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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 (R_g). This note suggests minimum and maximum values of R_g for the SupreMOS® MOSFETs in hard-switching applications. As too small R_g 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 R_g 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 R_g. The unit of R_g 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 R_g 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 R_g. 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 R_g 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 R_g Guidelines Ohms

R_g at 1/2 of I_d	dv/dt<100V/ns			dv/dt<50V/ns		
	SiC	Dx	S2	SiC	Dx	S2
FCP9N60N	0	0	0	0	33	36
FCP11N60N	0	0	0	0	33	36
FCP13N60N	0	0	0	27	36	39
FCP16N60N	0	0	6.8	27	33	36
FCP22N60N	0	13	18	27	36	39
FCP25N60N	0	13	18	22	36	36
FCA36N60N	6.8	13	16	22	33	36
FCA47N60N	6.8	11	13	22	27	27
FCA76N60N	6.8	6.8	6.8	13	16	16
R_g at Rated I_d	**dv/dt<100V/ns**			**dv/dt<50V/ns**		
	SiC	Dx	S2	SiC	Dx	S2
FCP9N60N	6.8	13	18	27	43	47
FCP11N60N	6.8	13	18	27	36	39
FCP13N60N	10	16	22	30	43	47
FCP16N60N	10	13	18	27	36	39
FCP22N60N	10	16	22	30	43	47
FCP25N60N	13	16	18	27	39	43
FCA36N60N	13	16	18	22	36	39
FCA47N60N	11	13	13	16	27	27
FCA76N60N	6.8	6.8	10	13	18	18

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 R_g is required. In this case, there should be a limit line for increasing the R_g or switching losses with SupreMOS MOSFET could be larger. Figure 19 through Figure 54 show switching losses according to R_g for each device. R_g for similar or less switching loss can be raised. For example, if 10Ω is used for a FCA35N60 SuperFET MOSFET, 33Ω achieves similar E_{ON} and E_{OFF} in under conditions of half of rated drain current and STEALTH™2 diode.

