Body Diode Reverse Recovery Loss: Reading the Datasheet Qrr for Your Buck

Philip Bassett · AN2026-06 · Revised 13 November 2026
https://switchmode.io/resources/body-diode-reverse-recovery-loss

When the high side of a synchronous buck turns on, it sweeps the stored charge out of the low side's body diode. This note turns the one or two reverse recovery charges a MOSFET datasheet prints into the charge and the loss in your converter. It covers hard-switched silicon MOSFETs in continuous conduction. The worked example is the 48 V to 12 V, 500 kHz converter from MOSFET Coss Loss in a Half-Bridge: Which Switch Pays, and How Much and Dead Time in a Synchronous Buck: Choosing Both Edges from the Datasheet.

The result

The datasheet figure is the reverse recovery charge Q_{rr}, measured at one forward current, one slew rate and one voltage, after a long conduction. Your converter differs from that test on all four counts. The usual estimate charges the printed figure as $Q_{rr} V_{in} f_{sw}$, where V_{in} is the input voltage and f_{sw} the switching frequency. On the worked example at full load, that reads low by 3.6 to 5.6 times, depending on the part. At light load it can read high.

Four corrections get the charge you actually pay for. Move it to your edge's slew rate. Take out any output charge it already contains. Scale it to the current the diode carries when it's swept out. Then charge it at the input voltage. In the worked example, ISC040N10NM7 prints 23 nC. At full load the method gives 83 nC, which is 2.0 W at 500 kHz against the 0.55 W the printed figure gives.

The total comes out within the spread of two simulations of the same edge. The split between the two switches doesn't. It depends on how soft the recovery is, and no datasheet states that.

Why the printed figure isn't the charge you pay for

A body diode that conducts stores charge in its drift region. When the high side turns on, the diode current falls at the slew rate the high side sets, di/dt, and then reverses. The reverse current sweeps the stored charge out against the input rail. Until the charge is gone, the diode holds the switch node low. So the high side carries the load current and the recovery current at the full input voltage.

The datasheet measures this in a test circuit, usually at 100 A/µs. A buck's edge is ten to a hundred times faster. Faster edges leave less time for the charge to recombine, so more of it is left to sweep out. The test also runs the diode at tens of amps, often at the part's full rating, and for far longer than a buck's dead time.

The measurement can't tell stored charge from output charge either. The reverse current also charges the diode's own output capacitance C_{oss}, and that charge is the output charge Q_{oss}. Vendors treat it differently. Nexperia states that its figure includes all of it, $Q_r = Q_s + Q_{oss}$ [2]. Here Q_r is Nexperia's name for the recovered charge and Q_s is the stored charge. Infineon says its JEDEC figure includes "a part of the output charge" [1]. TI's definition of Q_{rr} takes in the charge that fills the diode's depletion

capacitance [3]. The Coss note already charges all of the output charge to the high side. So any of it left in Q_{rr} is counted twice.

What you need from the datasheet

- **Every Q_{rr} line, with its conditions:** the forward current I_F, the slew rate di/dt and the voltage V_R (sometimes written V_{DS} or V_{DD}). Some parts print two lines at different slew rates. Use both.
- **The output charge at the Q_{rr} test voltage V_{test},** written $Q_{oss}(V_{test})$. If the datasheet only gives a C_{oss} curve, integrate it as in Step 2 of the Coss note.
- **What the vendor says Q_{rr} contains.** Look in the vendor's datasheet-parameter application note, not the datasheet.
- **The gate drive of the switch that turns on.** You need the driver's pull-up resistance, and the switch's gate resistance, input capacitance, threshold and plateau voltage. Step 2 turns them into a slew rate.

STEP 1

Test what the printed figure can contain

Compare the printed charge with the output charge at the same voltage. If $Q_{rr} < Q_{oss}(V_{test})$, the figure can't contain all of the output charge. That doesn't tell you how much of it the figure does contain.

In the switchmode.io component catalogue on 15 October 2026, this held for 63 of 100 Infineon silicon MOSFETs. Their printed Q_{rr} was smaller than their own Q_{oss} at the test voltage, with a median ratio of 0.80. That fits Infineon's "a part of" [1]. Nexperia states its convention outright, so for its parts the answer is all of it.

