AN-9068
Gate Resistor Design Guidelines for SupreMOS® MOSFETs

Summary
The faster switching of power MOSFETs enables higher power conversion efficiency. However, parasitic components in the devices and boards are involving switching characteristics more as the switching speed increases. This creates unwanted side effects, like voltage spikes or poor EMI performance. To achieve balance, it is important to have optimized gate drive circuitry because a power MOSFET is a gate-controlled device. One of critical control parameters in gate-drive design is external series gate resistor (Rg). This note suggests minimum and maximum values of Rg for the SupreMOS® MOSFETs in hard-switching applications. As too small Rg results in excessive dv/dt across drain and source of the MOSFET during switching-off, low limit is a value that makes switching dv/dt within the specification in the datasheets. Silicon Carbide (SiC) Schottky barrier diode, Deuxpeed® rectifier, and STEALTH™2 diodes are used for clamp diode since the diode characteristics affect the dv/dt. Too large Rg causes loss and poor efficiency; therefore, the upper limit is chosen to have the same switching losses as the SuperFET® MOSFETs or competitors.

Minimum Values According to dv/dt
Table 1 shows low limits of Rg. The unit of Rg in Table 1 is Ohm (Ω). Since the dv/dt varies by drain current level, it is tested with two conditions. For example, when using FCP76N60N with a SiC diode under half of rated current, at least 13Ω or larger Rg is required to keep the switching dv/dt under 50V/ns during switching-off transient.

The dv/dt with a SiC diode is lower than dv/dt with other diodes due to the bigger junction capacitance of SiC SBD. A gap of the dv/dt values is getting larger at lower drain current level and smaller Rg. This is because, at lower current, the dv/dt is relatively low and the effect of output capacitance of the MOSFET and diode junction capacitance on the dv/dt becomes more significant.

If a specific Rg value is needed for other dv/dt not shown in Table 1, it can be selected by referring to Figure 13 through Figure 18.

Table 1. Minimum Rg Guidelines Ohms

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<th>Device</th>
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<th>Dx</th>
<th>S2</th>
<th>SiC</th>
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The dv/dt at 1/2 of Id

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Upper Limits Considering Switching Losses
When the SuperFET® MOSFET or other previous-generation power MOSFET is directly replaced with the SupreMOS MOSFET, switching losses are reduced, but the dv/dt may be higher. To control the dv/dt of SupreMOS MOSFETs, increased Rg is required. In this case, there should be a limit line for increasing the Rg or switching losses with SupreMOS MOSFET could be larger. Figure 19 through Figure 54 show switching losses according to Rg for each device. Rg for similar or less switching loss can be raised. For example, if 10Ω is used for a FCA35N60 SuperFET MOSFET, 33Ω achieves similar EON and EOF in under conditions of half of rated drain current and STEALTH™2 diode.
Typical Performance Characteristics

Figure 1. FCA76N60N dv/dt at Half $I_D$

Figure 2. FCA76N60N dv/dt at Rated $I_D$

Figure 3. FCA47N60N dv/dt at Half $I_D$

Figure 4. FCA47N60N dv/dt at Rated $I_D$

Figure 5. FCA36N60N dv/dt at Half $I_D$

Figure 6. FCA36N60N dv/dt at Rated $I_D$
Typical Performance Characteristics

Figure 7. FCP25N60N dv/dt at Half I_D

Figure 8. FCP25N60N dv/dt at Rated I_D

Figure 9. FCP22N60N dv/dt at Half I_D

Figure 10. FCP22N60N dv/dt at Rated I_D

Figure 11. FCP16N60N dv/dt at Half I_D

Figure 12. FCP16N60N dv/dt at Rated I_D
Typical Performance Characteristics

Figure 13. FCP13N60N dv/dt at Half $I_d$

Figure 14. FCP13N60N dv/dt at Rated $I_d$

Figure 15. FCP11N60N dv/dt at Half $I_d$

Figure 16. FCP11N60N dv/dt at Rated $I_d$

Figure 17. FCP9N60N dv/dt at Half $I_d$

Figure 18. FCP9N60N dv/dt at Rated $I_d$
Typical Performance Characteristics

Figure 19. FCA76N60N $E_{on}$ vs. Competitor at Half $I_D$

Figure 20. FCA76N60N $E_{on}$ vs. Competitor at Rated $I_D$

Figure 21. FCA76N60N $E_{off}$ vs. Competitor at Half $I_D$

Figure 22. FCA76N60N $E_{off}$ vs. Competitor at Rated $I_D$

Figure 23. FCA47N60N $E_{on}$ vs. FCA47N60 at Half $I_D$

Figure 24. FCA47N60N $E_{on}$ vs. FCA47N60 at Rated $I_D$
Typical Performance Characteristics