Typical Performance Characteristics

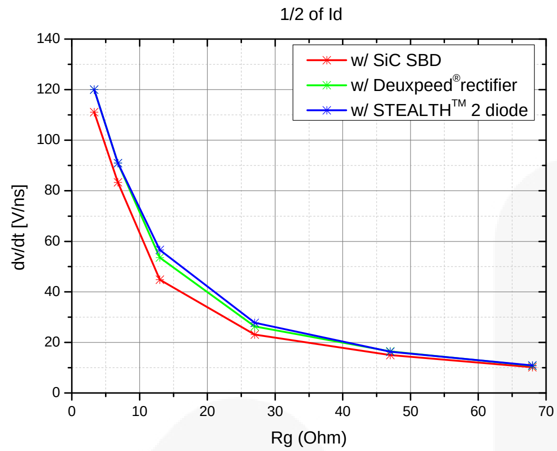

Figure 1. FCA76N60N dv/dt at Half I_D

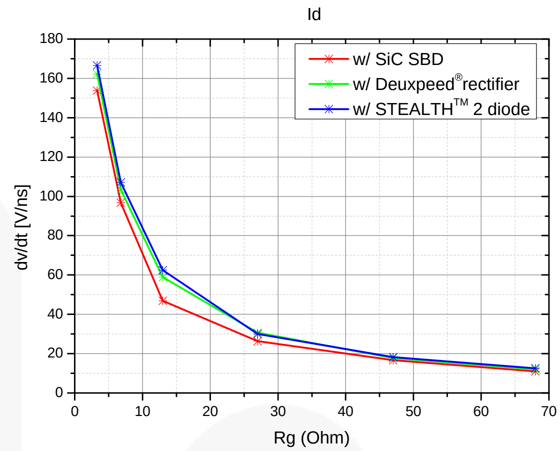

Figure 2. FCA76N60N dv/dt at Rated I_D

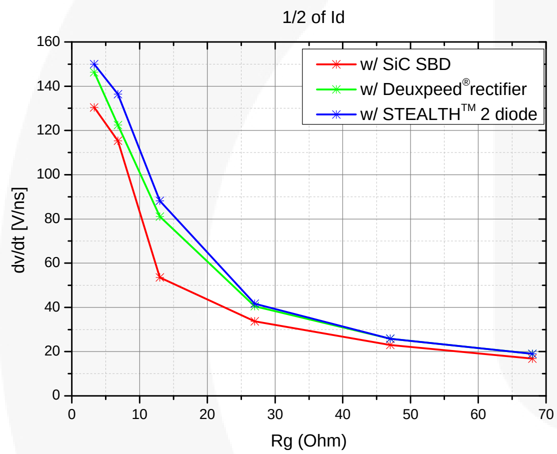

Figure 3. FCA47N60N dv/dt at Half I_D

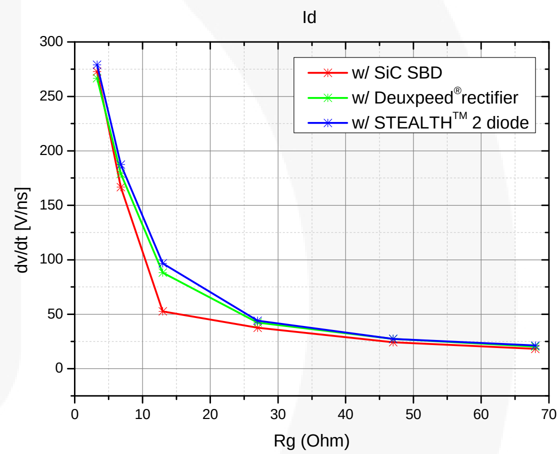

Figure 4. FCA47N60N dv/dt at Rated I_D

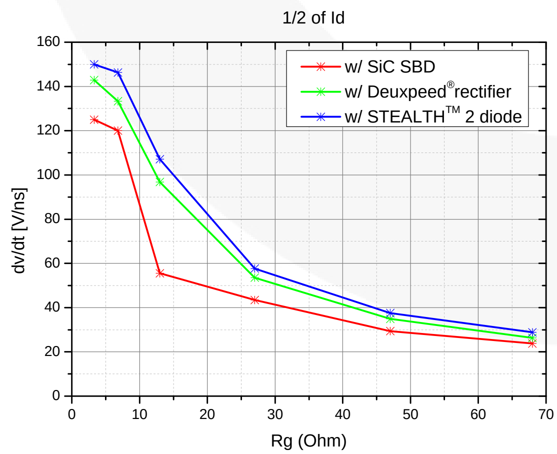

Figure 5. FCA36N60N dv/dt at Half I_D

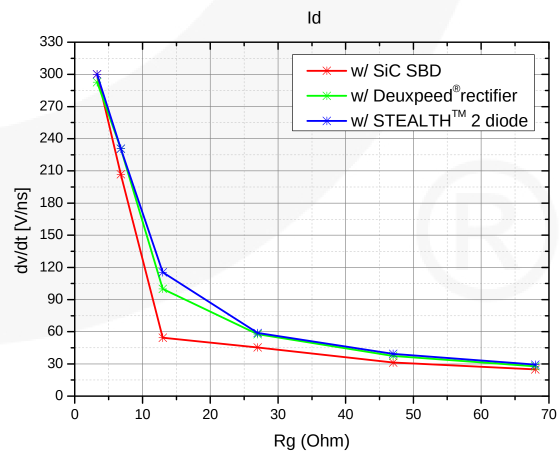

Figure 6. FCA36N60N dv/dt at Rated I_D

Typical Performance Characteristics

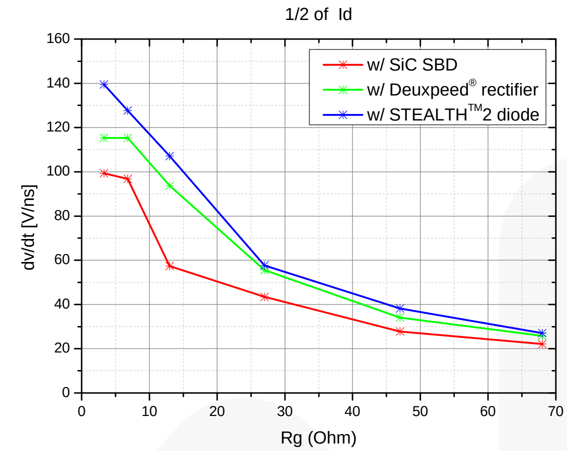

Figure 7. FCP25N60N dv/dt at Half I_D

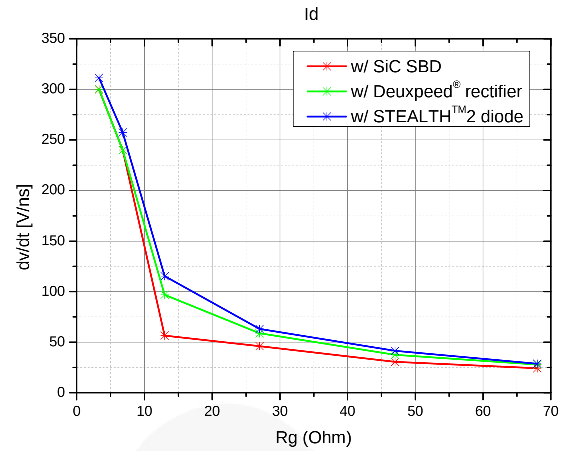

Figure 8. FCP25N60N dv/dt at Rated I_D

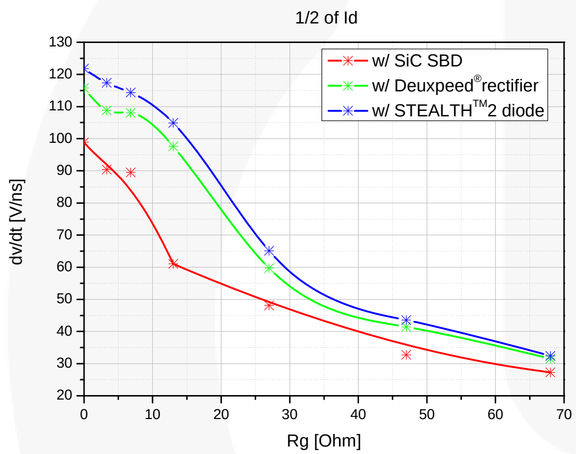

Figure 9. FCP22N60N dv/dt at Half I_D

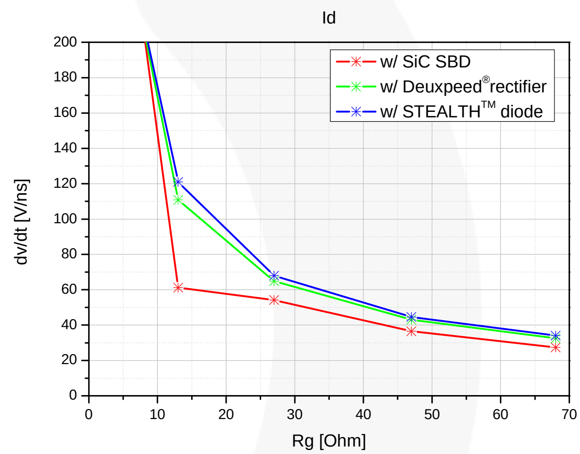

Figure 10. FCP22N60N dv/dt at Rated I_D

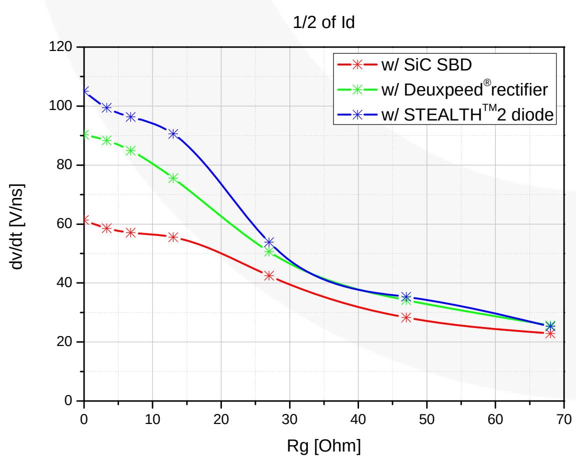

