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# AN-9068

## Gate Resistor Design Guidelines for SupreMOS<sup>®</sup> 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<sup>®</sup> 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<sup>®</sup> rectifier, and STEALTH<sup>™</sup>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<sup>®</sup> 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 ( $\Omega$ ). 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 13 $\Omega$  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.

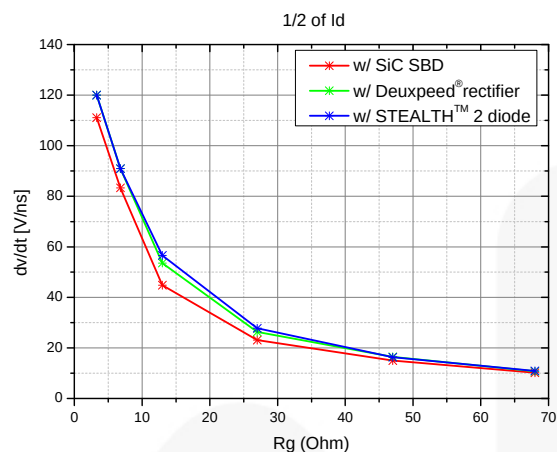
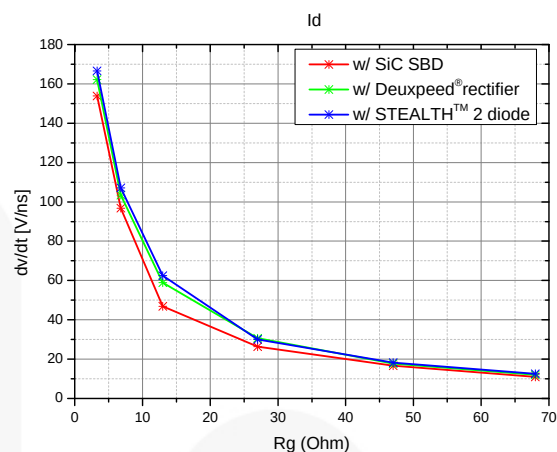
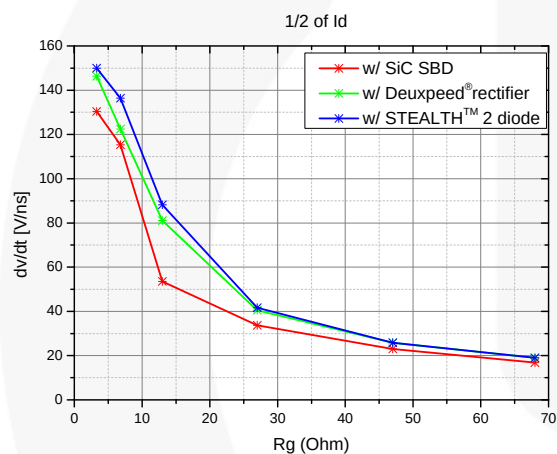
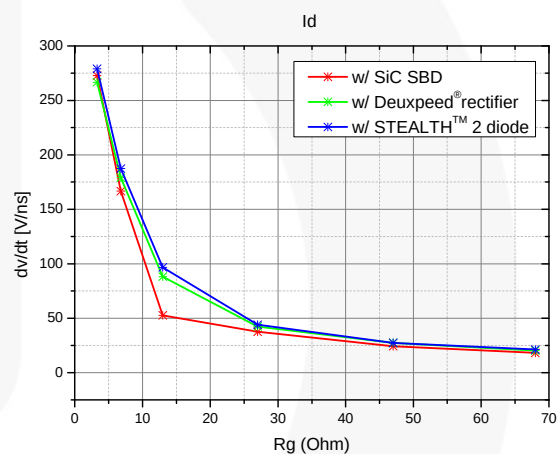
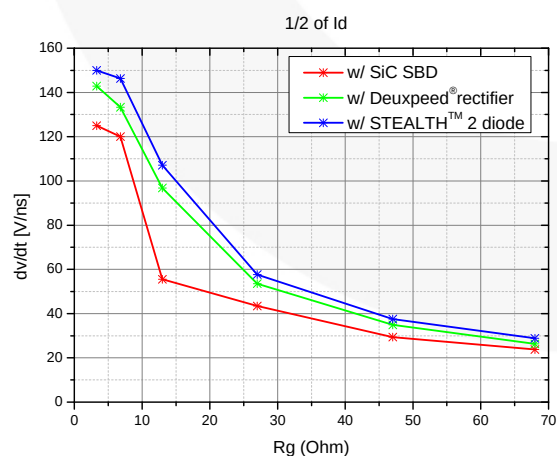
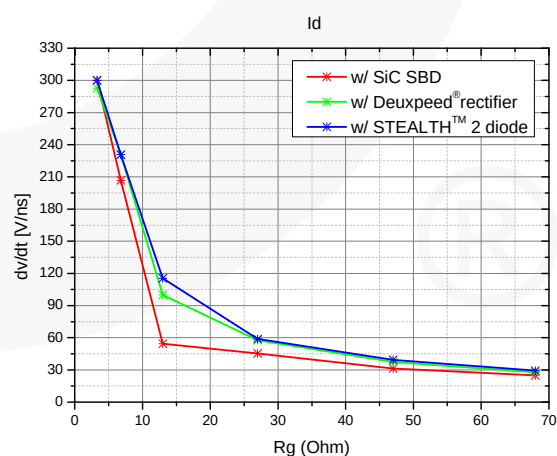
Table 1. Minimum  $R_g$  Guidelines Ohms

| $R_g$ 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<sup>®</sup> 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 10 $\Omega$  is used for a FCA35N60 SuperFET MOSFET, 33 $\Omega$  achieves similar  $E_{ON}$  and  $E_{OFF}$  in under conditions of half of rated drain current and STEALTH<sup>™</sup>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

