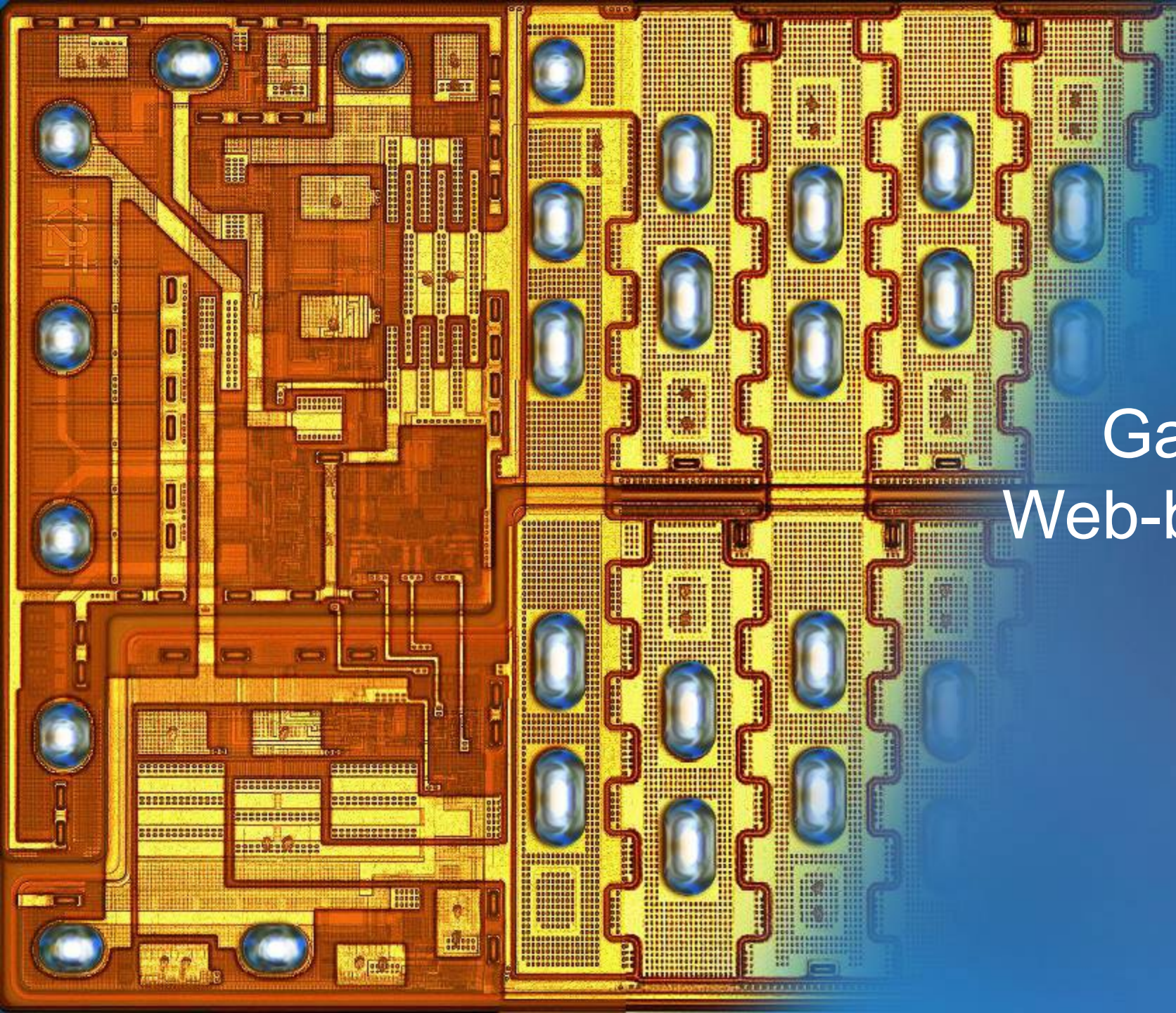
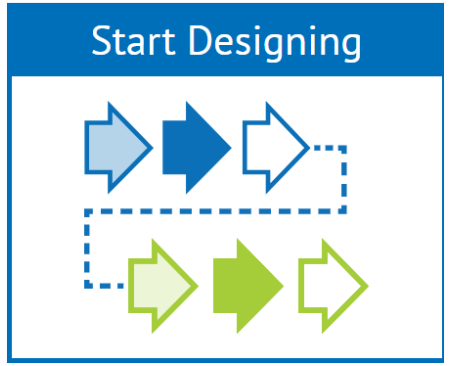


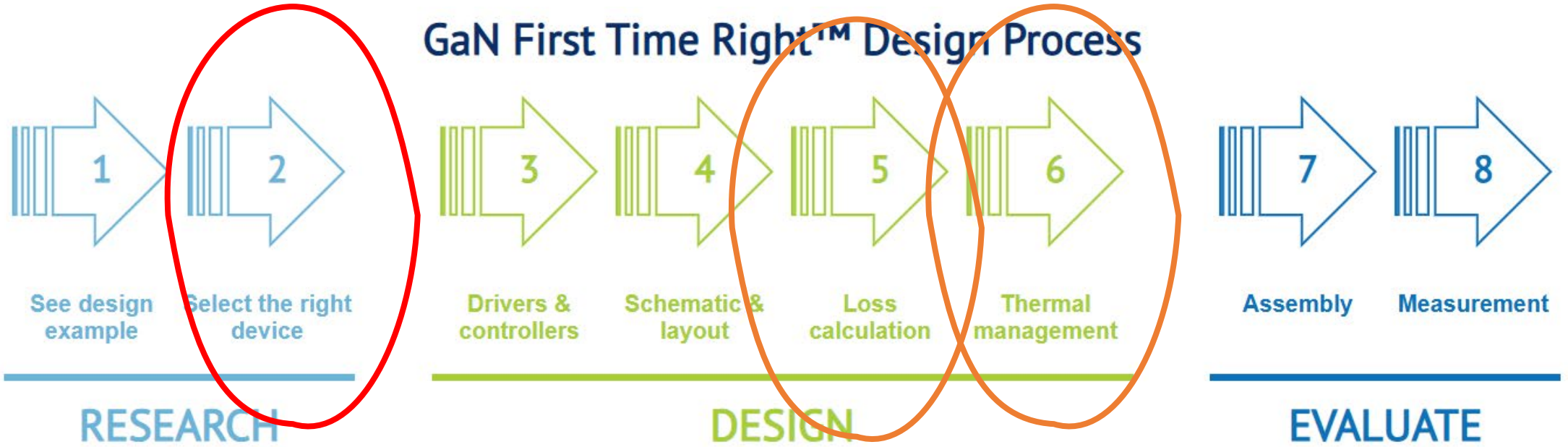
GaN First Time Right: Web-based Design Tools

Andrea Gorgerino
Director, WW FAE

EFFICIENT POWER CONVERSION

GaN First Time Right

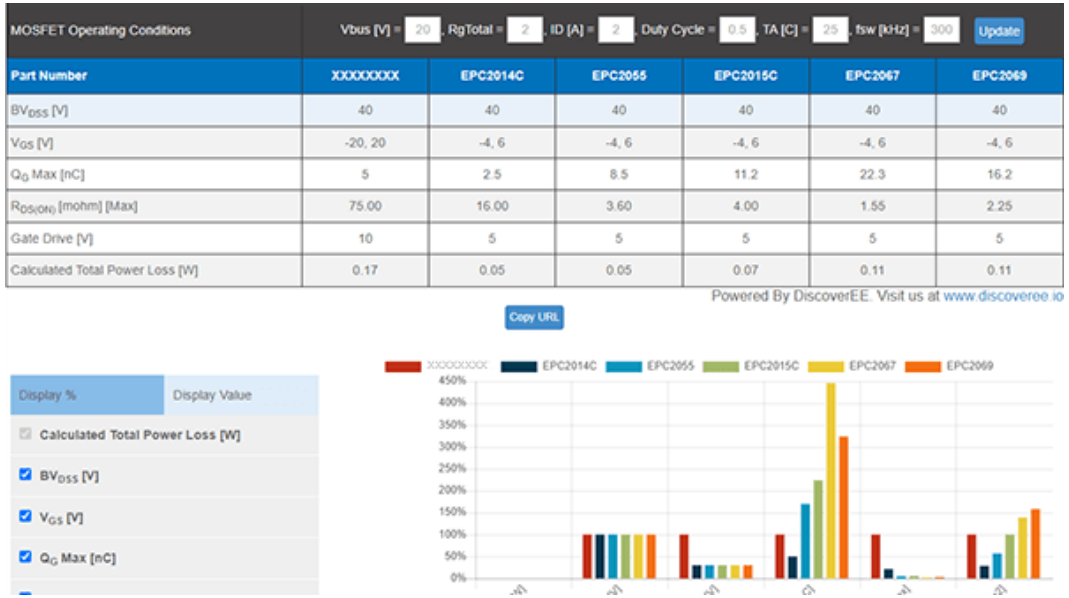




Tools

Cross reference tool

- Powered by DiscoverEE database: 20,000 MOSFETs from 28 manufacturers
- Compares the most cost-effective EPC products that beat Si MOSFET performance, in most cases at a lower cost
- Detailed datasheet comparison, including calculation of parameters in same conditions



