# Gating, Latching, and Holding of SCRs and Triacs

## Introduction

Gating, latching, and holding currents of thyristors are some of the most important parameters. These parameters and their interrelationship determine whether the SCRs and triacs will function properly in various circuit applications. The purpose of this application note is to show the users of SCRs and triacs how these parameters are related to each other and help the users in selecting best operating modes for various circuit applications.

## Gating of SCRs and Triacs

There are three general ways to switch thyristors to on-state condition:

(1) Applying proper gate signal

(2) Exceeding thyristor static dv/dt characteristics

(3) Exceeding voltage breakover point

For the purposes of this application note, only the “Application of proper gate signal” will be examined. Gate signal must exceed the $I_{GT}$ and $V_{GT}$ requirements of thyristor being used. $I_{GT}$ (gate trigger current) is defined as minimum gate current required to switch a thyristor from the off-state to the on-state. $V_{GT}$ (gate trigger voltage) is defined as the voltage required to produce the gate trigger current.

SCRs (unilateral device) require a positive gate signal with respect to the cathode polarity. Figure 15.1 shows the current flow in a cross-sectional view of the SCR chip.

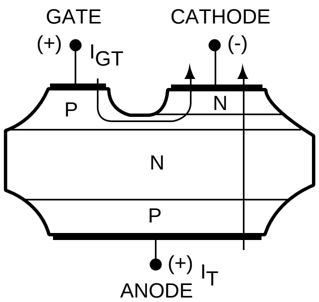


Figure 15.1 SCR Current Flow

In order for the SCR to latch on, the anode-to-cathode current ($I_T$) must exceed the latching current ($I_L$) requirement. Once it is latched on, the SCR will remain “on” until it is “turned off” when anode-to-cathode current drops below holding current ($I_H$) requirement.

Triacs (bilateral device) can be gated on with a gate signal of either polarity with respect to the MT1 terminal; however, different polarities have different requirements of $I_{GT}$ and $V_{GT}$. Figure 15.2 illustrates current flow through the triac chip in various gating modes.

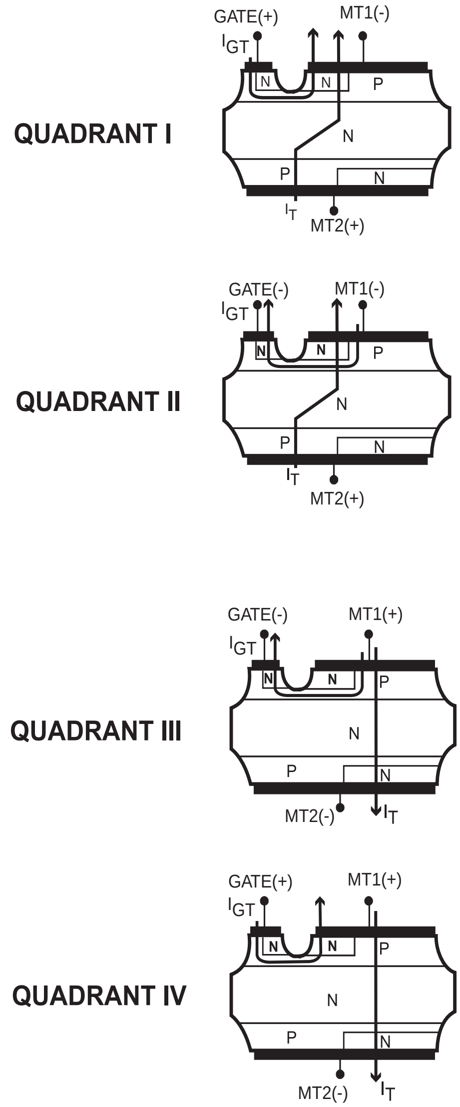


Figure 15.2 Triac Current Flow (4 Operating Modes)

Triacs can be gated on in four (4) basic gating modes as shown in Figure 15.3. The most common Quadrants for gating on triacs are Quadrants I and III, where the gate supply is synchronized with the main terminal supply; i.e., gate positive — MT2 positive, gate negative — MT2 negative. Optimum triac gate sensitivity is achieved when operating in Quadrants I and III due to the inherent thyristor chip construction. If, however, Quadrants I and III operation cannot be used, the next best operating modes are Quadrants II and III, where the gate supply is negative with respect to AC main terminal supply. Typically, the gate sensitivities of Quadrants I and II are approximately equal; however, quadrant II has the lowest latching current sensitivity. Therefore, it is difficult for triacs to latch on in Quadrant II when the main terminal current supply is very low in value.

