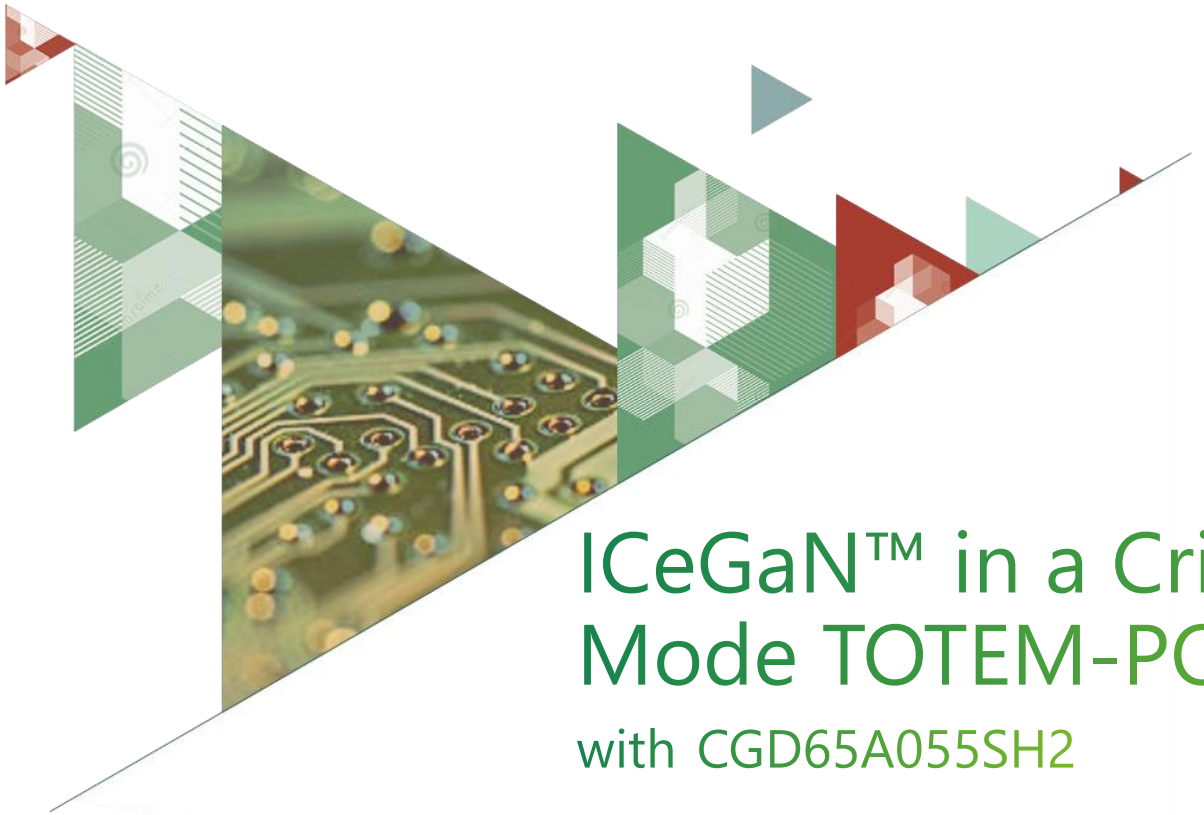


ICeGaN™ in a Critical Conduction Mode TOTEM-POLE PFC

with CGD65A055SH2

Digital WE Days Webinar

24th April 2024

Carlos Toyos Bada

Agenda

- CGD Introduction
- Adapter Trend
- Totem-pole PFC vs Standard Boost PFC
- Totem-Pole PFC Operation
- CrCM and CCM Operation
- ICeGaN Benefits for Totem-Pole PFC
- 350 W TPPFC Evaluation Board
  - TPPFC Daughter Card
  - Efficiency & No-load Power
  - PFC & THD
  - Thermal Operation
- CGD Portfolio

We are CGD

The Fast-paced Scaleup Making Green Electronics Possible – Inventor of ICeGaN™

A fabless semiconductor company designing, developing and commercialising **energy-efficient GaN-based power devices and ICs**

Operating from
5
Locations

Innovation
91+
Patent applications

Employees
~60
> 300% growth (2020– 2023)

Knowledge

Academic excellence and industry expertise combined

Innovation

Innovative power solutions that help protect the environment

Sustainability

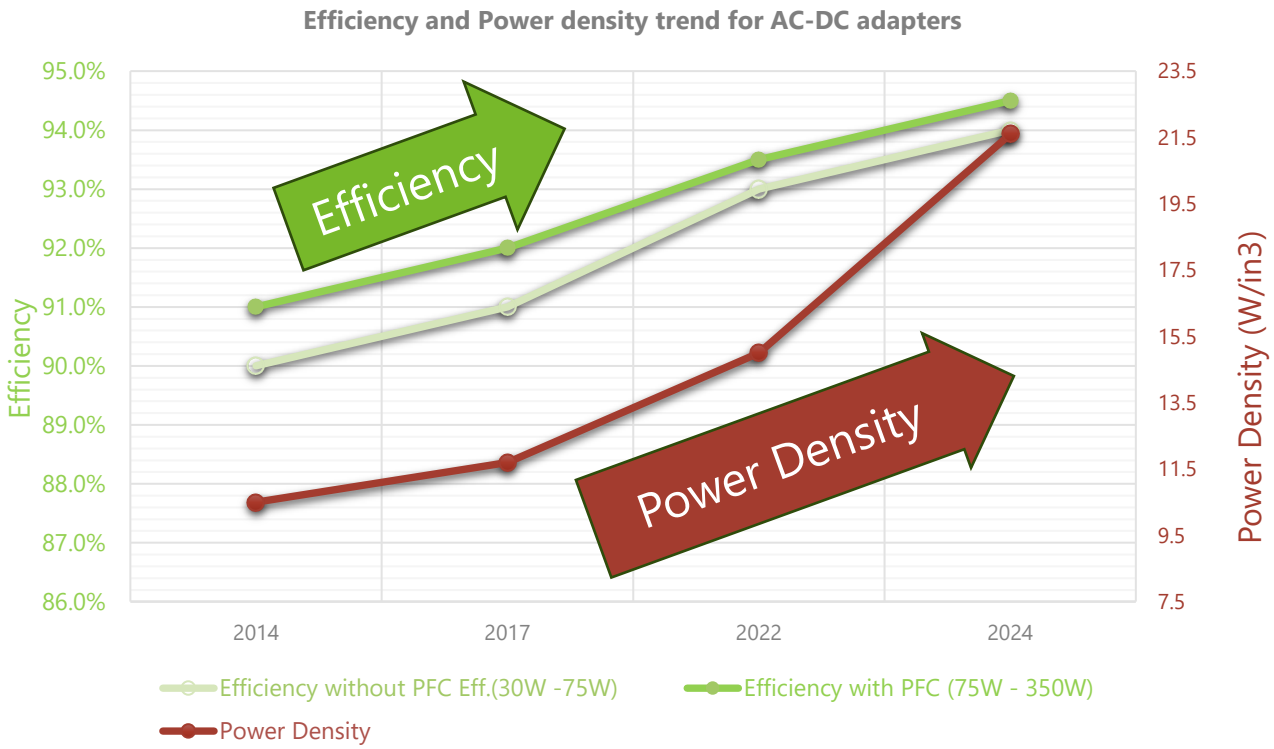
Eco-compatible business measures (**ESG**)

Collaboration

Cooperation, empowerment, respect, listening to customers, employees and partners

Adapter Trends

Higher Power, Higher Efficiency, Lighter Weight



High Power

- USB PD3.1 increased to 240W (48V/5A).
- Gaming laptops >300W (19.5V/16.9A).
- Multiple outputs