MOSFET Operating Conditions: Vbus [V] = 20, RgTotal = 2, ID [A] = 2, Duty Cycle = 0.5, TA [C] = 25, fsw [kHz] = 300, Update

Part Number	XXXXXXXX	EPC2014C	EPC2055	EPC2015C	EPC2067	EPC2069
BV_{DSS} [V]	40	40	40	40	40	40
V_{GS} [V]	-20, 20	-4, 6	-4, 6	-4, 6	-4, 6	-4, 6
Q_G Max [nC]	5	2.5	8.5	11.2	22.3	16.2
$R_{DS(ON)}$ [mohm] [Max]	75.00	16.00	3.60	4.00	1.55	2.25
Gate Drive [V]	10	5	5	5	5	5
Calculated Total Power Loss [W]	0.17	0.05	0.05	0.07	0.11	0.11

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Display % | Display Value

Calculated Total Power Loss [W]

BV_{DSS} [V]

V_{GS} [V]

Q_G Max [nC]

XXXXXXXX EPC2014C EPC2055 EPC2015C EPC2067 EPC2069

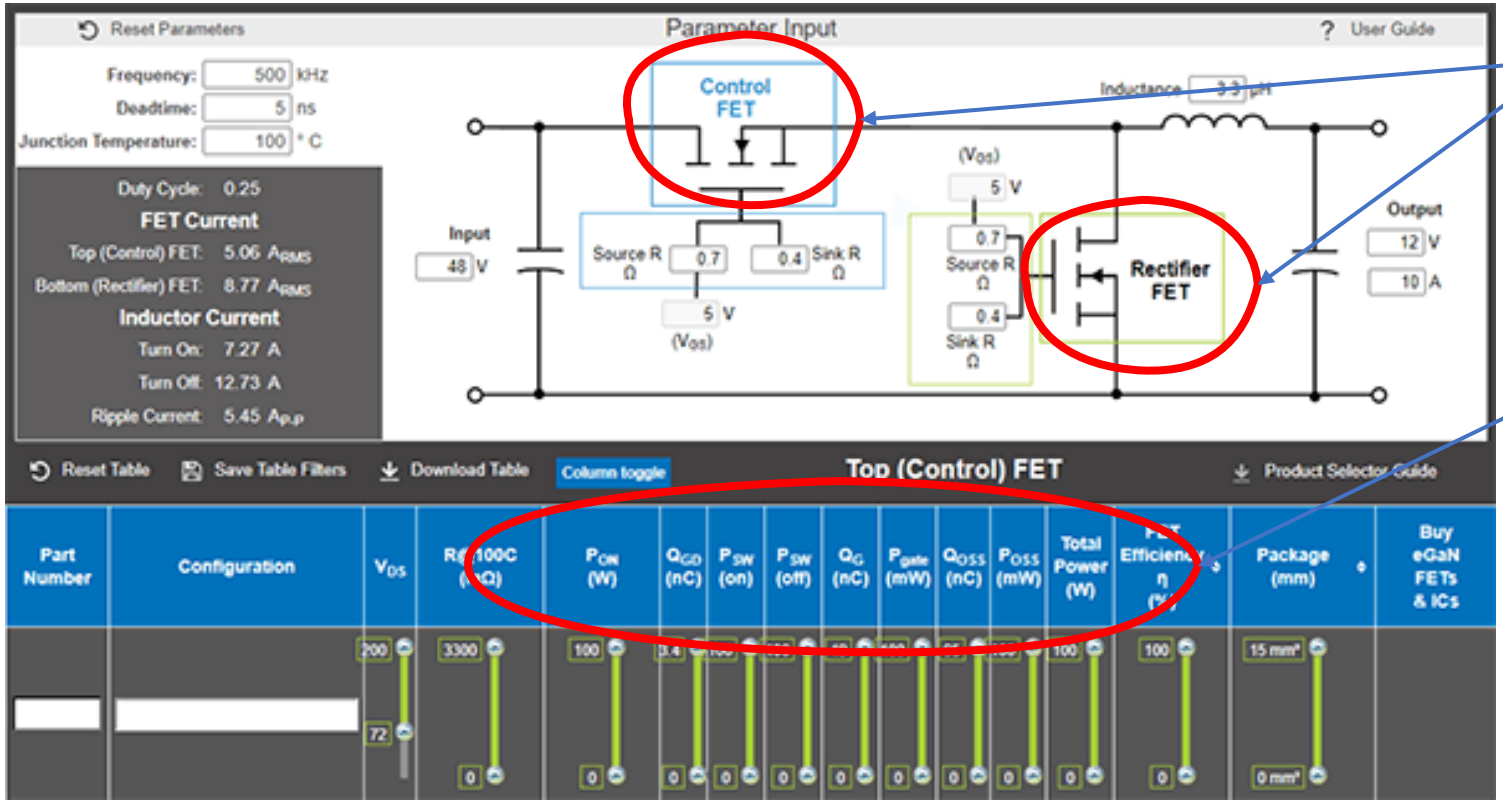
450% 400% 350% 300% 250% 200% 150% 100% 50% 0%

Table of Contents

Part Comparison Summary	Calculated I_D & P_D Ratings
Digikey Inventory & Price	Calculated Switching Times
Detail Parts Specifications	Power Loss Calculations
Figure of Merit	Power Loss Breakdown Chart

Sync buck tool

- Formula based loss analysis for synchronous buck converter
- Calculations for all EPC products

