TRIAC SPECIFICATIONS AND RECOMMENDATIONS (TURN-ON BEHAVIOR)

Wiki defines a TRIAC as an electronic component approximately equivalent to two silicon-controlled rectifiers (SCRs/thyristors) joined in inverse parallel (paralleled but with the polarity reversed) and with their gates connected together. This results in a bidirectional electronic switch which can conduct current in either direction when it is triggered (turned on) and thus doesn't have any polarity. It can be triggered by either a positive or a negative voltage being applied to its gate electrode. Once triggered, the device continues to conduct until the current through it drops below a certain threshold value, the holding current, such as at the end of a half-cycle of alternating current (AC) main power. This makes the TRIAC a very convenient switch for AC circuits, allowing the control of very large power flows with milliampere-scale control currents. In addition, applying a trigger pulse at a controllable point in an AC cycle allows one to control the percentage of current that flows through the TRIAC to the load (phase control).

Ansys was requested by a customer to identify the critical triac part parameters and determine the margins necessary to ensure the successful operation of their modular control system. The current TRIAC used is a sensitive gate type.

Turn on control circuit
Turn on (latch) when you apply the triggering voltage to the gate and support the valve station current and voltage output to energize the specified number and type of solenoid loads.

- Gate trigger current (quadrant specific)
  - Max, min, justification
- Potentially other minor loads

Turn off control circuit
Stay off unless you apply the triggering voltage to the gate, even when exposed to excessive dV/dt, noise on the main AC power source, or back EMF after de-energizing the inductive solenoid load.

- Gate trigger current
  - Max, min, justification
- Breakover voltage
  - Max, min, justification
- Minimum holding current
  - Max, min, justification
- Maximum dV/dt
  - Max, min, justification

Perform for 10 years
Turn off rapidly enough when the triggering voltage is removed to prevent circuit damage during an overcurrent condition for a station.

- Minimum holding current
  - Max, min, justification

Remain functional in the event of exposure to a specified surge on a valve wire.

- Breakover voltage
  - Max, min, justification
- Surge current
  - Max, min, justification

Ability to dissipate power and allow extended latching without part degradation.

- RMS on-state current
  - Max, min, justification
- Junction temperature
  - Max, min, justification

/ SPICE SIMULATION

A SPICE model of the circuitry between the TRIAC and the driver was simulated to determine the impact of solenoids and TRIAC parameters. The schematic of the model is shown in Figure 1. The TRIAC behavior was specified using a SPICE directive that accounts for:

- Holding current
- Critical value of dV/dt triggering
- Gate trigger current
- Gate trigger voltage
- On-state voltage
- On-state current
- Turn-on time

This was modified to investigate critical triac properties. The SPICE model predicts the behavior of the actual circuit reasonably well as shown in the comparison between the measured triac voltage drop and the simulated drop, shown in Figure 2.

Figure 1 : SPICE model of TRIAC circuit.

Figure 2 : Voltage drop across TRIAC, measured (left) and SPICE (right)

Triac loading as number of solenoids increases
The SPICE simulations for 1 to 3 solenoids attached are shown in Figure 3 through Figure 5. As shown by the figures the current increases proportionally with the number of TRIACs attached. The solenoids were assumed to have an inductance of 0.100 H and a resistance of 40 ohms.

A circuit with one solenoid was selected for modeling as this is worst case for turn-on operations. Because of the elevated inductance of the coil, the length of wire between the TRIAC and the solenoid was not considered.