The part then falls into one of three cases:

The vendor says	Convention	Step 3 does
Q_{rr} includes all of Q_{oss} (Nexperia [2])	includes	subtracts $Q_{oss}(V_{test})$
It includes part of Q_{oss} (Infineon [1])	part	routes up to $Q_{oss}(V_{test})$ to the high side
Nothing	unstated	the same as "part"

STEP 2

Move the charge to your edge's slew rate

The current in the low side's diode falls at the rate the high side's current rises. While the high side's gate climbs from threshold to the plateau, its current rises from zero to the valley current. That takes

$$t_{ri} = (R_{pu} + R_{G,int})\, C_{iss}\, \ln \frac{V_{drv} - V_{GS(th)}}{V_{drv} - V_{pl}}$$

so the slew rate is

$$\frac{di}{dt} = \frac{I_v}{t_{ri}}$$

where:

- t_{ri} is the current rise time of the high side.
- R_{pu} is the gate driver's pull-up resistance, and $R_{G,int}$ the switch's internal gate resistance.
- C_{iss} is the high side's input capacitance.
- V_{drv} is the gate drive voltage, $V_{GS(th)}$ the threshold and V_{pl} the plateau voltage.
- I_v is the valley current, the inductor current when the high side turns on. In a buck it's the output current less half the ripple.
- di/dt is the slew rate at which the diode current falls.

With one Q_{rr} line, carry it to that slew rate as

$$Q_{rr,read} = Q_{rr} \left(\frac{di/dt}{(di/dt)_{test}} \right)^{b}$$

where:

- $Q_{rr,read}$ is the charge at your slew rate.
- Q_{rr} is the printed charge, and $(di/dt)_{test}$ the slew rate it was measured at.
- di/dt is your slew rate, from above.
- b is the slope, 0.77 for silicon.

The slope comes from the catalogue. On 30 October 2026, 28 silicon MOSFETs in it printed two lines, mostly at 100 and 1000 A/µs. Their slopes have a median of 0.77, with half of them between 0.68 and 0.91. They differ by part, so a part's own two lines beat the median. Check it on ISC151N08NM6, which prints both. Carried from its 16 nC line, the median slope gives 94 nC at 1000 A/µs, against the 89 nC it prints [6].

With two lines, interpolate between them on log-log axes:

$$Q_{rr,read} = Q_1 \left(\frac{Q_2}{Q_1} \right)^{\ln[(di/dt)/(di/dt)_1] / \ln[(di/dt)_2/(di/dt)_1]}$$

where Q_1 and Q_2 are the two printed charges, $(di/dt)_1$ and $(di/dt)_2$ the slew rates they were measured at, and di/dt your slew rate.

Then hold it at 1000 A/µs. That's the fastest line any silicon datasheet in the catalogue prints. Nobody has measured where the charge stops rising. A hard-switched buck is usually faster. In the worked example the edge is 4.1 kA/µs at full load. If your edge is faster, read the charge at 1000 A/µs, and expect it to read low. The simulation later in this note says by how much.

STEP 3

Take out the output charge

For a part whose vendor says Q_{rr} includes all of Q_{oss}:

$$Q_s = Q_{rr,read} - Q_{oss}(V_{test}), \qquad Q_{cap} = 0$$

For a part whose vendor says "part", or says nothing:

$$Q_{cap} = \min\left[Q_{rr,read},\ Q_{oss}(V_{test}) \right], \qquad Q_s = Q_{rr,read} - Q_{cap}$$

where:

- Q_s is the stored charge, the part that's genuinely recovery.

- Q_{cap} is the part that may be output charge, which can't be told apart from recovery.
- $Q_{rr,read}$ is the charge from Step 2.
- $Q_{oss}(V_{test})$ is the output charge at the voltage Q_{rr} was measured at.

In the first case the output charge is already in the Coss note's loss, so it's removed. In the second you can't know how much is output charge. So Q_{cap} goes to the high side, where all capacitive loss belongs, and the total becomes an upper bound. If Q_s comes out negative in the first case, take it as zero.

STEP 4

Scale it to the valley current

The diode is swept out at the valley current, not at the test current. Scale both parts of the charge by

$$k_I = \min\left(\frac{I_v}{I_{test}},\ 1\right)^c$$

where:

- k_I is the current factor.
- I_v is the valley current, from Step 2.
- I_{test} is the forward current the Q_{rr} line was measured at. Where a datasheet prints "$I_F = I_S$", it's the part's continuous diode rating.
- c is the exponent, 0.38 for silicon.