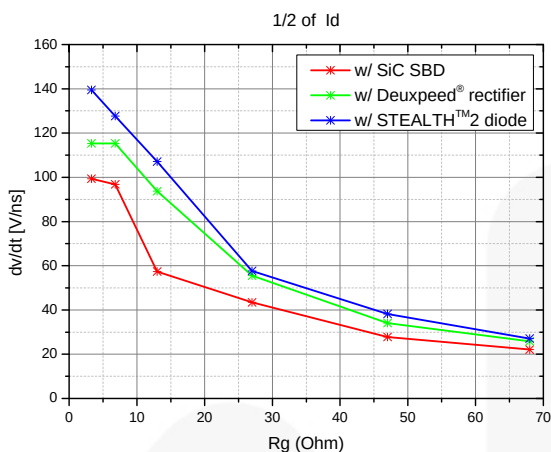


Figure 7. FCP25N60N dv/dt at Half  $I_D$

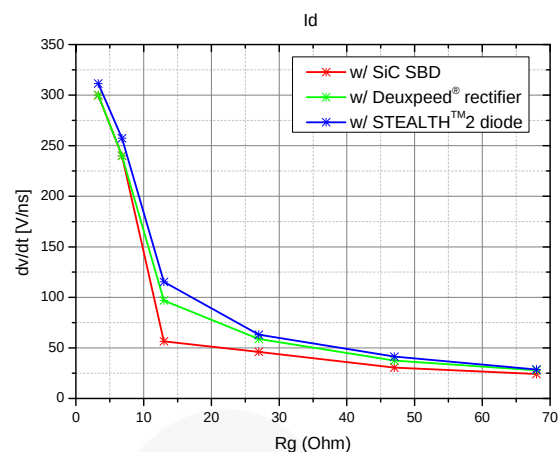


Figure 8. FCP25N60N dv/dt at Rated  $I_D$

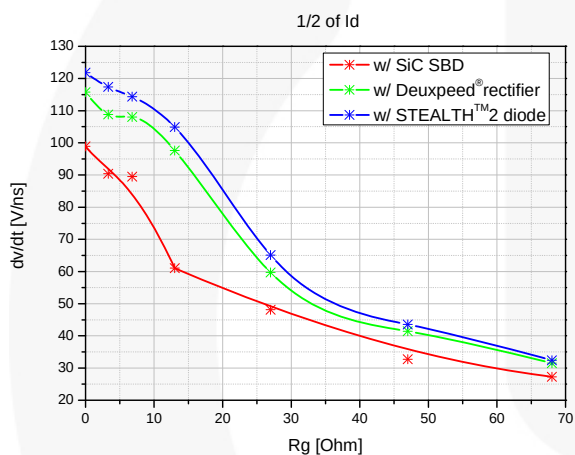


Figure 9. FCP22N60N dv/dt at Half  $I_D$

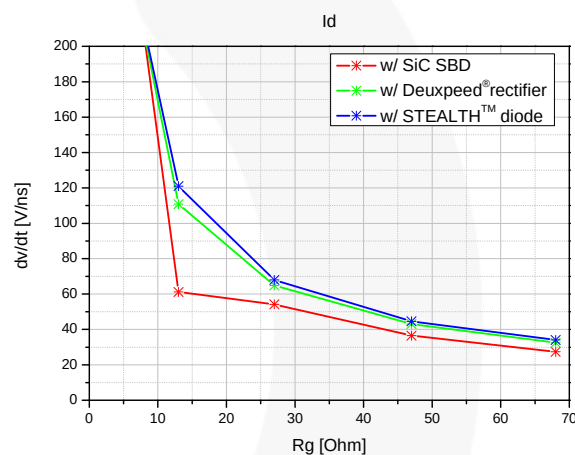


Figure 10. FCP22N60N dv/dt at Rated  $I_D$