Figure 25. FCA47N60N $E_{OFF}$ vs. FCA47N60 at Half $I_D$

Figure 26. FCA47N60N $E_{OFF}$ vs. FCA47N60 at Rated $I_D$

Figure 27. FCA36N60N $E_{ON}$ vs. FCA35N60 and Competitor at Half $I_D$

Figure 28. FCA36N60N $E_{ON}$ vs. FCA35N60 and Competitor at Rated $I_D$

Figure 29. FCA36N60N $E_{OFF}$ vs. FCA35N60 and Competitor at Half $I_D$

Figure 30. FCA36N60N $E_{OFF}$ vs. FCA35N60 and Competitor at Rated $I_D$
Typical Performance Characteristics

**Figure 31. FCP25N60N E\textsubscript{ON} vs. Competitor at Half \textit{I}_D**

**Figure 32. FCP25N60N E\textsubscript{ON} vs. Competitor at Rated \textit{I}_D**

**Figure 33. FCP25N60N E\textsubscript{OFF} vs. Competitor at Half \textit{I}_D**

**Figure 34. FCP25N60N E\textsubscript{OFF} vs. Competitor at Rated \textit{I}_D**

**Figure 35. FCP22N60N E\textsubscript{ON} vs. Competitor at Half \textit{I}_D**

**Figure 36. FCP22N60N E\textsubscript{ON} vs. Competitor at Rated \textit{I}_D**
Typical Performance Characteristics

Figure 37. FCP22N60N E\textsubscript{OFF} vs. Competitor at Half I\textsubscript{D}

Figure 38. FCP22N60N E\textsubscript{OFF} vs. Competitor at Rated I\textsubscript{D}

Figure 39. FCP16N60N E\textsubscript{ON} vs. FCP20N60 and Competitor at Half I\textsubscript{D}

Figure 40. FCP16N60N E\textsubscript{ON} vs. FCP20N60 and Competitor at Rated I\textsubscript{D}

Figure 41. FCP16N60N E\textsubscript{OFF} vs. FCP20N60 and Competitor at Half I\textsubscript{D}

Figure 42. FCP16N60N E\textsubscript{OFF} vs. FCP20N60 and Competitor at Rated I\textsubscript{D}
Typical Performance Characteristics

Figure 43. FCP13N60N $E_{ON}$ vs. FCP16N60 at Half $I_D$

Figure 44. FCP13N60N $E_{ON}$ vs. FCP16N60 at Rated $I_D$

Figure 45. FCP13N60N $E_{OFF}$ vs. FCP16N60 at Half $I_D$

Figure 46. FCP13N60N $E_{OFF}$ vs. FCP16N60 at Rated $I_D$

Figure 47. FCP11N60N $E_{ON}$ vs. Competitor at Half $I_D$

Figure 48. FCP11N60N $E_{ON}$ vs. Competitor at Rated $I_D$
Typical Performance Characteristics

Figure 49. FCP11N60N E_{OFF} vs. Competitor at Half I_{D}

Figure 50. FCP11N60N E_{OFF} vs. Competitor at Rated I_{D}

Figure 51. FCP9N60N E_{ON} vs. FCP11N60 and Competitor at Half I_{D}

Figure 52. FCP9N60N E_{ON} vs. FCP11N60 and Competitor at Rated I_{D}

Figure 53. FCP9N60N E_{OFF} vs. FCP11N60 and Competitor at Half I_{D}

Figure 54. FCP9N60N E_{OFF} vs. FCP11N60 and Competitor at Rated I_{D}
Related Datasheets

FCA76N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCH76N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCH76N60NF – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCH47N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCH47N60NF – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCB36N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCP36N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCA36N60NF – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCP25N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FC125N60N F102 – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCP22N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCP22N60NT – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCA22N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCH22N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCP16N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
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FC9N60N – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FC9N60NT – 600V N-Channel SupreMOS\(^\circ\) MOSFET
FCDF9N60NTM – 600V N-Channel SupreMOS\(^\circ\) MOSFET

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