No MOSFET datasheet in the catalogue prints Q_{rr} at more than one current. The exponent comes from four discrete fast-recovery diode families that do [11]–[14]. Read at 200 A/µs, their fitted exponents run from about 0.25 to 0.43, with a median of 0.38. Linear scaling would read low, since every measured family is concave.

Above the test current, the factor stays at 1, and the charge then reads low. At zero current it's zero, as it should be: a diode that carries nothing stores nothing.

STEP 5

The loss, and why the split is a guess

The recovery loss for the stage is

$$P_{rr} = k_I\,(Q_{cap} + Q_s)\,V_{in} f_{sw}$$

where:

- P_{rr} is the recovery power loss.
- k_I is the current factor from Step 4.
- Q_{cap} and Q_s are the two parts of the charge from Step 3.
- V_{in} is the input voltage.
- f_{sw} is the switching frequency.

The high side takes all of $k_I Q_{cap} V_{in} f_{sw}$. The stored part splits between the two switches, and nothing on a datasheet fixes how. A snappy diode holds the node low until its charge is nearly gone, so the high side takes most of the loss. A soft one supports voltage while it recovers, so it takes more itself. In simulation, at the same stored charge, the high side's share ran from 18% to 66% (see "Checking it in

simulation"). An even split is a defensible middle, and it's what the switchmode.io calculator uses. If the high side's thermal margin is thin, design it for the larger share.

Don't add an extra term for the load current. ST's AN5028 adds $I_0 t_a V$ for the load current carried while the diode is still recovering [4]. In the simulation it was 4–10% of the recovery loss at full load and under 1% at light load. ST's formula predicts 1.7 to 2.2 times that at full load, and more at lighter loads. It belongs in the margin, not in the sum.

Worked example: 48 V to 12 V at 500 kHz

The converter. An Infineon ISC040N10NM7 in both positions [5], 48 V to 12 V at 500 kHz. A 3.3 µH inductor gives 5.45 A of ripple. At full load, 16.7 A, the high side turns on into a 13.97 A valley. The driver is a TI UCC27282 at 10 V, with a 1.3 Ω pull-up and no external gate resistor.

From the datasheet [5]: Q_{rr} = 23 nC typical, 46 nC maximum, at I_F = 50 A, di/dt = 100 A/µs, V_R = 50 V. One line only. $R_{G,int}$ = 1.3 Ω, C_{iss} = 3.5 nF, $V_{GS(th),min}$ = 2.3 V, V_{pl} = 4.7 V.

1. **What it can contain.** Q_{oss}(50 V) = 91.5 nC from the C_{oss} curve, against 91 nC in the datasheet. 23 nC is less than that, so the line doesn't contain all of the output charge. The vendor says "part" [1].
2. **Slew rate.** t_{ri} = 2.6 Ω × 3.5 nF × ln(7.7/5.3) = 3.4 ns, so di/dt = 13.97 A / 3.4 ns = 4.1 kA/µs. That's past the 1000 A/µs hold, so read at 1000 A/µs: $Q_{rr,read}$ = 23 × 10^0.77 = 135.4 nC. It likely reads low.
3. **Output charge.** Q_{cap} = min(135.4, 91.5) = 91.5 nC and Q_s = 43.9 nC.
4. **Current.** k_I = (13.97/50)^0.38 = 0.616. The charge is 0.616 × 135.4 = 83.4 nC.
5. **Loss.** P_{rr} = 83.4 nC × 48 V × 500 kHz = **2.00 W**. The high side takes 0.616 × (91.5 + 21.9) nC, which is 1.68 W. The low side takes 0.616 × 21.9 nC, which is 0.32 W.