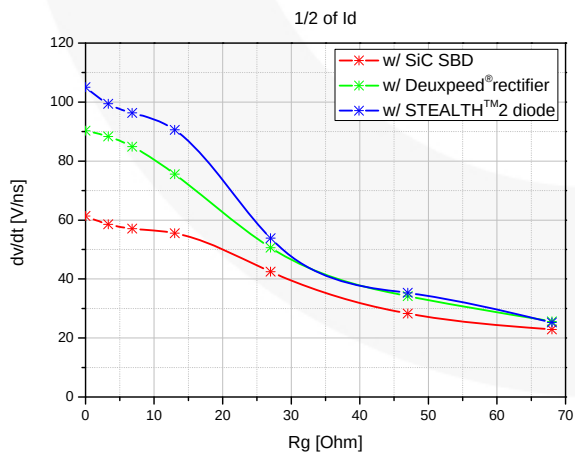


Figure 11. FCP16N60N dv/dt at Half  $I_D$

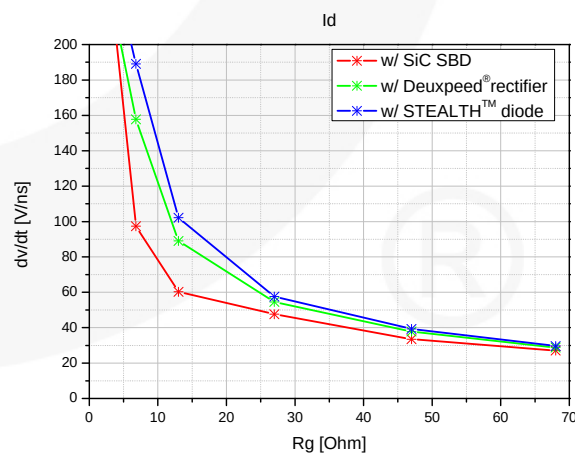
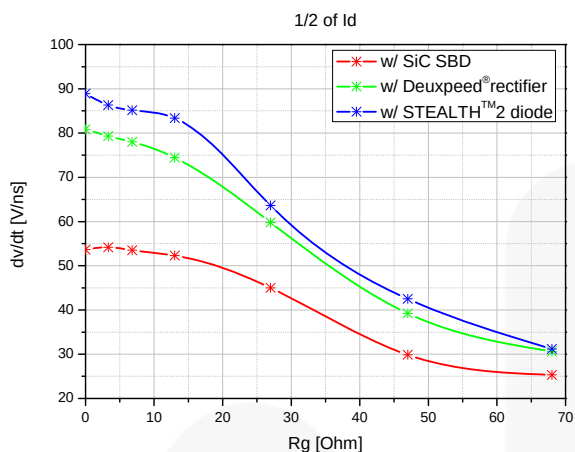
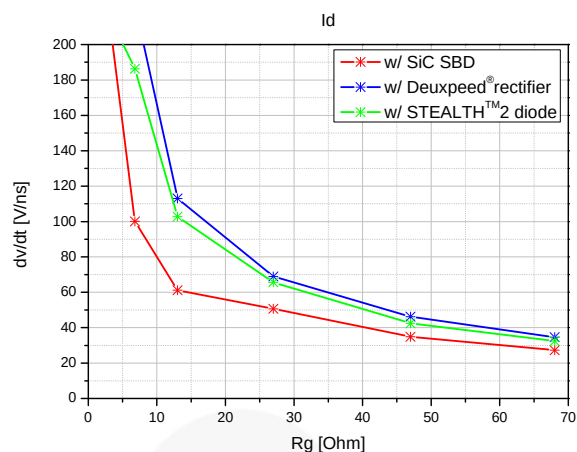
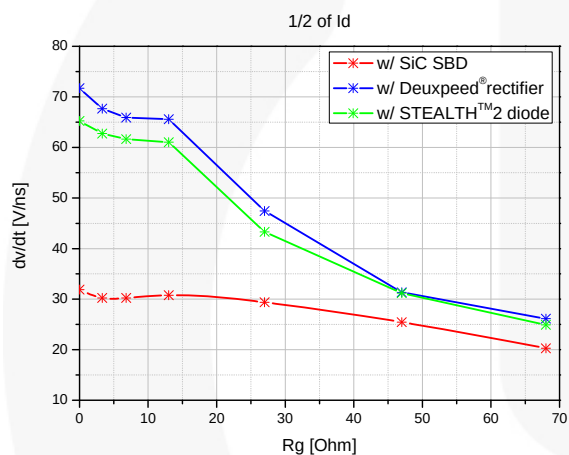
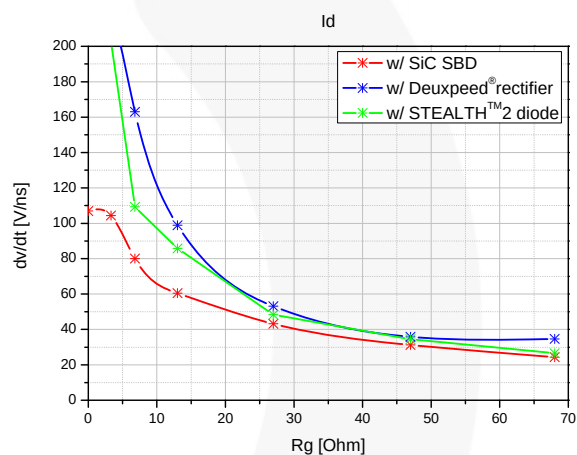
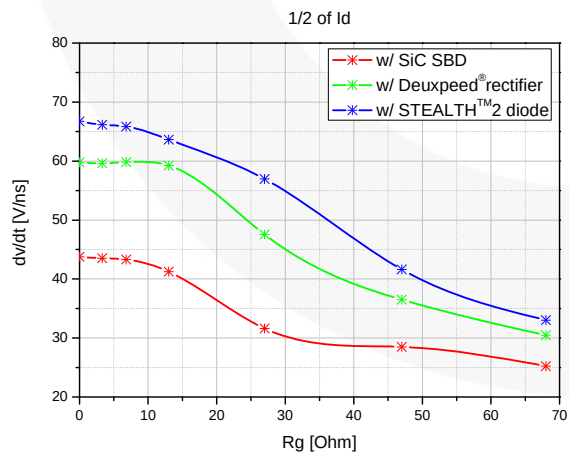
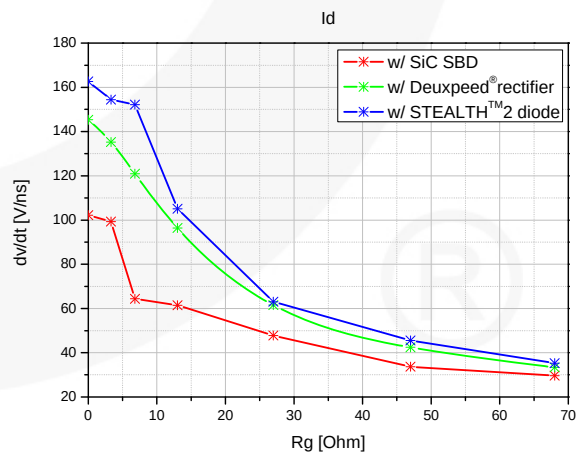