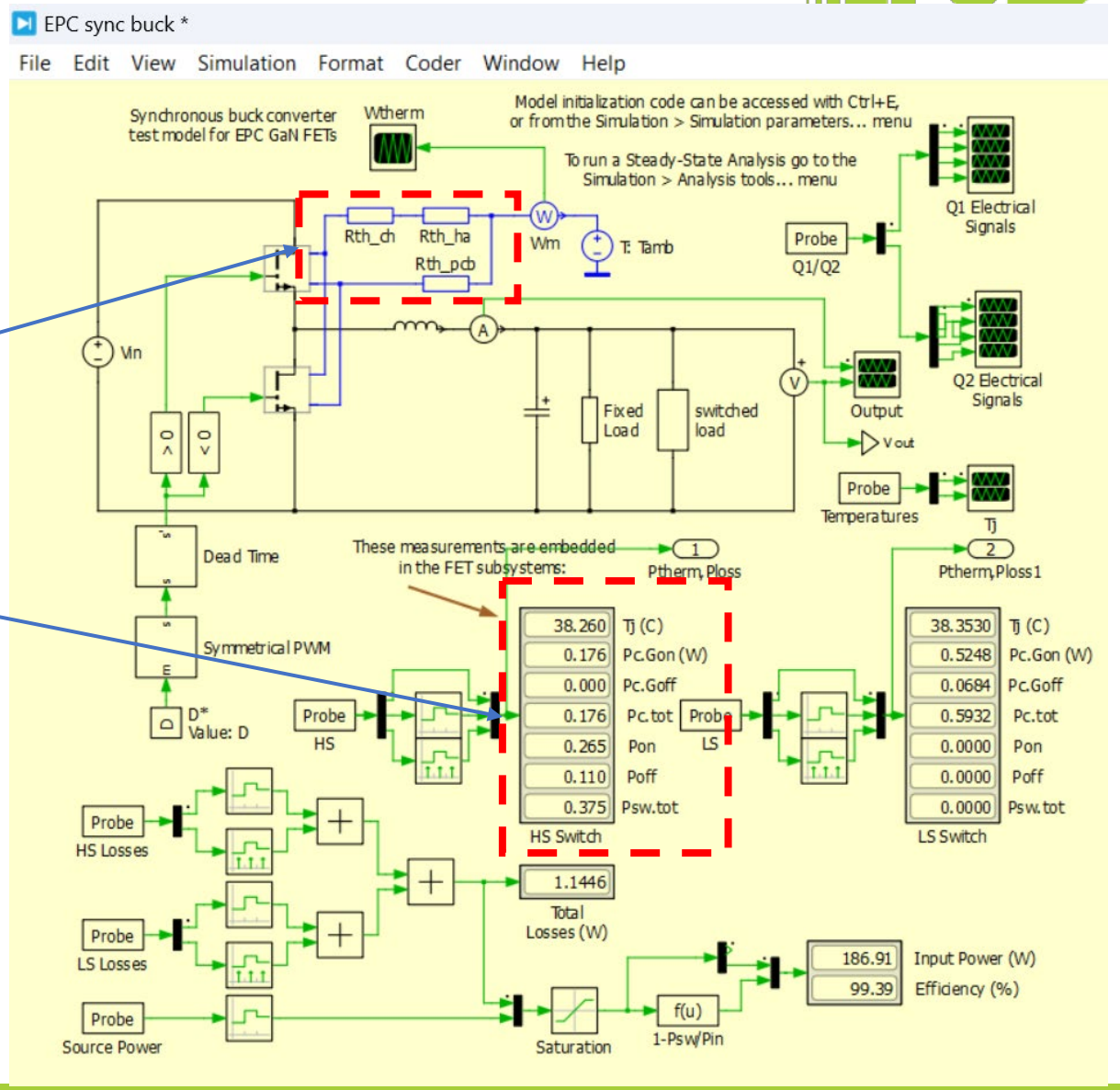


Calculations for both control and synchronous FETs

More detailed loss calculation

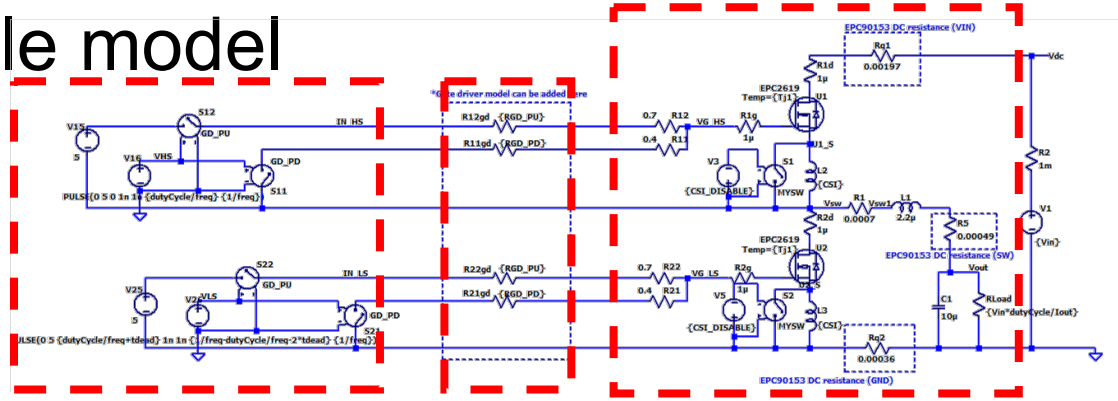
Electrical models: PLECS

- Custom thermal model based on formula loss calculations (for symmetrical half-bridge)
- Dual port models support dual sided cooling
- Custom models have internal measurement capabilities
- Example circuit



Electrical models: Spice

- Spice models: LTSpice, Pspice, Tspice, Spectre, SIMetrix/SIMPLIS
  - Continuous model for GaN FETs and circuit
  - Gate driver model
  - PCB parasitics, especially CSI
  - Passive components parasitics
- LTSpice example model



PWM generator based on simple application inputs (f_{SW}, duty cycle, V_{IN}/V_{OUT}, I_{OUT}, L)

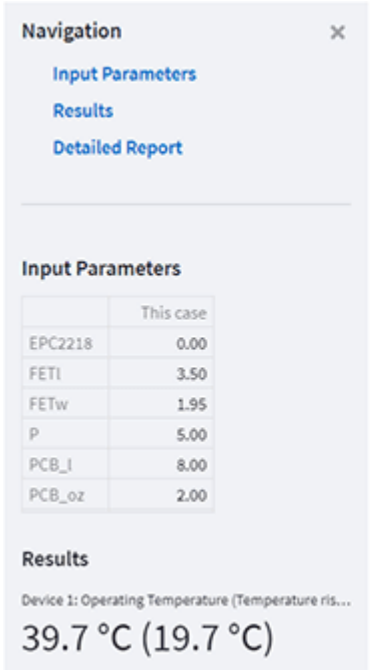
Simplified gate driver model

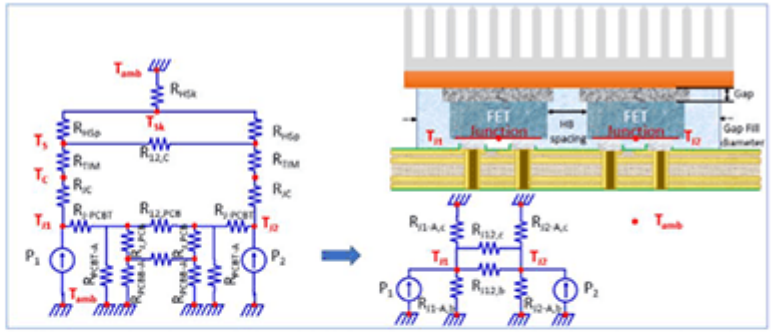
Circuit model with first level parasitic components (CSI, PCB resistance)

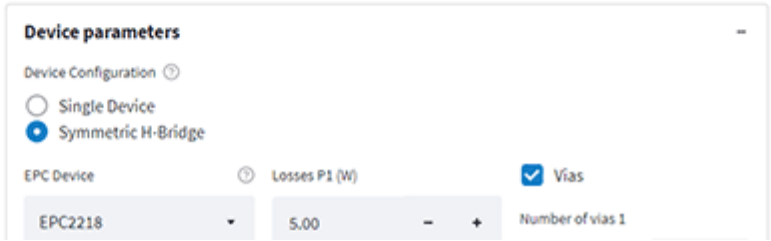
Loss analysis via .meas

Thermal calculator

- Parametrized tool based on FEA modeling: calculates temperature and thermal model parameters in steady state
- No detailed design required: suitable for initial device selection, iterative process with loss calculation
- PCB only cooling: vias, layers and airflow
- Heatsink cooling: TIM, heat-spreader, heatsink calculator, airflow





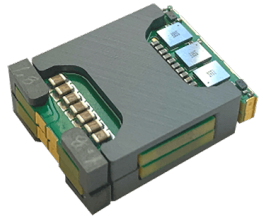


Demo boards

- EPC90xx: half-bridge boards for quick prototyping, available for all EPC GaN FETs

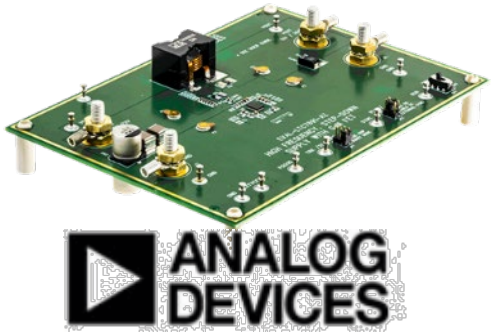
EPC90153 half-bridge board for EPC2619

- EPC91xx: application specific design



EPC9159 1kW LLC using EPC2619 and EPC2067

- Technology partner reference designs



Example

Simple buck converter

- Current design
  - 48/12V 300kHz
  - P= 260W (I_{OUT}=22A)
  - FDMS2D5N08C 80V, 2.2mΩ
- Goal: increase switching frequency and understand the value of GaN
  - 500kHz

Cross reference

Part Comparison Summary:

FET Operating Conditions: Vbus[V]= 40, RgTotal= 2, I_D[A]= 30, DC= 0.5, T_A[C]= 25, fsw[kHz]= 300, RthCA[°C/W]= 5 — Hard-switch | Update with same parts | Update with new recommendations