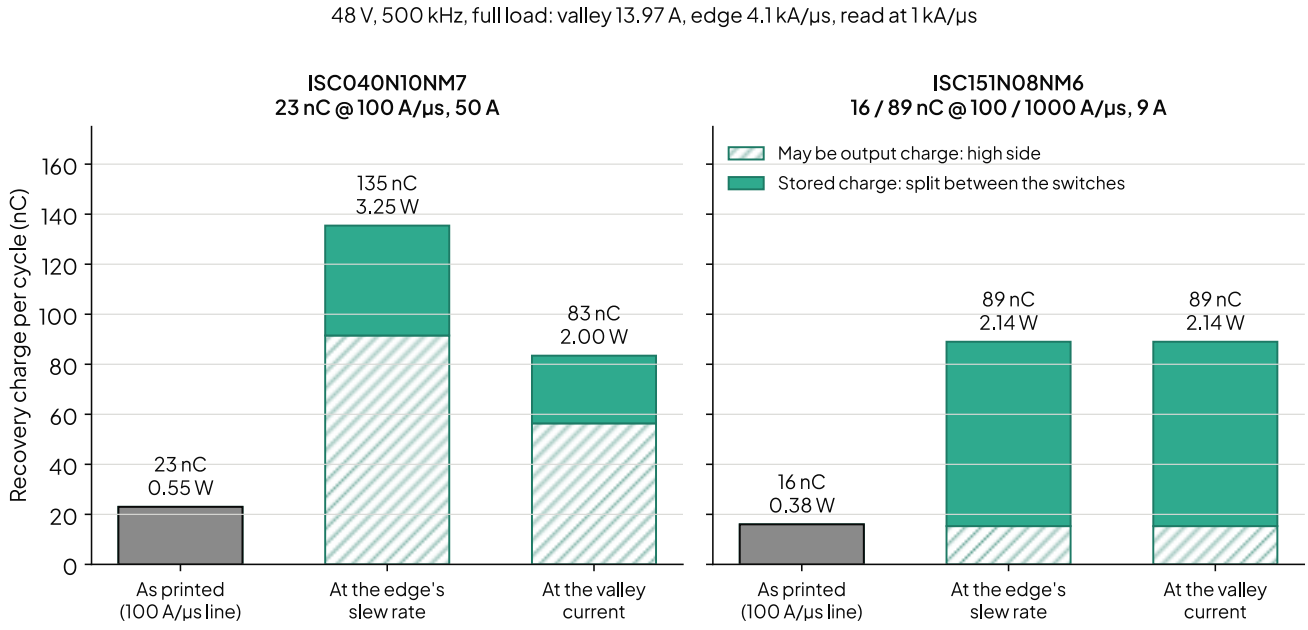


Fig. 1. The printed charge at each step, for the worked example's ISC040N10NM7 and for ISC151N08NM6 in the same position. The hatched part may be output charge and goes to the high side.

At 2.00 W, recovery is about the same size as the capacitive loss the Coss note finds on the same converter, 2.14 W. Both land mostly on the high side. Against the printed figure, the steps pull in

opposite directions. The slew rate raises the charge 5.9 times, and the valley current takes it back to 0.62 of that.

The same steps across the load range. The slew rate falls with the valley current. At light load the gate model gives 375 A/µs, below the hold.

Load	Valley	di/dt	$Q_{rr,read}$	k_I	Charge	P_{rr}	$Q_{rr}V_{in}f_{sw}$ as printed
Full, 16.7 A	13.97 A	4,112 A/µs, held at 1,000	135.4 nC	0.616	83.4 nC	2.00 W	0.55 W
Half, 8.35 A	5.63 A	1,655 A/µs, held at 1,000	135.4 nC	0.436	59.0 nC	1.42 W	0.55 W
Light, 4.0 A	1.28 A	375 A/µs	63.7 nC	0.248	15.8 nC	0.38 W	0.55 W

A part that prints two lines. ISC151N08NM6 prints 16 nC at 100 A/µs and 89 nC at 1000 A/µs, both at 9 A and 40 V [6]. Its Q_{oss}(40 V) is 15.3 nC. At full load the edge is past 1000 A/µs, so it reads 89 nC, with 15.3 nC of it routed to the high side. The valley is above its 9 A test current, so k_I = 1. That's 89 nC and **2.14 W**, of which the low side takes 0.88 W. The smaller part costs more recovery than ISC040N10NM7 at full load, although it prints less. At light load it costs 0.49 W against 0.38 W.

That's the case for reading the conditions, not just the number. ISC040N10NM7's 23 nC was measured at 50 A, so it falls a long way at a 14 A valley. ISC151N08NM6's 89 nC was measured at 9 A and doesn't fall at all.