Figure 12. FCP16N60N dv/dt at Rated  $I_D$

## 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

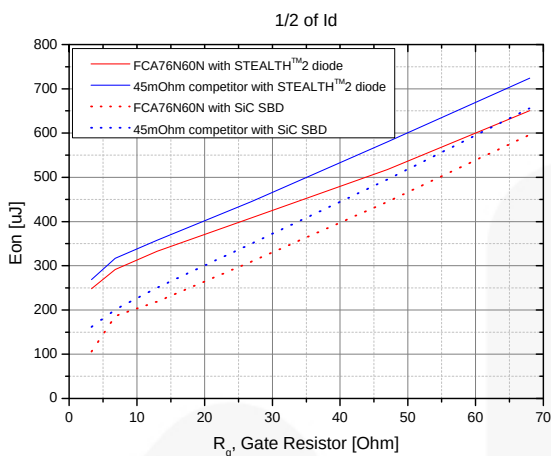


Figure 19.FCA76N60N  $E_{ON}$  vs. Competitor at Half  $I_D$

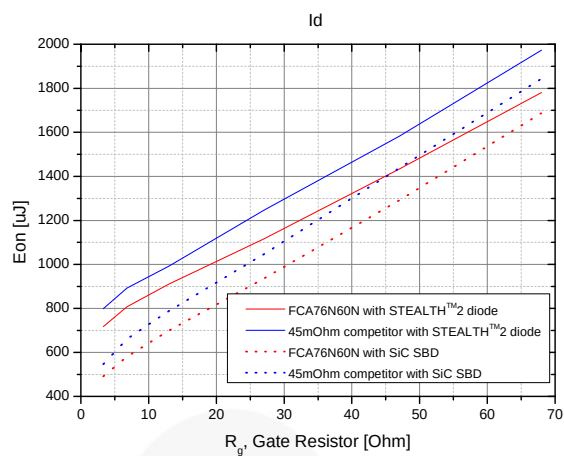


Figure 20.FCA76N60N  $E_{ON}$  vs. Competitor at Rated  $I_D$

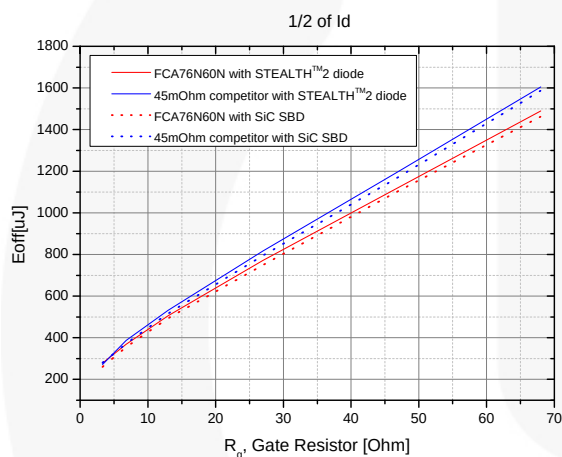


Figure 21.FCA76N60N  $E_{OFF}$  vs. Competitor at Half  $I_D$

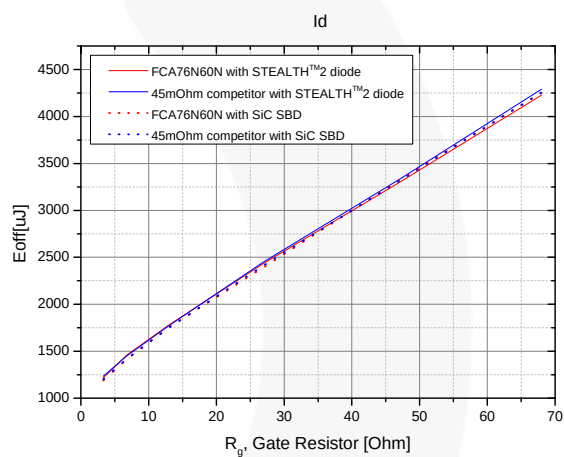


Figure 22.FCA76N60N  $E_{OFF}$  vs. Competitor at Rated  $I_D$

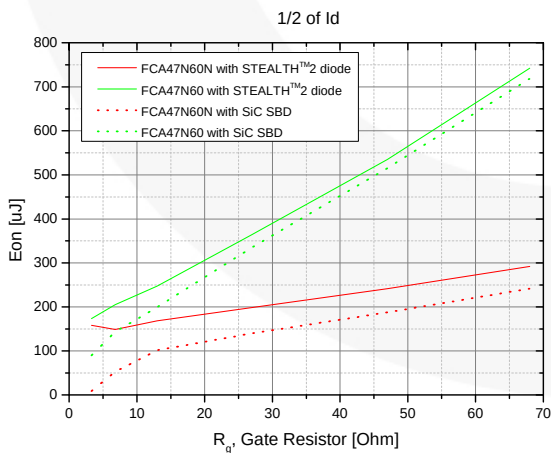


Figure 23.FCA47N60N  $E_{ON}$  vs. FCA47N60 at Half  $I_D$

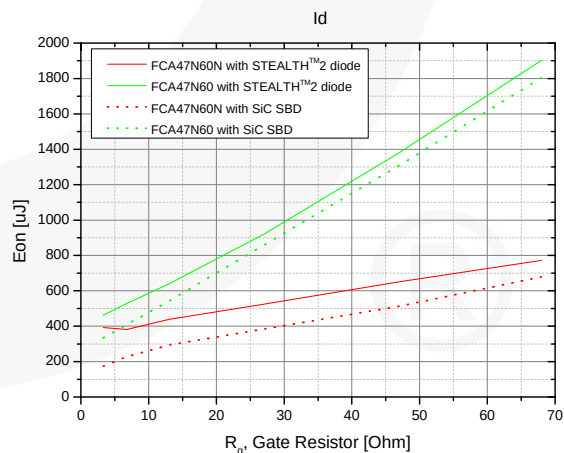


Figure 24.FCA47N60N  $E_{ON}$  vs. FCA47N60 at Rated  $I_D$

## Typical Performance Characteristics

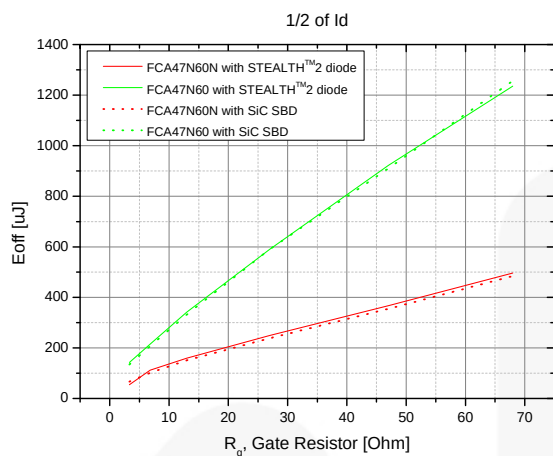


Figure 25. FCA47N60N  $E_{OFF}$  vs. FCA47N60 at Half  $I_D$

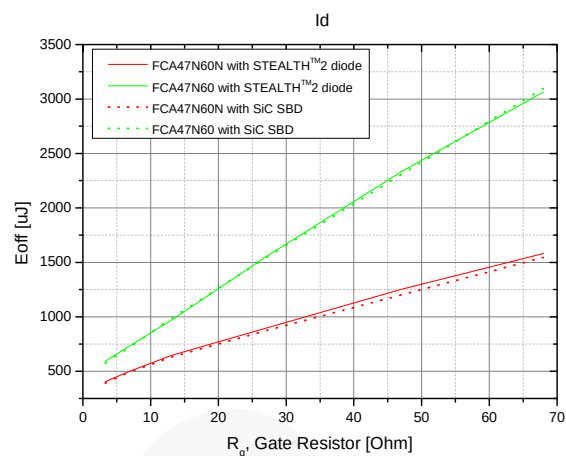


Figure 26. FCA47N60N  $E_{OFF}$  vs. FCA47N60 at Rated  $I_D$

