APPLICATION NOTE

Introduction to the characteristics and applications of Photo TRIAC

1. Function Description

Photo TRIAC is a contactless switching device, it can use a small signal to control TRIAC gate turns on and off, with input and output are isolate by photoelectric. When input receive DC voltage or pulse signal, this will change TRIAC output from off to on state. Photo TRIAC Driver has two types: zero cross and random phase.

2. TRIAC Operating Principle

TRIAC consists bidirectional thyristor (replaces two antipolar parallel thyristor) and use trigger circuit, the most ideal AC switch devices use in the industry. TRIAC can be bidirectional conductive, when positive or negative trigger voltages apply to gate, it can trigger bidirectional thyristor both in forward and reverse directions. Compare to single thyristor, bidirectional thyristor is bidirectional conductive after trigger. Regardless of polarity when trigger voltage absolute value reach trigger threshold then it conduct. Figure 1 shown bidirectional thyristor internal structure and circuit.

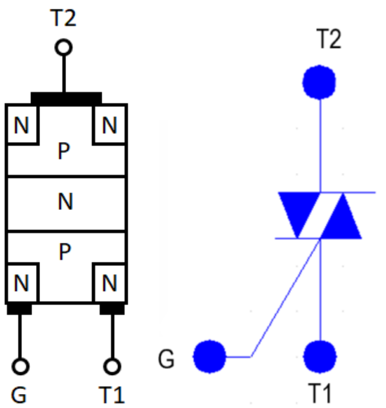

Figure 1. Bidirectional thyristor internal structure and circuit

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Since TRIAC is a bidirectional device, regardless of gate current I_G polarity, TRIAC will be in cut-off state if voltage between T_1 and T_2 is less than the breakover voltage. There is a small amount of leakage current pass through between the two anodes, when gate voltage is larger than breakover voltage, TRIAC will shift to low resistance, with current rises, terminal voltage will drop and stay in conduction state. Once breakover voltage turns into on state, gate control will be ineffective.

After remove gate signal, below methods can turn TRIAC into cut-off state:

(1) Interruption the voltage (open or short) at both ends (T_1 and T_2).

(2) Change voltage polarity of two terminals (positive and negative polarity reverse or turns off automatically when uses AC source).

(3) Reduce conduction current to holding current I_H(refer to figure 2)

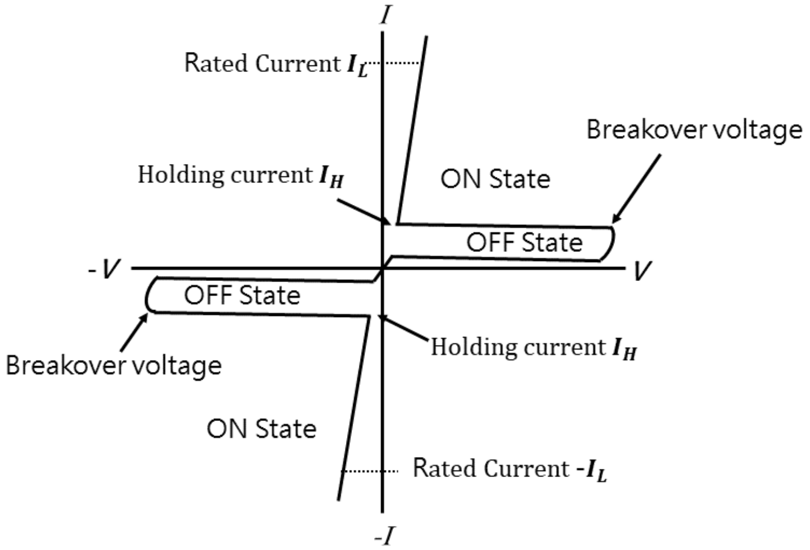

Figure 2. TRIAC I-V Curve

3. Category of Photo TRIAC drivers

3.1 Zero Cross

Generally use AC power control, such as relay drive, AC switch and etc., have high supply voltage. If high output power occurs, switch on or off might cause a spark to occur. This will affect contact devices like switches, relays and etc. lifetime. Also sparks will carbonize, this will cause increased contact resistance. If spark keep happens, it will create bad contact point, which easily generate heat and cause failure. Zero cross is to drive external contact at zero crossing point, with spark is induced by current, current is generate by voltage and AC has positive and negative periods, take 60 Hz AC as an example, there will be 60 zero crossing points per second, for which zero point is zero volt, so zero point would not have current, therefore at this time is most difficult to induced spark when turning switch on or off. Zero crossing circuit is design to trigger switch to turn on once the zero point is reach.