The subtraction case: a part whose figure includes all of the output charge

Nexperia's PSMN6R9-100YSF prints Q_r = 52.4 nC at I_S = 25 A, 100 A/µs and V_{DS} = 50 V [7]. Nexperia says that figure includes all of Q_{oss} [2]. The datasheet gives no Q_{oss}, only C_{oss} = 722 pF at 50 V. C_{oss} only falls as the voltage rises, so Q_{oss}(50 V) is at least 722 pF × 50 V = 36.1 nC.

So the stored charge is at most 52.4 − 36.1 = 16.3 nC. At least 69% of the printed figure is output charge, which the Coss note's term already charges to the high side. Add $Q_r V_{in} f_{sw}$ on top and you count that 69% twice. An even split would also put half of it on the low side, which dissipates nothing capacitive.

With the C_{oss} curve, integrate for the true Q_{oss}(50 V). It's larger than the bound, so the stored charge is smaller still.

Checking it in simulation

I simulated the full-load recovery edge of the worked example in ngspice. The switches were Infineon's own ISC040N10NM7 model [10], driven as in the dead-time note. Each run was paired with the same edge with the diode's stored charge switched off, so the difference is the recovery alone.

Infineon's model reproduces the datasheet. At the datasheet's test conditions it stores 20.3 nC, against the printed 23 nC. But it stores the charge on a capacitance, so the diode never stays forward-biased while the charge goes. The mechanism behind ST's $I_0 t_a$ term isn't in it.

A lumped-charge diode does hold the node. I added a Lauritzen–Ma model [9] inside the package, fitted so that it stores 23 nC at the datasheet's test conditions. It has two parameters, a lifetime and a transit time. Only one datasheet point fits them, so I swept the transit time over 1, 3 and 10 ns. The lifetime came out at 16 to 18 ns.

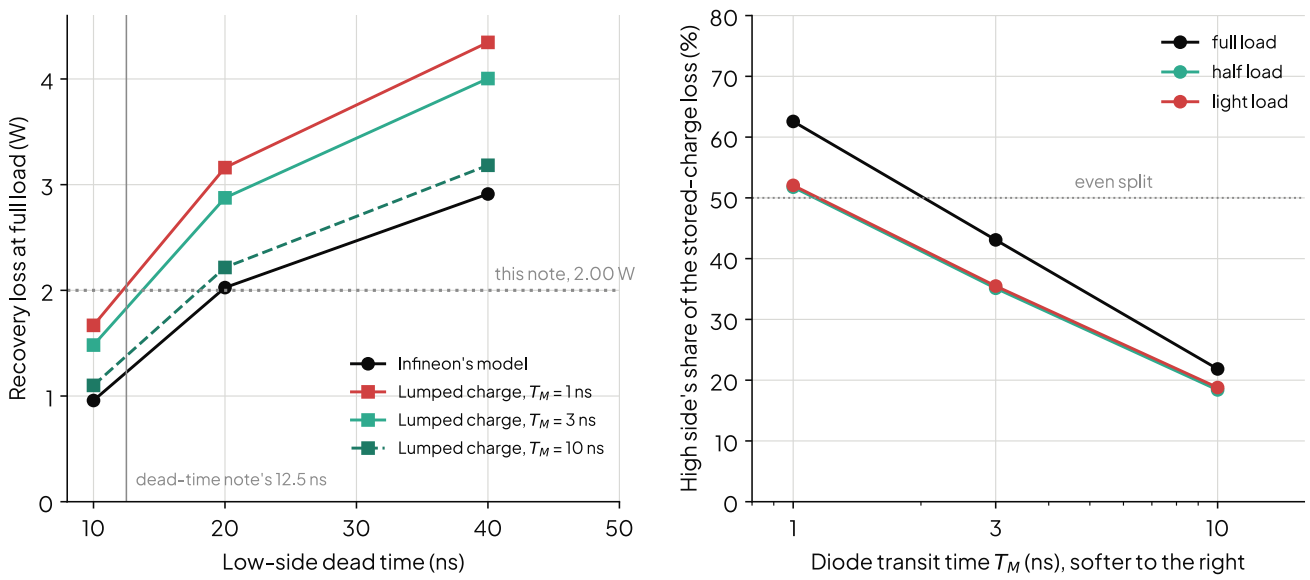


Fig. 2. Left: simulated recovery loss at full load against the low-side dead time, for Infineon's model and the lumped-charge diode at three transit times, with this note's 2.00 W. Right: the high side's share of the stored-charge loss, at three loads, against the transit time.

