‘Hi-Com’ — a three-quadrant triac

FS013 — Understanding high-commutation triacs

Philips Semiconductors offers a wide range of *three-quadrant triacs* and in particular, ‘Hi-Com’ (High Commutation) triacs. These devices are ‘insensitive,’ offering a high I_{GT} of 50 mA and the highest immunity to spurious conduction, whatever the cause. Of all three-quadrant triacs, Philips Semiconductors’ Hi-Com types are specifically designed to offer the highest commutation capability, for use with AC inductive loads. Specifically, they can be used with a wide variety of motor, transformer and other inductive loads without the need for a protective snubber. The use of a Hi-Com triac greatly simplifies circuit design and gives significant cost savings to the designer. What’s more, their superior characteristics and performance removes the design limitations of standard devices.

Triac commutation explained

A triac is an AC conduction device and may be thought of as two antiparallel thyristors monolithically integrated onto the same silicon chip.

In phase-control circuits, the triac often has to be triggered into conduction part way into each half cycle. This means that at the end of each half cycle, the on-state current in one direction must drop to zero and not resume in the other direction until the device is triggered again. This ‘commutation’ turn-off capability is at the heart of triac power control applications.

If the triac were truly two separate thyristors this requirement would not present any problems. However, the two are on the same piece of silicon. As one thyristor turns off, there is a possibility that its ‘reverse recovery current’ (due to unrecombined charge carriers) may act as gate current triggering the other thyristor as the voltage rises in the opposite direction. This is described as a ‘commutation failure’ and results in the triac continuing to conduct in the opposite direction instead of blocking.

The probability of any device failing commutation is dependent on the rate of rise of reverse voltage (dV/dt) and the rate of decrease of conduction current (dI/dt). The higher the dI/dt the more unrecombined charge carriers are left at the instant of turn-off. The higher the dV/dt the more probable it is that some of these carriers will act as gate current. Thus the commutation capability of any device is usually specified in terms of the turn-off dI/dt and the re-applied dV/dt it can withstand, at any particular junction temperature.

If a triac has to be operated in an inductive load circuit with a combination of dI/dt and dV/dt that exceeds its specification, an RC-snubber network in parallel with the device is needed to limit the dV/dt. This is at a penalty of extra circuit complexity and dissipation in the snubber. Hi-Com triacs are designed to have superior commutation capability, so that even at a high rate of turn-off (dI/dt) and a high rate of re-applied dV/dt, they can be used without the aid of a snubber network, thus greatly simplifying the circuit.

Design features

1. Geometric separation of the two anti-parallel thyristors

Commutation failure can be avoided by physically separating the two ‘thyristor halves’ of a triac. However, separating them into two discrete chips would remove the advantage of a triac being triggerable in both directions by the same gate connection. Within the integrated structure of a Hi-Com triac the two halves of the device are kept further apart by modifying the layout of the chip in order to lessen the chance of conduction in one half affecting the other half.

2. Emitter shorting

‘Emitter shorts’ refer to the on-chip resistive paths between emitter and base of a transistor. With more paths and lower resistance values in them, Hi-com triacs offer better emitter shorting than standard devices, and this has two effects that improve commutation.

Firstly, it reduces the gain of the internal transistors that make up the triac. This means that there are fewer carriers left to recombine when the conduction current falls to zero, so the probability that there are enough to re-trigger the triac is reduced. Secondly, any unrecombined carriers in the conducting thyristor at turn-off will have more chance of flowing out through the emitter shorts (of the opposite thyristor) rather than acting as gate current to trigger that thyristor on.

The Hi-Com triacs have a higher degree of emitter shorting both around the periphery of the device and in the central part of the active area. This both reduces the number of carriers available, and lessens the danger of any available carriers acting as gate current for undesirable triggering.

3. Modified gate structure

The gate of a standard 4-quadrant triac allows conduction in both directions to be initiated by either a positive or a negative current pulse between gate (G) and main terminal (MT1). The four different modes of triggering are often called 1+, 1-, 3- and 3+ (or sometimes quadrants 1, 2, 3 and 4) and are shown in Fig.1.

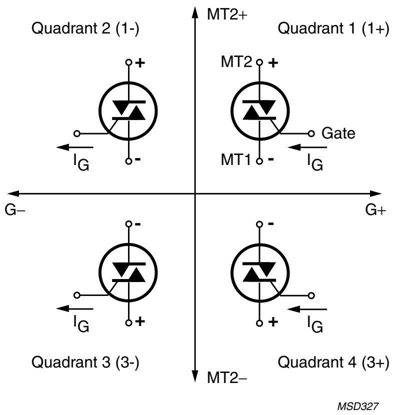

Fig.1 Standard (4-quadrant) triac triggering quadrants

This triggering versatility arises from the fact that the gate consists of some elements that conduct temporarily during the turn-on phase. In particular, one of the triggering modes, 3+ (or quadrant 4), relies on the main terminal 1 supplying electrons to trigger a thyristor element in the gate-MT1 boundary. Conduction then spreads to the main thyristor element from this boundary.

Unfortunately the carrier distribution in this triggering mode of operation is very similar to that existing when the triac is commutating in the 1 to 3 direction (i.e. changing from conduction with MT2 positive, to blocking with MT1 positive). The presence of the element in the gate to allow 3+ triggering will therefore always also undermine commutation capability in the 1 to 3 direction. For this reason 3-quadrant triacs have a modified gate design to remove this structure. This incurs the penalty that the 3+ trigger mode cannot be used, but it greatly improves the commutation performance of the device.

Conclusions

With a modified internal design and layout, Philips Semiconductors' Hi-Com triacs achieve a high commutation capability for use in inductive and motor load applications. The devices can be used in all typical motor control applications without the need for a snubber circuit. The commutation capability of the devices is well in excess of the operating conditions in typical applications.