The purpose of zero-trigger is usually used to extend switch life time, so apply zero crossing to relay is a very common design, however, there is a reaction time when relay is activate and is uncontrollable, usually the time is around milliseconds, which is almost impossible for zero crossing. Since TRIAC has shorter conduction time and easy to control, so TRIAC can replaces relay as switch control.

Zero crossing action sequence :
(1)Trigger zero crossing IC turns TRIAC on.
(2)Turn relay on or off
(3)Disable zero crossing

Because output only operates at zero point of the sine wave, so it can avoid surge or EMI/RFI, epically suitable for control resistance, capacitive and unsaturated inductance. Fig.3 show waveform changes during operation.

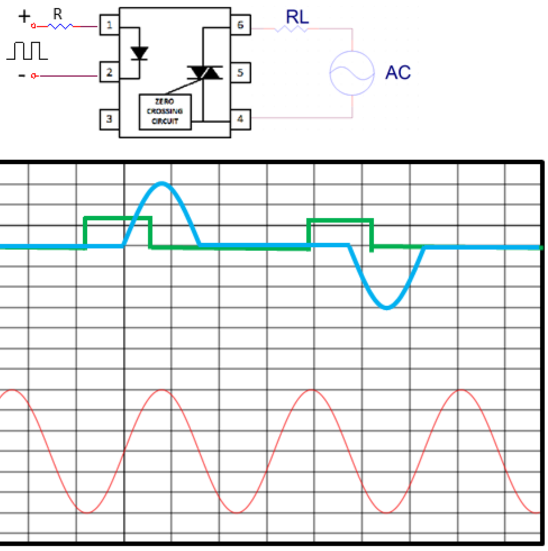

Figure 3. Photo TRIAC zero crossing operation waveforms

3.2 Random Phase

It can be used in solenoid valve control, lamp rectifier, AC switch, microcontroller with AC external setting interface, solid-state relay, incandescent lamp dimmer, temperature controller, motor controller and etc. Differences between zero crossing trigger are output can start at any angle of AC sinusoidal voltages and control TRIAC trigger angle to decide output power consumption. All types of voltage regulating module or solid state relay as output controllable contact devices are thyristor and use thyristor conduction trigger angle to achieve the purpose of regulating, cause output voltage waveform not in full sine wave. With waveform not in full sine wave cause high-order harmonics with noise exist and have stronger resistance of high voltage build-up rate (dv/dt) ability, which can ensure the switch reliability in control of the inductive load. Figure 4 show operation and variation of random phase waveform.

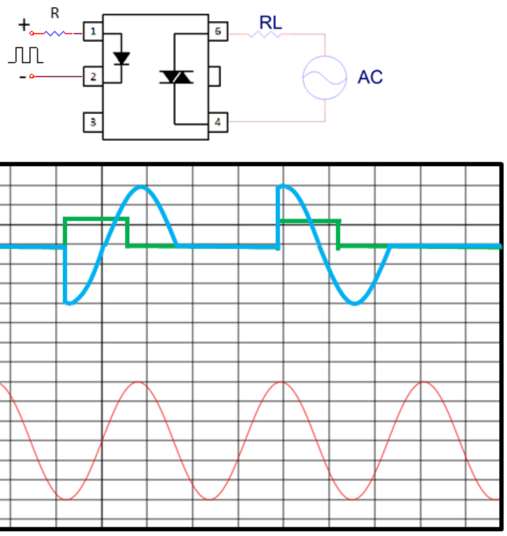

Figure 4. Photo TRIAC random phase operation and variation waveform

4. Static Voltage Rising Rate (dv/dt)

Figure 5 shows static dv/dt test circuit, when turns device under test (D.U.T) on and uses High Voltage Pulse Source to apply enough dv/dt to ensure trigger current is cut off, TRIAC remain conductive and lower dv/dt until D.U.T is off. Measure requires time τ_{RC} when reach to $0.632V_{PEAK}$, then use $0.632V_{PEAK}$ divide τ_{RC} to determine dv/dt.