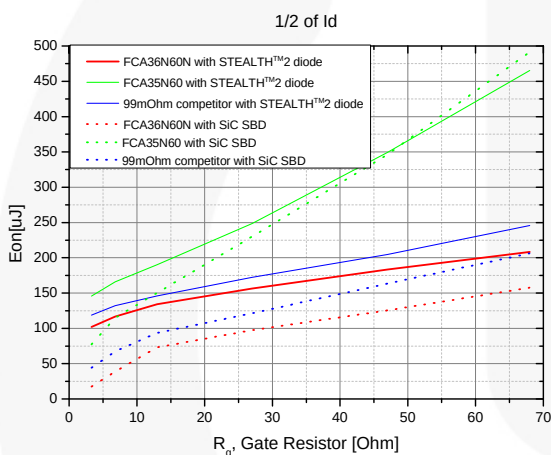


Figure 27. FCA36N60N  $E_{ON}$  vs. FCA35N60 and Competitor at Half  $I_D$

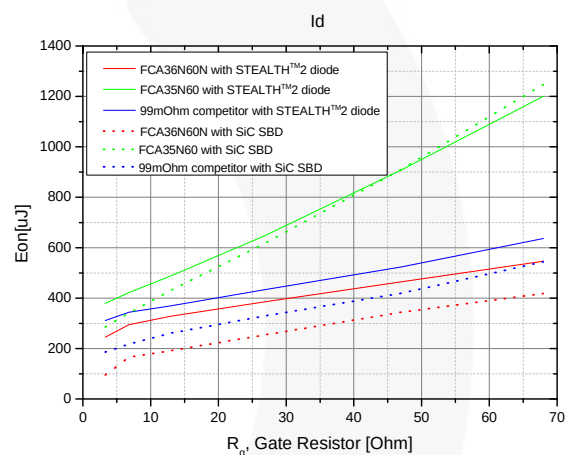


Figure 28. FCA36N60N  $E_{ON}$  vs. FCA35N60 and Competitor at Rated  $I_D$

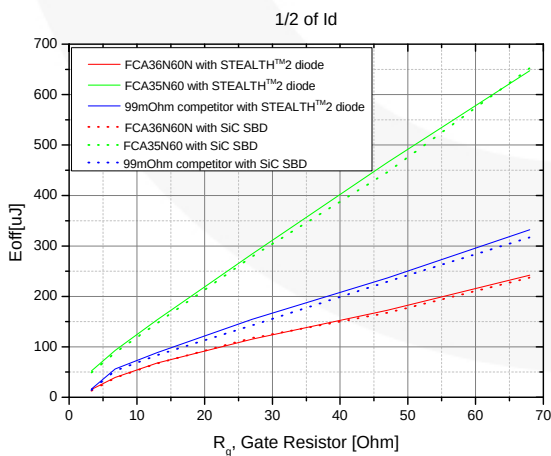


Figure 29. FCA36N60N  $E_{OFF}$  vs. FCA35N60 and Competitor at Half  $I_D$

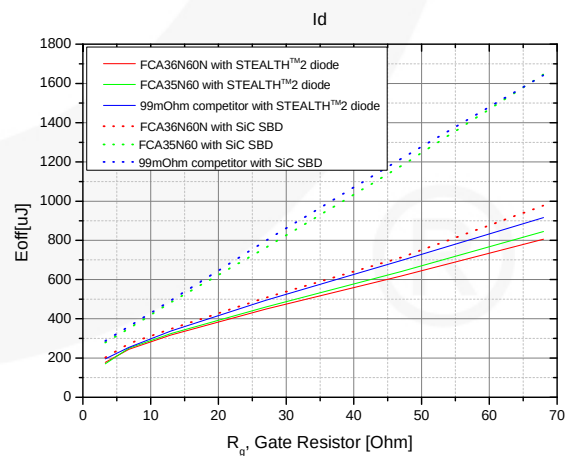


Figure 30. FCA36N60N  $E_{OFF}$  vs. FCA35N60 and Competitor at Rated  $I_D$



## Typical Performance Characteristics

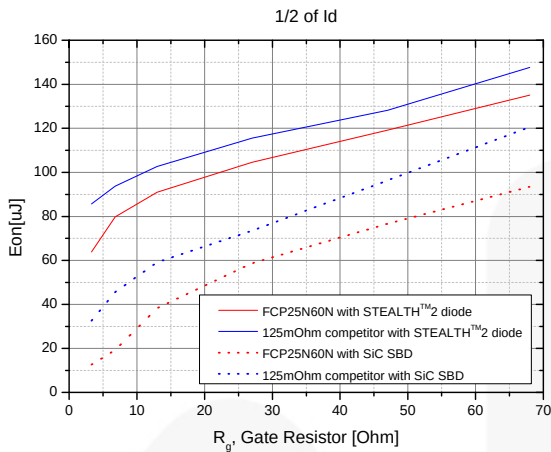


Figure 31.FCP25N60N  $E_{ON}$  vs. Competitor at Half  $I_D$

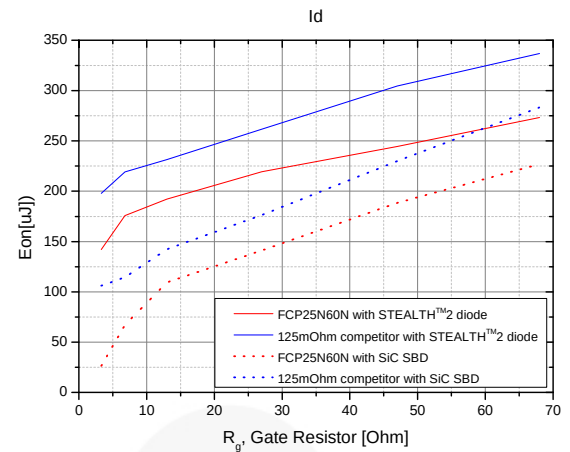


Figure 32.FCP25N60N  $E_{ON}$  vs. Competitor at Rated  $I_D$

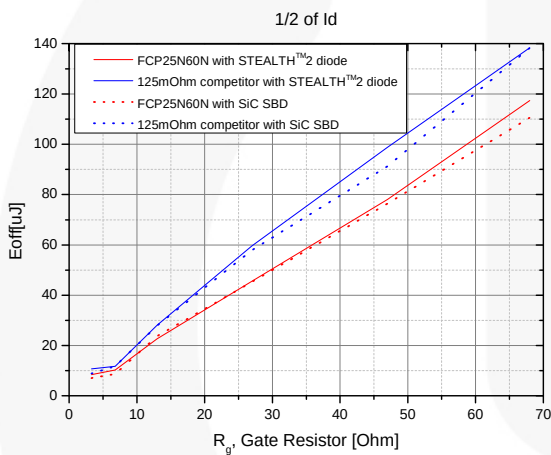


Figure 33.FCP25N60N  $E_{OFF}$  vs. Competitor at Half  $I_D$

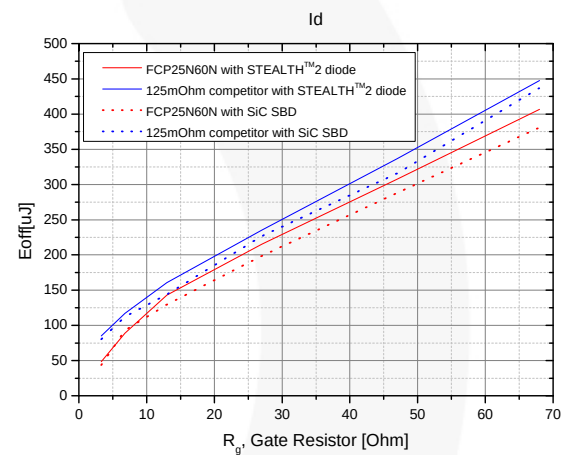


Figure 34.FCP25N60N  $E_{OFF}$  vs. Competitor at Rated  $I_D$

