Introduction

Light dimmer can use either Triac or MOSFET switches. MOSFET requires less power for control than a Triac, but they are less robust against lightning surges, which can appear on mains. Consequently, they need to be protected to avoid dimmer failure following a lightning surge.

The TVS (Transient Voltage Suppressor) is the first idea to protect MOSFET: however, due to mains voltage, TVS breakdown voltage must be higher than 350 V, which leads to a high power dissipation during lightning surge.

Another solution is to use a thyristor based surge protection (also called crowbar protection, Trisil), which also protects against lightning surge, and provide a lower power dissipation than a TVS: as it acts as a SCR, voltage during surge is low, so power dissipation is low.
1 EMC standard for lighting equipment

Equipment connected to the mains must be compliant with IEC 61000-4-5 standard (Testing and measurement techniques – Surge immunity test): AN4275 gives an overview of this standard, and measurement setups.

For lighting equipment, IEC 61547 gives EMC immunity requirements, where following IEC 61000-4-5 levels are specified:

- For input power < 25 W:
  - Line to line (differential mode) surge 1.2/50 µs (8/20 µs) wave shape: +/-0.5 kV (so 250 A in short circuit)
  - Line to ground (common mode) surge 1.2/50 µs (8/20 µs) wave shape: +/-1 kV (so 84 A in short circuit)

- For input power > 25 W:
  - Line to line (differential mode) surge 1.2/50 µs (8/20 µs) wave shape: +/-1 kV (so 500 A in short circuit)
  - Line to ground (common mode) surge 1.2/50 µs (8/20 µs) wave shape: +/-2 kV (so 167 A in short circuit)

In case of dimmer, where there is no connection to ground, only line to line surge is considered.
2 SMP100LC-400 to protect MOSFETs

2.1 Schematic

Figure 1. SMP100LC-400 to protect dimmer MOSFET gives a typical implementation of SMP100LC-400 on a MOSFET based dimmer: it is placed in parallel with dimmer MOSFETs, to clamp the voltage during surge, and to keep value lower than MOSFET $V_{DS\text{max}}$ (generally, 600 V – 700 V MOSFET are used).

![Schematic Diagram]

2.2 SMP100LC-400 characteristics

According to countries, mains voltage is not the same. The highest voltage riches 240 V\(_{\text{RMS}}\), which gives a peak voltage of 340 V.

SMP100LC-400 $V_{\text{RM}}$ is 360 V, as shown on Figure 2. SMP100LC-400 electrical characteristics, which is compliant with a max voltage of 340 V.

![Figure 2. SMP100LC-400 electrical characteristics]

Regarding maximum 8/20 µs current, SMP100LC-400 can withstand 400 A (see Figure 3. SMP100LC-400 absolute maximum rating).

As shown on Figure 1. SMP100LC-400 to protect dimmer MOSFET, bulb is in series with the SMP100LC-400: surge current will be limited, so 400 A is enough to withstand at least 2 kV, as shown on Section 3 Measurements examples.
Thyristor based protection advantages versus TVS

As mains is AC voltage, thyristor based protection can be used, as it will for sure turned-off with current polarity change.

Advantage of a thyristor based protection versus TVS is the 8/20 µs current capability. Indeed, the maximum current is limited by the power handling capability of a device:

- For a thyristor based protection, when triggered, the clamping voltage is low, due to SCR effect
- For a TVS, the clamping voltage is higher than the breakdown voltage, so higher than 340 V
- Consequently, for a same power device, maximum current that thyristor based protection can handle is much higher than one current that a TVS can handle
- On another way, package to get same current capability is smaller for a thyristor based protection than for a TVS

Thus, using a thyristor based protection allows to get a higher current capability than a TVS, with a smaller package.

Withstanding more current is particularly useful with incandescence bulb, as the resistance series are much lower than a Led bulb. As an example, a 200 W (240 V_{RMS}) incandescence bulb resistance series are 288 Ω when hot. However, when the bulb is off, so at ambient temperature, the resistance series are roughly divided by 10, giving 29 Ω. For 2 kV, this leads to a current of 69 A. High power TVS, or several in series, are needed to withstand this current, whereas SMP100LC-400 is suitable.
3 Measurement examples

Measurements have been performed with several LED bulbs, halogen bulb and incandescence bulb. Figure 4. Surge measurement setup with bulb shows the measurement setup: bulb is in series with SMP100LC-400, same configuration as Figure 1. SMP100LC-400 to protect dimmer MOSFET.