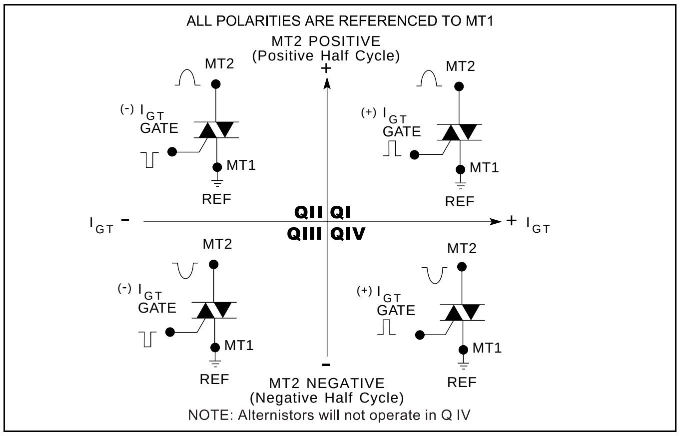


Figure 15.3 Definition of Operating Quadrants in Triacs

The following table gives a better understanding of how the different gating modes relate to each other in current required to gate on triacs. Quadrant IV has the lowest gate sensitivity of all four operating quadrants. Considerations should be given in gating circuit design when Quadrants I and IV are used in specific application.

| Typical Ratio of $\frac{I_{GT}(\text{In given Quadrant})}{I_{GT}(\text{Quadrant})}$ at 25°C | | | | |
|---|---|---|---|---|
| Type | Operating Mode | | | |
| | Quadrant I | Quadrant II | Quadrant III | Quadrant IV |
| 4 Amp Triac | 1 | 1.6 | 2.5 | 2.7 |
| 10 Amp Triac | 1 | 1.5 | 1.4 | |

Example of 4 Amp Triac:

If $I_{GT}(I)$ = 10mA, then
$I_{GT}(II)$ = 16mA
$I_{GT}(III)$ = 25mA
$I_{GT}(IV)$ = 27mA

Gate trigger current is temperature-dependent as shown in Figure 15.4. Thyristors become less sensitive with decreasing of temperature and vice versa.

For applications where low temperatures are expected, gate current supply should be increased to at least two (2) to eight (8) times the gate trigger current requirements at 25° C. The actual factor varies by thyristor type and the environmental temperature.

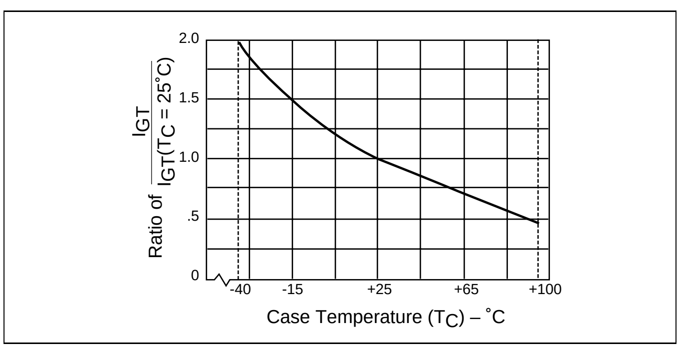


Figure 15.4 Typical DC Gate Trigger Current vs Case Temperature

Example of 10 Amp Triac:

If $I_{GT(I)}$ = 10mA at 25°C, then
$I_{GT(I)}$ = 20mA at -40°C

In applications where high di/dt, high surge, and fast turn on are expected, gate drive current should be steep rising (1µs rise time) and at least twice rated $I_{GT}$ or higher with minimum 3 µs pulse duration. However, if gate drive current magnitude is very high, then duration may have to be limited to keep from overstressing (exceeding the power dissipation limit of) gate junction.

## Latching Current of SCRs and TRIACS

Latching current ($I_L$) is defined as the minimum principal current required to maintain the thyristor in the on-state immediately after the switching from the off-state to the on-state has occurred, and the triggering signal has been removed. Latching current can best be understood by relating to the "pick-up" or "pull-in" level of a mechanical relay. Figures 15.5 and 15.6 illustrate typical thyristor latching phenomenon.

In Figure 15.5, the thyristor does not stay on after gate drive is removed due to insufficient available principal current (which is lower than the latching current requirement).