Compact

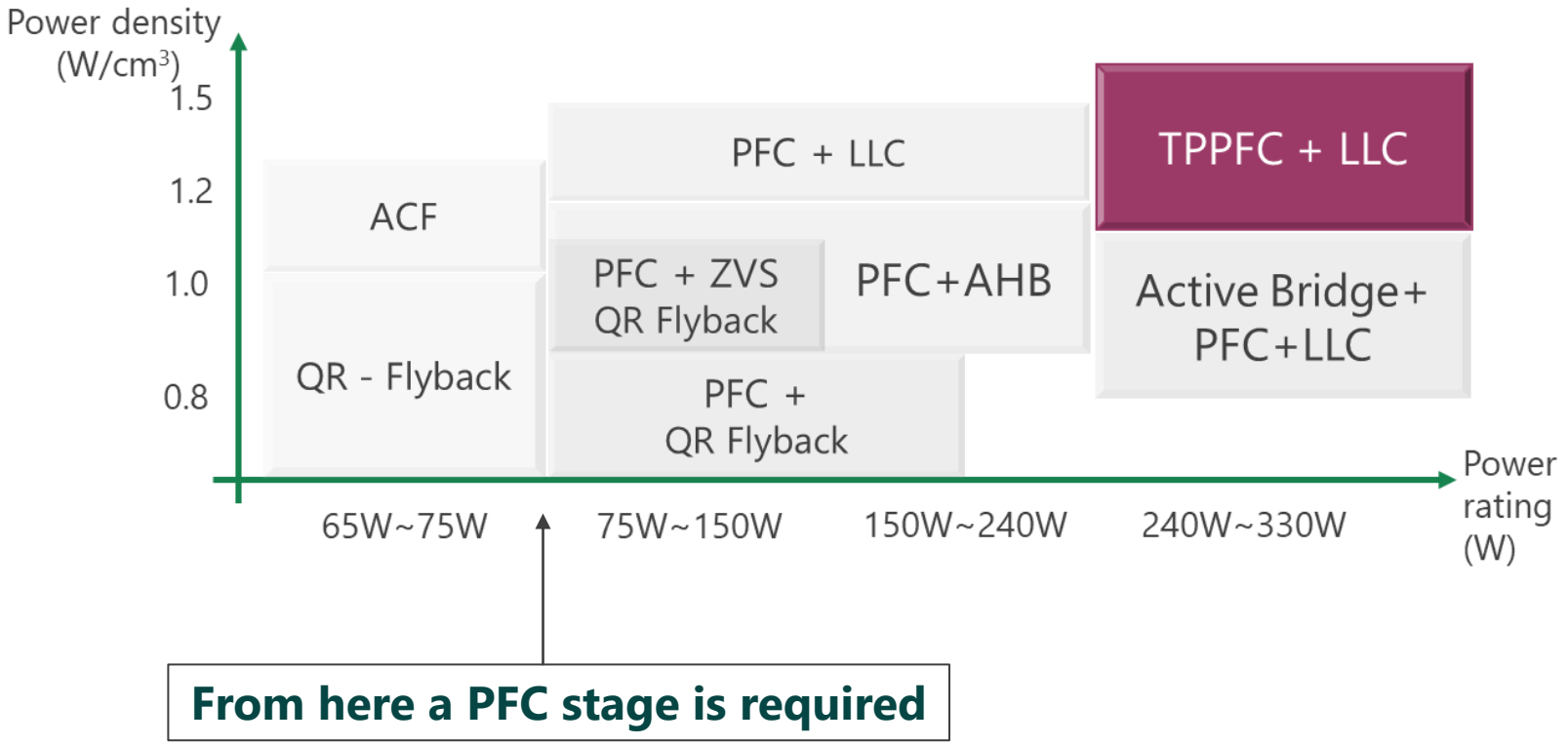
- Portable / Lighter weight.

International standards and certifications

- Higher efficiency
- No-load consumption getting lower
- Limits for Average Efficiency (4-point load)
- Limits for Efficiency at 10 % load

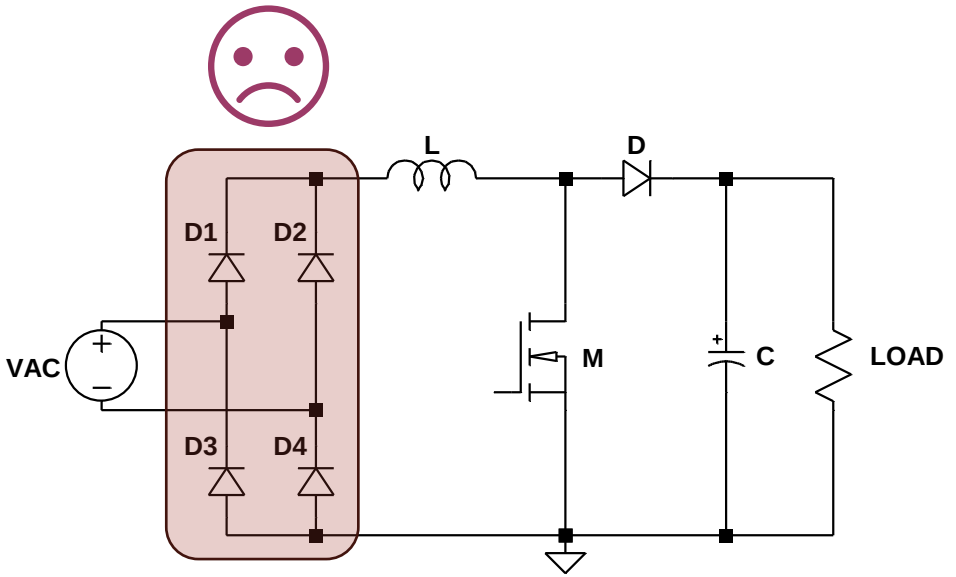
Adapter Trend

Topologies for Low Power AC-DC Applications: Power Density vs Power Rating

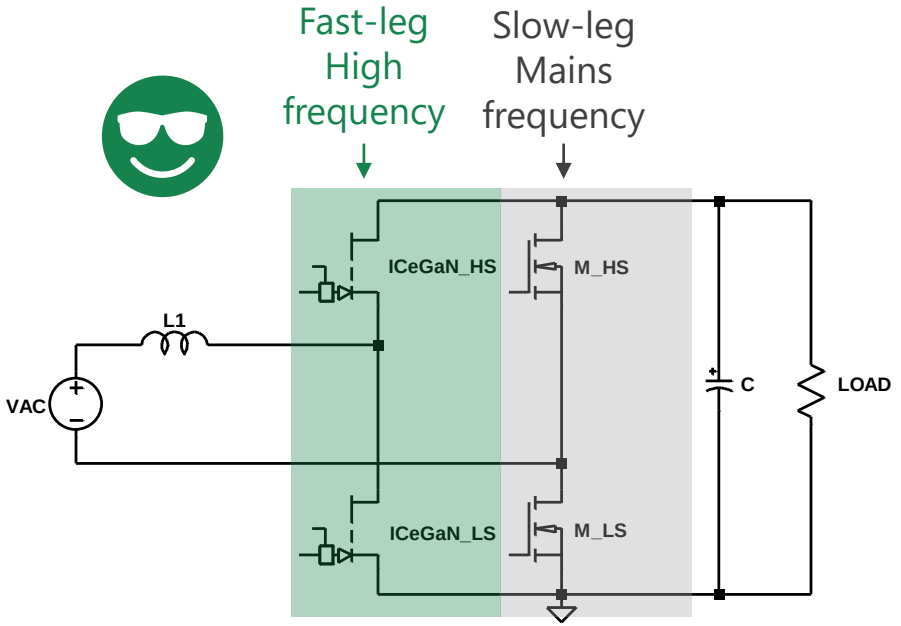


The Need for Bridgeless PFC

Totem-Pole is More Efficient than Standard Boost



The diode bridge is a major source of loss in boost PFC



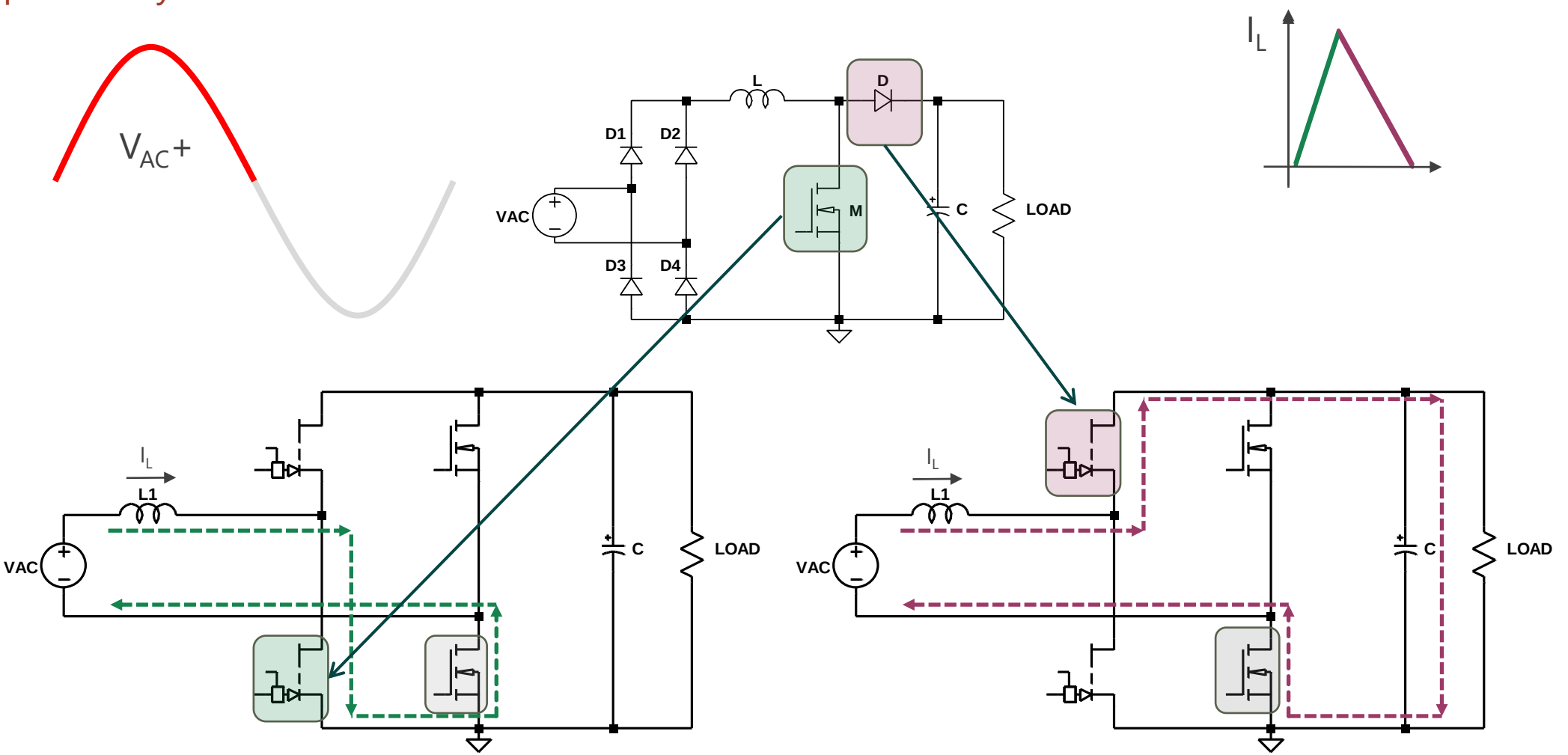
The totem-pole PFC is a good bridgeless solution for high efficiency and power density