Figure 11. FCP16N60N dv/dt at Half I_D

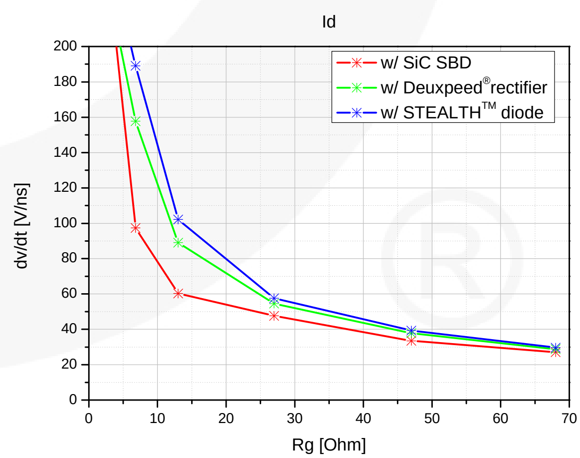

Figure 12. FCP16N60N dv/dt at Rated I_D

Typical Performance Characteristics

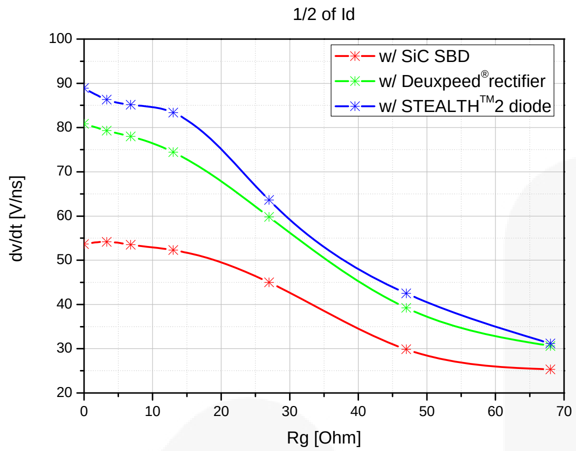

Figure 13. FCP13N60N dv/dt at Half I_D

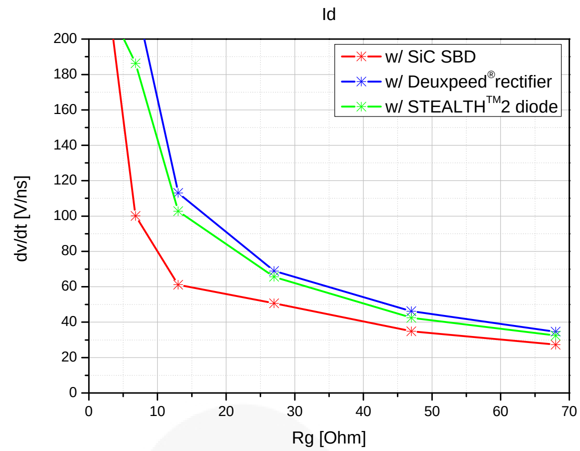

Figure 14. FCP13N60N dv/dt at Rated I_D

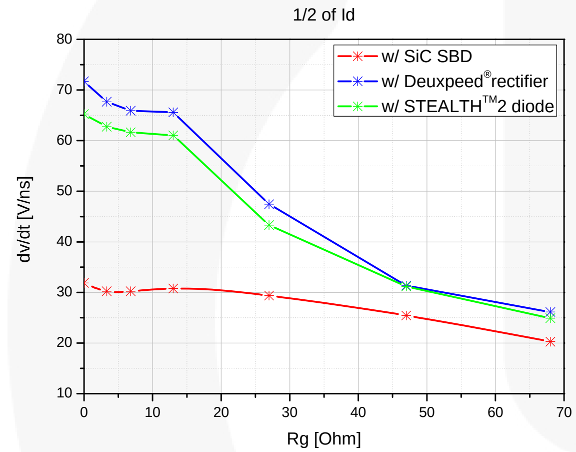

Figure 15. FCP11N60N dv/dt at Half I_D

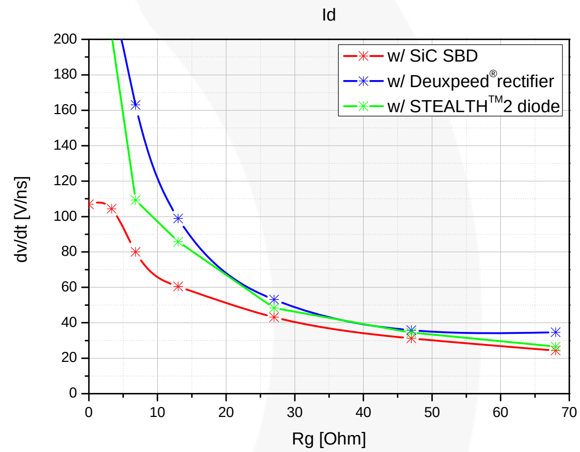

Figure 16. FCP11N60N dv/dt at Rated I_D

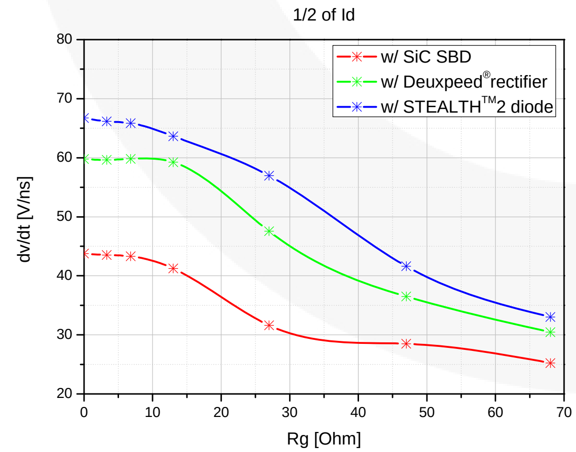

Figure 17. FCP9N60N dv/dt at Half I_D

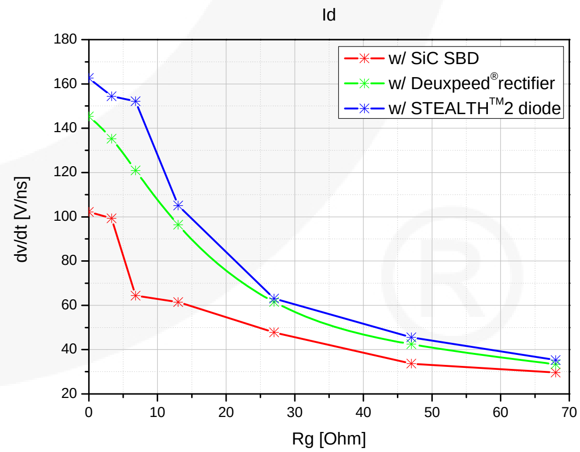

Figure 18. FCP9N60N dv/dt at Rated I_D

Typical Performance Characteristics

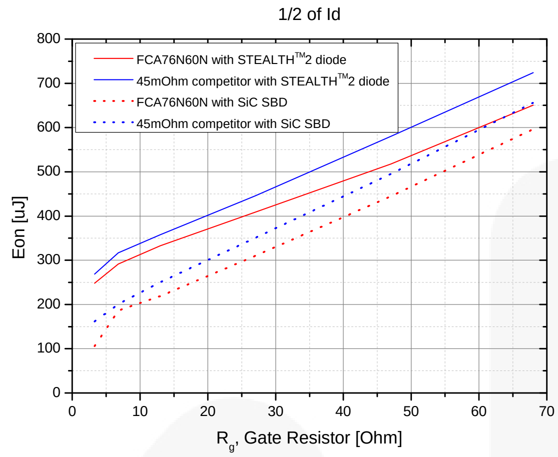

Figure 19. FCA76N60N E_{ON} vs. Competitor at Half I_D

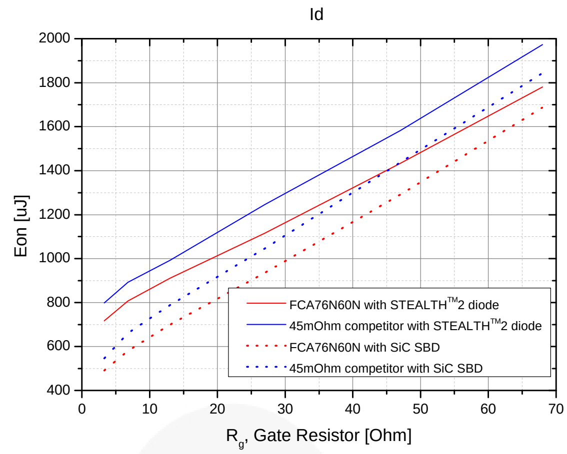

Figure 20. FCA76N60N E_{ON} vs. Competitor at Rated I_D

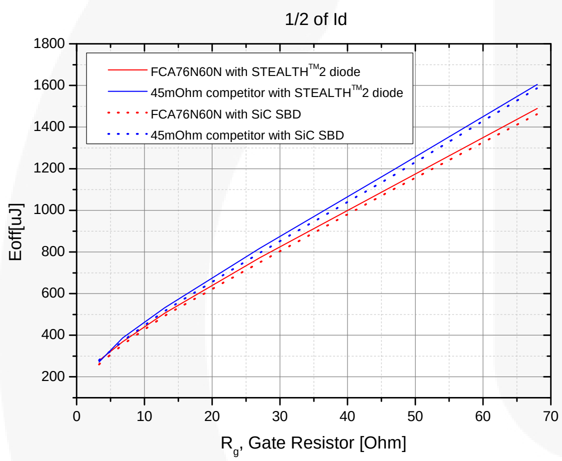