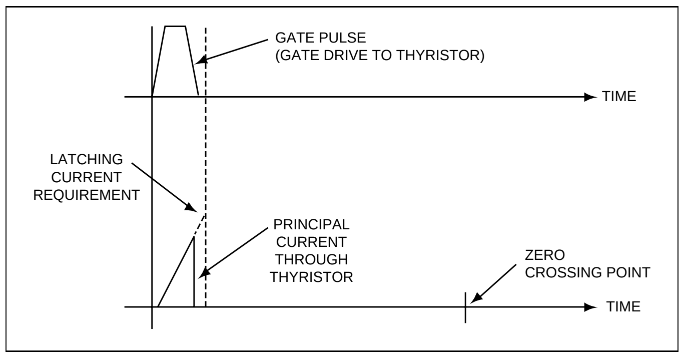


Figure 15.5 Latching Characteristic of Thyristor (device not latched)

Notice in Figure 15.6 that device stays on for the remainder of the half cycle until the principal current falls below the holding current level. Figure 15.5 shows the characteristics of the same device if gate drive is removed or shortened before latching current requirement has been met.

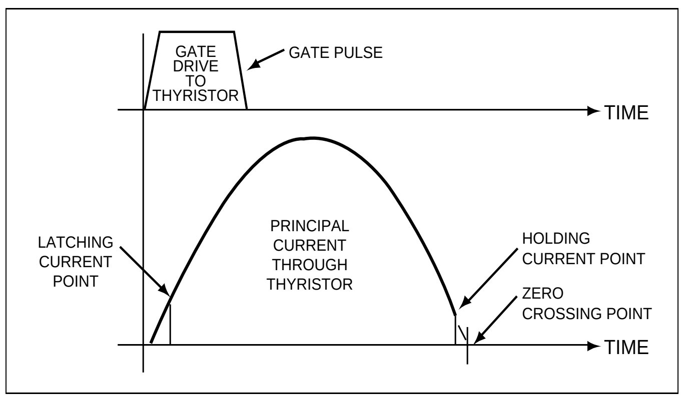


Figure 15.6 Latching and Holding Characteristics of Thyristor

Similar to gating, latching current requirements for triacs are different for each operating mode (quadrant). Definitions of latching modes (quadrants) are the same as gating modes; hence, Figures 15.2 and 15.3 can be used to describe latching modes (quadrants) as well. The following table shows how different latching modes (quadrants) relate to each other. As previously stated, Quadrant II has lowest latching current sensitivity of all four operating quadrants.

| Typical Ratio of $\frac{I_L(In\ given\ Quadrant)}{I_L(Quadrant I)}$ at 25°C | | | | |
|---|---|---|---|---|
| Type | Operating Mode | | | |
| | Quadrant I | Quadrant II | Quadrant III | Quadrant IV |
| 4 Amp Triac | 1 | 4 | 1.2 | 1.1 |
| 10 Amp Triac | 1 | 4 | 1.1 | 1 |

Example of 4 Amp Triac:

If $I_L(I)$ = 10mA, then
$I_L(II)$ = 40mA
$I_L(III)$ = 12mA
$I_L(IV)$ = 11mA

Latching current has even somewhat greater temperature dependence compared to the DC gate trigger current. Application with low temperature requirements should have sufficient principal current (anode current) available to insure thyristor latch on.

Two key test conditions on latching current specifications are gate drive and available principal (anode) current durations. Shortening the gate drive duration can result in higher latching current values.

## Holding Current of SCRs and Triacs

Holding current (IH) is defined as the minimum principal current required to maintain the thyristor in the on-state. Holding current can best be understood by relating it to the “drop-out” or “must release” level of a mechanical relay. Figure 15.6 shows the sequences of gate, latching, and holding currents. Holding current will always be less than latching. However, the more sensitive the device, the closer the holding current value approaches its latching current value.

Holding current is independent of gating and latching, but the device must be fully latched on before a holding current limit can be determined.

Holding current modes of the thyristor are strictly related to the voltage polarity across the main terminals. The following table illustrates how the positive and negative holding current modes of triacs relate to each other.

| Typical Triac Holding Current Ratio | | |
|---|---|---|
| Type | Operating Mode | |
| | $I_H(+)$ | $I_H(-)$ |
| 4 Amp Triac | 1 | 1.1 |
| 10 Amp Triac | 1 | 1.3 |

Example of 10 Amp Triac:

If $I_H(+)$ = 10mA, then
$I_H(-)$ = 13mA

Holding current is also temperature dependent like gating and latching as shown in Figure 15.7. Notice that the initial on-state current is 200 mA to ensure that the thyristor is fully latched on prior to holding current measurement. Again, applications with low temperature requirements should have sufficient principal (anode) current available to maintain the thyristor in the on-state condition.