Only 4 power devices

Single inductor

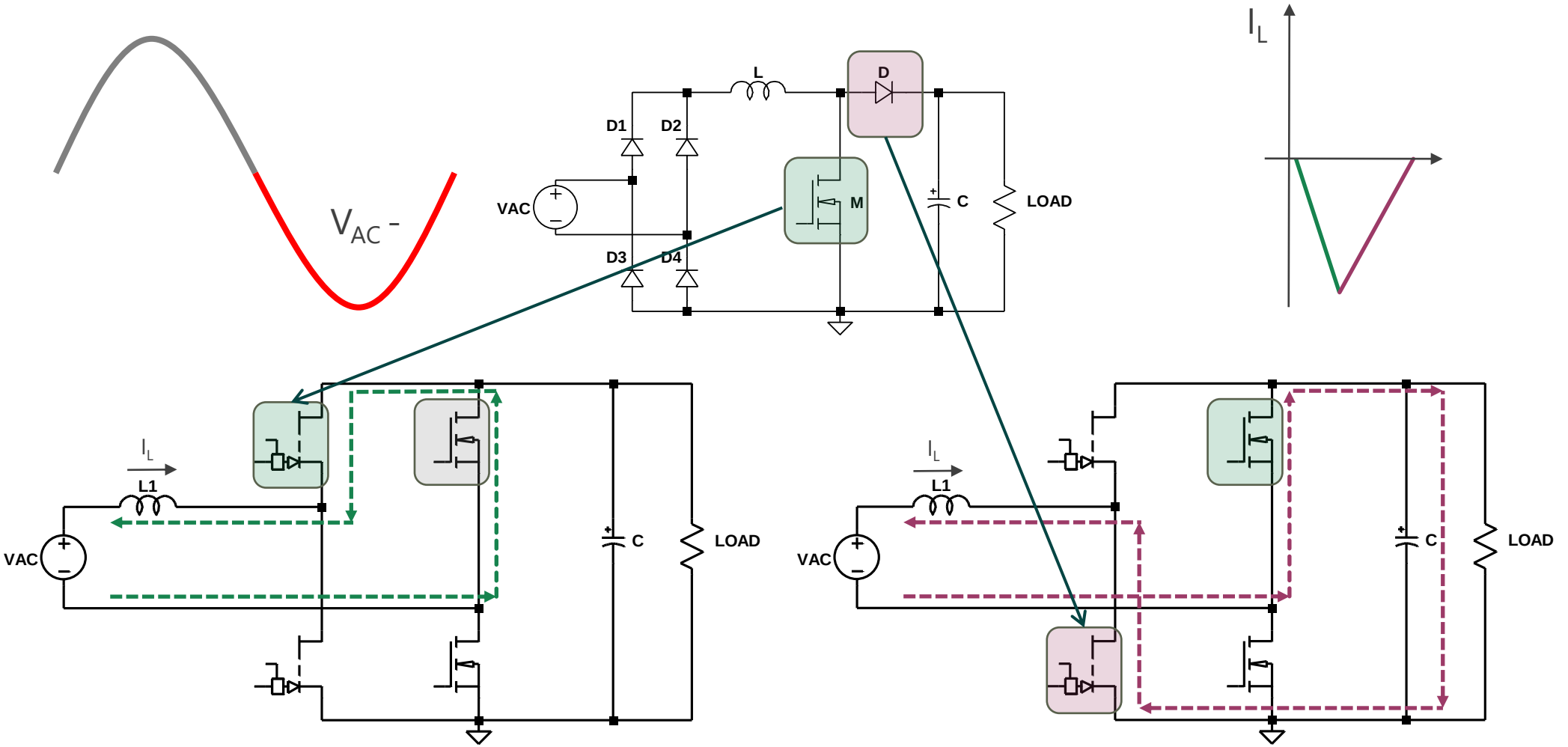
Totem-Pole PFC Operation

AC positive cycle

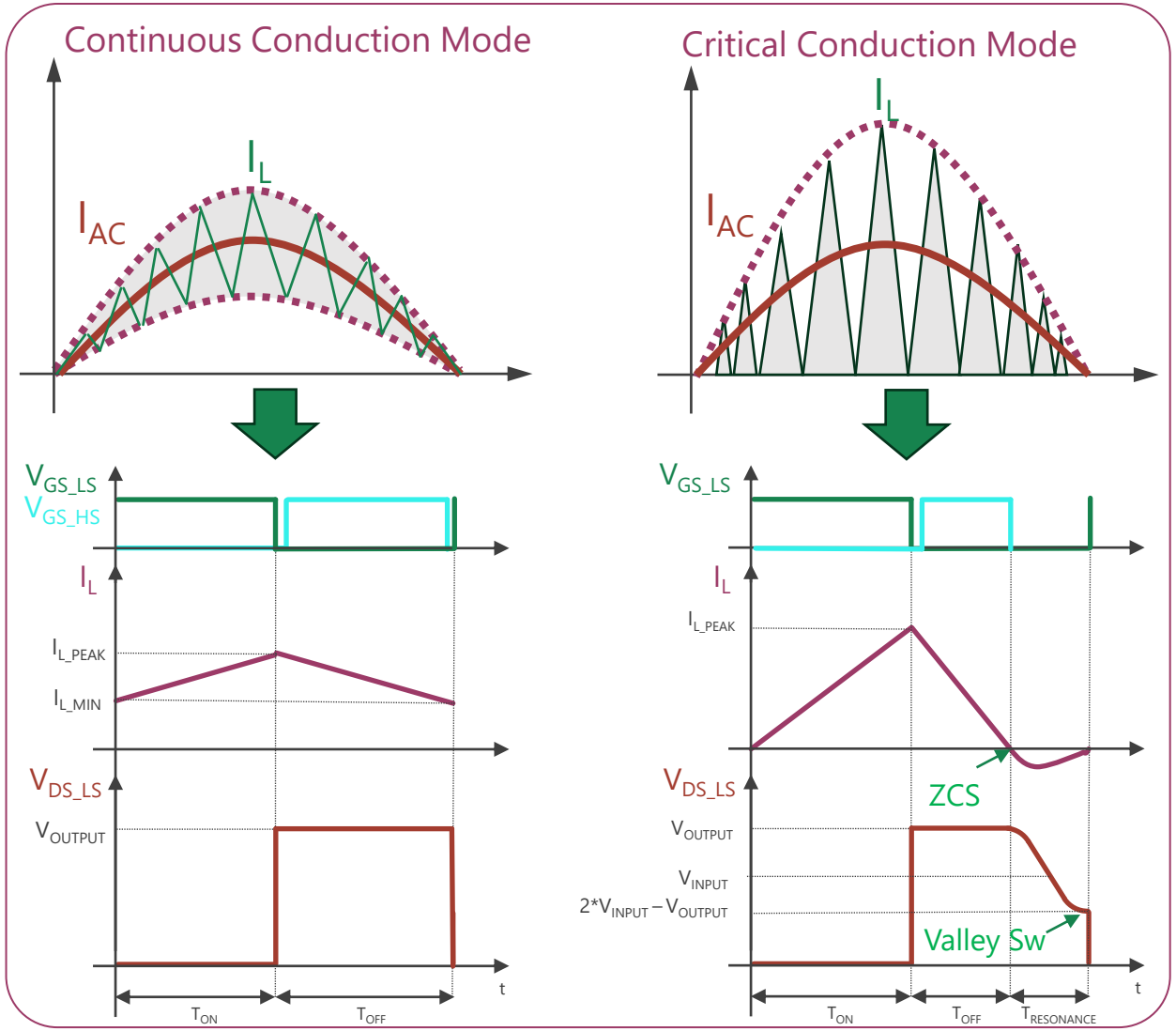


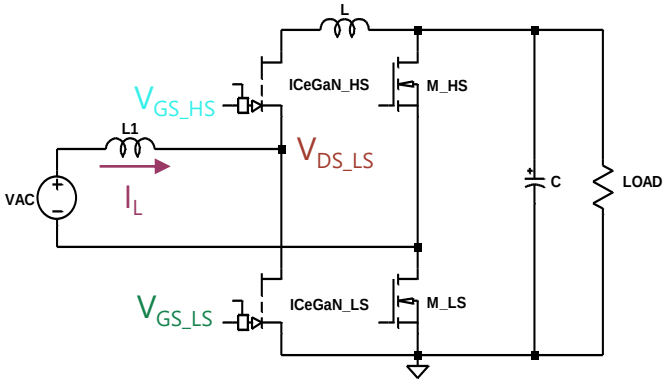
Totem-Pole PFC Operation

AC negative cycle



Totem-Pole Current Mode Operation





CCM

Best at higher power levels (>350W)