In AC operation, turn-on in TRIACs is a primarily a function of the gate trigger current. The gate trigger current is needed to re-bias the junctions within the TRIAC every half cycle when the load current passes through zero. Secondarily, if the holding current is too low and leakage current or noise is experienced in the TRIAC or line, respectively, there is unintended turn-on of the TRIAC in the absence of gate trigger signal. Turn-on time is only an issue in high frequency circuits, and is not an issue for 60Hz usage.
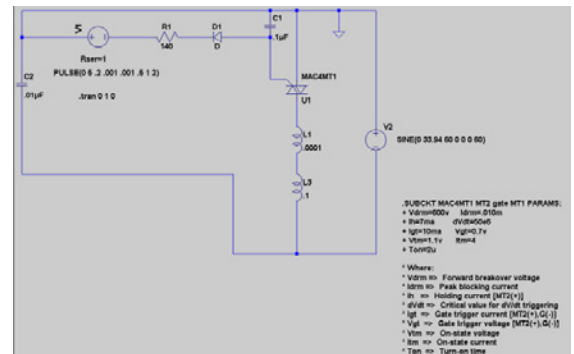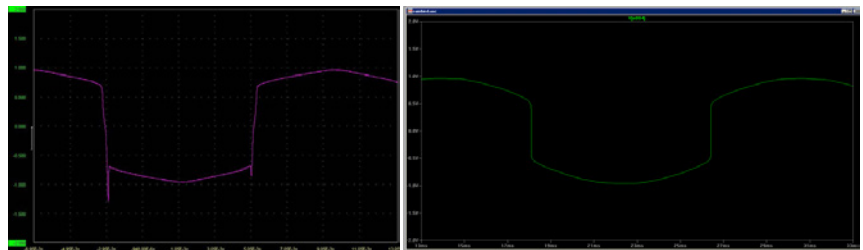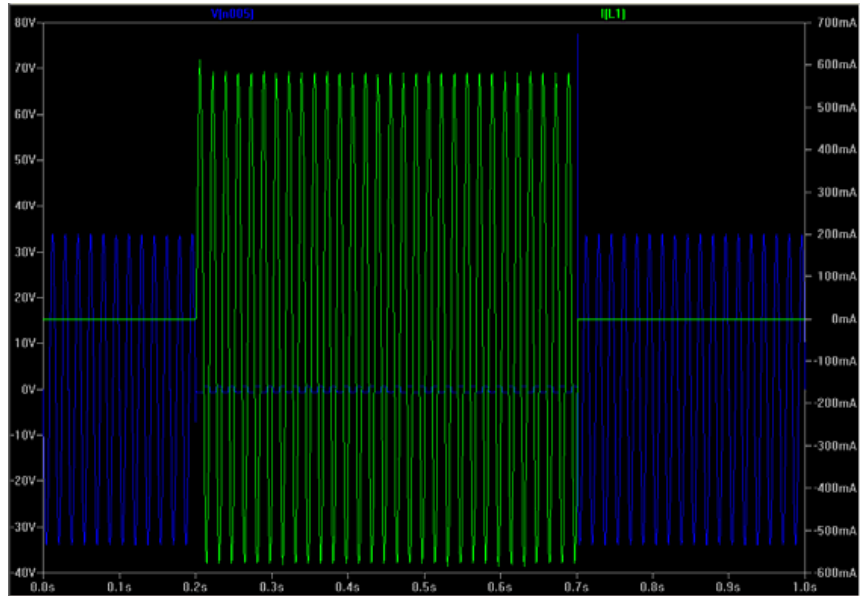
Figure 3: Triac voltage drop and solenoid current, one solenoid – 600 mA.
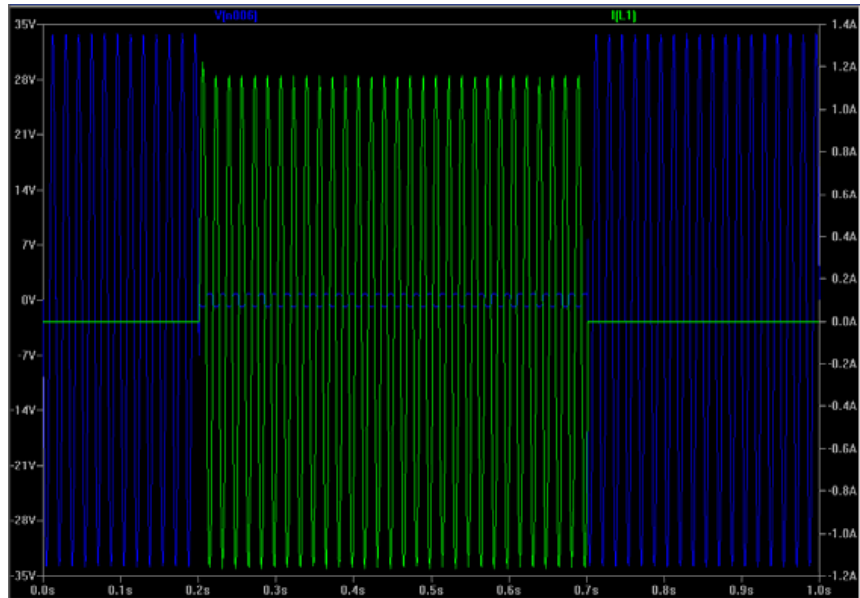

