggered to on state accidentally. This can happen by exceeding the maximum blocking voltage V_{DRM} of 600 V or by applying very steep rising signals to the output. Such transient signals or noise may exceed the dV/dt rating of the triac driver and hence cause the device to proceed into on state. The dV/dt ratings of the triac and its driver are very important when switching inductive loads since load voltage and current are not necessary in phase. Since a triac turns off when the load current is zero, load voltage is not necessarily zero. Due to this fact, the triac may produce a sudden rise in load voltage to its own output, which may exceed its dV/dt rating.

In order to increase voltage rise time, a snubber circuit can be used. In most cases, one snubber circuit will protect the main triac and the phototriac. We will take a look at designing a snubber circuit for a non zero-crossing phototriac (e.g. APT1221), which also protects the main triac in most cases.

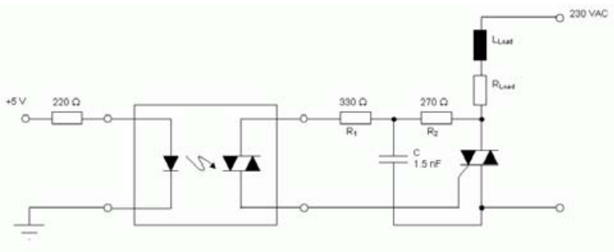

Figure 2: Triac driving circuit with RC snubber network

When designing the RC snubber network for triac drivers, detailed knowledge about the load is necessary. By knowing the power factor PF, one can easily calculate the maximum turn off voltage that may appear across the output:

$$V_{T\max} = V_{in\max} \cdot \sin(\arccos(PF))$$

Assuming V_{tmax} = 200 V we will choose R_1 to limit the current peak at maximum voltage

$$R_1 = \frac{V_{in\max}}{I_{FP}} = \frac{325V}{1A} = 325\Omega \approx 330\Omega$$

Since the peak current is limited by the resistor R_1, the time constant for limiting dV/dt has to be set with R_2 and C:

$$\frac{dV}{dt} = \frac{V_{T\max}}{\tau} = \frac{V_{T\max}}{R_2 C}$$ and with dV/dt = 500 V/µs

$$\tau = R_2 C = \frac{V_{T\max}}{\frac{dV}{dt}} = \frac{200V}{500V/\mu s} = 400 \cdot 10^{-9}\, s$$

In the next step, the value of R_2 is set by determining the smallest trigger voltage requirement. Assuming a triac gate trigger current I_{GT} = 50 mA and a required load voltage of 30 V:

$$R_1 + R_2 = \frac{V_{inT}}{I_{GT}} = \frac{30V}{50mA} = 600\Omega$$

$$\Rightarrow R_2 = 600\Omega - R_1 = 600\Omega - 330\Omega = 270\Omega$$

$$\Rightarrow C = \frac{\tau}{R_2} = \frac{400 \cdot 10^{-9}\, s}{270\Omega} = 1.5nF$$

The snubber circuit in this example is designed to meet the dV/dt rating of the phototriac. If the dV/dt rating of the main triac is different, the worst case value has to be chosen for designing the snubber network.

As can be seen above, there is no easy method for selecting the parts and their values for a snubber network. In particular detailed knowledge about the load circuit and the power factor is required. These facts make snubber design empirical and result in detailed measurements to verify the parameters calculated.

If the user wants to save work when designing the circuit or have fewer parts and more space on his PCB board, he can choose an SSR (solid state relay). Besides the phototriac and a main triac, these relays may have an input protection circuit, integrated snubber circuits, or a varistor inside. The customer can choose among various alternatives based on his needs, e.g. space, number of parts, costs, input / output conditions. Panasonic Electric Works offers various products to provide the customer the freedom to choose the optimum part for his application.

Phototriac types from Panasonic Electric Works:

Max. peak OFF-state voltage / On state current	Type	Package	THT	SMT
600 V / 50 mA	ZC	SOP4	n. a.	APT1211S
	LZC	SOP4	n. a.	APT1231S
	NZC	SOP4	n. a.	APT1221S
600 V / 100 mA	ZC	DIP4	APT1211	APT1211A
	LZC	DIP4	APT1231	APT1231A
	NZC	DIP4	APT1221	APT1221A
	ZC	DIP6	APT1212	APT1212A
	LZC	DIP6	APT1232	APT1232A
	NZC	DIP6	APT1222	APT1222A
	ZC	DIP4 Wide	APT1211W	APT1211WA
	LZC	DIP4 Wide	APT1231W	APT1231WA
	NZC	DIP4 Wide	APT1221W	APT1221WA
	ZC	DIP6 Wide	APT1212W	APT1212WA
	LZC	DIP6 Wide	APT1232W	APT1232WA
	NZC	DIP6 Wide	APT1222W	APT1222WA

ZC: Zero-cross type
LZC: Low zero-cross type
NZC: Non zero-cross type
SOPx: Small outline package, x pins
DIPx: Dual In-line package, x pins
THT: Through hole technology
SMT: Surface mount technology