- RMS currents are lower
- Smaller peak currents than CrCM operation

CrCM

Best low power applications (<350W)

Higher efficiency

Zero current switching - ZCS

- Zero Voltage Switching at low line - ZVS
- Valley switching at high line

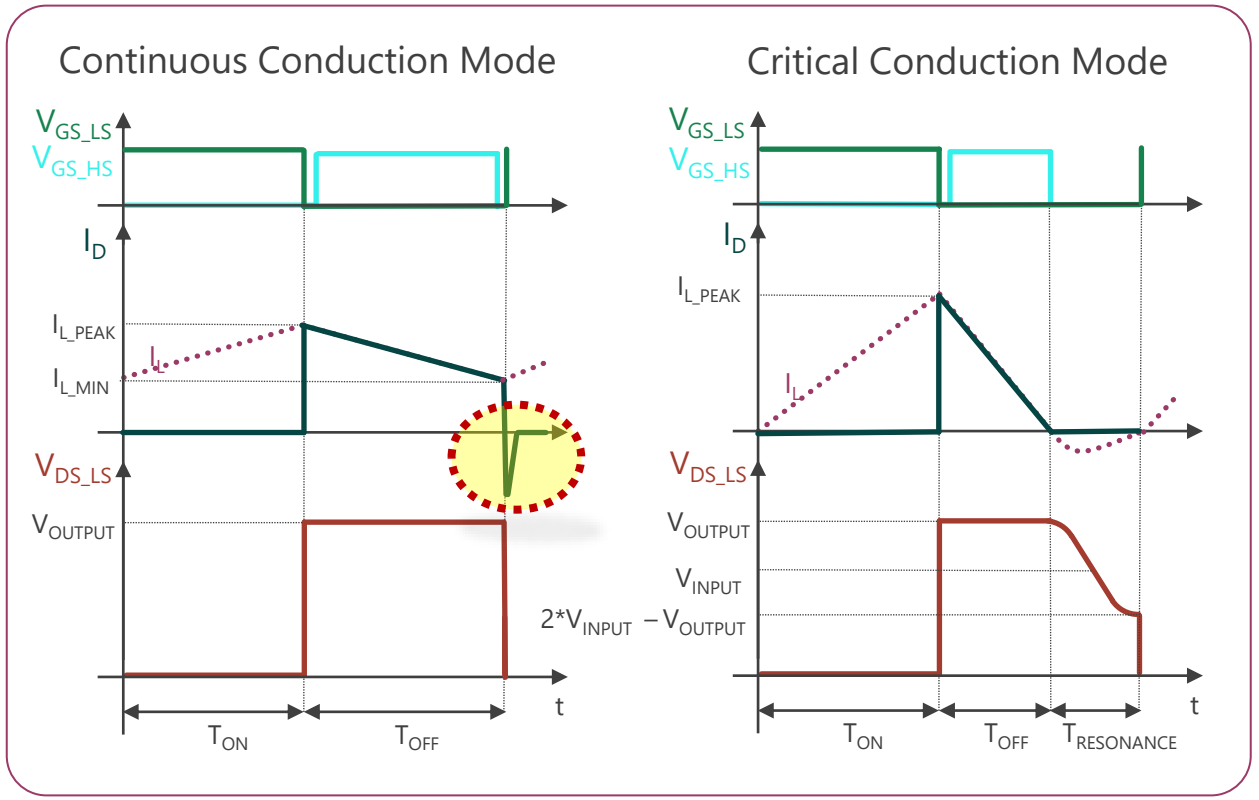
Better density

- Smaller inductor than CCM operation

ICeGaN Benefits for Totem-Pole PFC

CCM TPPFC is only feasible with WBG devices. Body diode recovery losses make super-junction Si MOSFETs impractical

CrCM TPPFC could operate with MOSFETS because ZCS and ZVS (low line) / Valley switching (highline)



ICeGaN outperforms Si for the same $R_{DS(on)}$

switching losses are not zero. Energy loss still present in the switching transitions particularly at high switching frequencies:

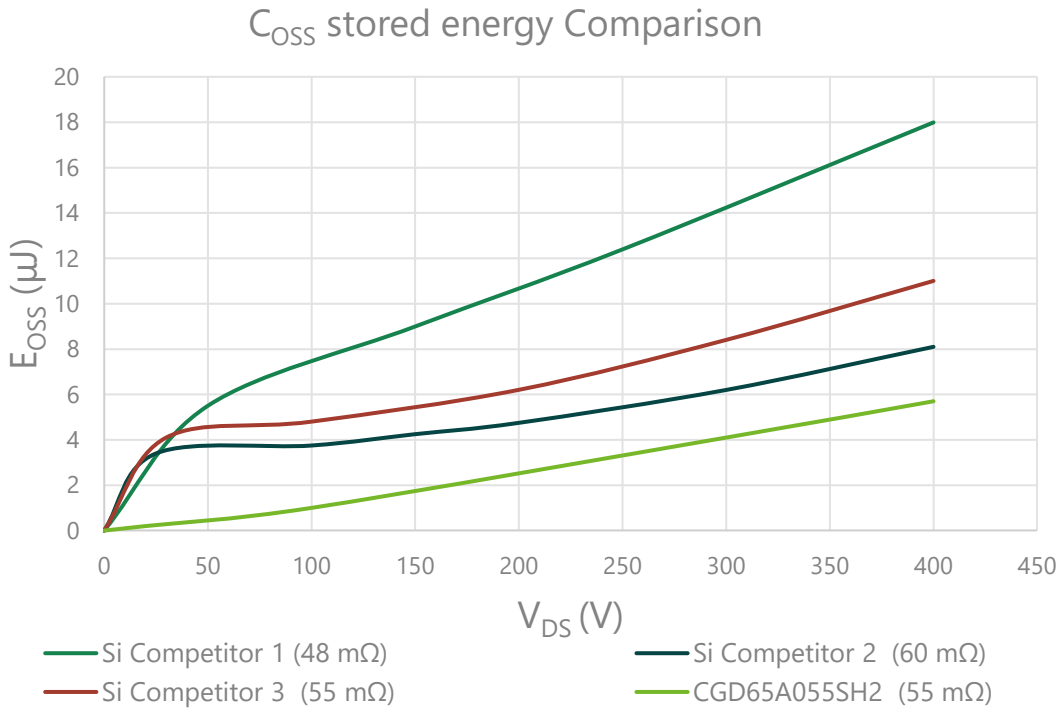
- High line operation – no ZVS
- Light load operation (10% load)
- No-Load Burst mode operation

ICeGaN is a GaN HEMT and it is driven like a MOSFET

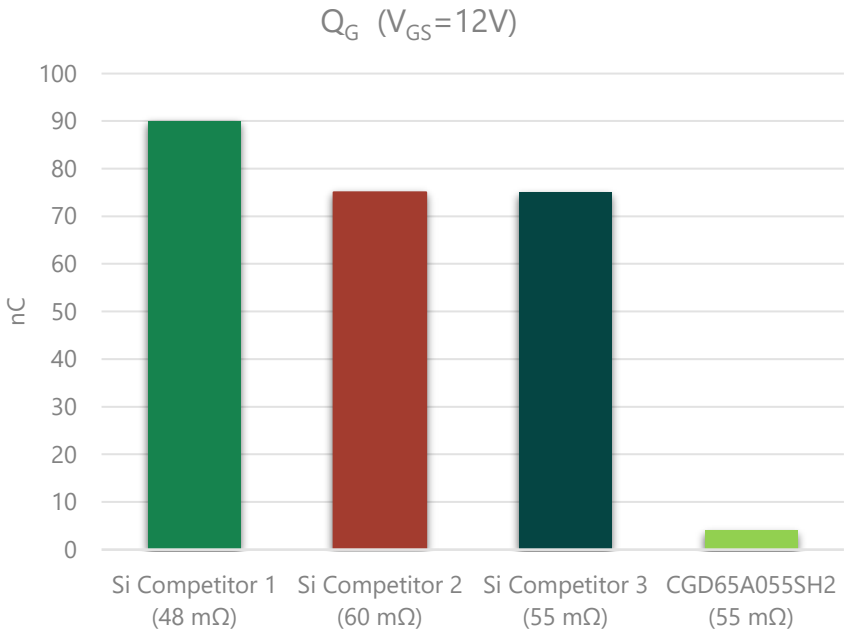
- ✓ R_{DSON} * C_{OSS} F.O.M. significantly smaller
- ✓ Q_G more than 10 times smaller
- ✓ Easy to Drive