Both minimum and maximum holding current specifications may be important, depending on application. Maximum holding current must be considered if the thyristor is to stay in conduction at low principal (anode) current; whereas, the minimum holding current must be considered if the device is expected to turn off at a low principal (anode) current.

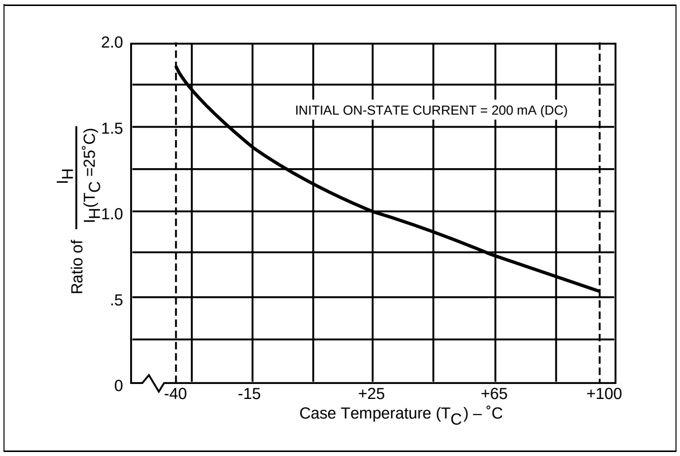


Figure 15.7 Typical DC Holding Current vs Case Temperatures

Example of 10 Amp Triac:

If $I_H(+)$ = 10mA at 25°C, then
$I_H(+)$ ≈ 7.5mA at 65°C

## Relationship of Gating, Latching, and Holding Currents

Although gating, latching, and holding currents are independent of each other in some ways, the parameter values are related. If gating is very sensitive, latching and holding will also be very sensitive and vice versa. One way to obtain a sensitive gate and not-so-sensitive latching-holding characteristics is to have an “amplified gate” as shown in Figure 15.8.

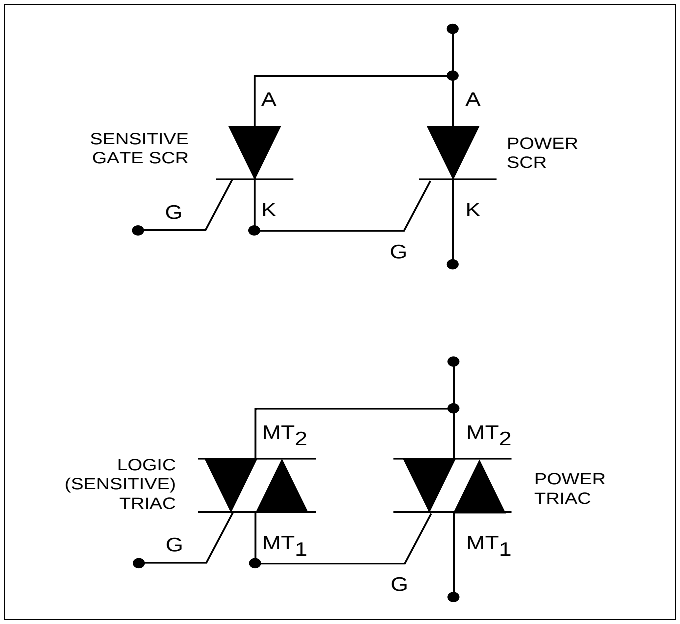


Figure 15.8 “Amplified Gate” Thyristor Construction

The following table and Figure 15.9 show the relationship of gating, latching, and holding of a 4 Amp device in table and graphic forms.

| Typical 4 Amp Triac Gating, Latching, and Holding Relationship | | | | |
|---|---|---|---|---|
| Parameter | Quadrants or Operating Mode | | | |
| | Quadrant I | Quadrant II | Quadrant III | Quadrant IV |
| $I_{GT}$ (mA) | 10 | 16 | 25 | 27 |
| $I_L$ (mA) | 12 | 48 | 15 | 13 |
| $I_H$ (mA) | 10 | 10 | 11 | 11 |

The relationships of gating, latching, and holding for several device types are shown in the following table. All the ratios are referenced to Quadrant I gating for convenience.

