Temperature and Overload Protected Triac – TOPTriac™

For decades, triacs have been used as solid-state AC power switches. The emergence of smart appliances and greater emphasis on safety has suggested a need for triacs with self-protection features and smart monitoring capability. This need can be met by TOPTriac™.

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Introduction
Triacs are the most widely used solid state AC power switches for controlling AC mains loads of 50/60Hz or even 400Hz. They are widely used in home appliances, commercial and industrial equipment. They are designed to withstand high blocking voltage while conducting very low leakage current, or latch into the on-state to conduct load current in response to a low level current pulse on the gate.

As with all power semiconductors, triacs are available at many different current levels from <1A upwards. At higher currents, a heatsink will be required to remove the heat.

[Due to the fixed voltage drop inherent with their technology, triacs will dissipate typically around 1 Watt per Ampere of load current.]

If the triac should become too hot for any reason ($T_j > T_{j(max)}$), it may lose control, i.e. be unable to commutate (turn itself off at the end of a half-cycle) and continue to conduct even without trigger commands applied to the gate. This may lead to thermal runaway and destructive failure of the triac and possibly the load. To avoid such danger, the application must be over-designed to allow for all possible fault or overload conditions. Over-design strategies may include:

- A larger triac than necessary to allow for fault conditions;
- A larger heatsink than necessary to allow for fault conditions;
- A larger enclosure than necessary to allow for fault condition cooling;
- Additional thermal protection;
- Additional overcurrent protection;
- Artificial limitation of duty cycle on intermittent loads.

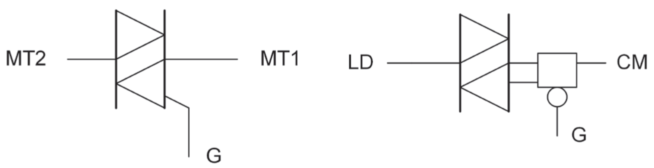


Figure 1: Triac and TOPTriac symbols.

Temperature and Overload Protected Triac (TOPTriac™) does not require any such over-design because it protects itself against overheating, turning itself off well below the temperature at which it would lose control. This allows the application to be designed exclusively for normal operation only, in the safe knowledge that TOPTriac will take care of its own thermal overload conditions.

In addition to over-temperature protection with indefinite latch-off until reset, TOPTriac can communicate its status back to the system microcontroller via gate feedback. The system can report when it is conducting or blocking normally or whether it is in over-temperature trip state, with or without gate trigger commands applied. Its capability to communicate its status to the microcontroller gives the designer a unique opportunity to implement a smart overload monitoring function, with manual or automatic reset applied according to the needs of the application.

The over-temperature protection and smart monitoring features of TOPTriac improve the overall safety of the end-product, remove the need to over-design for fault conditions, remove the need for additional protection components and reduce the chance of field failures.

How it works
TOPTriac is based on WeEn's planar-passivated three-quadrant Hi-Com Triac technology. It is a solid-state AC power switch with semiconductor-based on-chip thermal protection. The protection disables the Triac element, preventing conduction before excessive die temperature causes loss of control and damage to the device or the circuit. Protection is activated at a junction temperature between 125°C and 150°C.

As a two-quadrant device, TOPTriac is triggered exclusively by negative gate current.

TOPTriac is triggered like a standard Triac by applying current to its gate. Trigger current can be DC (for continuous conduction) or pulsed (for any phase angle). Pulsed triggering requires an additional low level continuous DC bleed current to be applied to the gate. Bleed current is in the range 0.5mA – 2mA.

When TOPTriac goes into the over-temperature protection condition, "tripped", it will remain latched-off indefinitely even after cooling, thanks to the continuous DC gate trigger current or bleed current.

Reset is achieved by removing and re-applying the DC gate drive. Normal conduction will be restored, provided by then T_j is below the trip temperature.

WeEn Hi-Com triac	WeEn TOPTriac
High dV_D/dt	High dV_D/dt
High dI_{com}/dt	High dI_{com}/dt
High dV_{com}/dt	High dV_{com}/dt
High $T_{j(max)}$	High $T_{j(max)}$
No need for snubbers	No need for snubbers
Voltage-rugged	Voltage-rugged
Planar passivated	Planar passivated
	Thermal self-protection
	Status feedback

Table 1: Three-quadrant Hi-com triac and TOPTriac compared.