ICeGaN Benefits for Totem-Pole PFC

Better switching performance and lower switching losses than equivalent Si MOSFETS



E_{OSS} is smaller and more linear

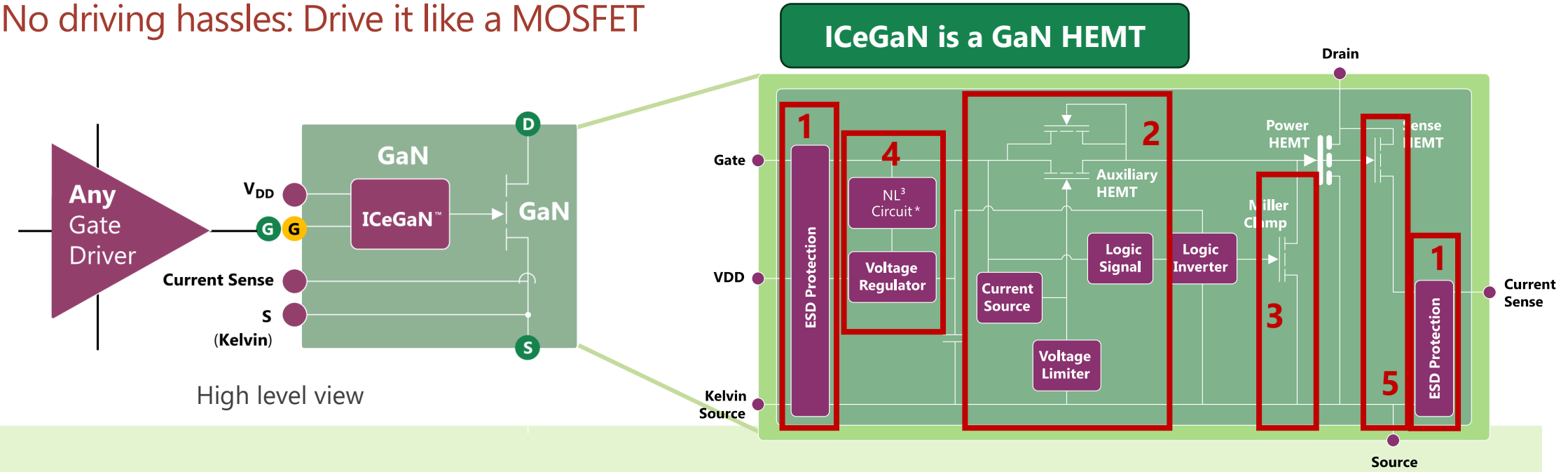


Q_G is an order of magnitude smaller than in Si

- ✓ Low switching energy loss increase highline, light load efficiency and no-load consumption
- ✓ Faster transitions
- ✓ Low sink/source current 600V bootstrap HB driver IC can be used

ICeGaN™ All-In-One GaN Chip

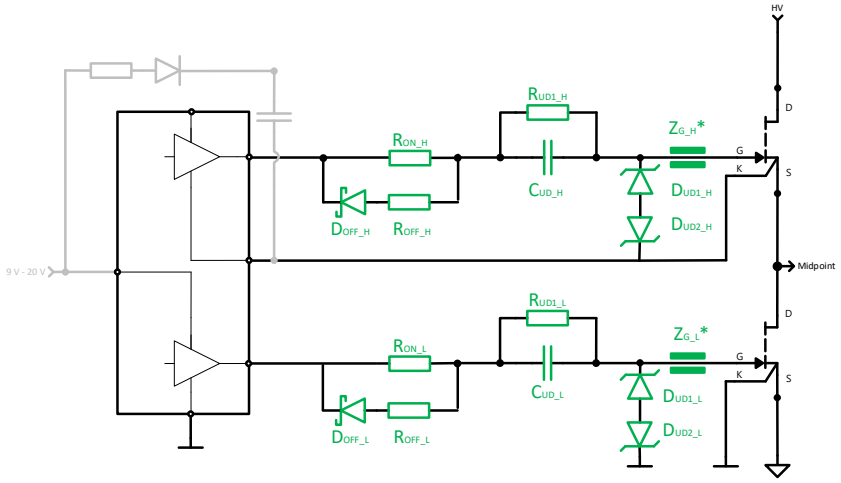
No driving hassles: Drive it like a MOSFET



1. ESD Protection
2. Gate voltage operation (9 V-20 V) / Gate voltage threshold voltage is 3 V
3. Internal Miller Clamp and logic to ensure high dv/dt, fast switching and achieve true 0 V turn-off
4. No Load Light Load (NL^3) circuit enables ultra-low power losses is in stand-by mode
5. Current Sense
6. Turn on slew rate can be adjusted with the external R_G

External Driving Components

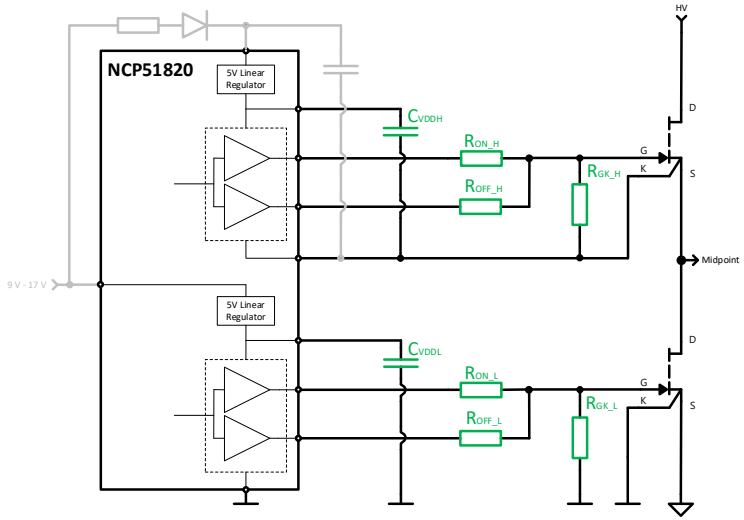
ICeGaN requires simple HB Si driver and fewer external components



Discrete GaN Competitor

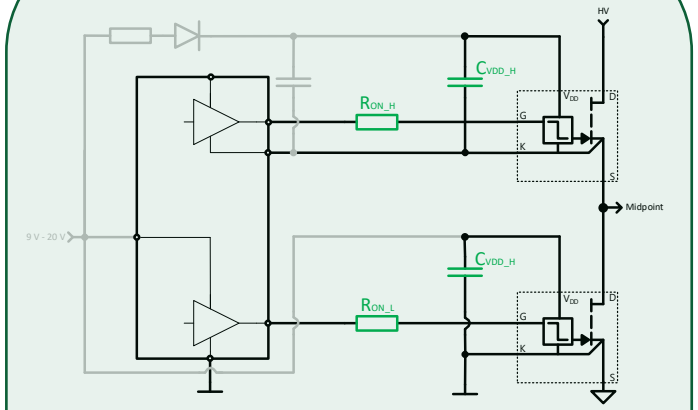
- Standard Si HB no-isolated Driver
- **16 External Components**
  - 6 resistors | 2 Capacitors | 6 diodes | 2 beads

This solution adds reverse conduction voltage VSD and impact the efficiency



Discrete GaN Competitor

- GaN HEMT no-isolated low gate voltage Driver
- **8 External Components**
  - 6 Resistors | 2 Capacitors

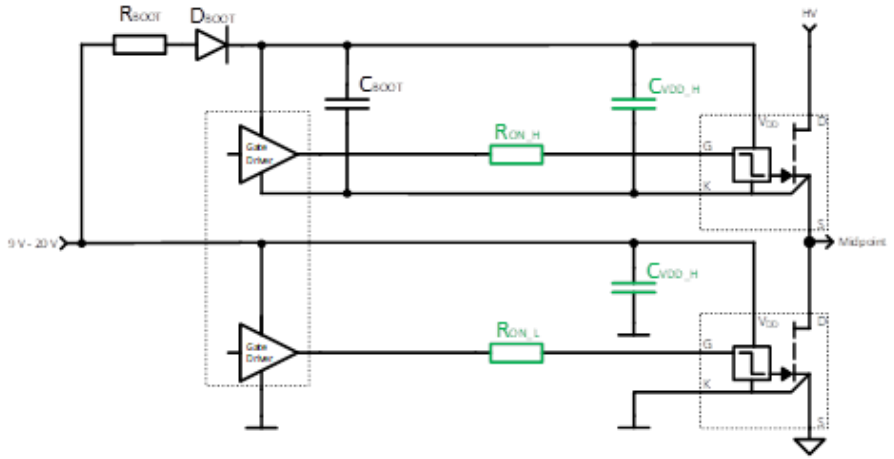


ICeGaN

- Standard Si HB no-isolated Driver
- **4 External Components**
  - 2 resistors | 2 Capacitors