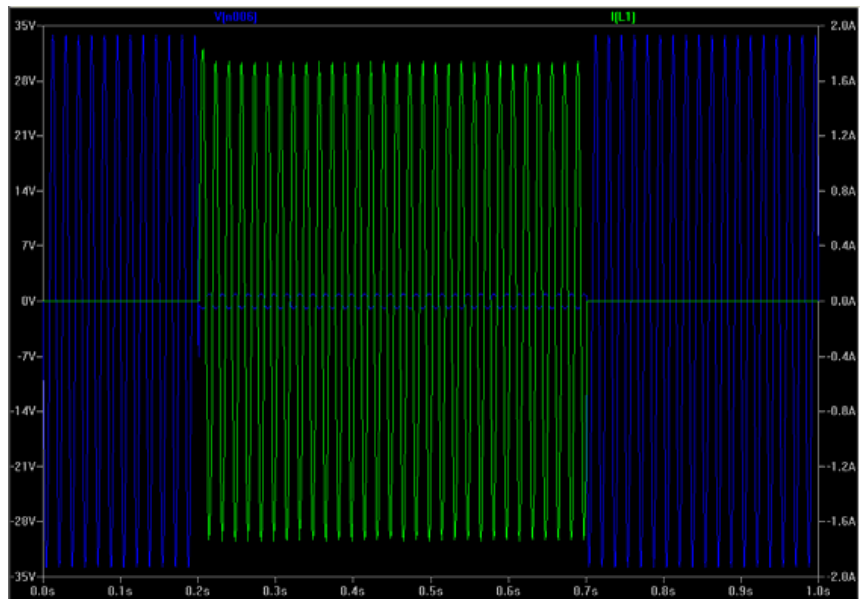Figure 4: Triac voltage drop and solenoid current, two solenoids – 1200 mA.

Figure 5 :Triac voltage drop and solenoid current, three solenoids – 1800 mA.

Gate Trigger Current
In order to more accurately map the required gate current values a SPICE simulation was run with varying gate trigger currents. The result of which shows that a gate trigger current of 16.7mA is the maximum IGT at which turn-on occurs properly. Figure 6 and Figure 7 show proper turn on at 16.7mA.

At gate trigger currents of above 16.7mA, improper turn-on is observed. In Figure 8, the voltage spikes across the TRIAC every half cycle, as well as the larger spikes present at turn-on shown in detail in Figure 9.

Further increase in gate trigger current parameters of the test TRIAC results in ever degrading turn-on characteristics. See Figure 10 and Figure 11. Voltage spikes across the TRIAC indicate intermittent power driving the solenoid valves which may not allow the solenoids to operate properly.

When the gate trigger current is increased further the voltage spikes become more severe. At a trigger current of 17.2mA the TRIAC is only active for half a cycle (Figure 12 and Figure 13). This is a function of the quadrant specificity of the gate trigger current.

Complete failure to operate when the gate signal is applied occurs as the TRIAC gate trigger current reaches 17.3mA, as seen in Figure 14.