Figure 21. FCA76N60N E_{OFF} vs. Competitor at Half I_D

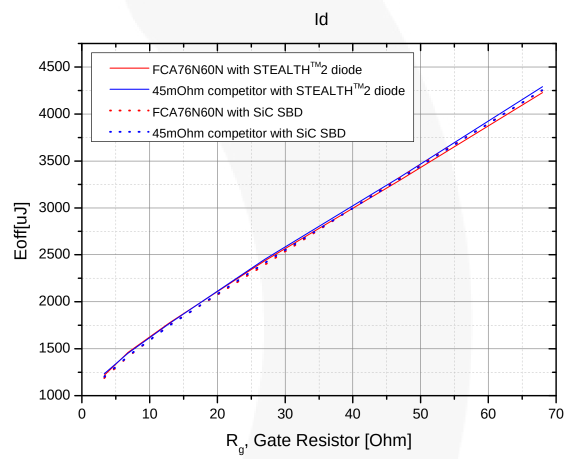

Figure 22. FCA76N60N E_{OFF} vs. Competitor at Rated I_D

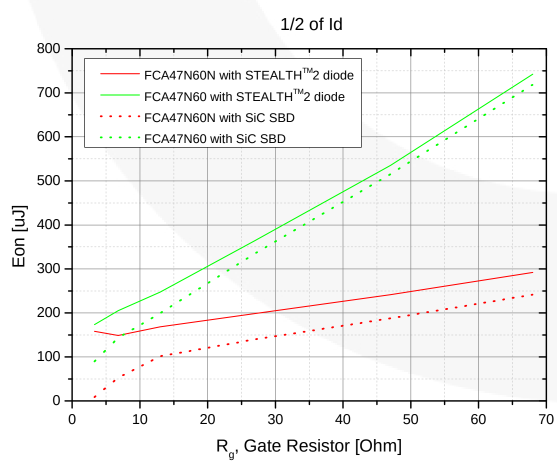

Figure 23. FCA47N60N E_{ON} vs. FCA47N60 at Half I_D

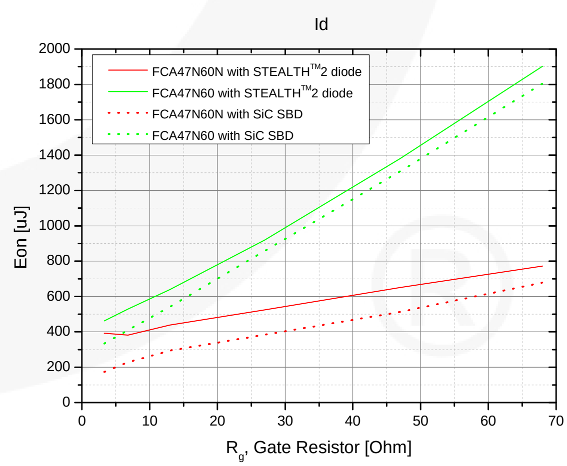

Figure 24. FCA47N60N E_{ON} vs. FCA47N60 at Rated I_D

Typical Performance Characteristics

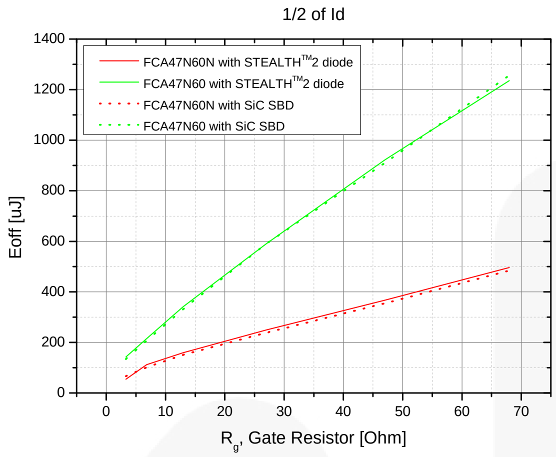

Figure 25. FCA47N60N E_{OFF} vs. FCA47N60 at Half I_D

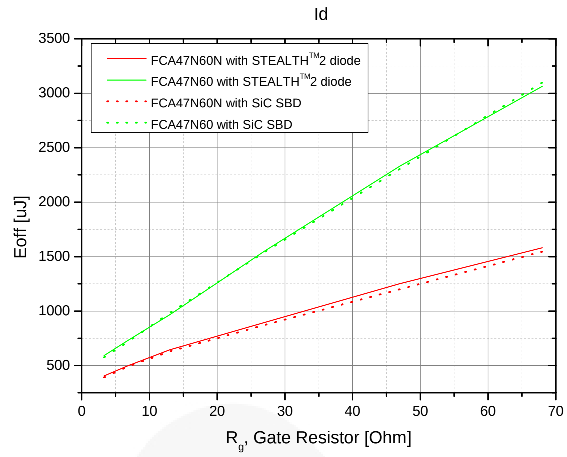

Figure 26. FCA47N60N E_{OFF} vs. FCA47N60 at Rated I_D

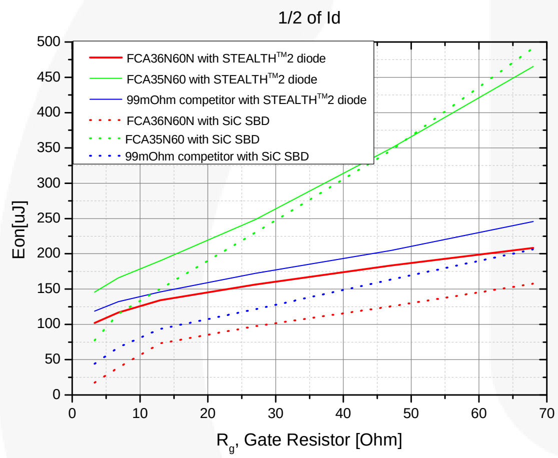

Figure 27. FCA36N60N E_{ON} vs. FCA35N60 and Competitor at Half I_D

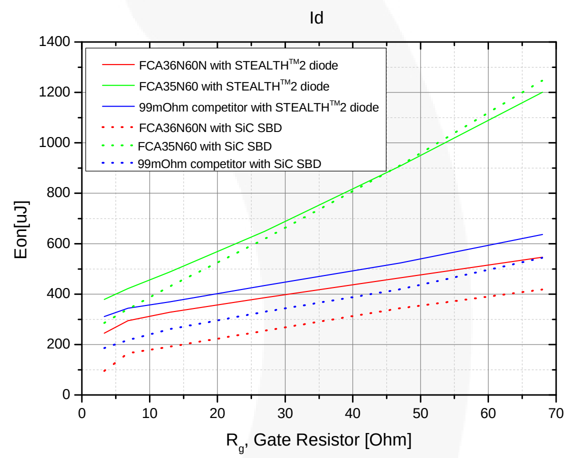

Figure 28. FCA36N60N E_{ON} vs. FCA35N60 and Competitor at Rated I_D

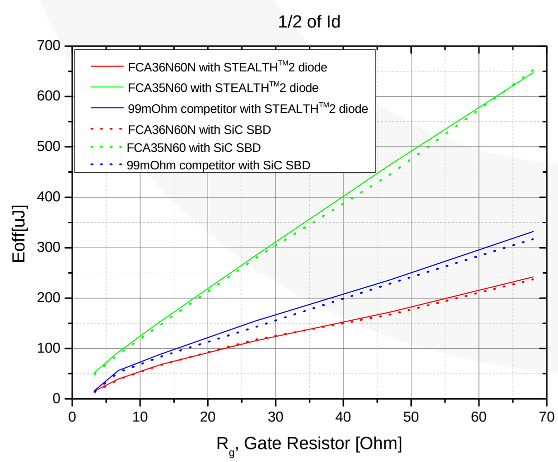

Figure 29. FCA36N60N E_{OFF} vs. FCA35N60 and Competitor at Half I_D

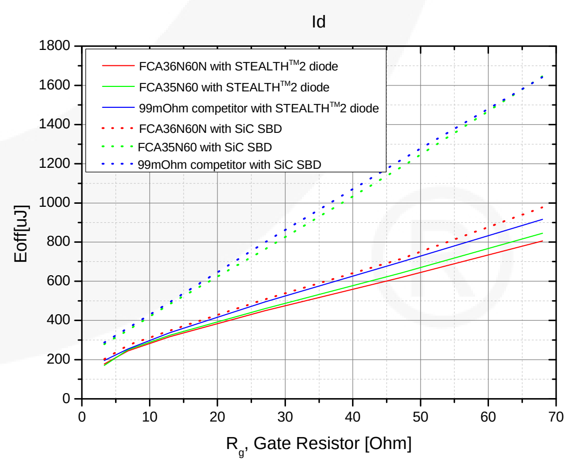

