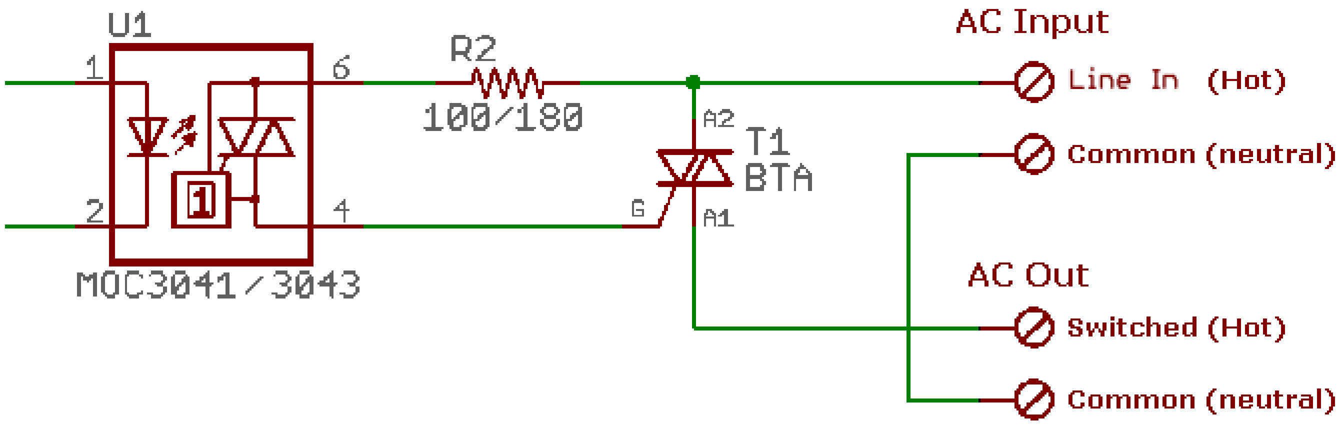
[Design Center](#) » [TriacOut Series Gate Resistor Application Note](#)

This Application Note discusses the series gate resistor in the optoisolator and triac circuit. This resistor is in series with the AC line input, the high side of the opto, and the triac gate. It limits the peak current through the optoisolator. Its value is a balance between limiting peak current, and allowing enough gate current to turn on the triac. Typical values range from 100 to 180 ohms, but specific applications may require adjusting the value.

These application notes provided very helpful information:
Littlefuse/Teccor AN1002 Gating, Latching, and Holding of SCRs and Triacs
Littlefuse/Teccor AN1007 Teccor Thyristors Used as AC Static Switches and Relays
Fairchild Semi AN-3003 Applications of Non Zero Crossing Triac Drivers Featuring the MOC3011

These and the other app notes on these sites provide a lot of detail.

This is meant to be a general discussion, but assumes some basic electrical knowledge. We assume no liability for any content here, or what you do with it; experiment at your own risk, and with low voltages. Please let me know if you have any corrections or suggestions (including the math :)



Series Gate Resistor

This note shows simplified portions of the SimpleIO TriacOut4 and TriacOut8 boards. The schematic above shows an optoisolator U1, the series gate resistor R2, and a triac T1. The triac terminals are labeled G for the gate, and A1 and A2 for the AC terminals. These labels come from the datasheet; many application notes label these G, MT1, and MT2. The connectors on the right are for line input and the switched output for the load. This omits the line fuse for simplicity.

The SimpleIO boards have the following values:

TriacOut4: MOC3041, 100 ohm resistor, BTA08-400B 50 mA gate Triac.
TriacOut8: MOC3043, 180 ohm resistor, BTA08-400B 50 mA gate Triac.

The change in the resistor from 100 to 180 ohms are the from evolution of the design, and the subject of this note. The opto difference from 3041 to 3043 is discussed elsewhere, in the DC Logic Input note (TODO).

Resistor value

The value of the series gate resistor is a balancing act between limiting the peak current through the opto, and allowing enough gate current to turn on the triac.

From the Fairchild Application Note AN-3003:
The max surge current rating of the optoisolator, I_{TSM}, is 1 A for the MOC series of optos.
The peak voltage for a 120 VAC line is 120 x 1.414 = 170 V, so R = 170 V / 1 A = 170 ohms minimum.
Round up to **180 ohms** for a standard value.

The balance comes in here for the gate current and the line voltage to drive it. The minimum voltage needed to turn on the triac is determined by adding up the gate current through the resistor I_{GT}, the triac gate voltage V_{GT}, and the opto on-state output voltage V_{TM}.
R x I_{GT} + V_{GT} + V_{TM} = 180 ohms x 50 mA + 1.3 V + 3 V = 13 V.

The Littlefuse/Teccor Application Note AN1007 suggests dropping it to 100 ohms with a different opto:

"A common mistake in this circuit is to make the series gate resistor too large in value. A value of 180 ohms is shown in a typical application circuit by optocoupler manufacturers. The 180 ohms is based on limiting the current to 1 A peak at the peak of a 120 V line input for Fairchild and Toshiba optocoupler I_{TSM} rating. This is good for protection of the optocoupler output triac, as well as the gate of the power triac on a 120 V line; however, it must be lowered if a 24 V line is being controlled, or if the RL (resistive load) is 200 W or less. This resistor limits current for worst case turnon at the peak line voltage, but it also sets turn-on point (conduction angle) in the sine wave, since triac gate current is determined by this resistor and produced from the sine wave voltage. The load resistance is also important, since it can also limit the amount of available triac gate current. A 100 ohms gate resistor would be a better choice in most 120 V applications with loads greater than 200 W and optocouplers from Quality Technologies or Vishay with optocoupler output triacs that can handle 1.7 A_{PK} (I_{TSM} rating) for a few microseconds at the peak of the line. For loads less than 200 W, the resistor can be dropped to 22 ohms. Remember that if the gate resistor is too large in value, the triac will not turn on at all or not turn on fully, which can cause excessive power dissipation in the gate resistor, causing it to burn out."

