Buck Converter Thermal modelling using PLECS

For a buck converter PLECS needs only 4 things from the datasheet:

1. Vblock =MOSFET blocking voltage during OFF
2. Ion =Switch current at turn-on / turn-off
3. Eon, Eoff =Switching energy
4. RDS(on) + thermal network =conduction + junction temperature

1. Vblock for Buck converter

From datasheet of -SCT4090KWAHR (ROHM)

VDSS = 1200 V (page 1)

But in a buck ,Vblock is not equal to rated voltage

Vblock=Vin

Examples

Buck input	What to enter in PLECS
400 V DC	400 V
600 V DC	600 V
800 V DC	800 V

ROHM measured switching losses at VDD = 800 V, exactly buck relevant.

2. Ion in a buck converter

For a buck Ion=Il(tsw), Inductor current at switching instant, Output current (CCM)

Example. Buck: 800 V --- 400 V

Vin = 800 V

Vout = 400 V

Output current (DC) = 8 A

Inductor ripple = ±0.5 A, Ion =8.3 ,as given in datasheet

In CCM, inductor current is triangular around the DC value:

$$I_L(t) = I_{DC} \pm \frac{\Delta I_L}{2}$$

$$I_{DC} = 8 \text{ A}$$

Ripple = ±0.5 A =peak-to-peak = 1 A

Minimum current

$$I_{min} = 8 - 0.5 = 7.5 \text{ A}$$

Maximum current

$$I_{max} = 8 + 0.5 = 8.5 \text{ A}$$

Datasheet switching curves use ID = 8.3 A is a perfect match.

3. Eon & Eoff

In datasheet

Page 3, numerical value

Page 11,curves (Fig.22, Fig.21)

Test conditions (critical)

- VDD = 800 V
- ID = 8.3 A
- VGS = +18 V / 0 V
- RG = 0 Ω
- Tvj = 25 °C

Switching energies (typical)

From datasheet:

- Eon ≈ 100 µJ
- Eoff ≈ 20 µJ
  In a buck:

- Eon dominates
- Eoff is much smaller (true for SiC)

So switching loss:

$$P_{sw} = f_{sw}(E_{on} + E_{off})$$

4.Entering switching loss in PLECS

Eon table

Current (A)	Energy (J)
5	80e-6
8.3	100e-6
12	130e-6
17	170e-6

Eoff table

Current (A)	Energy (J)
5	12e-6
8.3	20e-6
12	30e-6
17	45e-6

(Extracted from Fig.22, page 11 of datasheet)

Voltage scaling required (if Vin ≠ 800 V)

For buck converters this is unavoidable:

Escaled=EdsxVin/800

Example:

Vin = 600 V, Eon = 100 μJ. So Eon = 100X(600/800)=75uJ

4. Conduction loss (dominant at low fsw)

From datasheet (pages 2 & 9)

Junction temp	RDS(on)
25 °C	90 mΩ
150 °C	180 mΩ

Buck conduction loss

$$P_{cond} = D \cdot I_{out}^2 \cdot R_{DS(on)}(T)$$

5.Thermal model Cauer network already given in datasheet

Page 2 gives exact Cauer network

Use directly in PLECS

Element	Value
Rth1	0.30 K/W
Rth2	0.58 K/W
Rth3	0.72 K/W
Cth1	2.4e-4 Ws/K
Cth2	1.0e-3 Ws/K
Cth3	2.7e-3 Ws/K

Given (datasheet)

RthJC (typ) = 1.6 K/W