Figure 30. FCA36N60N E_{OFF} vs. FCA35N60 and Competitor at Rated I_D

Typical Performance Characteristics

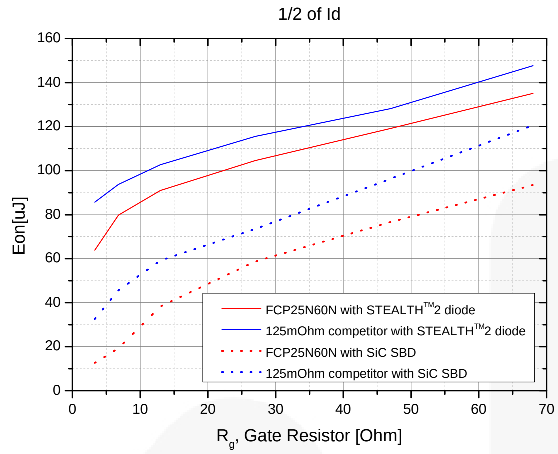

Figure 31. FCP25N60N E_{ON} vs. Competitor at Half I_D

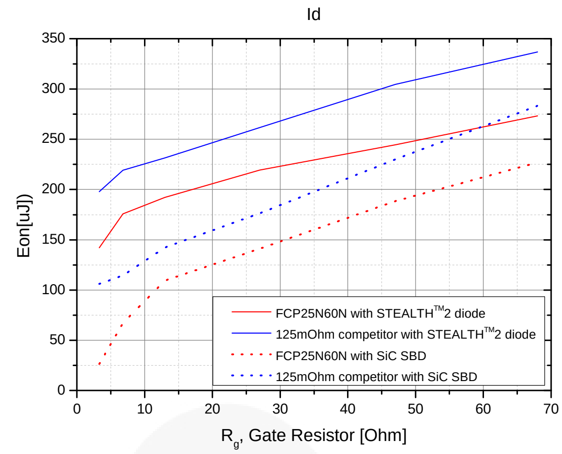

Figure 32. FCP25N60N E_{ON} vs. Competitor at Rated I_D

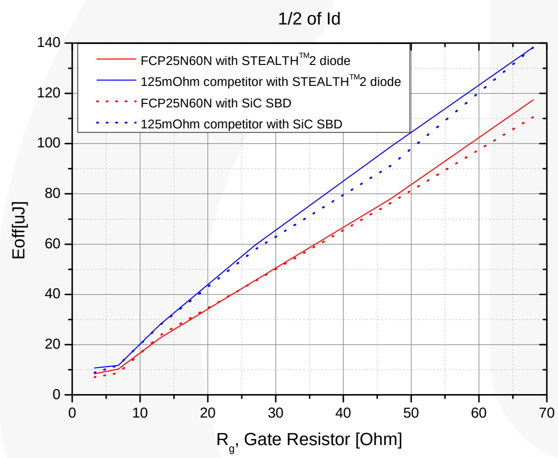

Figure 33. FCP25N60N E_{OFF} vs. Competitor at Half I_D

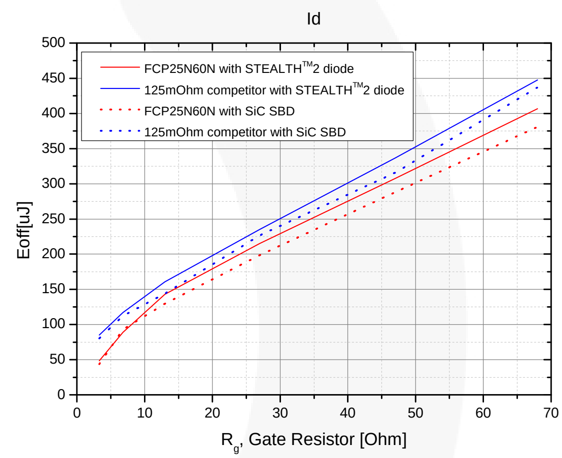

Figure 34. FCP25N60N E_{OFF} vs. Competitor at Rated I_D

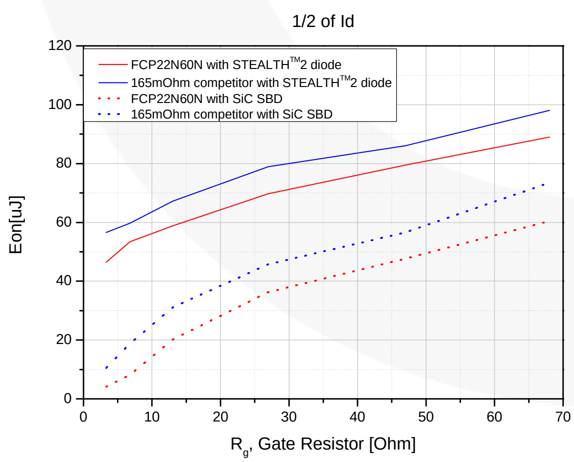

Figure 35. FCP22N60N E_{ON} vs. Competitor at Half I_D

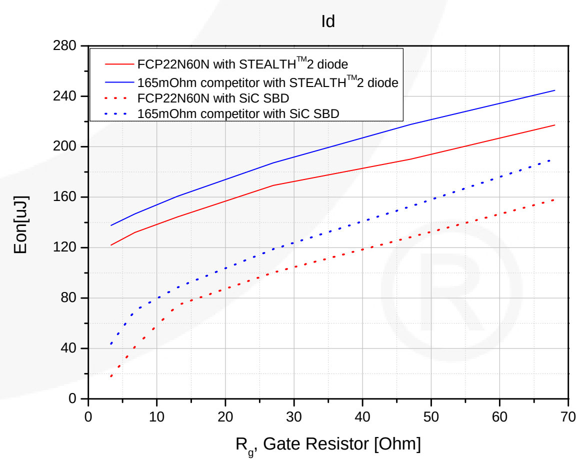

Figure 36. FCP22N60N E_{ON} vs. Competitor at Rated I_D

Typical Performance Characteristics

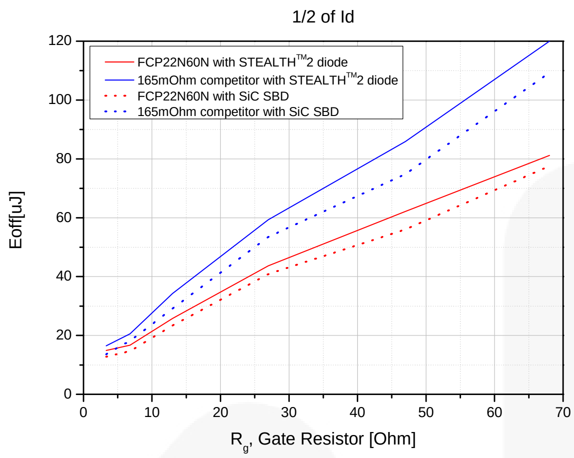

Figure 37. FCP22N60N E_{OFF} vs. Competitor at Half I_D

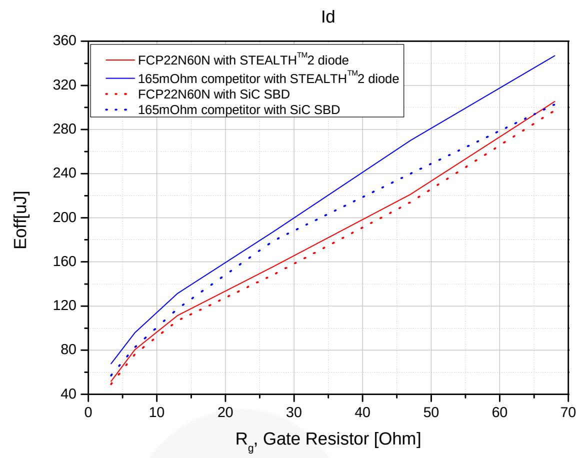

Figure 38. FCP22N60N E_{OFF} vs. Competitor at Rated I_D