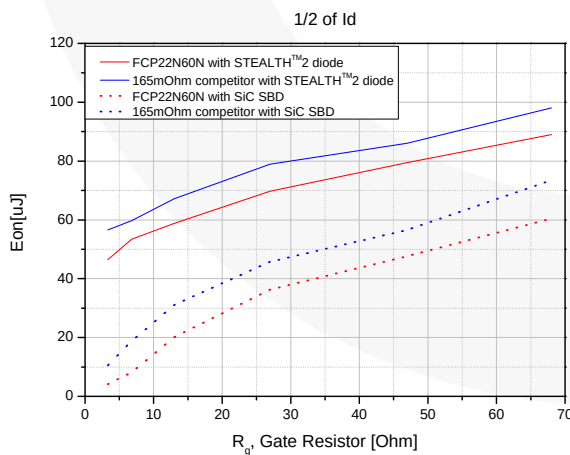


Figure 35.FCP22N60N  $E_{ON}$  vs. Competitor at Half  $I_D$

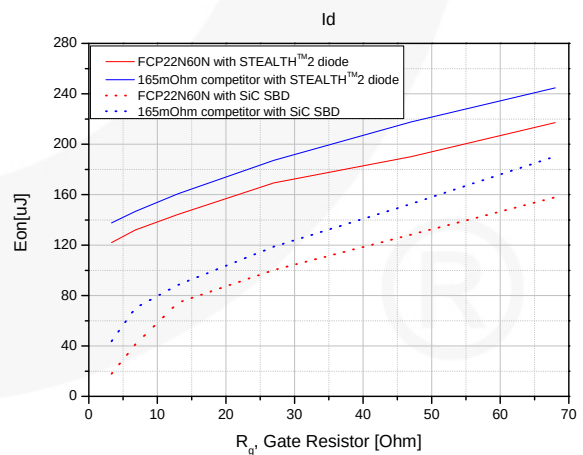


Figure 36.FCP22N60N  $E_{ON}$  vs. Competitor at Rated  $I_D$



## Typical Performance Characteristics

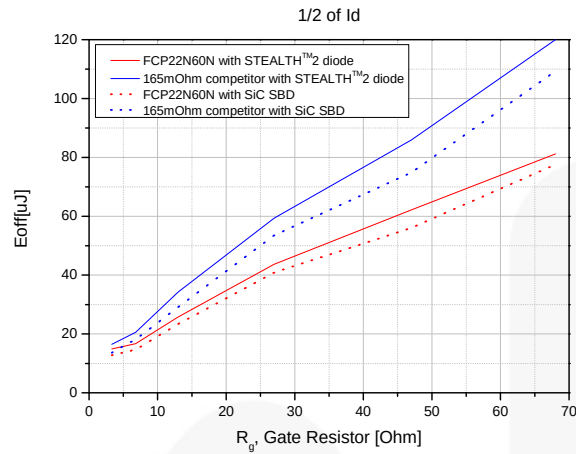


Figure 37.FCP22N60N  $E_{OFF}$  vs. Competitor at Half  $I_D$

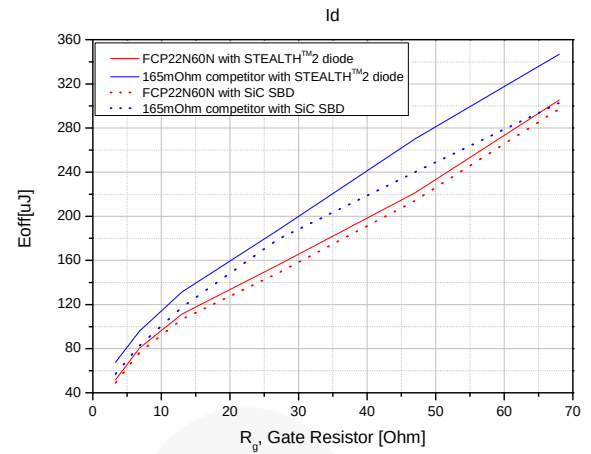


Figure 38.FCP22N60N  $E_{OFF}$  vs. Competitor at Rated  $I_D$

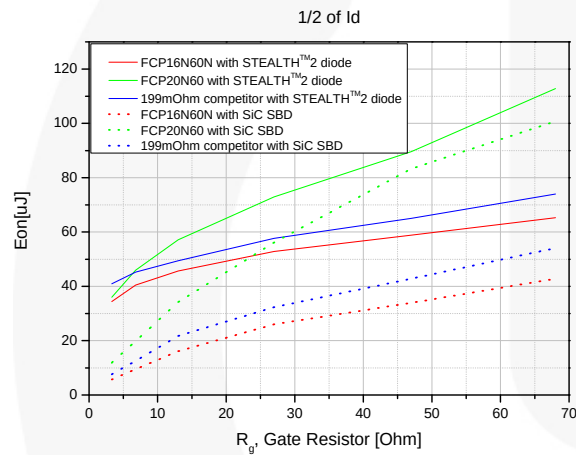


Figure 39.FCP16N60N  $E_{ON}$  vs. FCP20N60 and Competitor at Half  $I_D$

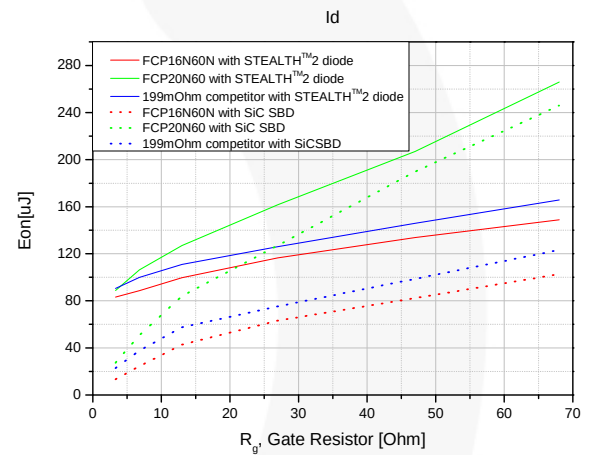


Figure 40.FCP16N60N  $E_{ON}$  vs. FCP20N60 and Competitor at Rated  $I_D$

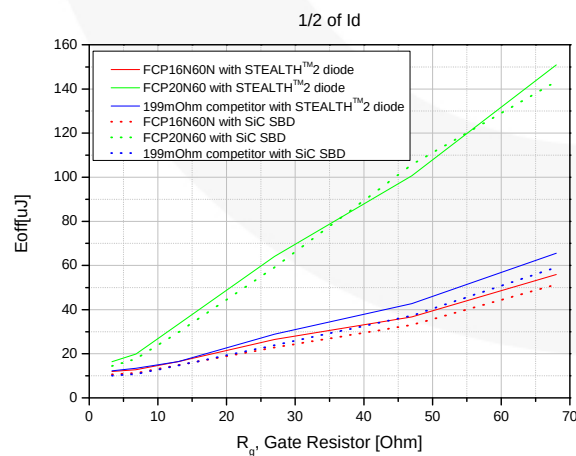


Figure 41.FCP16N60N  $E_{OFF}$  vs. FCP20N60 and Competitor at Half  $I_D$

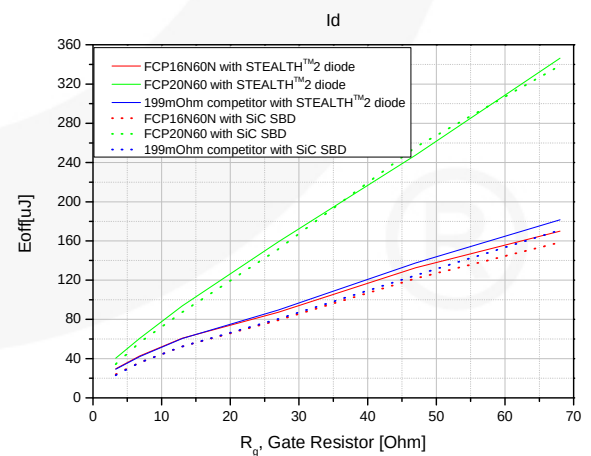


Figure 42.FCP16N60N  $E_{OFF}$  vs. FCP20N60 and Competitor at Rated  $I_D$