The quadrant specific rating of TRIAC gate trigger currents is normally only relevant for DC operation, when the bias of trigger voltages as well as the bias for load voltage is known and constant. The control system is an AC system, with an inductive load. For this reason, the TRIAC needs to operate in all quadrants. As the threshold of the gate current rating is reached, one or possibly two quadrants will fail before the others, resulting in half wave operation.

Noise on the gate of the TRIAC may further decrease the required IGT parameter by a value equal to those measured in the typical operating environment.

Holding Current
Holding current was found by setting the gate trigger current at 15mA. The minimum operating holding current was found to be 0.302mA. At 0.301 mA, partial turn-on was observed in the absence of a gate trigger current as shown in Figure 15 and Figure 16. Noise on the load line will increase the minimum value of the holding current by a value equal to the noise current. Adjusting the trigger current to values under the maximum of 16.7 had no effect on the value attained.
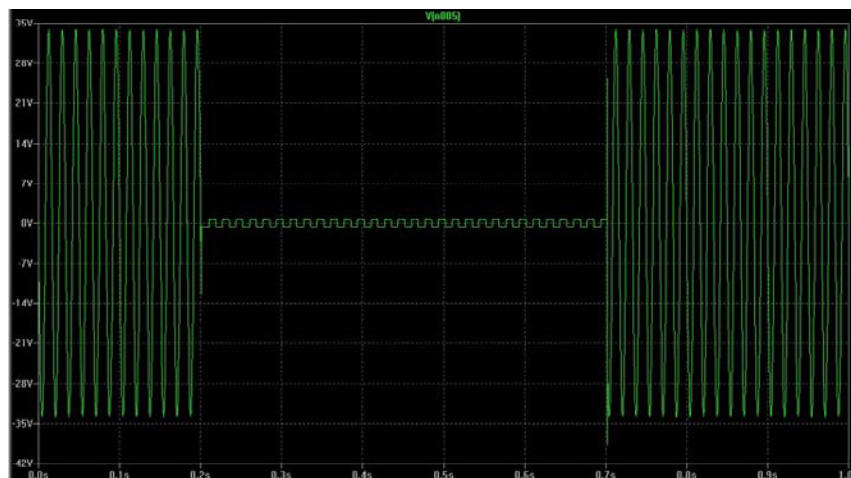

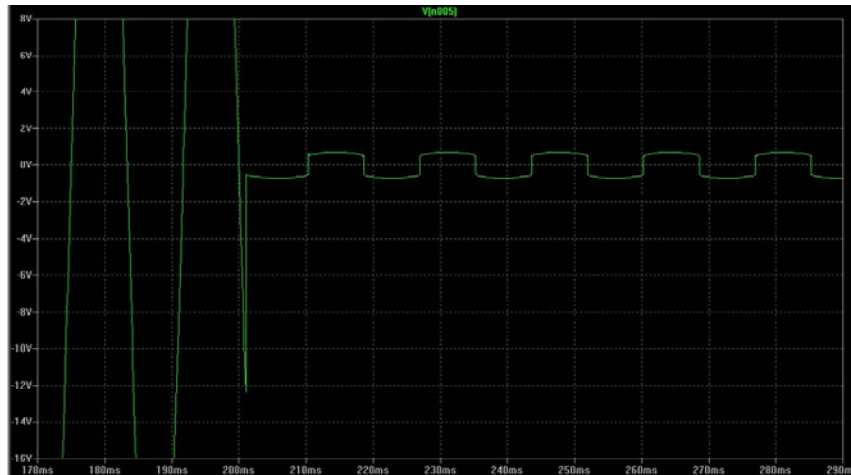
Figure 6 : Variable TRIAC, 16.7mA gate current.