Part Number	FDMS2D5N08C (ON Semi)	EPC2204 x	EPC2204A x	EPC2065 x	EPC2059 x	EPC2619 x
Modify EPC Part						
BV_{DSS} [V]	80.0	100.0	80.0	80.0	170.0	100.0
$R_{DS(ON)}$ [mΩ] [Typ]	2.20	4.40	4.40	2.70	6.80	3.30
R_{THJC} [°K/W]	0.90	1.00	1.00	0.50	0.90	1.00
Q_G Typ [nC]	60.0	5.70	5.70	9.40	5.70	8.50
Gate Drive [V]	10.0	5.00	5.00	5.00	5.00	5.00
Gate Drive Loss [W]	0.18	0.0086	0.0086	0.014	0.0086	0.013
Package Area [mm²]	W=5.00mm, L=6.00mm Area=30.0 mm²	W=1.50mm, L=2.50mm Area=3.8 mm²	W=1.50mm, L=2.50mm Area=3.8 mm²	W=1.95mm, L=3.5mm Area=6.8 mm²	W=1.40mm, L=2.80mm Area=3.9 mm²	W=1.50mm, L=2.50mm Area=3.8 mm²
Calculated Total Power Loss [W]	**5.98**	**2.73**	**2.66**	**2.30**	**4.08**	**2.28**
Auto Qualified	No	No	Yes	No	No	No
Status	Promotion	Preferred	Preferred	Preferred	Preferred	Preferred

Quantity Available at Digi-Key	FDMS2D5N08C: 2651	EPC2204A: 17025	EPC2204A: 17025	EPC2065: 3471	EPC2059: 20814	EPC2619ENGRT: 0
Digi-Key Pricing	FDMS2D5N08C: 1 = $2.88, 10 = $2.417, 100 = $1.9556, 500 = $1.73834, 1000 = $1.48845	EPC2204A: 1 = $2.9, 10 = $2.405, 100 = $1.9144, 500 = $1.61984, 1000 = $1.37441	EPC2204A: 1 = $2.9, 10 = $2.405, 100 = $1.9144, 500 = $1.61984, 1000 = $1.37441	EPC2065: 1 = $3.21, 10 = $2.697, 100 = $2.1816, 500 = $1.9392	EPC2059: 1 = $3.32, 10 = $2.787, 100 = $2.2543, 500 = $2.003[illegible], 1000 = $1.715	EPC2619ENGRT: 1 = $3.48
Lead Weeks	24 week(s)	16 week(s)	16 week(s)	16 week(s)	16 week(s)	No lead time information available

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Default conditions

Expected 50% reduction of losses

Update your conditions

Part Comparison Summary:

FET Operating Conditions: Vbus[V]= 48, RgTotal= 2, I_D[A]= 26, DC= 0.25, T_A[C]= 50, fsw[kHz]= 500, RthCA[°C/W]= 5 — Hard-switch | Update with same parts | Update with new recommendations

Part Number	FDMS2D5N08C (ON Semi)	EPC2052 x	EPC2044 x	EPC2252 x	EPC2619 x	EPC2214 x
Modify EPC Part						
BV_{DSS} [V]	80.0	100.0	100.0	80.0	100.0	80.0
$R_{DS(ON)}$ [mΩ] [Typ]	2.20	10.0	7.00	8.00	3.30	15.0
R_{THJC} [°K/W]	0.90	2.00	1.30	1.60	1.00	2.70
Q_G Typ [nC]	60.0	3.50	4.30	3.50	8.50	1.80
Gate Drive [V]	10.0	5.00	5.00	5.00	5.00	5.00
Gate Drive Loss [W]	0.30	0.0088	0.011	0.0088	0.021	0.0045
Package Area [mm^2]	W=5.00mm, L=6.00mm Area=30.0 mm^2	W=1.50mm, L=1.50mm Area=2.3 mm^2	W=1.25mm, L=2.15mm Area=2.7 mm^2	W=1.50mm, L=1.50mm Area=2.3 mm^2	W=1.50mm, L=2.50mm Area=3.8 mm^2	W=1.35mm, L=1.35mm Area=1.8 mm^2
Calculated Total Power Loss [W]	**8.51**	**2.83**	**2.12**	**2.21**	**1.92**	**3.73**
Auto Qualified	No	No	No	Yes	No	Yes
Status	Promotion	Preferred	Preferred	Preferred	Preferred	Active

Quantity Available at Digi-Key	FDMS2D5N08C: 2651	EPC2052: 133145	EPC2044: 6937	EPC2252: 24884	EPC2619ENGRT: 0	EPC2214: 20060
Digi-Key Pricing	FDMS2D5N08C: 1 = $2.88, 10 = $2.417, 100 = $1.9556, 500 = $1.73834, 1000 = $1.48845	EPC2052: 1 = $1.52, 10 = $1.262, 100 = $1.0044, 500 = $0.84992, 1000 = $0.72114	EPC2044: 1 = $1.67, 10 = $1.386, 100 = $1.1029, 500 = $0.93324, 1000 = $0.79184	EPC2252: 1 = $1.79, 10 = $1.485, 100 = $1.1817, 500 = $0.9999, 1000 = $0.8484	EPC2619ENGRT: 1 = $3.48	EPC2214: 1 = $1.19, 10 = $0.992, 100 = $0.7892, 500 = $0.7125
Lead Weeks	24 week(s)	16 week(s)	16 week(s)	12 week(s)	No lead time information available	16 week(s)

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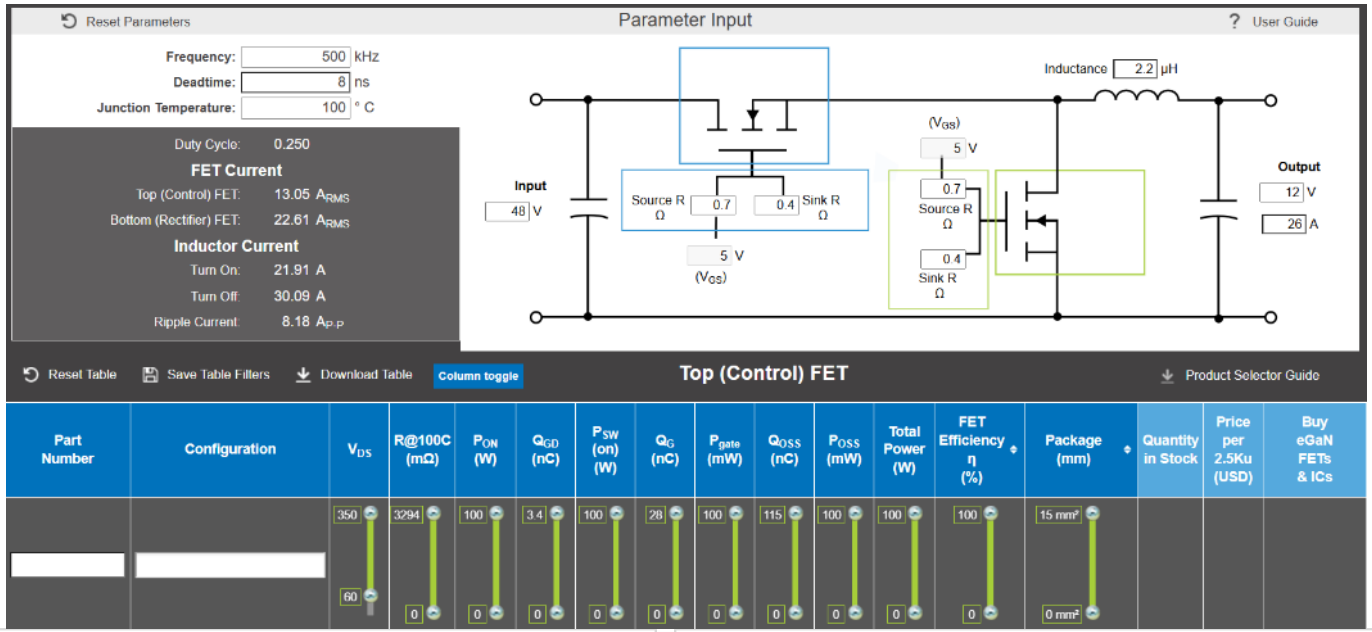
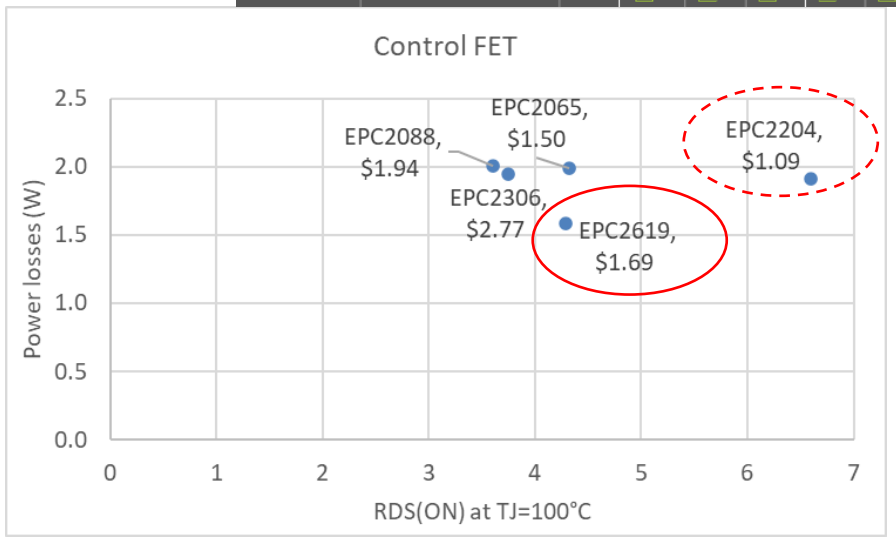
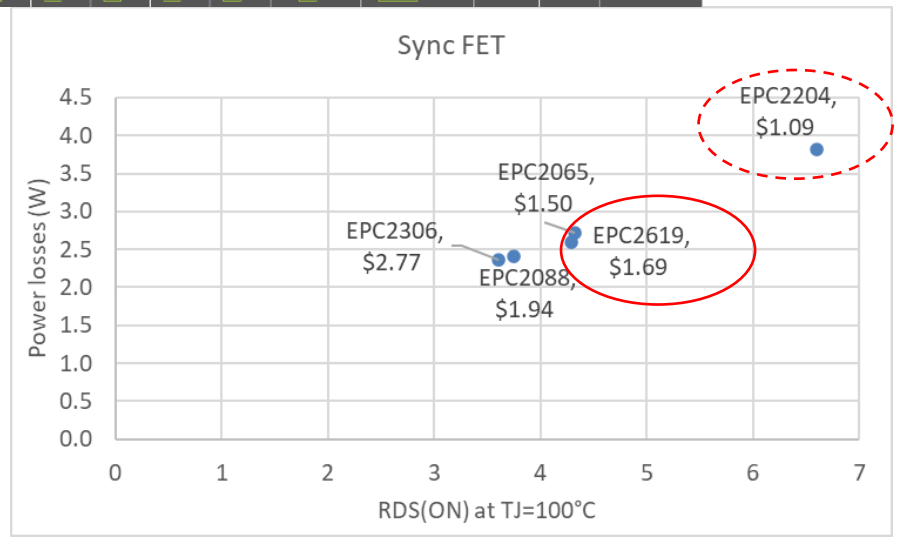
500kHz increases the advantage of GaN: Si MOSFET losses increase much more than GaN FETs