## Typical Performance Characteristics

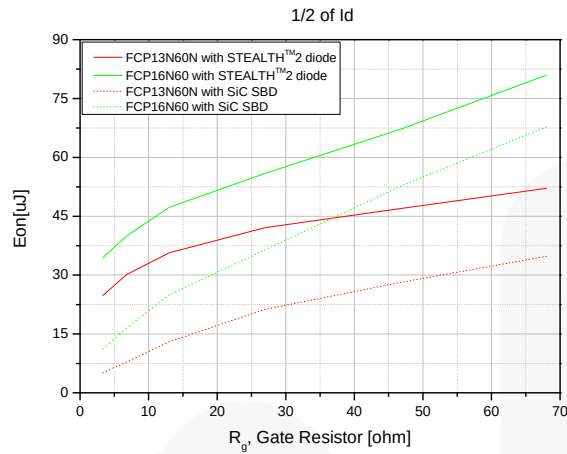


Figure 43.FCP13N60N  $E_{ON}$  vs. FCP16N60 at Half  $I_D$

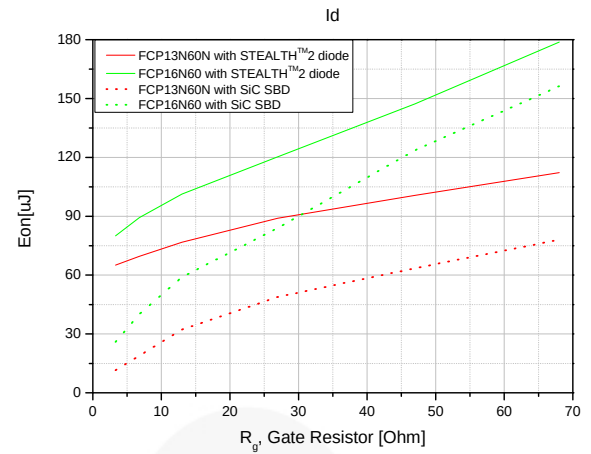


Figure 44.FCP13N60N  $E_{ON}$  vs. FCP16N60 at Rated  $I_D$

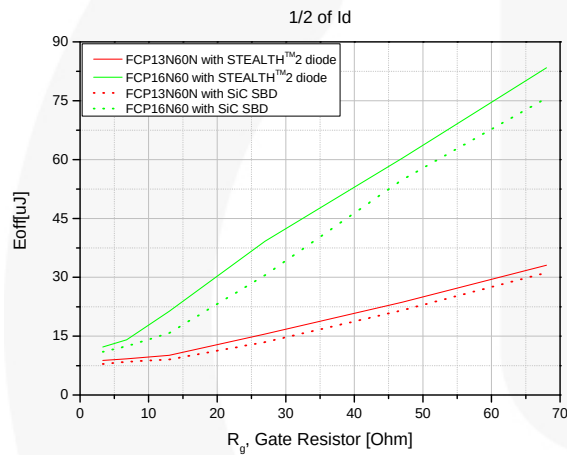


Figure 45.FCP13N60N  $E_{OFF}$  vs. FCP16N60 at Half  $I_D$

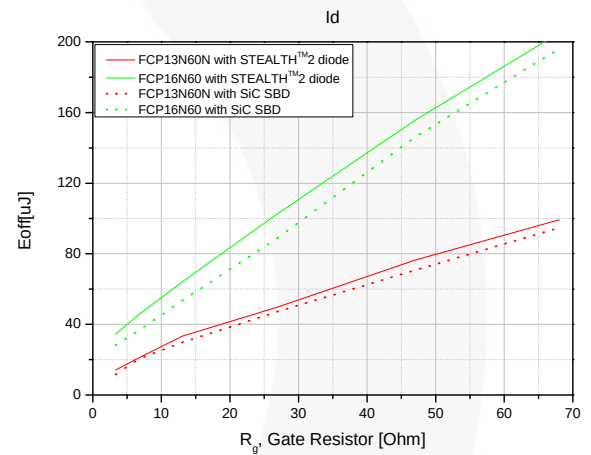


Figure 46.FCP13N60N  $E_{OFF}$  vs. FCP16N60 at Rated  $I_D$

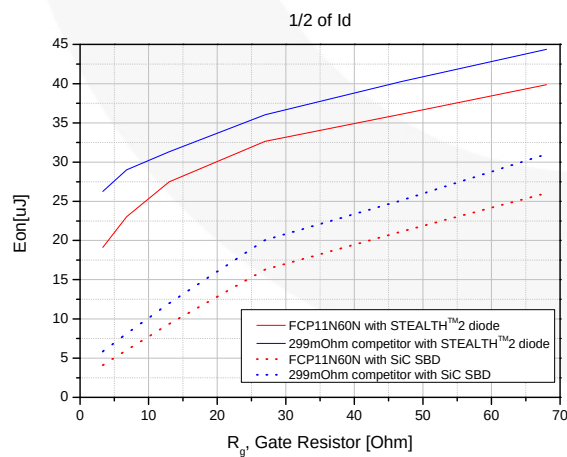


Figure 47.FCP11N60N  $E_{ON}$  vs. Competitor at Half  $I_D$

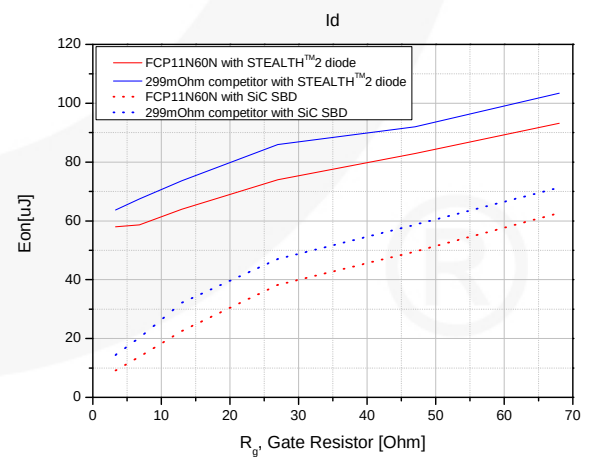


Figure 48.FCP11N60N  $E_{ON}$  vs. Competitor at Rated  $I_D$

## Typical Performance Characteristics

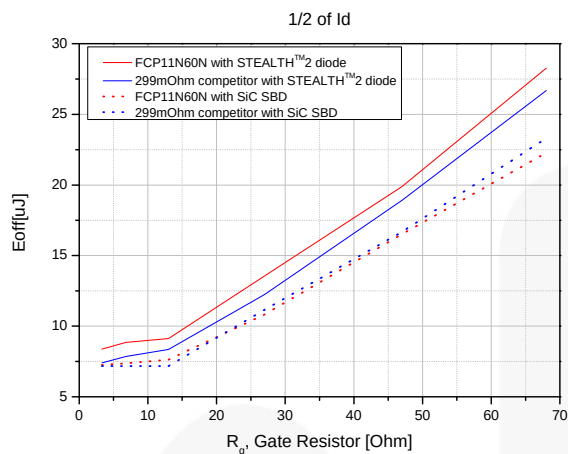


Figure 49. FCP11N60N  $E_{OFF}$  vs. Competitor at Half  $I_D$

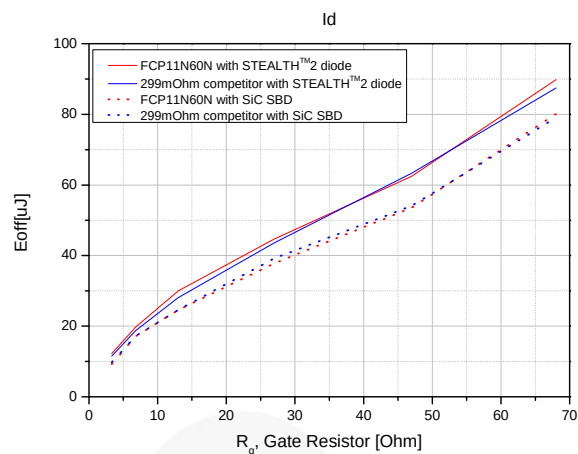


Figure 50. FCP11N60N  $E_{OFF}$  vs. Competitor at Rated  $I_D$

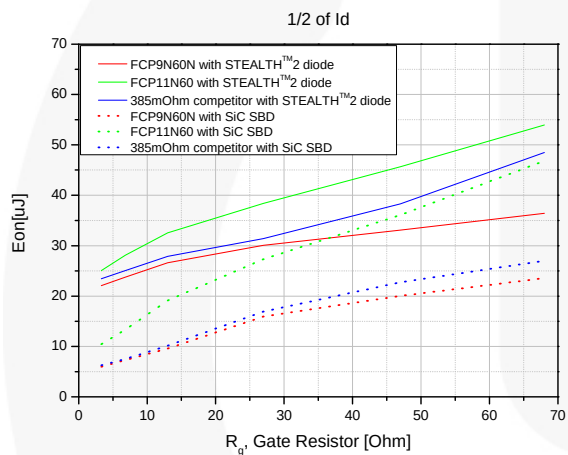