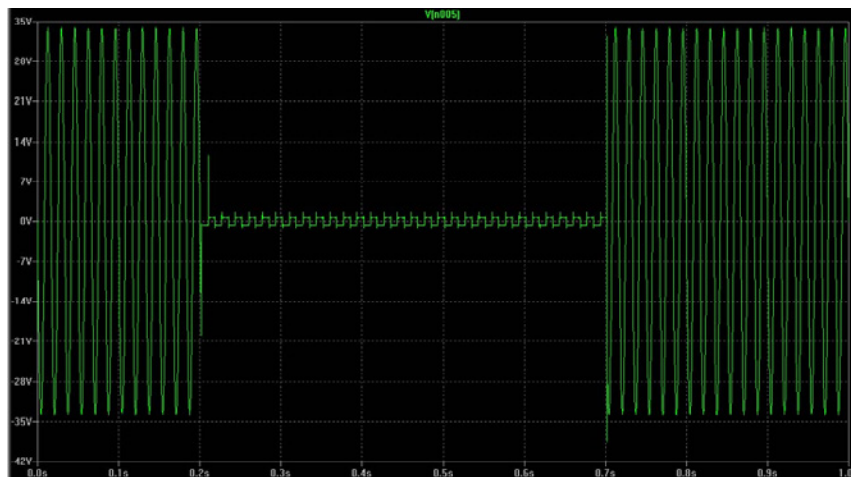Figure 7 : Variable TRIAC, gate current 16.7mA. (close-up of turn-on characteristics)

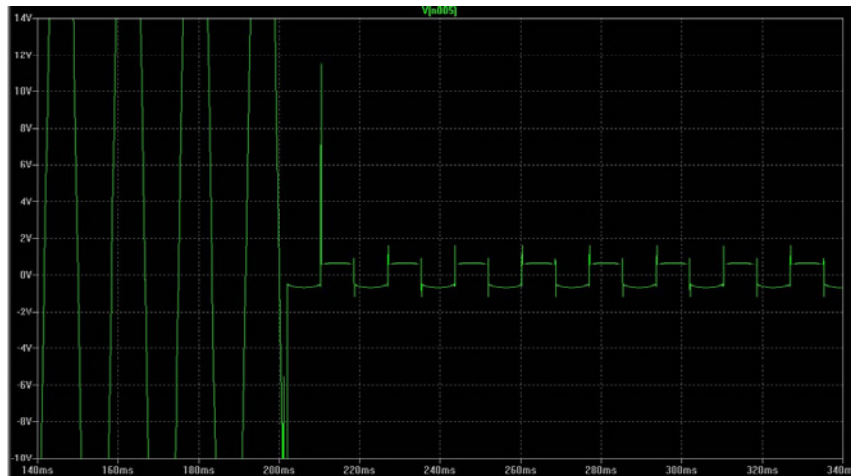Figure 8 : Variable TRIAC, 16.8mA gate current.

Figure 9 : Variable Triac, gate current 16.8mA. Close up of turn-on characteristics.
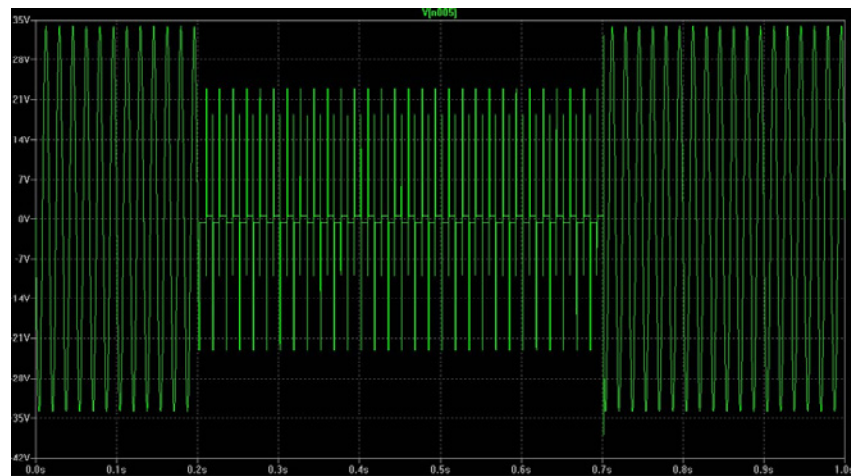

Figure 10 : Variable TRIAC, 16.9mA gate current.