As the loss of the fourth trigger quadrant can usually be tolerated in most designs, Hi-Com triacs can be used in existing motor control applications without the snubber network required for a standard device. This gives the designer significant savings in design simplicity, board space and system cost.

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Commutation with various loads

For resistive loads, a triac’s current is in phase with the line voltage. Under such conditions triac turn-off (commutation) occurs at the voltage ‘zero-crossover’ point. This is not a very severe condition for triac commutation: the slow rising dV_{COM}/dt gives time for the triac to turn off (commutate) easily. Consequently, commutation capability is not an issue, and standard 4-quadrant triacs are usually the most appropriate devices for resistive load applications.

The situation is quite different with inductive or motor loads. For these circuits, conduction current lags behind the line voltage as shown in Fig.1. When triac commutation occurs, the rate of rise of voltage in the opposite direction can be very rapid and is governed by the circuit and device characteristics. This high dV_{COM}/dt means there is a much higher probability of charge carriers in the device re-triggering the triac and causing a commutation failure.

Hi-Com triacs

The significant advantage of a Hi-Com triac is that it can withstand a very high rate of rise of reapplied voltage at commutation. This removes the requirement for a snubber circuit in inductive load circuits. An additional advantage of the Hi-Com design is that the off-state (static) dV_D/dt capability of the device is also significantly improved.

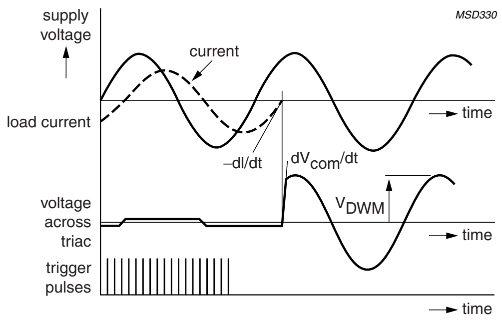

Fig.1 Triac commutation waveforms

When using 3-quadrant triacs, the trigger circuit cannot trigger the device in the fourth (3+) quadrant (Fig.2). Fortunately the vast majority of circuit designs do not require this mode of operation and so are suitable for use with 3-quadrant triacs without modification. The circuit of Fig.3 is a typical example of the simplest type of trigger circuit.

Three-quadrant triacs are equally suitable for use with micro-controller trigger circuits. More sensitive gate versions with I_{GT} down to 5 mA suit their limited drive capabilities. There is always an unavoidable penalty in commutation capability as sensitivity increases. The designer will need to balance commutation requirements with gate sensitivity for his application.

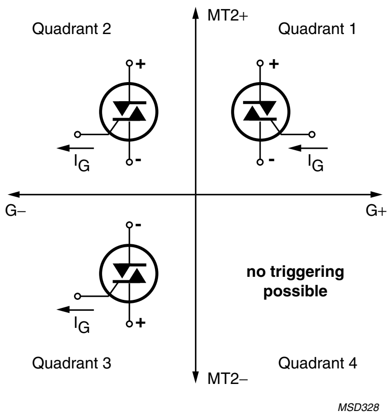

Fig.2 Three-quadrant triac triggering quadrants

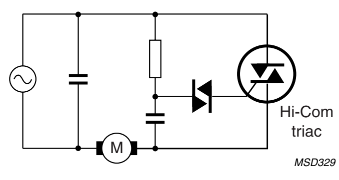

Fig.3 Phase-control circuit using a Hi-Com triac

Device limiting values

1. Trigger current, I_{GT}

Trigger current for the Hi-Com triacs is in the 2 mA to 50 mA range. This means that gate currents (due to noise) below 2 mA in amplitude can be guaranteed not to trigger the devices. This gives the devices a noise immunity feature that is important in many applications. The trigger current delivered by the trigger circuit must be greater than 50 mA, under all conditions, to guarantee triggering of the device when required. As discussed above, triggering is only possible in the 1+, 1- and 3- quadrants.

2. Rate of change of current, dI_{com}/dt

Hi-Com triacs do not require a snubber network as long as the rate of change of current prior to commutation is less than the rating specified in the device data sheet. This dI_{COM}/dt limit is well in excess of the currents that occur in the device under normal operating conditions, during transients (e.g. at start-up) and faults (e.g. the stalled-motor condition).

As an example, a 12 A Hi-Com triac's commutating current limit is typically 24 A/ms at 125 °C. This corresponds to an RMS current of 54 A at 50 Hz. For 16 A Hi-Com triacs, the commutating current limit is typically 28 A/ms at 125 °C. This corresponds to an RMS current of 63 A at 50 Hz. Typical stall currents for an 800 W domestic appliance motor are in the 15 – 20 A range. So the commutation capability of the Hi-Com triacs is well above the requirement for this type of application.

Conclusions

Philips Semiconductors' Hi-Com triac range can be used in all typical motor control applications without the need for a snubber circuit. The commutation capability of the devices is well in excess of the operating conditions in typical applications.

As the loss of the fourth trigger quadrant can usually be tolerated in most designs, Hi-Com triacs can be used in existing motor control applications. By removing the snubber, the use of a Hi-Com triac gives the designer significant savings in design simplicity, board space and system cost.

Philips Semiconductors' 3-quadrant triac range includes the original Hi-Com types, with highest commutation performance and 50 mA I_{GT}. The range extends through intermediate types, offering a compromise between commutation performance and gate sensitivity, to the most sensitive types, with 5 mA I_{GT} and an enhanced commutation performance compared to that offered by standard 4-quadrant triacs.

To order or receive more information, please contact your local Philips Semiconductors Sales Office (see below). Data Sheets are available on our website and in Data Handbook SC03.

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