Application circuits

TOPTriac triggering and gate monitoring circuits can be as simple or as complicated as the application requires. A simple discrete circuit (open loop, no monitoring or feedback, manual reset) can be applied to low cost designs and simple systems, while for higher end applications with microcontroller, full status monitoring and any combination of manual or automatic reset become possible.

Discrete phase control with manual reset

TOPTriac is a two-quadrant device with I_{GT} of 5mA min to 35mA max. Negative gate current pulses of at least 35mA amplitude and adjustable phase angle are applied for variable power control. A bleed current of ~0.8mA is applied via R7 to ensure continued latch-off after over-temperature trip. Reset is achieved by opening the switch momentarily in series with the gate.

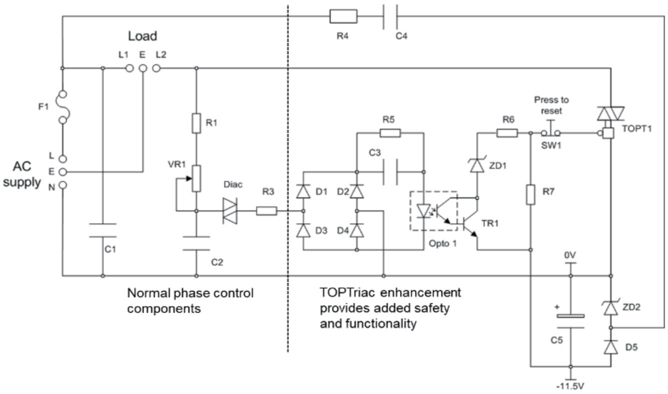


Figure 2: Discrete phase control circuit

Name	Value
C1, C4	220n 275V AC Class X2
C2	33n 400V
C3	10n 400V
C5	220µ 63V
D1 - D4	1N4007
D5	1N4148
Diac	DB3
F1	10A Antisurge
Opto1	TCET1100G opto transistor (4 pin DIL) *
R1	22k 0.6W
R3	1k 0.6W
R4	100R 2W
R5	470k 0.6W
R6	100R 0.6W
R7	12k 0.6W
SW1	Push switch SPNC
TOPT1	TOPT12-800C0
TR1	BC547*
VR1	1M
ZD1	BZX79-C5V6
ZD2	BZX79-C12V
	* Opto1 and TR1 can be replaced by an opto-coupler with Darlington output - e.g. Vishay SFH655A.

Table 2: Bill of materials for discrete phase control circuit.

Microcontroller controlled

Combining TOPTriac with a microcontroller allows full functionality. Triggering can be continuous DC or pulsed with bleed current (minimum pulse duration 10µs). Gate voltage feedback indicates TOPTriac's status:

- Presence of mains frequency square wave means load current is flowing;
- Low level continuous DC offset and no AC signal means over-temperature tripped.

Gate feedback also allows detection of load current zero-crossing because the gate voltage AC signal reflects load current. This is critical for Triacs, which commutate at current (not voltage) zero-crossing, so pulse triggering needs to be synchronized to current zero-crossing for continuous conduction.

When the TOPTriac has gone into an over-temperature trip condition, the microcontroller will spontaneously detect its status and automatically send an alert signal after a programmed time delay. For instance, it could be hazardous to allow cycling through an over-temperature trip (e.g. it may be unsafe to have an unexpected start-up of the machine). In such a scenario, the system can be programmed to send an early warning signal that the user could self-evaluate and intervene in the process allowing the circuit to be manually reset.