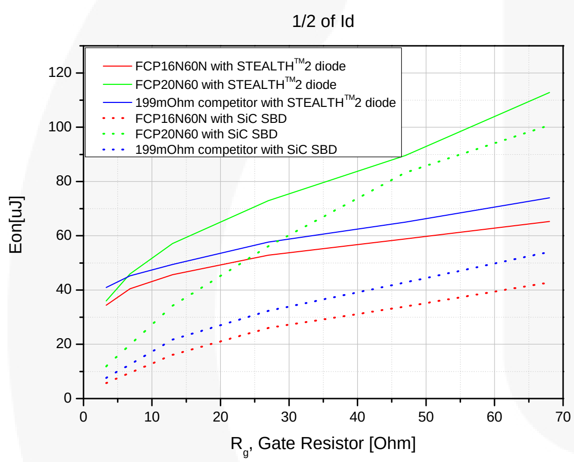

Figure 39. FCP16N60N E_{ON} vs. FCP20N60 and Competitor at Half I_D

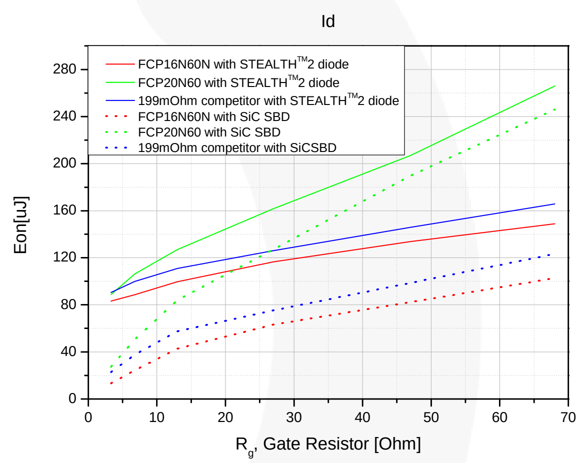

Figure 40. FCP16N60N E_{ON} vs. FCP20N60 and Competitor at Rated I_D

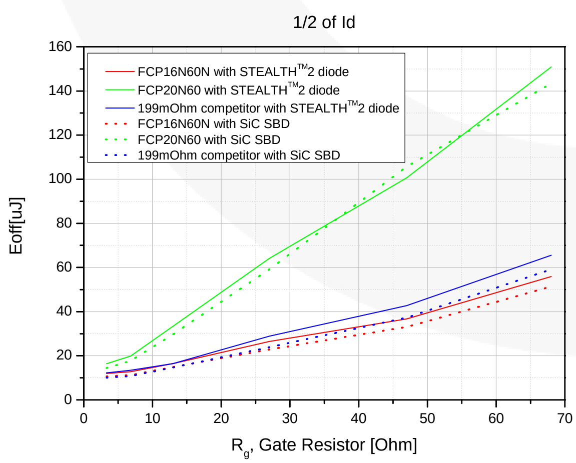

Figure 41. FCP16N60N E_{OFF} vs. FCP20N60 and Competitor at Half I_D

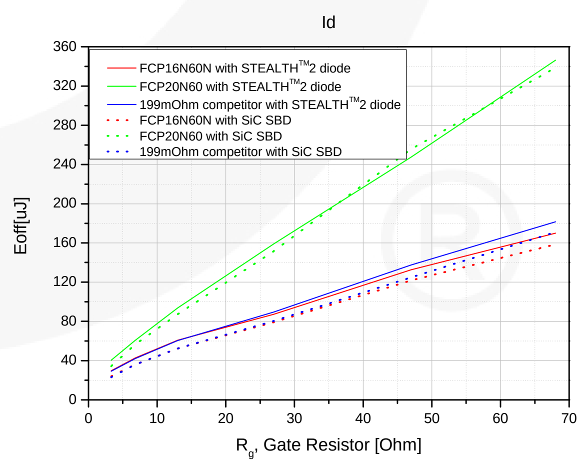

Figure 42. FCP16N60N E_{OFF} vs. FCP20N60 and Competitor at Rated I_D

Typical Performance Characteristics

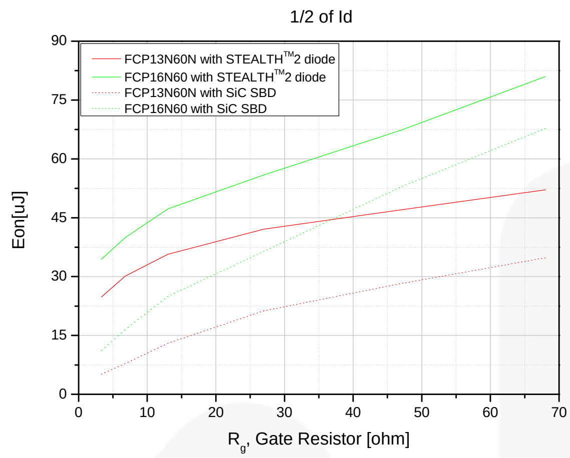

Figure 43. FCP13N60N E_{ON} vs. FCP16N60 at Half I_D

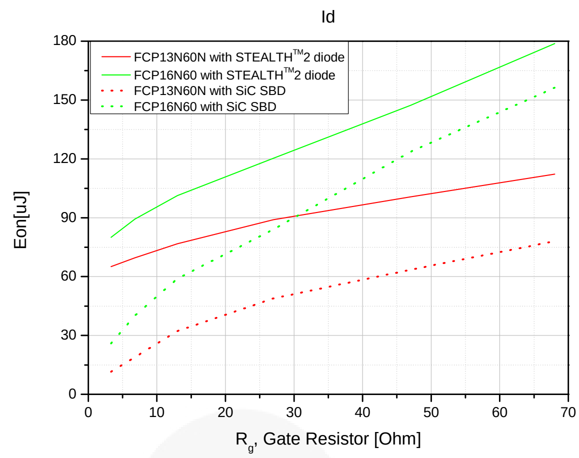

Figure 44. FCP13N60N E_{ON} vs. FCP16N60 at Rated I_D

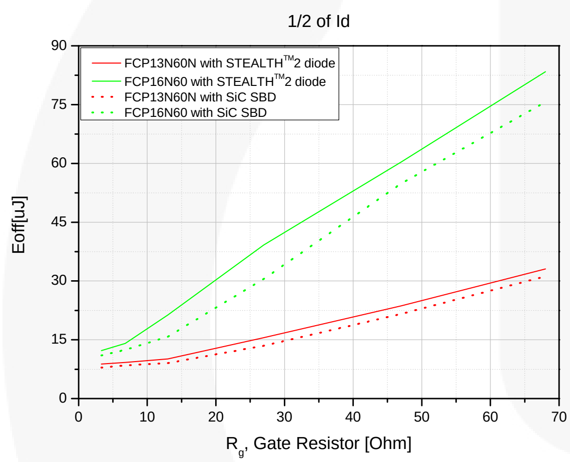

Figure 45. FCP13N60N E_{OFF} vs. FCP16N60 at Half I_D

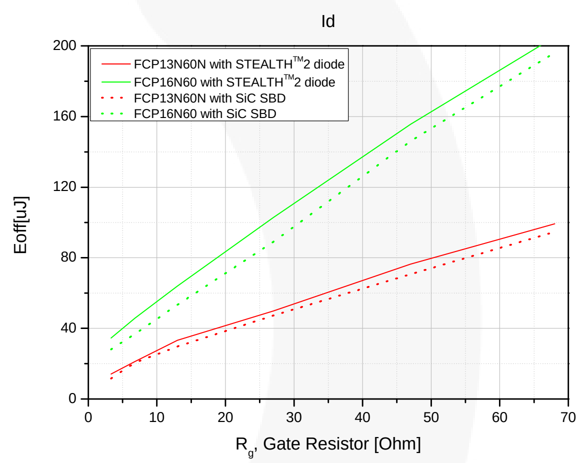

Figure 46. FCP13N60N E_{OFF} vs. FCP16N60 at Rated I_D

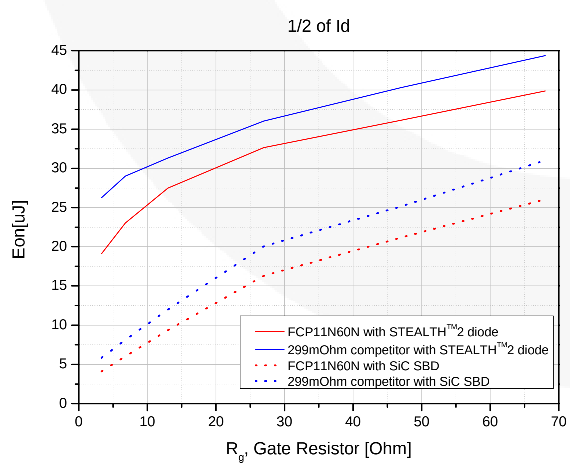