Sync buck losses







A few more input parameters provides a more detailed analysis

Different recommendations for both control and sync FETs

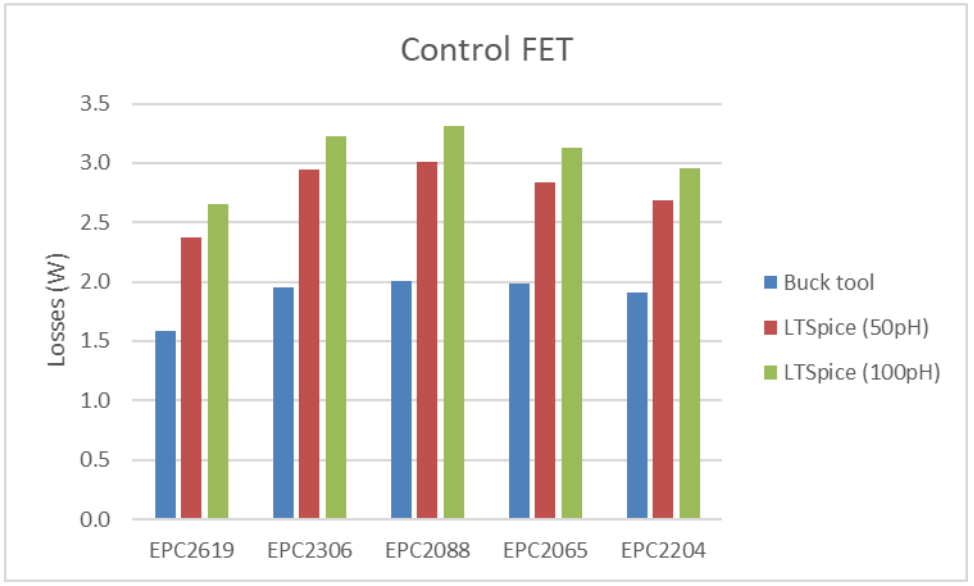
Losses and price for all EPC GaN FETs

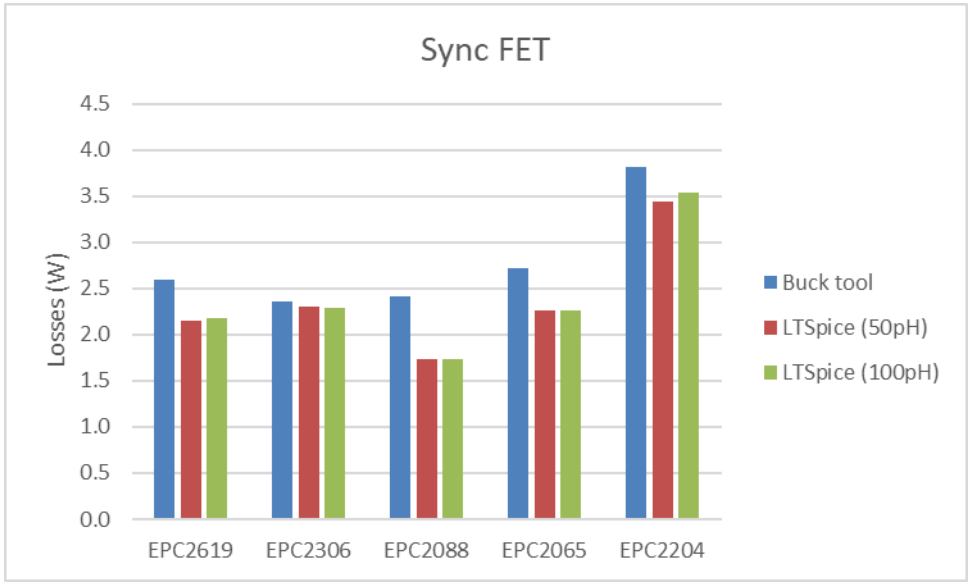
EPC2619 latest generation eGaN FET

Detailed loss simulation

Example model from EPC LTSPice library (CSI= 100pH)

- HS: 1.6 W → 2.7 W
- LS: 2.6 W → 2.2 W





Impact of CSI: 50-100pH

Thermal verification - datasheet

Thermal Characteristics			
PARAMETER		TYP	UNIT
$R_{\theta JC}$	Thermal Resistance, Junction-to-Case (Case TOP)	1	°C/W
$R_{\theta JB}$	Thermal Resistance, Junction-to-Board (Case BOTTOM)	2.6	
$R_{\theta JA\_JEDEC}$	Thermal Resistance, Junction-to-Ambient (using JEDEC 51-2 PCB)	66	
$R_{\theta JA\_EVB}$	Thermal Resistance, Junction-to-Ambient (EPC90153 EVB)	46	

- R_{thJC}: Used for double sided cooling, the best way to take advantage of the power density of GaN
- R_{thJB}: PCB cooling only path
- R_{thJA_JEDEC}: PCB cooling only path measured in a std condition (natural convection)
- R_{thJA_EVB}: PCB cooling only path measured on a real board EPC90153 (natural convection)
  - Control FET: 2.7 W → ΔT = 124 °C
  - Sync FET: 2.2 W → ΔT = 101 °C
    - → Need different thermal concept

Thermal verification – thermal tool

- Application conditions

Device Parameters

Device Configuration

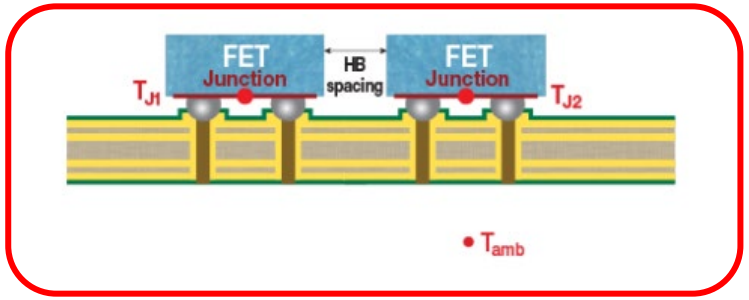
- ○ Single Device
- ◉ Two Devices: Symmetric
- ○ Two Devices: Asymmetric