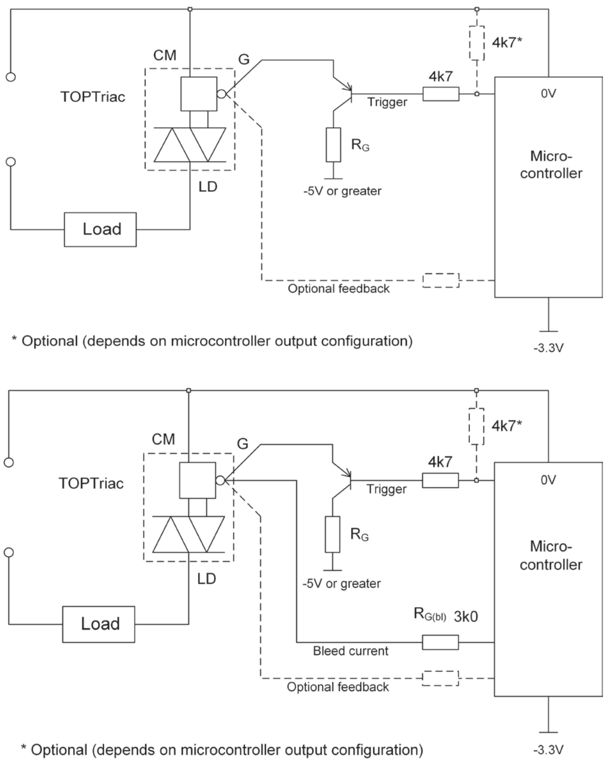


Figure 3: DC and pulse trigger using 3.3V microcontroller.

TOPTriac vs conventional Hi-Com triac

The performance of TOPTriac was evaluated and compared with a conventional Hi-Com triac. The test board used was designed to function well for both TOPTriac and conventional triacs. Hi-Com triac BTA312-600CT was compared with TOPTriac TOPT12-800C0. The devices were controlled by a microcontroller and triggered at a phase angle of 90 degrees with a 230V 1,200W heating element used as the load. Functionality was evaluated under general environment working conditions and an extreme temperature environment which exceeded $T_{j(max)}$.

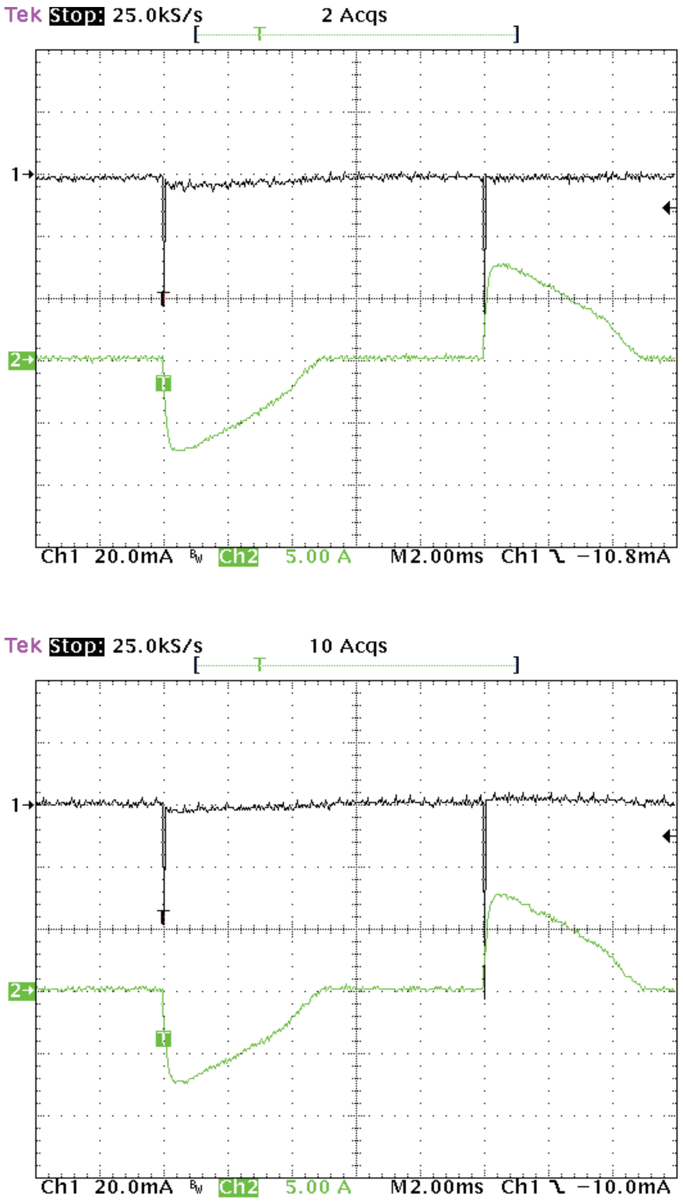
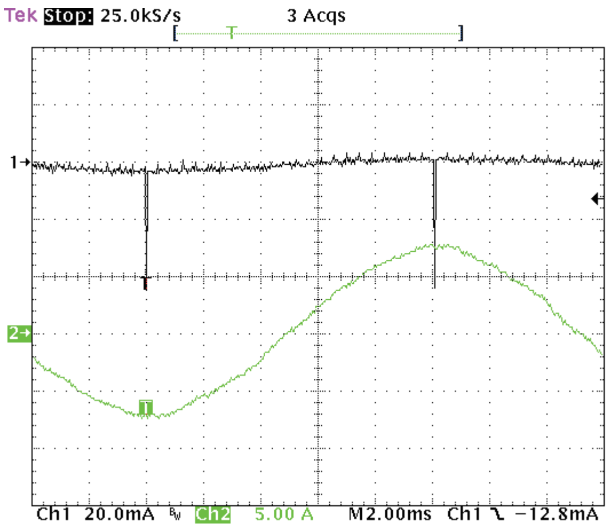