Figure 47. FCP11N60N E_{ON} vs. Competitor at Half I_D

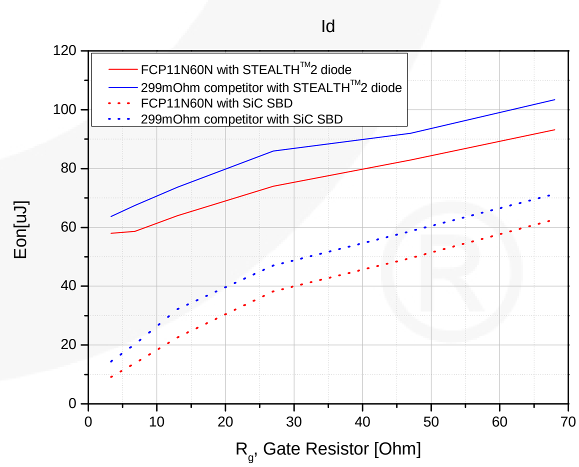

Figure 48. FCP11N60N E_{ON} vs. Competitor at Rated I_D

Typical Performance Characteristics

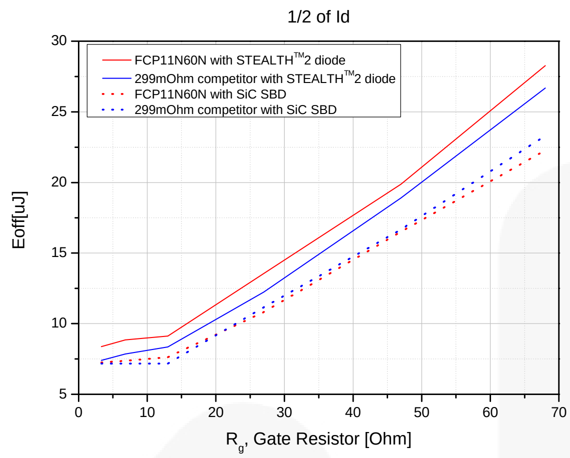

Figure 49. FCP11N60N E_{OFF} vs. Competitor at Half I_D

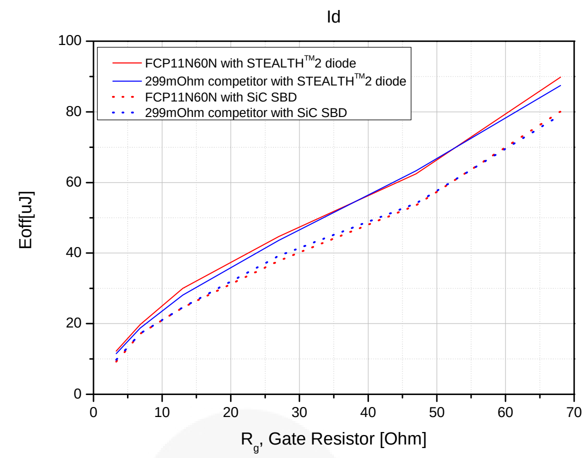

Figure 50. FCP11N60N E_{OFF} vs. Competitor at Rated I_D

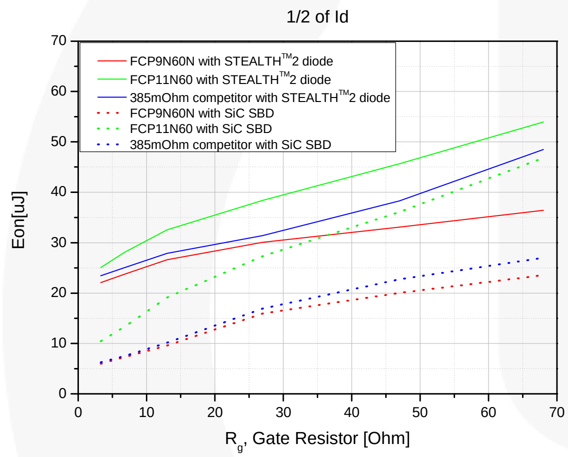

Figure 51. FCP9N60N E_{ON} vs. FCP11N60 and Competitor at Half I_D

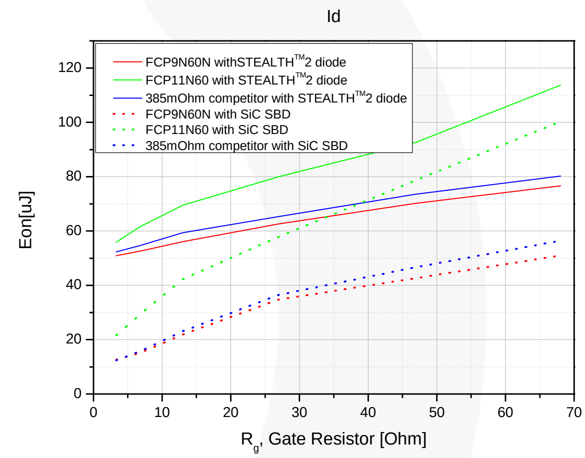

Figure 52. FCP9N60N E_{ON} vs. FCP11N60 and Competitor at Rated I_D

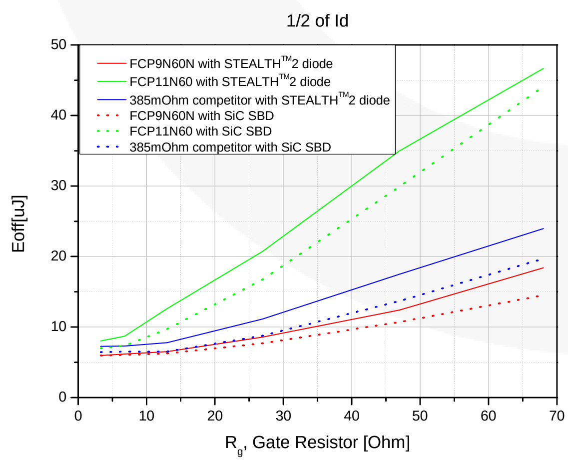

Figure 53. FCP9N60N E_{OFF} vs. FCP11N60 and Competitor at Half I_D

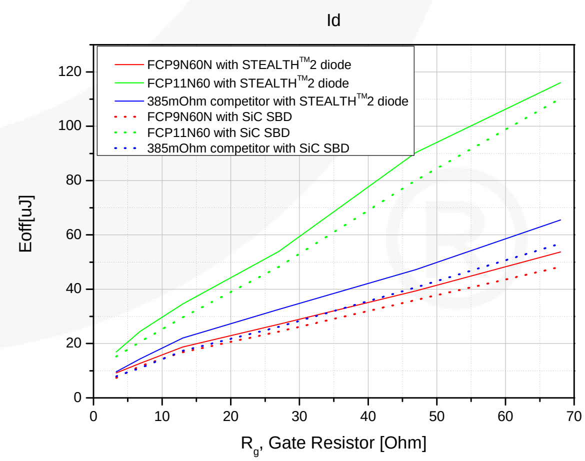

Figure 54. FCP9N60N E_{OFF} vs. FCP11N60 and Competitor at Rated I_D

Related Datasheets

FCA76N60N – 600V N-Channel SupreMOS® MOSFET
FCH76N60N – 600V N-Channel SupreMOS® MOSFET