Dead time	Infineon's model	Lumped charge, T_M = 1 / 3 / 10 ns	This note
10 ns	0.96 W	1.67 / 1.48 / 1.10 W	2.00 W
20 ns	2.03 W	3.16 / 2.88 / 2.22 W	2.00 W
40 ns	2.91 W	4.35 / 4.00 / 3.18 W	2.00 W

Four things come out of it.

- **The total is at the top of the range.** The dead-time note sets this edge at 12.5 ns. Interpolated to 12.5 ns, the simulations give about 1.2 to 2.0 W, so this note's 2.00 W sits at the top. At half and light load the method reads high against both models.
- **Conduction time matters as much as current.** The stored charge keeps rising with dead time, from 63 to 119 to 163 nC at 10, 20 and 40 ns (T_M = 1 ns). The method has no term for it, because no datasheet says how long its diode conducted.
- **The split depends on the transit time.** Across the three loads, the high side's share of the stored-charge loss was 51–66% at T_M = 1 ns, 35–46% at 3 ns and 18–23% at 10 ns. The datasheet can't tell you which you have.
- **The current exponent depends on the slew rate.** At 100 A/µs both models stored the same charge at 9 A and at 50 A. At 1000 A/µs the lumped-charge diode gave exponents of 0.37 to 0.42, and Infineon's model 0.41. That's the 0.38 of Step 4, in the regime a buck runs in. It also means a line measured at 100 A/µs tells you almost nothing about the current dependence.

Assumptions and limits

- **Silicon body diodes, hard-switched.** The slope, the exponent and the 1000 A/µs hold are silicon figures. SiC body diodes need their own, and a SiC Schottky or GaN switch has no stored charge to recover. If the inductor current reverses in the dead time, the diode isn't conducting when the high side turns on, and there's nothing to recover.

- **The slew rate past 1000 A/µs.** The charge is held at the 1000 A/µs value, and it reads low there. In the simulation, the method's 83 nC at full load compared with 81–119 nC at 20 ns of dead time.
- **The slew-rate estimate is rough at light load.** The gate model gives 375 A/µs at the 1.28 A valley, and the simulated edge ran at 3.7 kA/µs. The current rises faster than I_v/t_{ri} says when the valley is small.
- **Conduction time.** Datasheet Q_{rr} is measured after the diode has conducted for a long time. A short dead time leaves less charge, and iDEAL Semiconductor reports large reductions at 150 V and up [8]. No datasheet states its conduction time, so the method has no correction for it.
- **Temperature.** Q_{rr} rises with junction temperature. ISC040N10NM7 prints no temperature curve. Where a datasheet prints a hot line, use it.
- **The datasheet's maximum.** ISC040N10NM7's maximum is twice its typical. The method's figures scale with it.
- **The split.** The even split is a choice, not a result. See Step 5.
- **The load current during recovery.** Left out, at up to 10% at full load in simulation. See Step 5.

What this means for switchmode.io

This procedure gets the stage's total recovery loss from the datasheet to within the spread of two simulations. It can't say which switch dissipates the stored part, or how much a short dead time saves. Both depend on the diode's softness and its conduction history, which no datasheet prints. A double-pulse measurement at your own dead time is the only thing that settles them today.

In the current alpha, the switchmode.io design workspace reads every silicon MOSFET's Q_{rr} lines in its catalogue through these five steps. It names the line it read and how it was carried, and it gives the high side the part that may be output charge. The MOSFET power loss calculator asks what your Q_{rr} includes, and at what voltage, and nets the output charge as Step 3 does. It takes the figure at the conditions you typed, though. Move it to your slew rate and valley current with Steps 2 and 4 before you enter it.

For the capacitive loss on the same edge, see MOSFET Coss Loss in a Half-Bridge: Which Switch Pays, and How Much. For setting the dead time that decides how long the diode conducts, see Dead Time in a Synchronous Buck: Choosing Both Edges from the Datasheet. For a full 48 V loss budget built on these terms, see Buck Converter Efficiency: Why the Smallest MOSFET Wins at 48V.