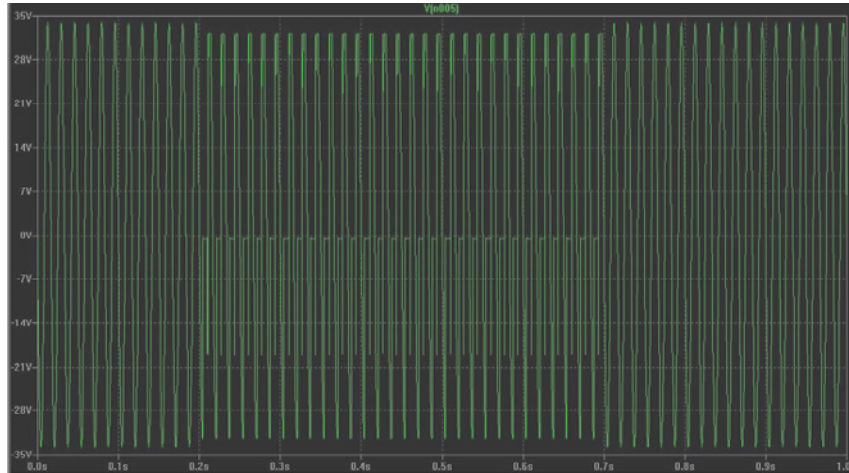Figure 11 : Variable TRIAC, gate current 16.9mA. (close-up of turn-on characteristics)

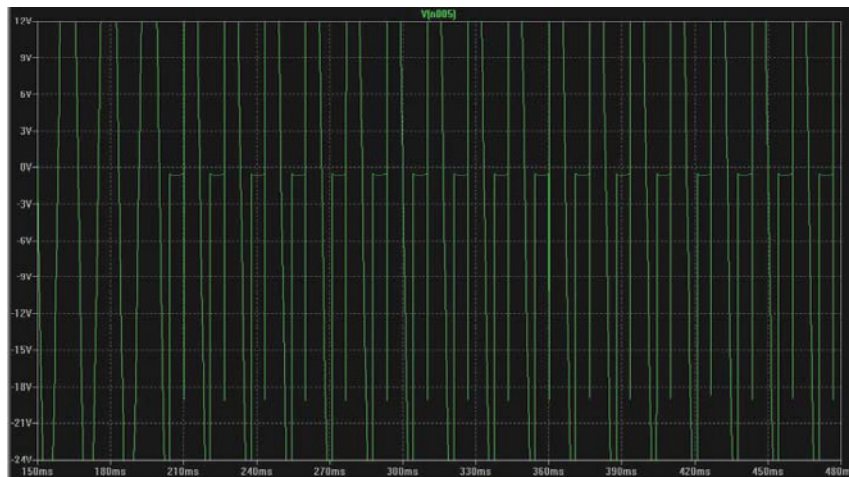Figure 12 : Variable TRIAC, 17.2mA gate current.

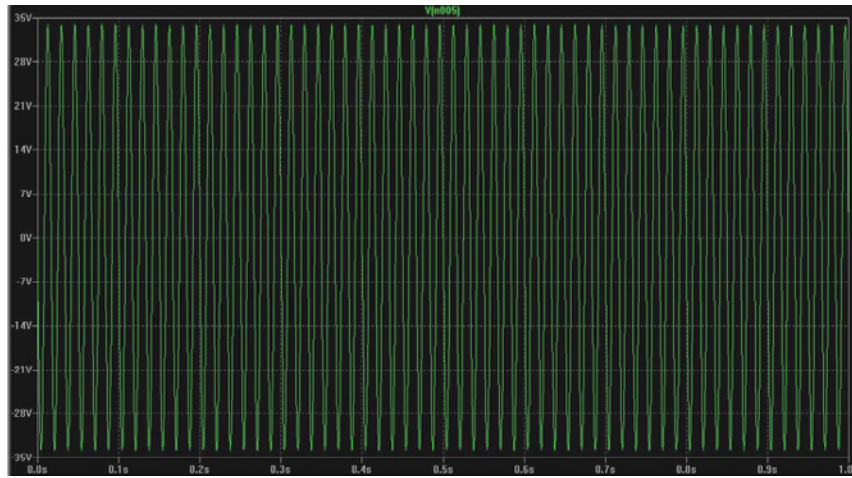Figure 13 : Variable TRIAC, gate current 17.2mA. (close-up of turn-on characteristics)

