

# AN6148

## Thyristor Gate Drives

### Application Note

Replaces AN6148-1

AN6148-2 January 2023 (LN42306)

#### Introduction

The output of the electronics that control the sequence of firing of thyristors is at logic level of a few volts, negligible current and usually at ground potential. The thyristors require a firing signal that is tens of volts and tens to hundreds of milliamps. In addition, the thyristor is often at a high potential above ground. The circuit that links these disparate conditions is the gate drive circuit. The purpose of the gate drive circuit is to provide a current pulse of the required shape, peak value, duration and frequency when prompted by the output from the control electronics. Also, the outputs from the gate drives invariably have to be isolated from one another because the thyristors in a converter normally have potentials that differ by many hundreds of volts. This isolation is realised with the use of pulse transformers as shown in figure 1.

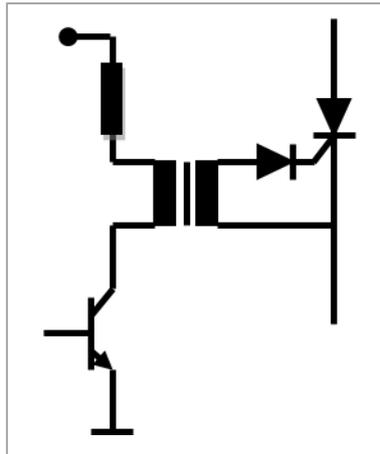


Figure 1: Typical gate drive circuit

Usually triggering is inhibited when the anode voltage of the thyristor is negative. This is because, in that mode, the thyristor acts like a low gain transistor and amplifies the gate current which is seen as an increase in anode leakage current. This, together with the blocking voltage across the device, gives a significant increase in power dissipation in the thyristor. The extra power loss has to be considered when dimensioning the heat-sinks, otherwise the device can overheat. But perhaps its most significant effect is associated with series connected thyristors where the increase in leakage current can make achieving voltage sharing between the thyristors much more difficult.

## Trigger current shape

Whilst almost any shape of current pulse will turn a thyristor into conduction as long as it exceeds the  $V_{GT}$  and  $I_{GT}$  values given in the datasheet, thyristors experience high rates of rise of anode/cathode current from the discharge of the R-C snubber circuit every time the thyristor is fired and from the commutation of other thyristors in the converter. Additionally, if thyristors are connected in series or parallel, all thyristors in an arm of the converter need to be turned on together. This reduction in delay time and the ability to receive a high  $di/dt$  is enhanced by the gate current pulse having a sharply rising front edge with a rate of rise in excess of  $1A/\mu s$ , and a peak value of 5 to 10 times the  $I_{GT}$  value. The rate of rise of the current is determined by the stray inductance of the pulse transformer. Dynex Application Note AN4840 discusses the use of gate drive load lines and the thyristor gate current - gate voltage characteristics.

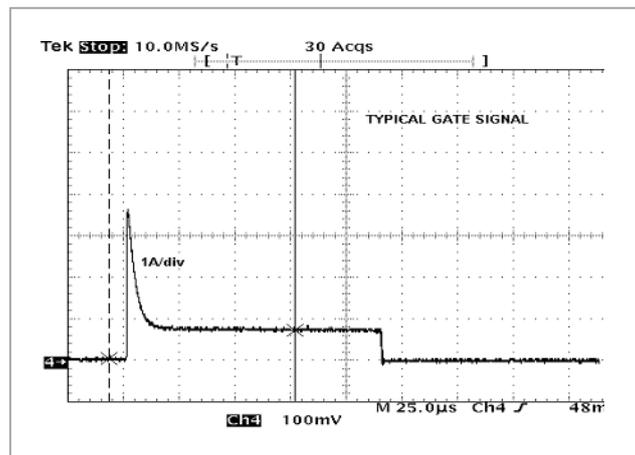


Figure 2: Typical gate pulse

The duration of the gate pulse has to be long enough for the anode current in the thyristor to reach the Latching Current specified in the datasheet or the thyristor might drop out of conduction when the gate signal is removed. Typically,  $100\mu s$  to  $150\mu s$  is adequate to allow for delay, turn-on and spreading times. However, to reduce the load on the gate driver, the gate current does not need to be maintained at the peak value but can be reduced to a lower level of about 1A known as the back-porch current.