References

[1] P. B. Green, S. Mazzer, O. Guillemant, C. Moesslacher and K. Ream, "OptiMOS device selection for synchronous rectification," Infineon Technologies AG, Appl. Note AN_2212_PL15_2301_094414, V1.1, Feb. 2023. [Online]. Available: https://www.infineon.com/dgdl/Infineon-MOSFET_OptiMOS_device_selection_for_synchronous_rectification-ApplicationNotes-v01_00-EN.pdf?fileId=8ac78c8c85ecb34701865afe0f7d3f05

[2] Nexperia, "Understanding power MOSFET data sheet parameters," Application Note AN11158, rev. 7.0, Feb. 2025. [Online]. Available: https://assets.nexperia.com/documents/application-note/AN11158.pdf

[3] D. Jauregui, B. Wang and R. Chen, "Power loss calculation with common source inductance consideration for synchronous buck converters," Texas Instruments Application Report SLPA009A, Jul. 2011. [Online]. Available: https://www.ti.com/lit/an/slpa009a/slpa009a.pdf

[4] STMicroelectronics, "Calculation of turn-off power losses generated by an ultrafast diode," Application Note AN5028, rev. 1, Oct. 2017. [Online]. Available: https://www.st.com/resource/en/application_note/an5028-calculation-of-turnoff-power-losses-generated-by-a-ultrafast-diode-stmicroelectronics.pdf

[5] Infineon Technologies AG, "ISC040N10NM7 OptiMOS 7 Power-Transistor, 100 V," datasheet, rev. 1.0, Nov. 2025. [Online]. Available: https://www.infineon.com/assets/row/public/documents/24/49/infineon-isc040n10nm7-datasheet-en.pdf

[6] Infineon Technologies AG, "ISC151N08NM6 OptiMOS 6 Power-Transistor, 80 V," datasheet, rev. 2.0, Mar. 2023. [Online]. Available: https://www.infineon.com/assets/row/public/documents/24/49/infineon-isc151n08nm6-datasheet-en.pdf

[7] Nexperia, "PSMN6R9-100YSF," datasheet, Dec. 2017. [Online]. Available: https://assets.nexperia.com/documents/data-sheet/PSMN6R9-100YSF.pdf

[8] D. Jauregui, "Reverse recovery charge is not a constant," EEPower, May 2026. [Online]. Available: https://eepower.com/technical-articles/reverse-recovery-charge-is-not-a-constant/

[9] P. O. Lauritzen and C. L. Ma, "A simple diode model with reverse recovery," IEEE Trans. Power Electron., vol. 6, no. 2, pp. 188–191, Apr. 1991, doi: 10.1109/63.76804.

[10] Infineon Technologies AG, "OptiMOS power MOSFET 100 V N-channel SPICE simulation models," model library. [Online]. Available: https://www.infineon.com/assets/row/public/documents/24/50/infineon-optimos-power-mosfet-spice-100-v-n-channel-simulationmodels-en.zip

[11] Vishay Semiconductors, "VS-HFA15TB60S-M3, VS-HFA15TB60-1-M3 HEXFRED ultrafast soft recovery diode, 15 A," datasheet, doc. 96313, rev. 16 Dec. 2021. [Online]. Available: https://www.vishay.com/docs/96313/vs-hfa15tb60s-m3.pdf

[12] Vishay Semiconductors, "VS-HFA25TB60-M3 HEXFRED ultrafast soft recovery diode, 25 A," datasheet, doc. 96193, rev. 16 Dec. 2021. [Online]. Available: https://www.vishay.com/docs/96193/vs-hfa25tb60-m3.pdf

[13] STMicroelectronics, "STTH812 ultrafast recovery - 1200 V diode," datasheet, rev. 1, Mar. 2006. [Online]. Available: https://www.st.com/resource/en/datasheet/stth812.pdf

[14] IXYS, "DSEP30-06A HiPerFRED high performance fast recovery diode," datasheet, 2021.

CITE AS

P. Bassett, "Body Diode Reverse Recovery Loss: Reading the Datasheet Qrr for Your Buck," switchmode.io Application Note AN2026-06, rev. 13 Nov. 2026. [Online]. Available: https://switchmode.io/resources/body-diode-reverse-recovery-loss.pdf