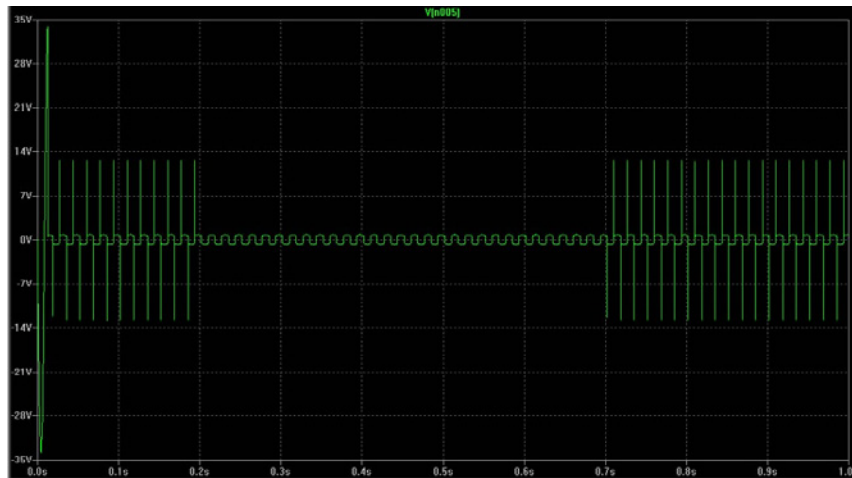Figure 14 : Variable TRIAC, 17.3mA gate current.

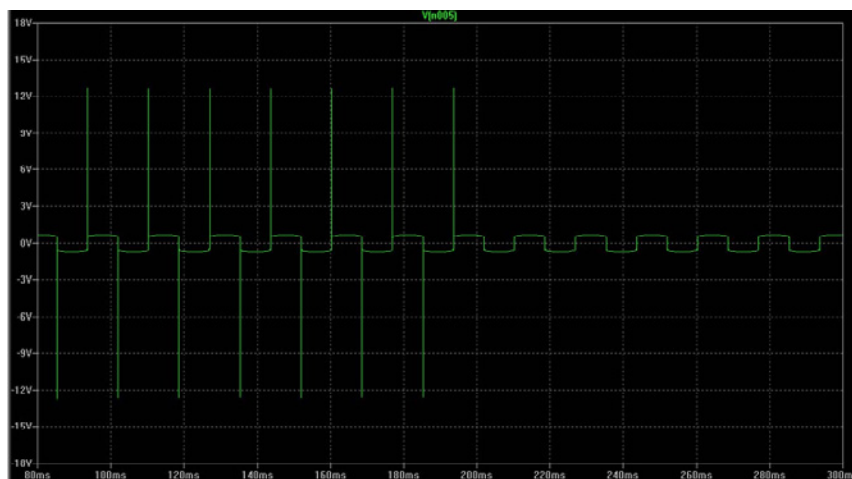
Figure 15 : Variable TRIAC, Holding current 0.301mA.

Figure 16 : Variable TRIAC, Holding current 0.301mA. Close-up of turn-on.

/ DISCUSSION/CONCLUSION

Turn-on characteristics are dependent on the gate trigger current rating and the minimum holding current rating. In noise-free simulation, the critical values are as follows:

- I_{gt}: 16.7mA (maximum)
- I_h: 0.302mA (minimum)

Continued analysis of the circuit and TRIAC properties with regards to triac turn-off and lifetime reliability may further limit these values. Noise issues should also be considered when establishing appropriate margins.

For more information, and to request a quote from our Ansys Reliability Engineering Services Team, visit: https://upl.inc/a5b0679

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