Figure 4: Hi-Com triac BTA312-600CT (top) and TOPTriac TOPT12-800C0 (bottom), phase control at 90 degrees phase angle, 230V 1.2kW load, T_j below $T_{j(max)}$.

Figure 4 shows normal operation of conventional triac and TOPTriac with T_j below $T_{j(max)}$. Gate pulse and load current waveforms are identical and the devices are in full control, operating within normal parameters.

Figure 5 shows the benefit of TOPTriac. Junction temperature has been allowed to rise to the point where the Hi-Com triac has lost control (T_j exceeding $T_{j(max)}$ by a considerable margin). It is failing to commutate at current zero-crossings and is now conducting continuously. It is in a thermal runaway condition and will be destroyed if the power is not turned off very soon. By contrast, the TOPTriac has detected high junction temperature exceeding 125°C and has turned itself off. Gate pulses are still being applied but it is tripped and now cooling down to ambient temperature. It will remain safely tripped until it is reset manually by the user or automatically the microcontroller.



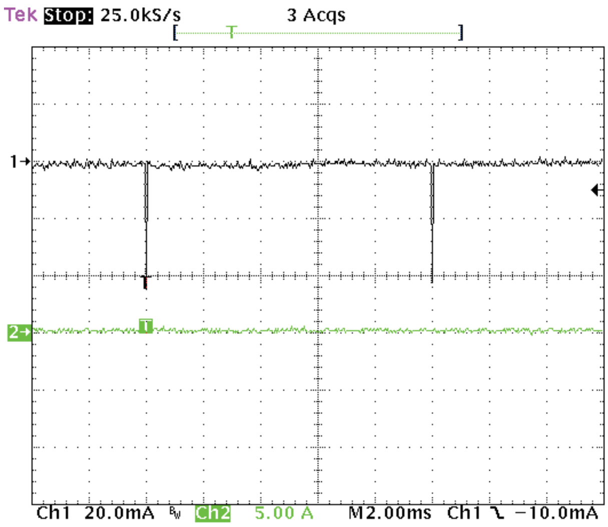


Figure 5: Hi-Com triac BTA312-600CT (top) has lost control with $T_j >> T_{j(max)}$ and is in thermal runaway condition. TOPTriac TOPT12-800C0 (bottom), has detected $T_j >$ 125°C and has gone into over-temperature trip mode. Gate pulses are still being applied at 90 degrees phase angle but both devices are ignoring them. Only TOPTriac is safely off (non-conducting).

Conclusion

In this article, TOPTriac with its Temperature and Overload Protection functionality has been compared with a conventional Hi-Com triac up to and beyond normal operating temperature conditions. TOPTriac operates as a standard triac with the additional unique capability to protect itself against overheating and overload scenarios, so preventing loss of control of power supplied to the load. In this way, TOPTriac provides an enhanced safety and reliability option for appliance designers. This eliminates the need for overdesign and extra protection strategies and can reduce the risk of field failures. Total cost of ownership can be reduced, while the reliability of the appliance and the reputation of its manufacturer can be enhanced.

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