Figure 51. FCP9N60N  $E_{ON}$  vs. FCP11N60 and Competitor at Half  $I_D$

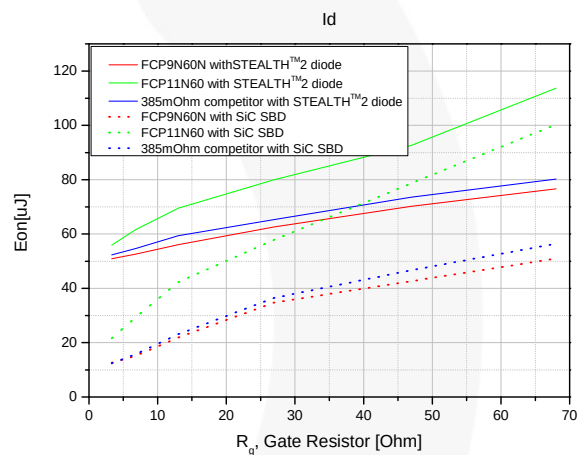


Figure 52. FCP9N60N  $E_{ON}$  vs. FCP11N60 and Competitor at Rated  $I_D$

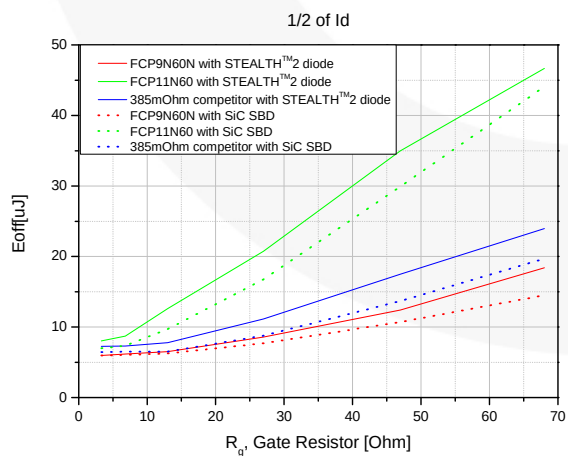


Figure 53. FCP9N60N  $E_{OFF}$  vs. FCP11N60 and Competitor at Half  $I_D$

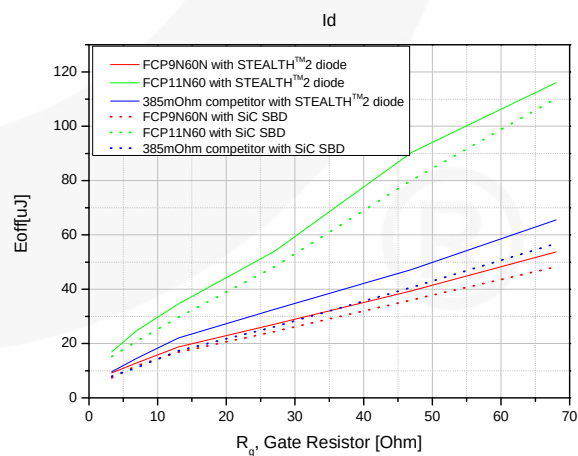


Figure 54. FCP9N60N  $E_{OFF}$  vs. FCP11N60 and Competitor at Rated  $I_D$

## Related Datasheets

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[FCH76N60N – 600V N-Channel SupreMOS<sup>®</sup> MOSFET](#)  
[FCH76N60NF– 600V N-Channel SupreMOS<sup>®</sup> MOSFET](#)  
[FCH47N60N– 600V N-Channel SupreMOS<sup>®</sup> MOSFET](#)  
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[FCP9N60N – 600V N-Channel SupreMOS<sup>®</sup> MOSFET](#)  
[FCPF9N60NT – 600V N-Channel SupreMOS<sup>®</sup> MOSFET](#)  
[FCD9N60NTM – 600V N-Channel SupreMOS<sup>®</sup> MOSFET](#)

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