$$dv/dt = \frac{0.632 \times V_{PEAK}}{\tau_{RC}}$$

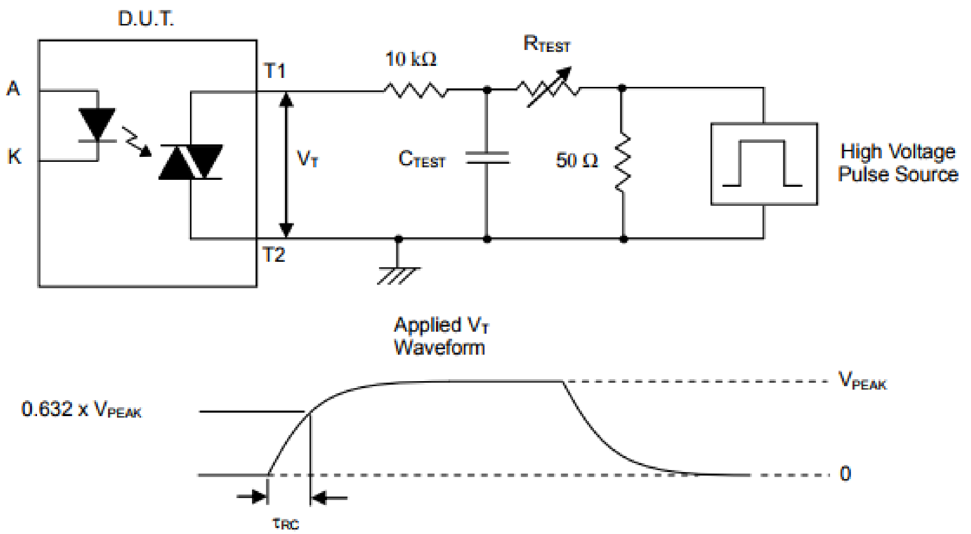

Figure 5. Static dv/dt test circuit and waveform

Take EL306X series as an example，let V_{PEAK}=600V :

$$dv/dt = \frac{0.632 \times 600}{\tau_{RC}} = \frac{379.2}{\tau_{RC}}$$

5. Photo TRIAC Driver trigger circuit

Figure 6 is Photo TRIAC Driver trigger circuit, Photo TRIAC input use IR light to trigger TRIAC and I_{FT} (minimum electric current requires to drive TRIAC). Take EL3031 as an example : When I_F = 15mA, output turns on, even if I_F drops below 15mA, output still be on until TRIAC current falls below I_H. It also conduct when output voltage is higher than TRIAC forward blocking voltage V_{DRM}. Also transient voltage or noise commonly see in AC, if is larger than static voltage build-up rate of dv/dt rate also can trigger TRIAC. To avoid false trigger happens, circuit will add a buffer (Snubber circuit).

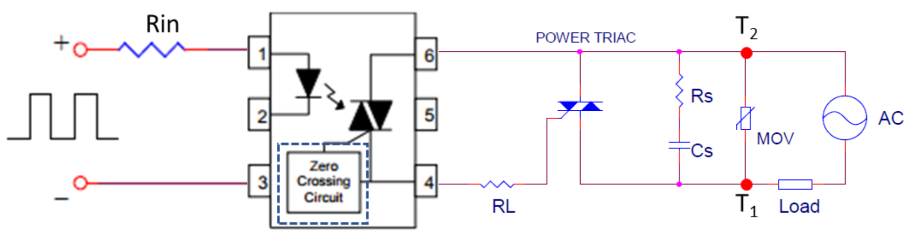

Figure 6. Photo TRIAC Driver trigger circuit

If load is resistive load, then voltage and current are in phase, when current falls to zero, it will reaches zero power point. At that moment, voltage turns to zero and TRIAC can easily become off. If load is reactive (inductor or capacitor), which voltage and current are not in phase, then switch TRIAC off will be different than resistive load. Consider inductive load like motor, current will fall behind voltage, so when current fall to zero, voltage is not zero and cross both sides of TRIAC and might have enough to turn TRIAC on and cause false trigger. Also static voltage can affects TRIAC, static voltage usually has noise, and noise might be large enough to turns TRIAC on. Thyristor is mad of PN junctions, which transform to depletion area while is off. Depletion region is an insulator and is consider as capacitor dielectric layer. These capacitors will react to impulsive voltage and induced charging current. This charging current can be used as gate current and turns TRIAC on, which cause false trigger.

Snubber circuit can reduce false trigger in TRIAC control circuit. Use characteristics of capacitor resist voltage change in RC Snubber circuit. RC circuit is connect between TRIAC T2 and T1. Snubber circuit shunts the charging current out of non-conductive thyristor.

5.1 Zero Cross

Figure 7 shows zero crossing trigger circuit. When R_L is a resistive load, since current is limited by Power TRIAC gate trigger current(I_{GT}), resistor R can be eliminate. This is mainly use in inductive loads to prevent possible damage cause by TRIAC Driver.

If the value of current-limit resistor R is too high, may cause TRIAC has false phase control. If TRIAC enters a non-conducting state near peak voltage and the Snubber capacitor discharges to TRIAC, then resistor R may limit current flow through TRIAC Driver.