ICeGaN Advantages

Summary



Efficiency and Power Density

ICeGaN vs a super-junction Si MOSFET

- GaN HEMT
- No Q_{RR}
- 10 times lower Q_G
- Lower and more linear C_{OSS}
- **Faster transitions and lower losses**
- **Low sink/source driver IC works**

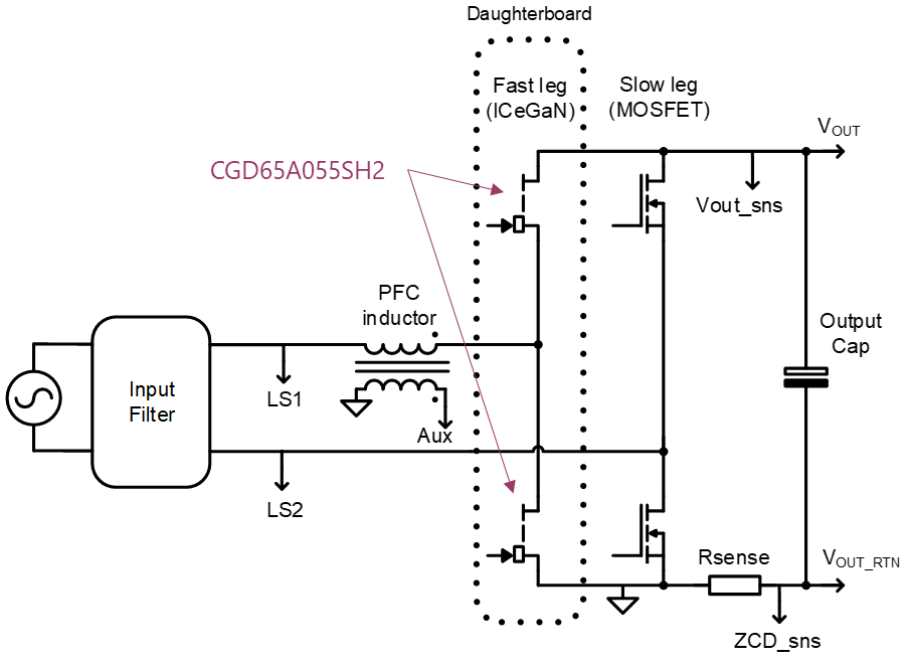
Easy to drive

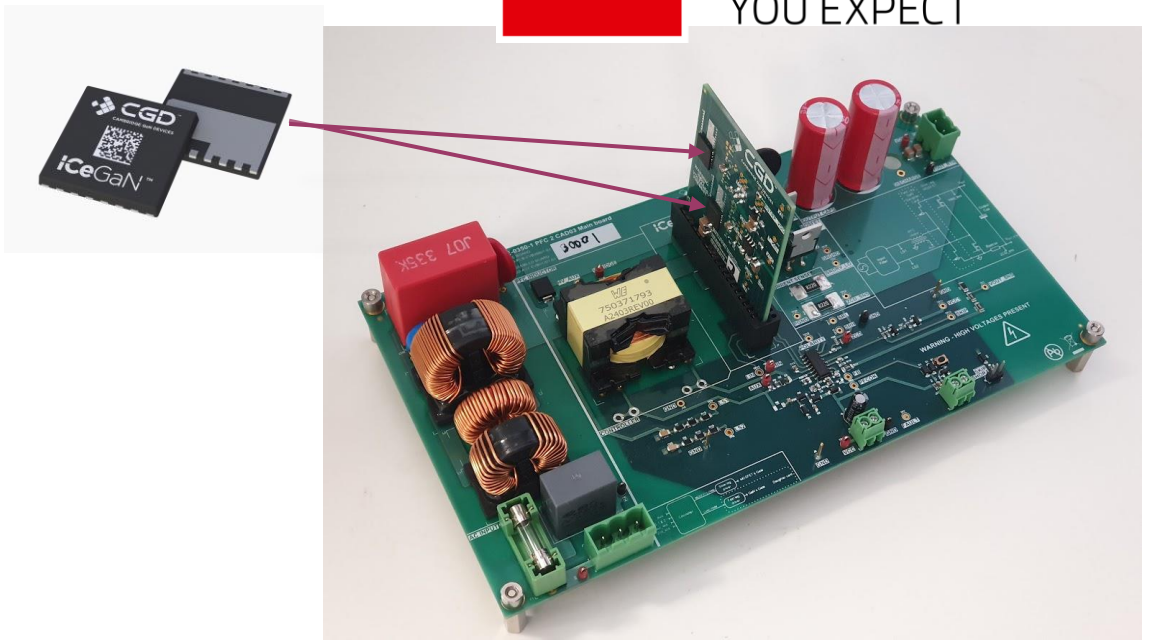
ICeGaN vs discrete GaN

- Gate voltage range is 9 V – 20V
- Gate voltage threshold is 3V
- Internal Miller Clamp
- **No need for negative drive**
- **No need for external turn off path**
- **Only 2 external SMD components required per ICeGaN**
- **Work with traditional bootstrap HB gate drivers**