| Typical Ratio of Gating, Latching, and Holding Currents at 25°C | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ratio | | | | | | | | |
| Devices | $\frac{I_{GT}(II)}{I_{GT}(I)}$ | $\frac{I_{GT}(III)}{I_{GT}(I)}$ | $\frac{I_{GT}(IV)}{I_{GT}(I)}$ | $\frac{I_L(I)}{I_{GT}(I)}$ | $\frac{I_L(II)}{I_{GT}(I)}$ | $\frac{I_L(III)}{I_{GT}(I)}$ | $\frac{I_L(IV)}{I_{GT}(I)}$ | $\frac{I_H(+)}{I_{GT}(I)}$ | $\frac{I_H(-)}{I_{GT}(I)}$ |
| 4 Amp Triac | 1.6 | 2.5 | 2.7 | 2.7 | .9.5 | 3.0 | 2.0 | 2.5 | 2.6 |
| 10 Amp Triac | 1.5 | 1.4 | 8.5 | 1.6 | 4.0 | 1.8 | 2.0 | 1.1 | 1.6 |
| 15 Amp Alternistor | 1.5 | 1.8 | – | 2.4 | 7.0 | 2.1 | – | 2.2 | 1.9 |
| 1 Amp Sensitive SCR | – | – | – | 25 | – | – | – | 25 | – |
| 6 Amp SCR | – | – | – | 3.2 | – | – | – | 2.6 | – |

Examples of 10 Amp Triac:

If $I_{GT}(I)$ = 10mA, then
$I_{GT}(II)$ = 15mA
$I_{GT}(III)$ = 14mA
$I_{GT}(IV)$ = 85mA

If $I_L(I)$ = 16mA, then
$I_L(II)$ = 40mA
$I_L(III)$ = 18mA
$I_L(IV)$ = 20mA

If $I_H(+)$ = 11mA at 25°C, then
$I_H(+)$ = 16mA

## Summary

Gating, latching and holding currents characteristics of thyristors are quite important yet predictable (once a single parameter value is known). Their interrelationships (ratios) can also be used to help designers in both initial circuit application design as well as device selection.

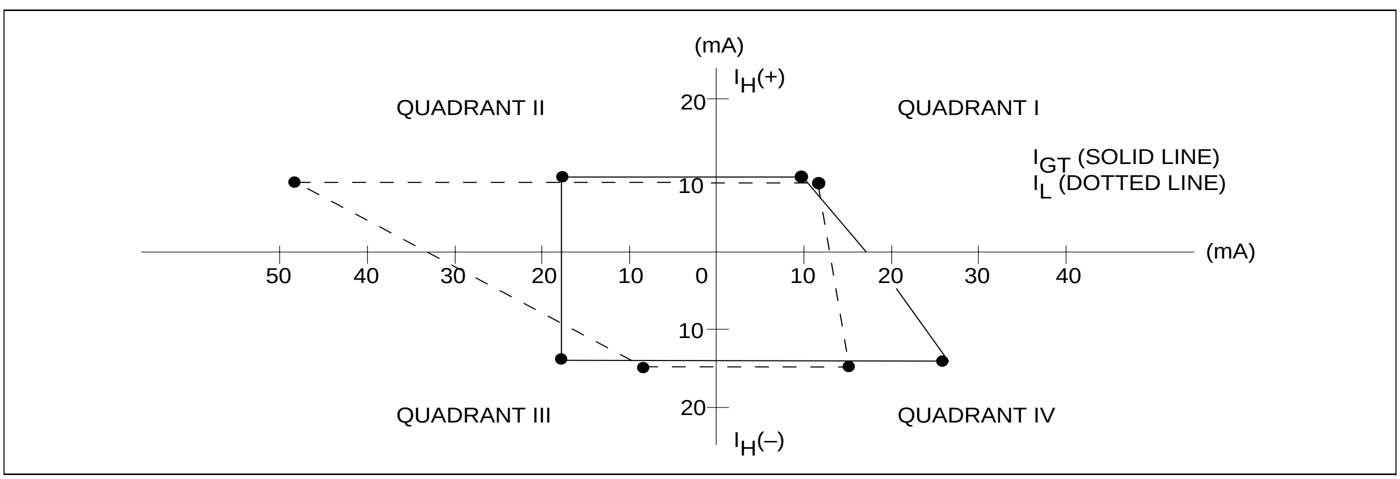


Figure 15.9 Typical Gating, Latching, and Holding Relationships of 4 Amp Triac at 25°C