Figure 4. Surge measurement setup with bulb

\[1.2 \, \mu s/50 \, \mu s, \, 8/20 \, \mu s\]
\[R_s = 2 \, \Omega\]

Figure 5. Measurement results for 1 kV surge IEC61000-4-5 gives measurement results for 1 kV surge IEC61000-4-5: peak voltage is 466 V, lower than MOSFET \(V_{D\text{Smax}}\).

Figure 5. Measurement results for 1 kV surge IEC61000-4-5

Figure 6. Measurement results for 2 kV surge IEC61000-4-5 gives measurement results for 2 kV surge IEC61000-4-5: SMP100LC-400 still OK, and clamping voltage is 472 V, lower than MOSFET \(V_{D\text{Smax}}\). The current on SMP100LC-400 is 6 A.

Figure 6. Measurement results for 2 kV surge IEC61000-4-5
Figure 6. Measurement results for 2 kV surge IEC61000-4-5

50 ms/div

20 µs/div

Current (5 A/div)

Current (100 A/div)

Figure 7. Measurement results for 4 kV surge IEC61000-4-5 gives measurement results for 4 kV surge IEC61000-4-5: SMP100LC-400 still OK, and clamping voltage is 472 V, lower than MOSFET $V_{D\text{Smax}}$. The current on SMP100LC-400 is 10.4 A.

Figure 7. Measurement results for 4 kV surge IEC61000-4-5

50 ms/div

20 µs/div

Current (5A/div)

Current (100A/div)

Below figure show measurements results on several bulbs, with state of SMP100LC-400 after tests. We can notice that up to 2 kV, the SMP100LC-400 is still OK.

For 4 kV surge, SMP100LC-400 state depends on the bulb state:

- SMP100LC-400 is still Ok if the bulb still Ok, or fails in open circuit after surge
- When bulb fails in short circuit, SMP100LC-400 fails also, as there is no more impedance in series with the SMP100LC-400 (it will be the same for a TVS)
<table>
<thead>
<tr>
<th>Bulb type</th>
<th>Plug</th>
<th>SMP100LC-400 1 kV</th>
<th>SMP100LC-400 2 kV</th>
<th>SMP100LC-400 4 kV</th>
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<tr>
<td>Dimmable LED bulb A</td>
<td>E27</td>
<td>Ok</td>
<td>Ok</td>
<td>Failed (due to bulb failure in short)</td>
</tr>
<tr>
<td>Dimmable LED bulb B</td>
<td>E27</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
<tr>
<td>Dimmable LED bulb C</td>
<td>E27</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
<tr>
<td>Dimmable LED bulb D</td>
<td>E27</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
<tr>
<td>Dimmable LED bulb E</td>
<td>GU10</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
<tr>
<td>Dimmable LED bulb F</td>
<td>GU10</td>
<td>Ok</td>
<td>Ok</td>
<td>Failed (due to bulb failure in short)</td>
</tr>
<tr>
<td>Dimmable LED bulb G</td>
<td>GU10</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
<tr>
<td>Dimmable LED bulb H</td>
<td>E27</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
<tr>
<td>Dimmable LED bulb I</td>
<td>E27</td>
<td>Ok</td>
<td>Ok</td>
<td>Failed (due to bulb failure in short)</td>
</tr>
<tr>
<td>60 W Incandescence bulb</td>
<td>B22</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
<tr>
<td>Halogen Spot</td>
<td>E27</td>
<td>Ok</td>
<td>Ok</td>
<td>Ok</td>
</tr>
</tbody>
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As shown on Figure 5. Measurement results for 1 kV surge IEC61000-4-5, Figure 6. Measurement results for 2 kV surge IEC61000-4-5 and Figure 7. Measurement results for 4 kV surge IEC61000-4-5, when SMP100LC-400 is Ok after tests, this implies that dimmer MOSFET is also Ok, as voltage is limited by SMP100LC-400 to a lower value than $V_{DSmax}$. 
Conclusion

Measurement results, on several bulbs, show that the SMP100LC-400 can efficiently protect dimmer MOSFET at least up to 2 kV (IEC61000-4-5, line to line surge), which exceeds IEC 61547 requirements.

It can also be efficient for 4 kV surge, if bulb withstands 4 kV, or failed in open circuit.

In comparison with TVS, thyristor based protection (also called crowbar surge protection, Trisil) offers better performance (8/20 µs maximum current is higher), with a smaller package.

The SMP100LC-400 is suitable to well protect dimmer MOSFET, to make it compliant with IEC 61547 standard for IEC 61000-4-5 surge tests.
# Revision history

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<td>17-Sep-2019</td>
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