On the SimpleIO boards, we went from 100 ohms to 180 ohms, just to follow the peak current limit more precisely.

The TriacOut4 board has 100 ohms from the original design. This is good for lower input voltages and turning on the triac. It is a little low for the peak current on the opto, but has been ok as a practical matter.

The TriacOut8 board has 180 ohms to help with the peak current. This may be too high for 24 Vac inputs, but the option above to use other optos was too expensive.

The resistor values can be changed to suit specific applications.

Line input voltage

The above discussion notes the input voltage also affects the resistor value. For **115 Vac**, **100** or

180 ohms will work fine for most loads. The 180 is a little too high for a 24 Vac line to trigger the gate, and too low for a 220 Vac line for the opto peak current limit.

For **24 Vac** line, the triac will turn on with the 100 ohm and 180 ohm resistors, but I think the initial turn-on cycle will be 'late', at 13 V max (but I think it stays on once turned on). A resistor value better suited is:
24 x 1.414 = 34 V, so R = 34 V / 1 A = 34 ohms minimum. Round to **33 ohms** for a standard value.
The max triac turn-on voltage will be:
R x I_{GT} + V_{GT} + V_{TM} = 33 ohms x 50 mA + 1.3 V + 3 V = 6.0 V.

For **220 Vac** line (use 230 to be consistent with the 115 math):
230 x 1.414 = 325 V, so R = 325 V / 1 A = 325 ohms minimum. Round to **360 ohms** for a standard value.
The max triac turn-on voltage will be:
R x I_{GT} + V_{GT} + V_{TM} = 360 ohms x 50 mA + 1.3 V + 3 V = 22 V.

Resistor wattage

The resistor has a 1/4 W power rating, determined by measuring a typical board for timing, then applying the max current spec. The average power is very small.

Measuring the voltage across the resistor when the triac is on showed a 5 mA pulse for about 50 us every half cycle of AC. Apparently, this is when the triac is switching, and draws current on the gate.

To calculate the Root-Mean-Square (RMS) power through the resistor, let's use the 50 us as the pulse time, but increase the current to the 50 mA max spec'ed for the triac.

The square of the max current is $(50 \text{ mA})^2$ = 2500 uA^2.
The mean (average) over the time is 50 us / 16.6 ms for the AC half cycle.
So the average squared current is 2500 x 50 us / 16.6 ms = 7.5.
Take the square root to get 2.7 mA as the RMS current.

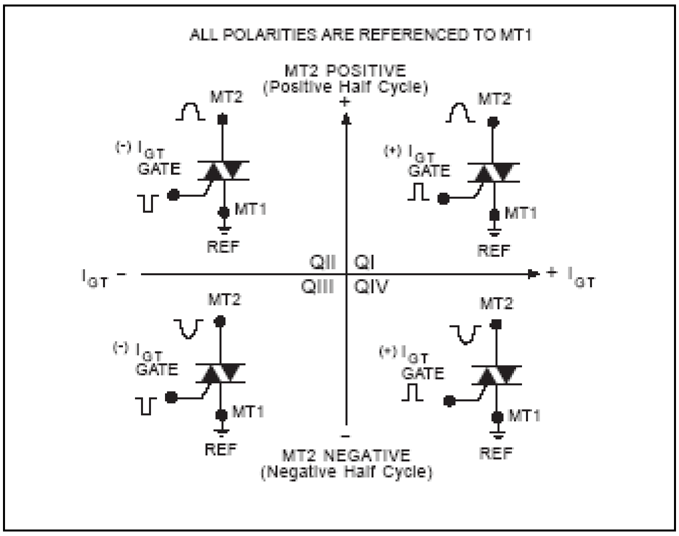
The RMS power is then simply I^2 x R = $(2.7 \text{ mA})^2$ x 100 ohms = 1.5 mW.
For the 180 ohm resistor, the RMS power is $(2.7 \text{ mA})^2$ x 180 ohms = 2.7 mW.
These are both well under 1/4 W.

The SimpleIO boards use a miniature resistor from Panasonic, to keep the physical size small to help with clearances from the high voltage traces. This drove the goal of determining that the 1/4 W rating was ok.

Quadrants

Just a side note on operating quadrants.
The max gate current spec, I_{GT}, is 50 mA in quadrant I, II, and III; and 100 mA in quadrant IV.

With A1 as the reference, Quadrant I is where the gate is positive when A2 is positive. Quadrant III is where the gate is negative when A2 is negative. Since this circuit has the hot coming into A2 and around to the gate, the gate always matches A2, so it always operates in quadrants I and III. So, we used the 50 mA spec above.



Operating Quadrants in Triacs
Figure from Littlefuse Teccor Application Note AN1002
Gating, Latching, and Holding of SCRs and Triacs

Author: Bob Cooley