Assume voltage is 110V rms and maximum peak drive current is 1A, then resistor is calculate as follow:

$$\mathrm{R} = \frac{V_{Peak}}{I_{Peak}} = \frac{110\sqrt{2}}{1} = 155\ ohm$$

Notes: Choose 160 ohm is also acceptable.

R_G only requires if Power TRIAC or SCR internal gate impedance is extremely high. Without R_G, anti-noise performance and thermal stability will have poor performance, R_G resistance range from 100 ~ 500 ohm, R_G can increases I_{GT} current. If R_G and R is use together, it will cause zero crossing time and Power TRIAC trigger time has unexpected delay or phase shift.

Power TRIAC needs a specific trigger current (I_{GT}) and trigger voltage (V_{GT}) to turn on, between T_1 and T_2 there is a minimum line voltage V_T even if TRIAC Driver has be trigger on. V_T is obtain by adding all the voltage drops in the trigger circuit:

$$V_T = V_R + V_{TM} + V_{GT}$$

Current I contains I_{GT} plus the current flowing through R_G.

$$I = I_{RG} + I_{GT}$$

I_{RG} value is from Power TRIAC gate requires trigger voltage V_{GT} divide by R_G

$$I_{RG} = \frac{V_{GT}}{R_G}$$

In the end

$$I = \frac{V_{GT}}{R_G} + I_{GT}\,, \qquad V_R = IR = (\frac{V_{GT}}{R_G} + I_{GT})R$$

V_{GT} and I_{GT} can be obtain from Power TRIAC datasheet, V_{TM} value can be found in TRIAC Driver datasheet, so that R and R_G are determined by the value of V_T.

If the value of V_T is known, then unexpected phase delay angle θ_d and the trigger delay timet_d can be obtain from the following equation:

$$\theta_d = sin^{-1}\frac{V_T}{V_{peak}} = sin^{-1}\frac{R(V_{GT}/R_G+I_{GT})+V_{TM}+V_{GT}}{V_{peak}}$$

$$t_d = \frac{\theta_d}{90} \text{ X } \frac{1}{4} f$$

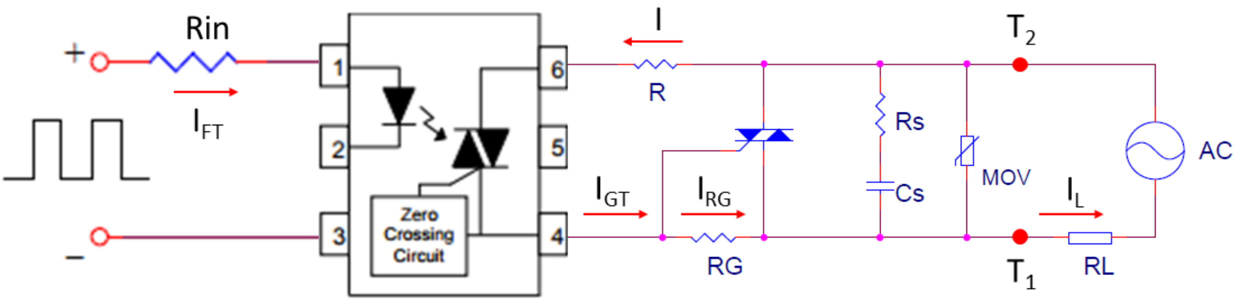

Figure 7. Zero crossing trigger circuit

5.2 Random Phase

Output can be turn on at any phase, but it will turn off at the next voltage zero crossing. It should be noted that it will cause transient voltage interference since it can be triggered in any phase. When select Power TRIAC, is important to know voltage de-rating and the surge voltage for operating conditions and to select high tolerance components. For incandescent lamp, Power TRIAC should be protect by fuse or use high rating value components to avoid peak current damage. When transient voltage disturbance occurs on AC line and exceed the device's static dv/dt rate can cause Power TRIAC to be on by TRIAC Driver false trigger. However, under normal circumstances, Power TRIAC will off at the next zero crossing, and most of the load can take the impact of occasionally half cycle power.

To Power TRIAC and TRIAC Driver, inductive load (motor, solenoid valve, magnet...) cause voltage and current in different phases, TRIAC will be off at zero current, because when current turns to zero and apply high voltage, it may try to turn off. For TRIAC, if rising rate exceeds over transition dv/dt of the Power TRIAC or static dv/dt of the TRIAC Driver, then TRIAC will turn on. In order to use a Snubber circuit to reduce voltage rising rate, sometime Snubber are added to Power TRIAC and TRIAC Driver, power factory (PF) should be known to properly design Snubber.

The information in this application manual is only for customers' design reference. Please verify when actually use it. If have any other questions, please contact Everlight for further technical support.

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