350 W Totem-Pole PFC Evaluation Board

with CGD65A055SH2



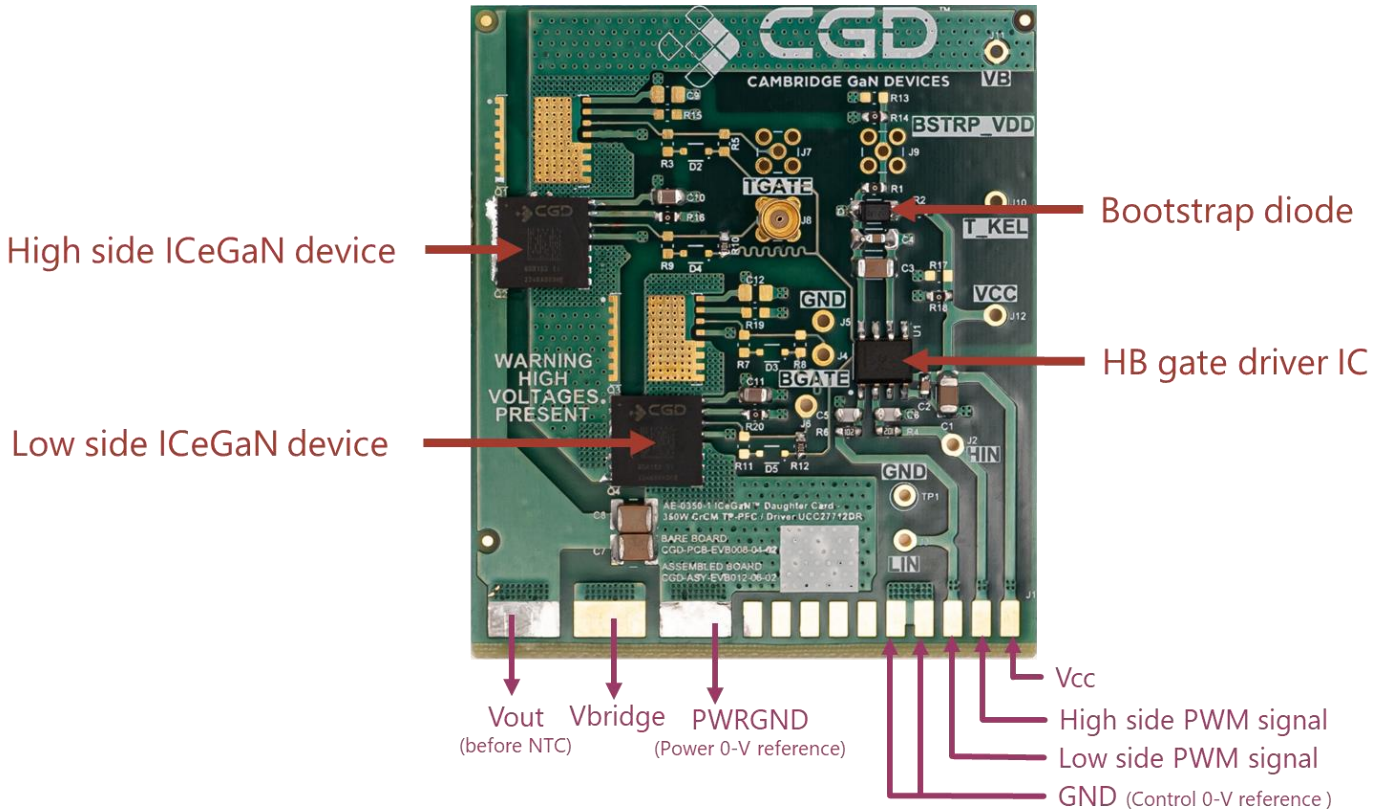


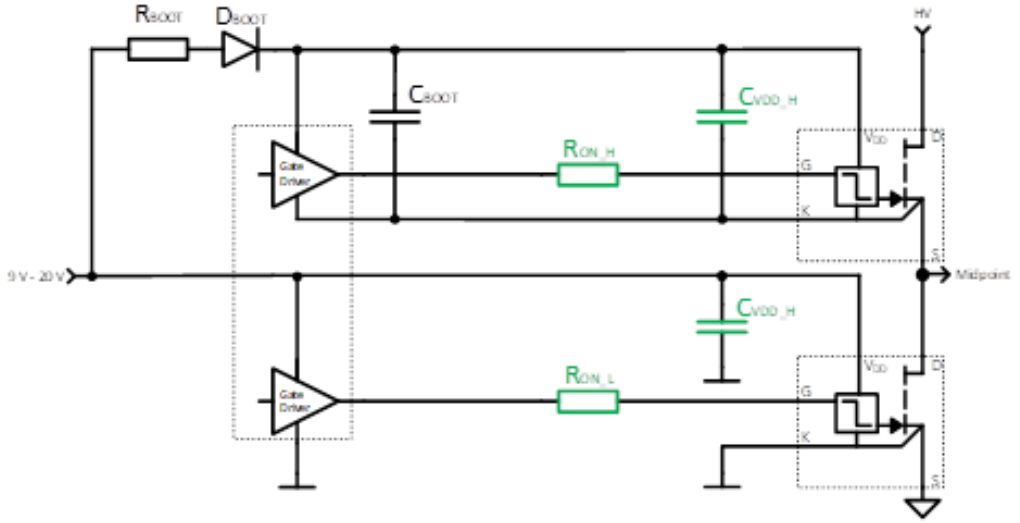
WÜRTH ELEKTRONIK
MORE THAN YOU EXPECT

[350 W Totem-Pole PFC Evaluation Board | Cambridge GaN Devices]

350 W Totem-Pole PFC Evaluation Board

Daughter Card

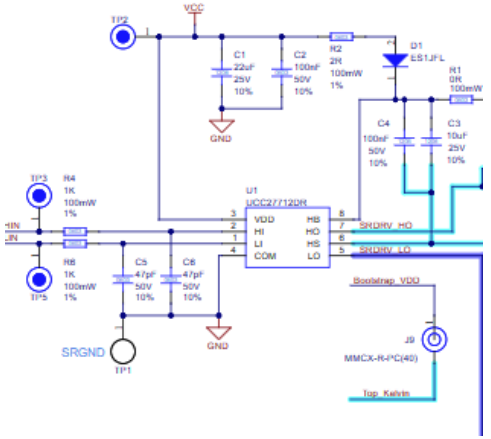




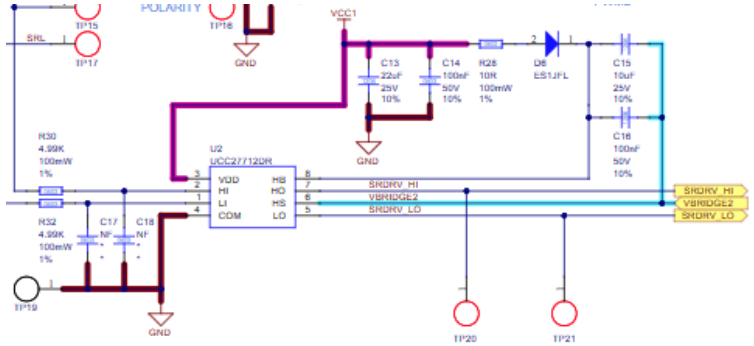
350 W Totem-Pole PFC Evaluation Board

Driving

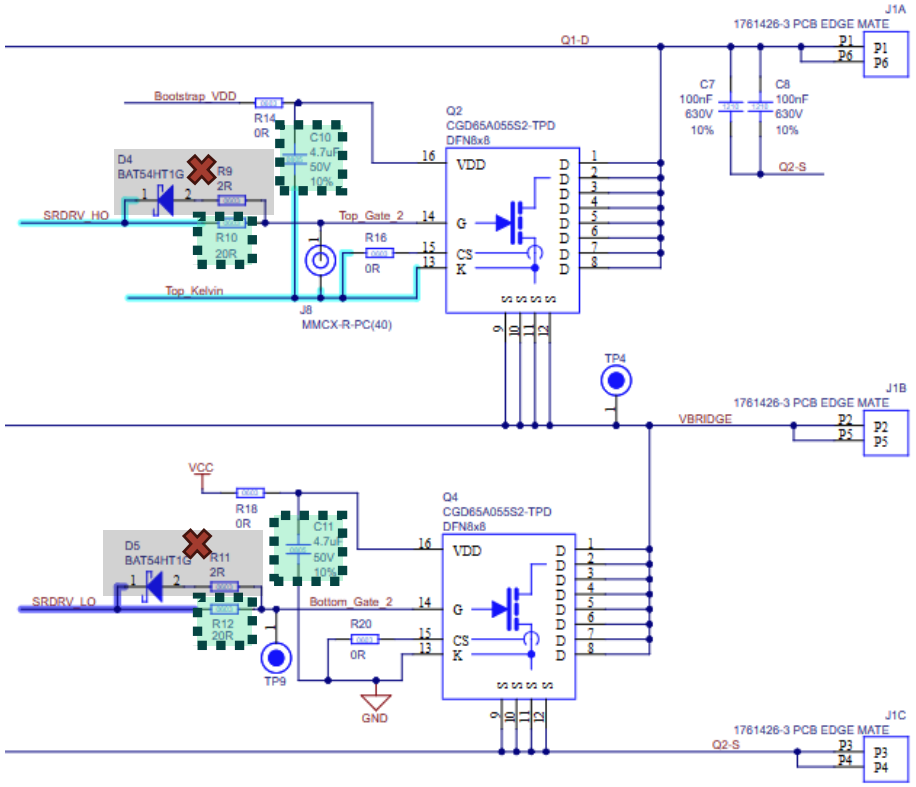
Same HB driver IC P/N for the fast leg ICeGaN