Ambient Temperature (°C): 25

☑ Vias in Pad

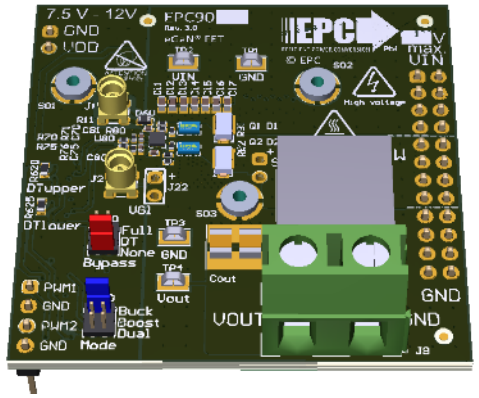
Spacing (mm)

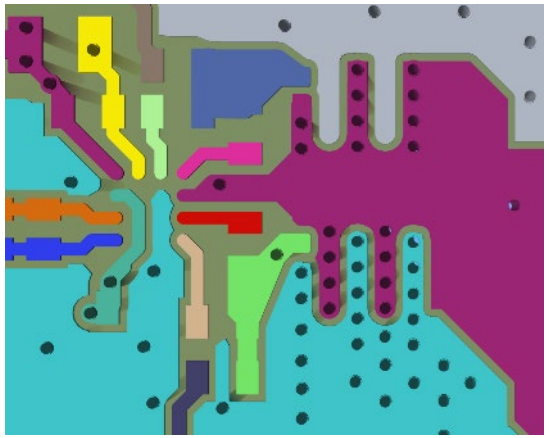
EPC FETs and ICs	Device 2
EPC2619	EPC2619
Rth,JC= 1.0 °C/W	Rth,JC2= 1.0 °C/W
Rth,JB= 2.5 °C/W	Rth,JB2= 2.5 °C/W
2.5mmx1.5mm=3.8mm^2	2.5mmx1.5mm=3.8mm^2
Losses (W): Device#1	Losses (W): Device#2
2.70	2.20



PCB parameters: concept design

- Customer PCB concept
- Half-bridge demo board EPC90153 (EPC2619)





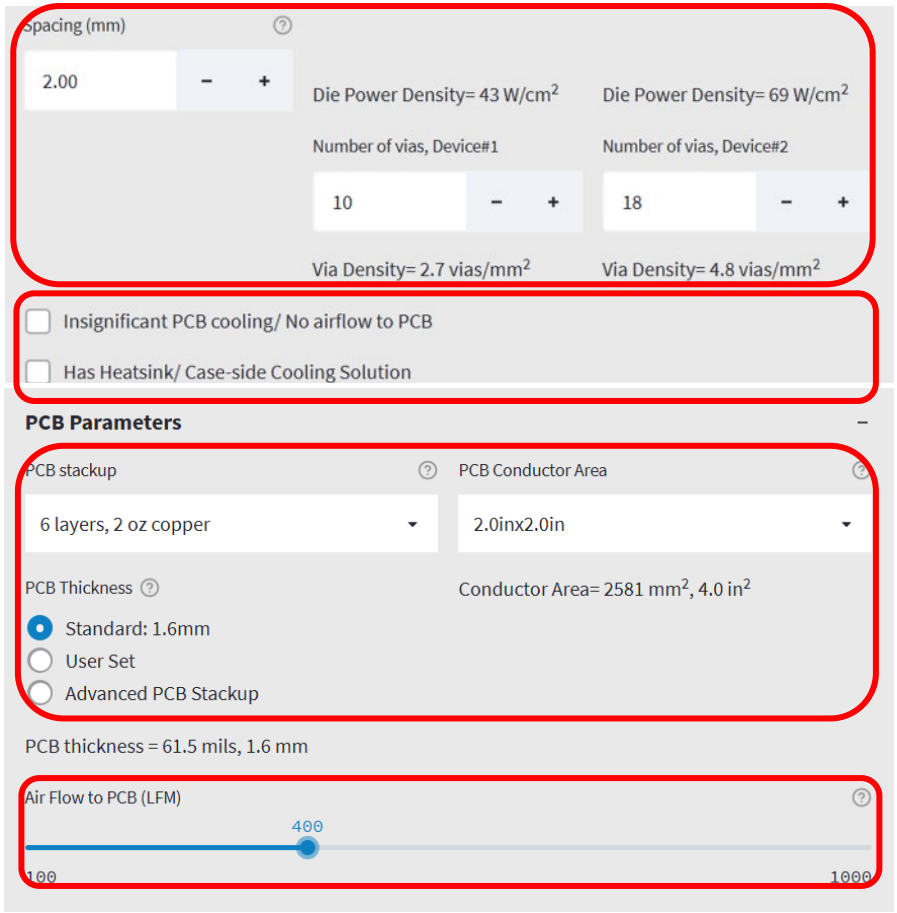
EPC2619 via pattern on EPC90153

Board Stack Report

Stack Up		Layer Stack			
Layer	Board Layer Stack	Name	Material	Thickness	Constant
1		Top Paste			
2		Top Overlay			
3		Top Solder	Solder Resist	0.40mil	3.5
4		Top Layer	Copper	2.76mil	
5		Dielectric 1	FR370-HR	5.00mil	4.4
6		Mid-Layer 1	Copper	2.76mil	
7		Dielectric 2	FR370-HR	9.70mil	4.4
8		Mid-Layer 2	Copper	2.76mil	
9		Dielectric 3	FR370-HR	15.00mil	4.4
10		Mid-Layer 3	Copper	2.76mil	
11		Dielectric 4	FR370-HR	9.70mil	4.4
12		Mid-layer 4	Copper	2.76mil	
13		Dielectric 5	FR370-HR	5.00mil	4.4
14		Bottom Layer	Copper	2.76mil	
15		Bottom Solder	Solder Resist	0.40mil	3.5
16		Bottom Overlay			
17		Bottom Paste			

Height : 61.76mil

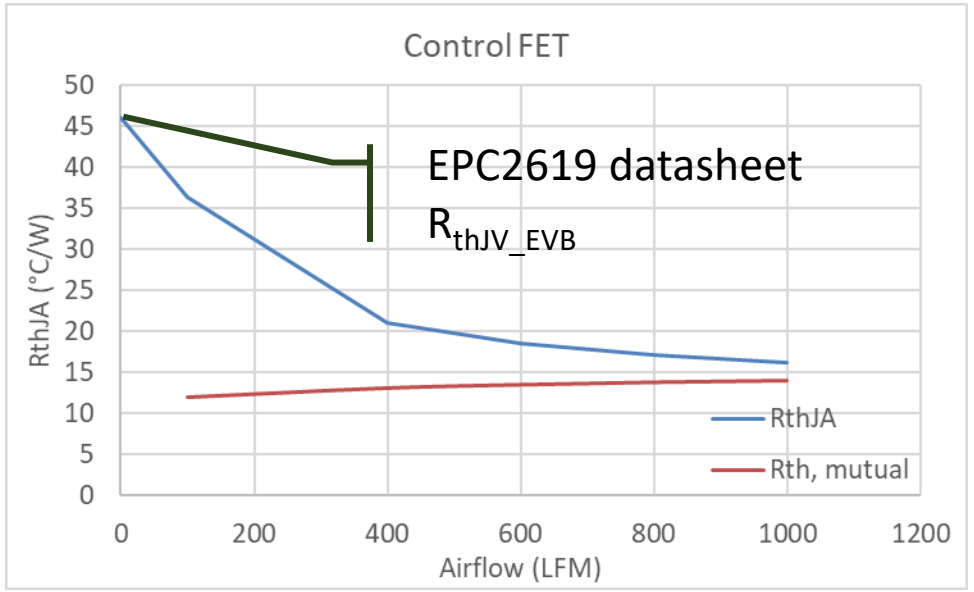
Layer stack-up for EPC90153

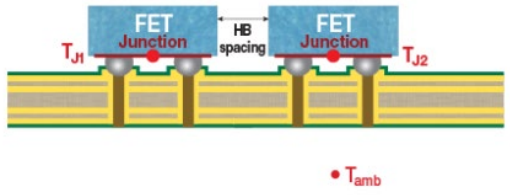


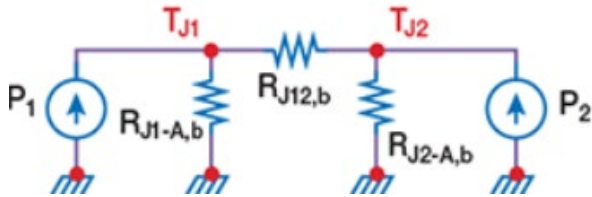
Thermal verification results

Analyze impact of:

- PCB, heatsinking and airflow
- High side and low side differentiation
- Mutual heating







With 400LFM:

Device 1:

Junction Temperature (Temperature Rise):

77.6°C (52.6°C)

P1 = 2.7 W

Device 2:

Junction Temperature (Temperature Rise):

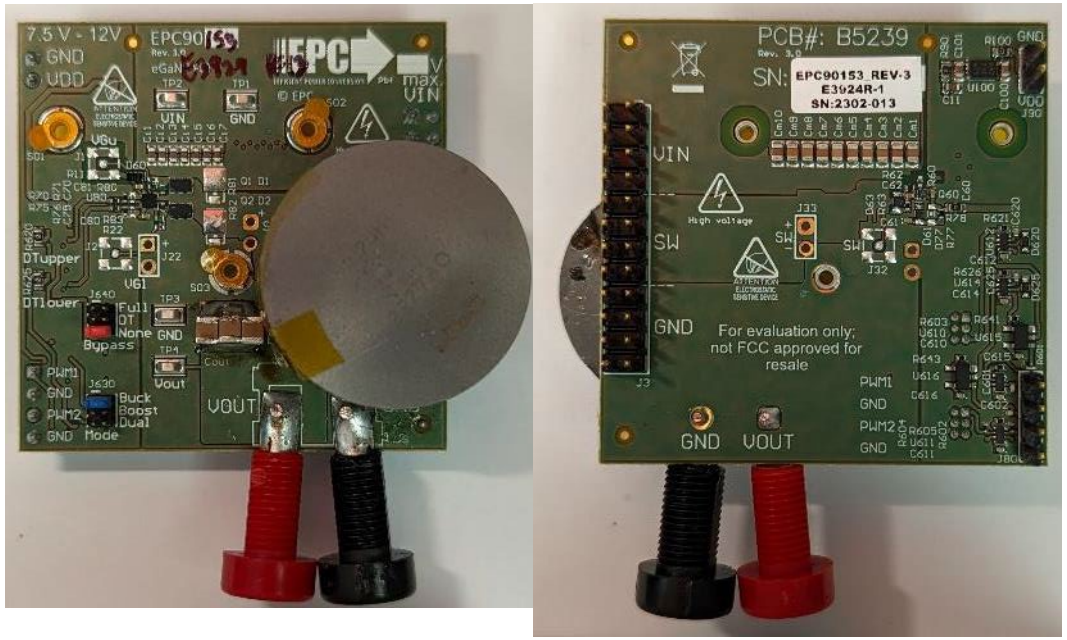
75.0°C (50.0°C)

P2 = 2.2 W

R_J1-A,b (°C/W)=	R_J12,b (°C/W)=	R_J2-A,b (°C/W)=
21.0	13.1	20.9

Real measurements

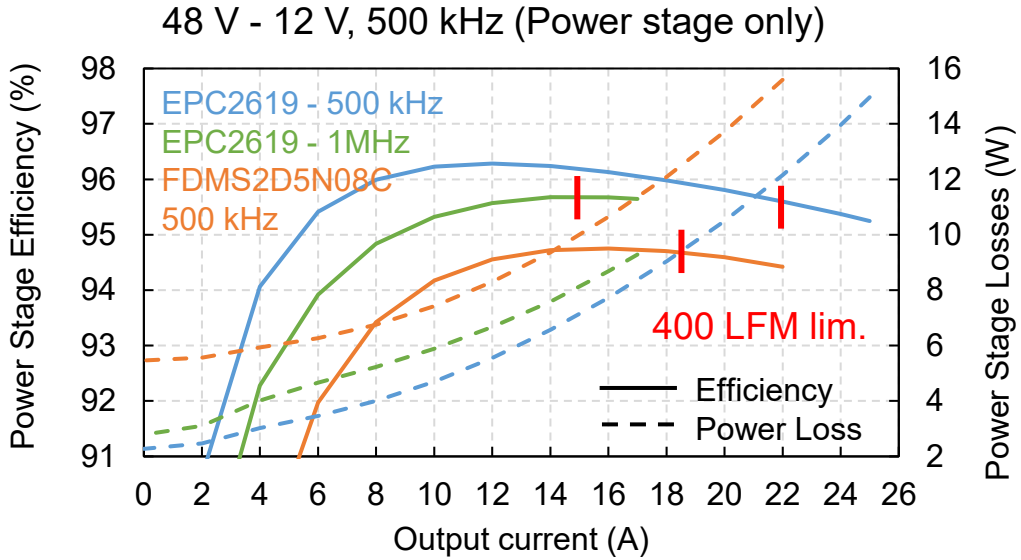
EPC2619 on EPC90153



FDMS2D5N08C

Performance comparison

Measurements confirm that EPC2619 has lower losses and can carry more current



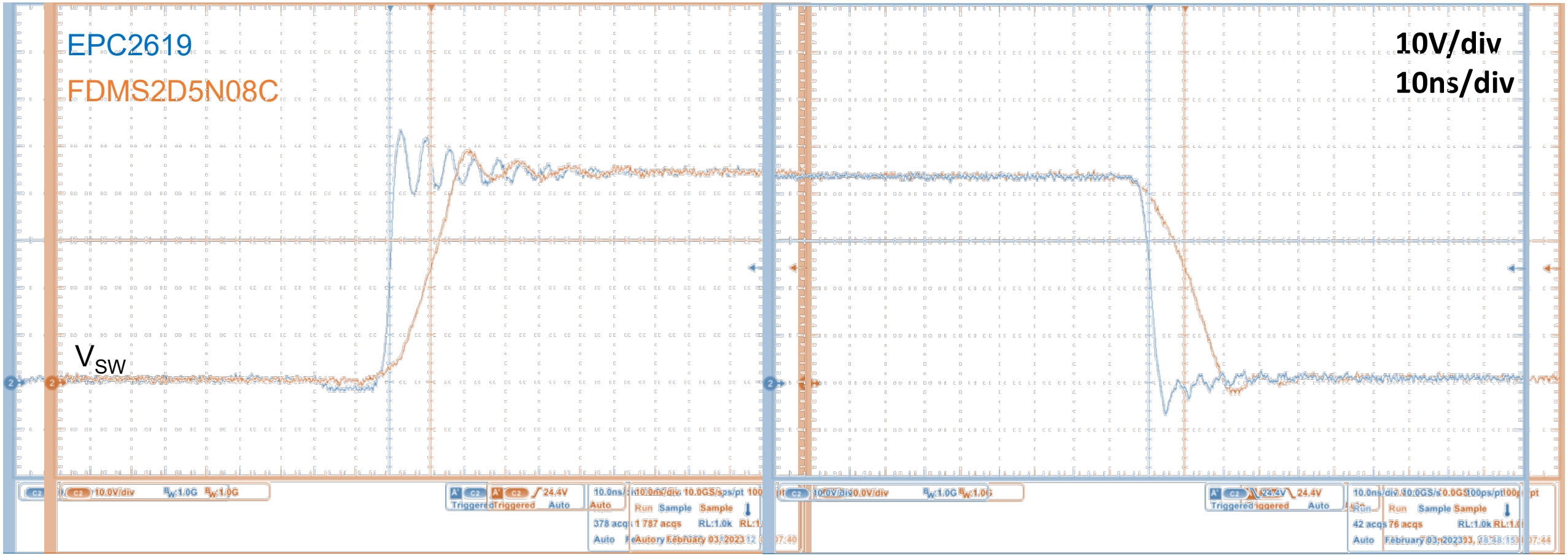
	400 LFM	1000 LFM
EPC2619 (500 kHz)	22 A	24.5 A
EPC2619 (1 MHz)	15 A	17 A
FDMS2D5N08C	18.5 A	22 A

- Power Stage Efficiency and losses include FET losses and inductor
- Maximum current displayed corresponds to a maximum case temperature of ~105°C in thermal steady state with 1000 LFM