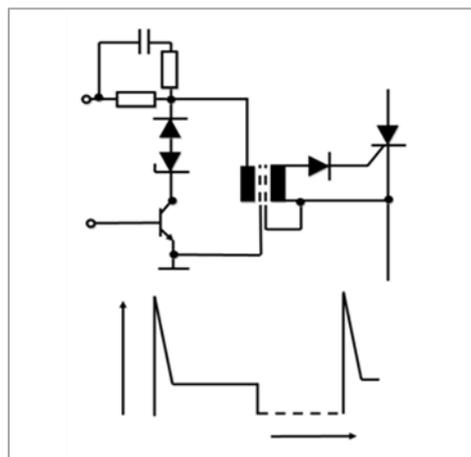
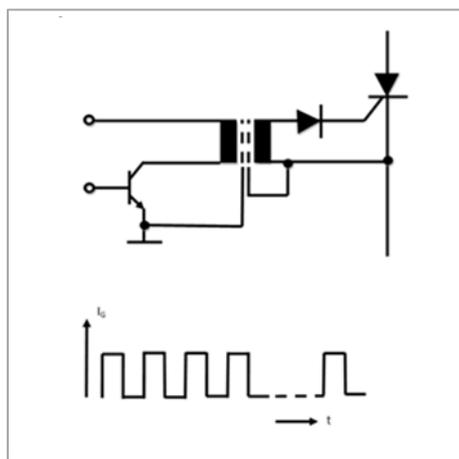


Figure 3: Long pulses with high initial peak

Although with many power circuits a pulse of  $100\mu\text{s}$  to  $150\mu\text{s}$  is sufficient to turn the thyristor on and maintain it in conduction, some circuits require the gate current to continue throughout the conducting period, while in other cases a train of short pulses during the conduction period is sufficient. The voltage may temporarily reverse during the conduction period or there may not be positive volts present at the initial point of firing. In the extreme, in the case of an AC converter with an inductive load for instance, a pulse duration of  $180^\circ - \alpha$  is required, i.e. up to 10ms for 50Hz. The most suitable system depends upon the power circuit being employed. However, the gate pulse should only be made as long as is necessary, because the magnitude of the average gate power has to be considered. The longer the gate pulse, the higher the average power which may lead to additional heating and possible destruction of the thyristor.

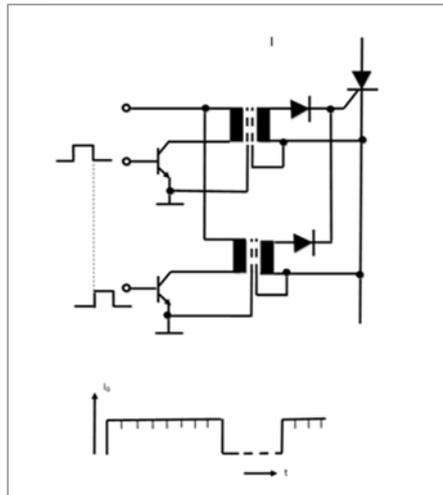
In practice it is uneconomic to produce gate drives with very long pulses for reasons of power requirements and availability of pulse transformers with suitable inductance.



**Figure 4: Short pulse picket fence**

A chain of short pulses with a frequency in the region of 5kHz to 10kHz is often used. This is sometimes called a “picket fence” waveform.

If the gaps between the pulses cause interference, a second time shifted pulse chain can be superimposed to produce a continuous long pulse. The pulse transformer only has to be dimensioned for a single pulse in the chain, say  $50\mu\text{s}$  to  $100\mu\text{s}$ .



**Figure 5: Interleaved pulses**

Note that in the above circuits a diode is included between the pulse transformer and the thyristor to eliminate negative gate pulses that are mentioned in the introduction.

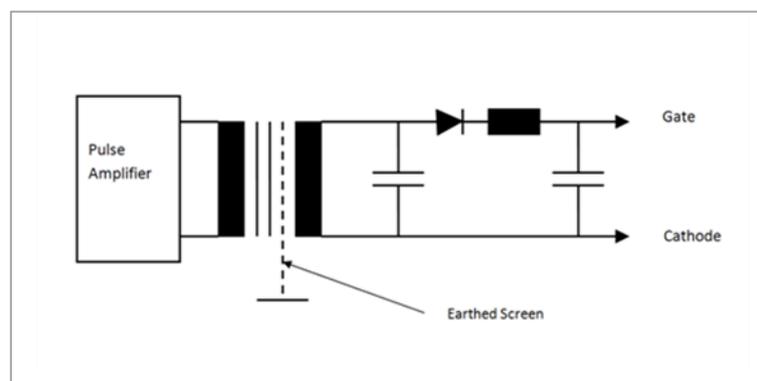
## Interference

The gate drive is what determines the performance of the equipment. Incorrect firing of the gate drive can lead to disastrous consequences. One of the frequent causes of gate drive misfiring is interference transmitted into the firing circuit from either the power circuit or from the operation of relays and contactors located in close proximity. It is therefore advisable to incorporate components into the output stage of the gate drive to improve noise immunity. These would include the blocking diodes, capacitors and earth screens on the pulse transformers.

## The output circuit of the firing circuit

The typical output circuit would therefore include:

- Pulse transformer for circuit isolation.
- Resistor to limit the maximum gate current.
- Diode, capacitors, and earth screening to prevent spurious triggering.



**Figure 6: Output of firing circuit**

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