FCH76N60NF– 600V N-Channel SupreMOS® MOSFET
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FCP36N60N – 600V N-Channel SupreMOS® MOSFET
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FCH25N60N – 600V N-Channel SupreMOS® MOSFET
FCP25N60N_F102 – 600V N-Channel SupreMOS® MOSFET
FCI25N60N_F102 – 600V N-Channel SupreMOS® MOSFET
FCP22N60N – 600V N-Channel SupreMOS® MOSFET
FCPF22N60NT – 600V N-Channel SupreMOS® MOSFET
FCA22N60N – 600V N-Channel SupreMOS® MOSFET
FCH22N60N – 600V N-Channel SupreMOS® MOSFET
FCP16N60N – 600V N-Channel SupreMOS® MOSFET
FCPF16N60NT – 600V N-Channel SupreMOS® MOSFET
FCA16N60N – 600V N-Channel SupreMOS® MOSFET
FCP13N60N- 600V N-Channel SupreMOS® MOSFET
FCPF13N60NT – 600V N-Channel SupreMOS® MOSFET
FCP11N60N – 600V N-Channel SupreMOS® MOSFET
FCPF11N60NT – 600V N-Channel SupreMOS® MOSFET
FCP9N60N – 600V N-Channel SupreMOS® MOSFET
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