Table with maximum output current for different airflow and $T_C \leq 105°C$ -107°C

Waveform 20A (48 Vin, 12 Vout)

Switch node Waveform Comparison: Rg tuning

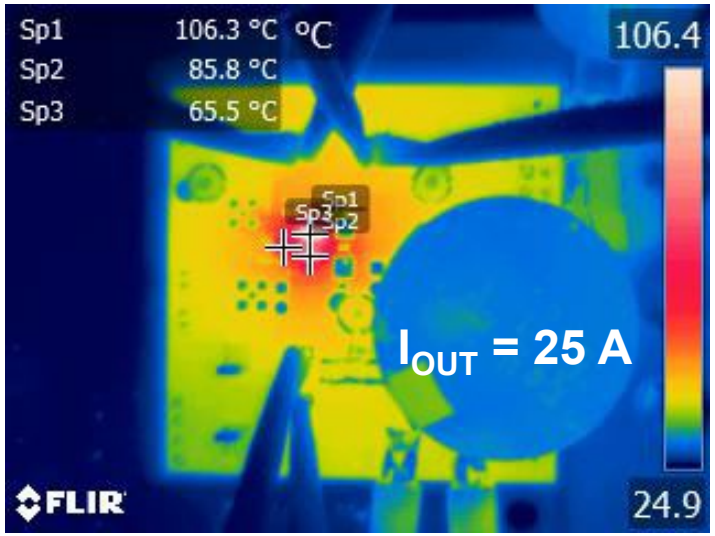


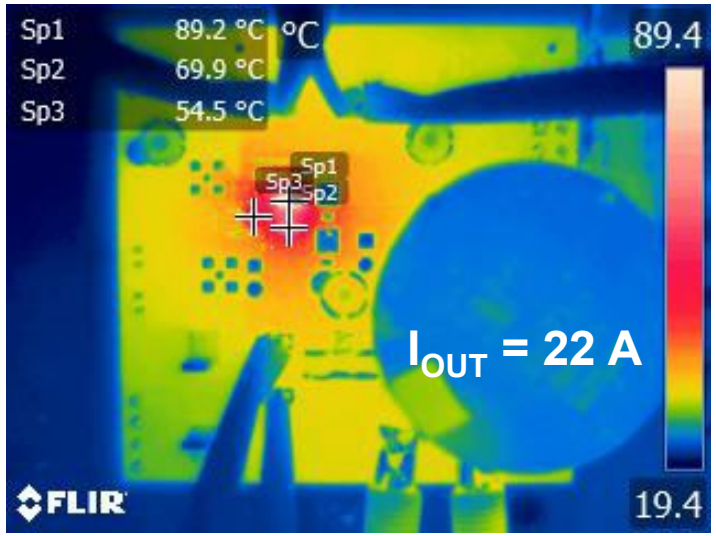
Thermal Equilibrium 48/12 V, 500 kHz

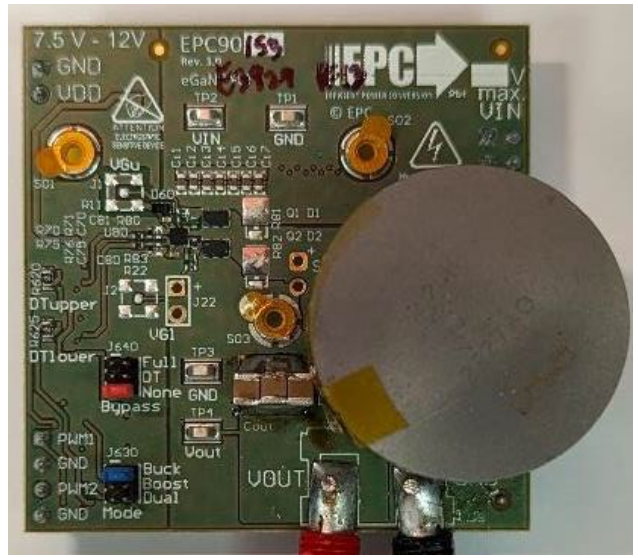
EPC2619

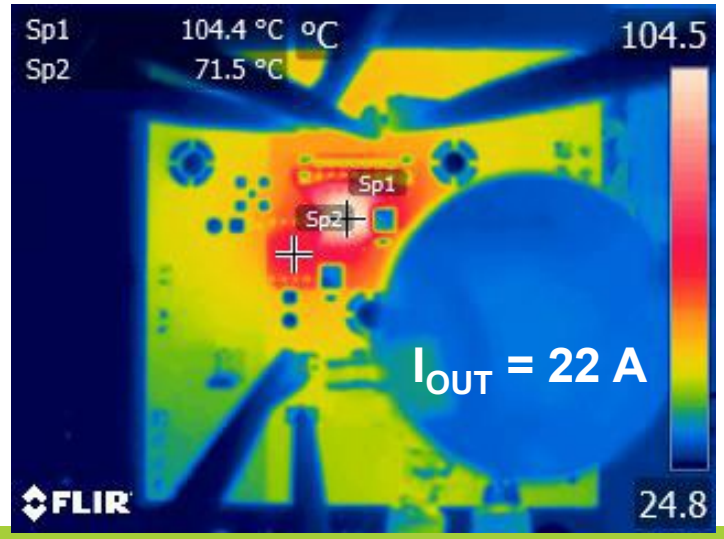
FDMS2D5N08C

No heatsink, 1000 LFM



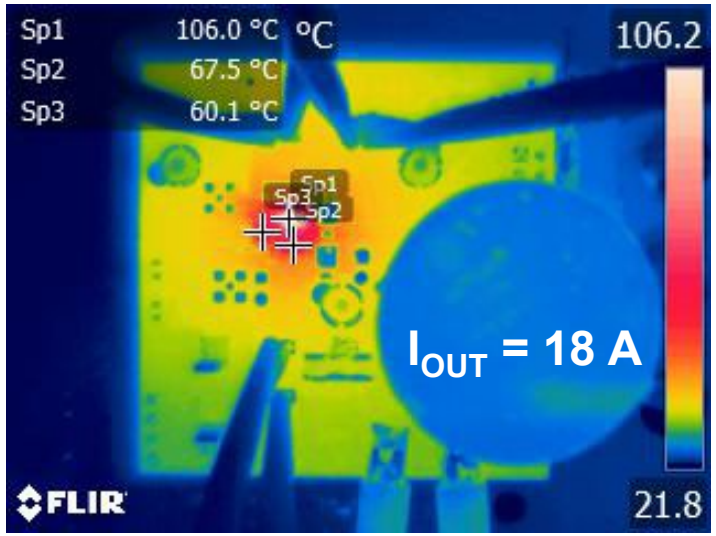


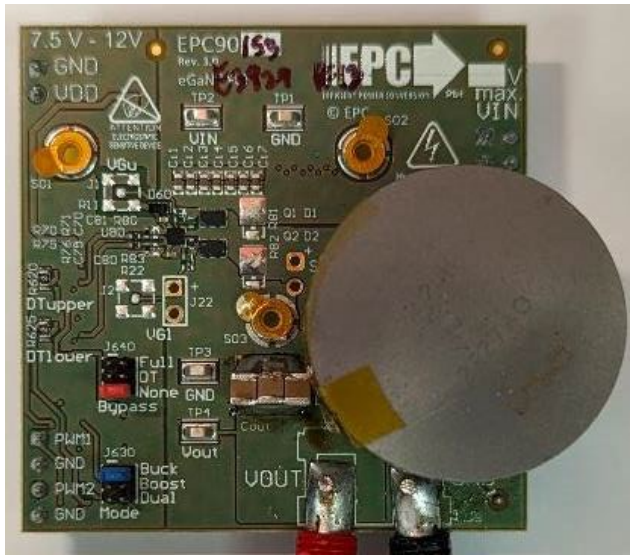




Thermal Equilibrium 48/12 V, 1 MHz

EPC2619





No heatsink, 1000 LFM

Summary

In the example we used the web tools to compare a Si MOSFET to EPC eGaN FETs, and confirmed via measurements that EPC2619 has lower losses, can carry more current and is cheaper than the original Si MOSFET

1. The cross reference provides the easiest way to compare Si MOSFET to GaN, including pricing
2. The loss calculators and simulations provide mode detailed device optimization and trade-off analysis
3. The thermal tool provides a fast and flexible way to assess thermal concepts and trade-off analysis
4. Finally, the hardware boards help to validate the device selection