and the slow leg MOSFET

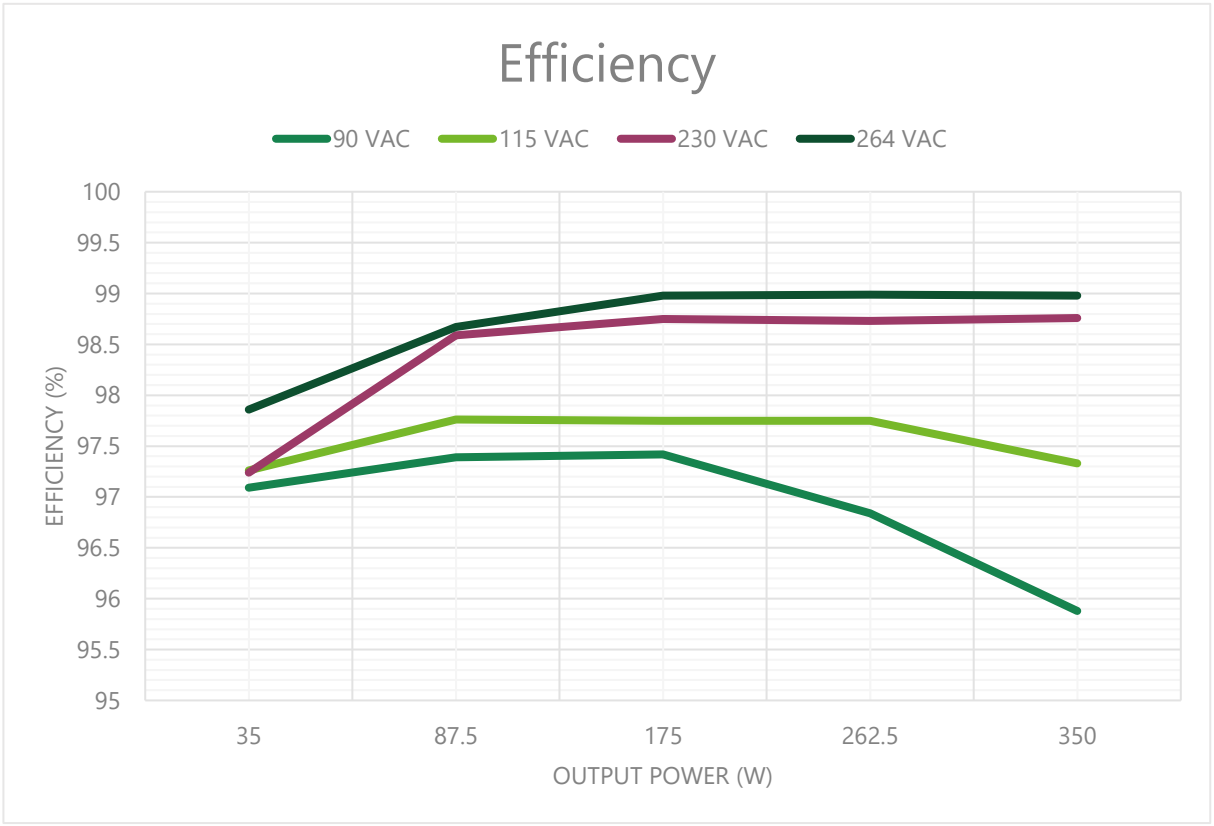


2 External components per ICeGaN



Test Results

Efficiency and no-load power

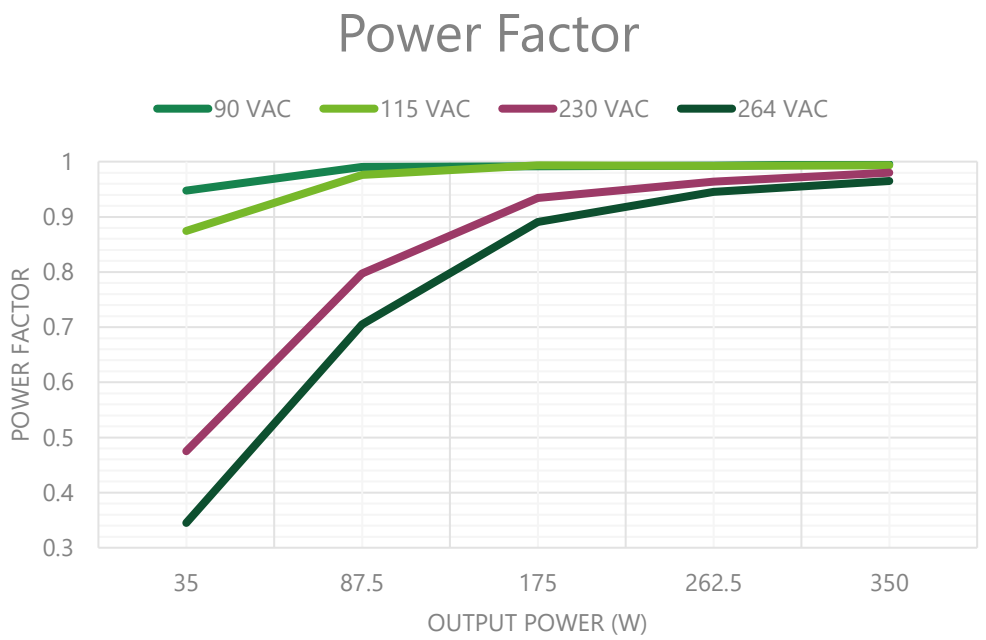


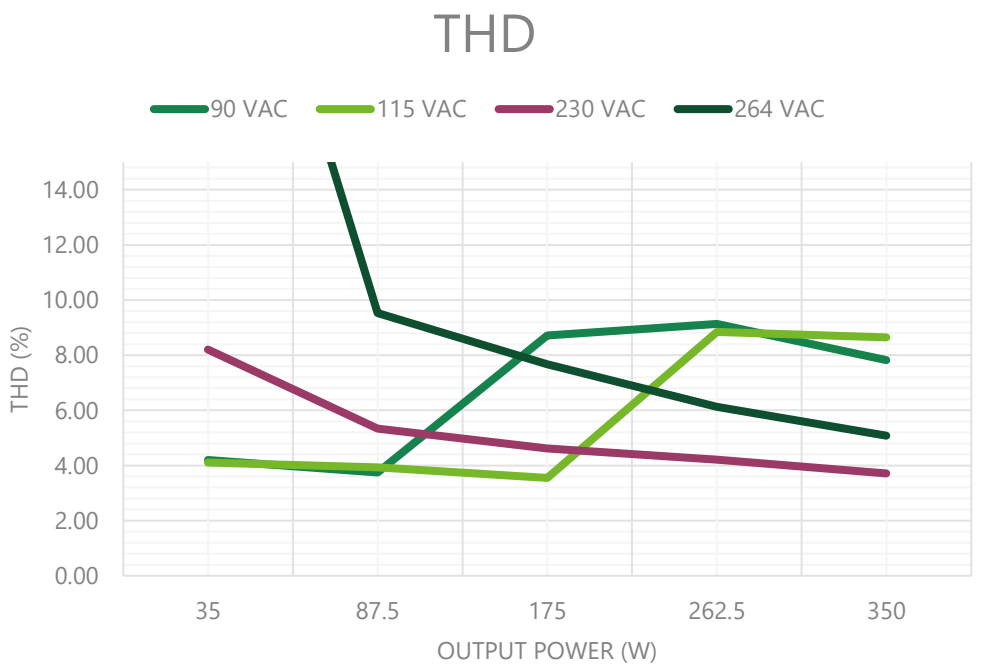
CGD 350 W TPPFC EVB No load Power	
90 V_{AC}	30 mW
115 V_{AC}	34 mW
230 V_{AC}	77 mW
265 V_{AC}	90 mW

High efficiency (peak, average and 10%) & very low no-load power

Test Results

Power Factor & Total Harmonic Distortion



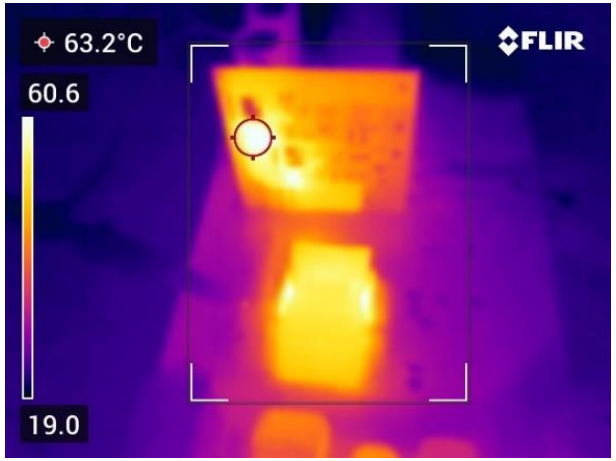


Power Factor over 95% and THD lower than 10% at full load

Test Results

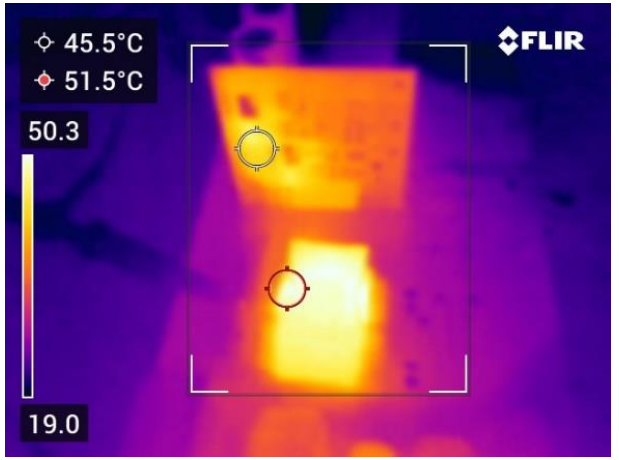
Thermal Operation at Full Load 350 W

115 V_{AC}



+ 40 ºC

230 V_{AC}



+ 26 ºC

Thermal measurements with no Heatsink. Good efficiency translates into less thermal stress.

ICEGAN™ PRODUCT PORTFOLIO

= In Production = Consumer = Server and Industrial

H1 SERIES

- CONSUMER
- LP INDUSTRIAL

4 PRODUCTS

2022

H2 SERIES

- CONSUMER
- LP INDUSTRIAL
- OPTIMISED FOR **STDBY**

4 PRODUCTS

2023

H1 SERIES	H2 SERIES
CGD65A055S2 650 V, 55 mΩ, 27 A, 8x8 DFN	**CGD65A055SH2** 650 V, 55 mΩ, 27 A, 8x8 DFN
CGD65A130S2 650 V, 130 mΩ, 12A, 8x8 DFN	**CGD65A130SH2** 650 V, 130 mΩ, 12 A, 8x8 DFN
CGD65B130S2 650 V, 130 mΩ, 12A, 5x6 DFN	**CGD65B130SH2** 650 V, 130 mΩ, 12 A, 5x6 DFN
CGD65B200S2 650 V, 200 mΩ, 8.5 A, 5x6 DFN	**CGD65B240SH2** 650 V, 240 mΩ, 7 A, 5x6 DFN

H1+H2 SERIES

- 1 monolithic chip
- NormOFF eMode GaN
- ICeGaN gate technology
- Advanced clamping structure
- Integrated Miller Clamp
- Industry first 2D barcode
- Portfolio of SMD packages
- Integrated current sensing

- **H2 series:** Innovative fully integrated NL[3]* Circuit

APPLICATIONS

Other Relevant Boards

350 W half bridge LLC Evaluation Board

350W LLC SMPS Evaluation Board | Cambridge GaN Devices

300 W CrCM totem-pole PFC + HB LLC reference design

A 300 W High-power Density, Compact and Low-profile Design | Cambridge GaN Devices

APPLICATIONS

Dare to innovate differently

Thank You

CGD™
CAMBRIDGE GaN DEVICES