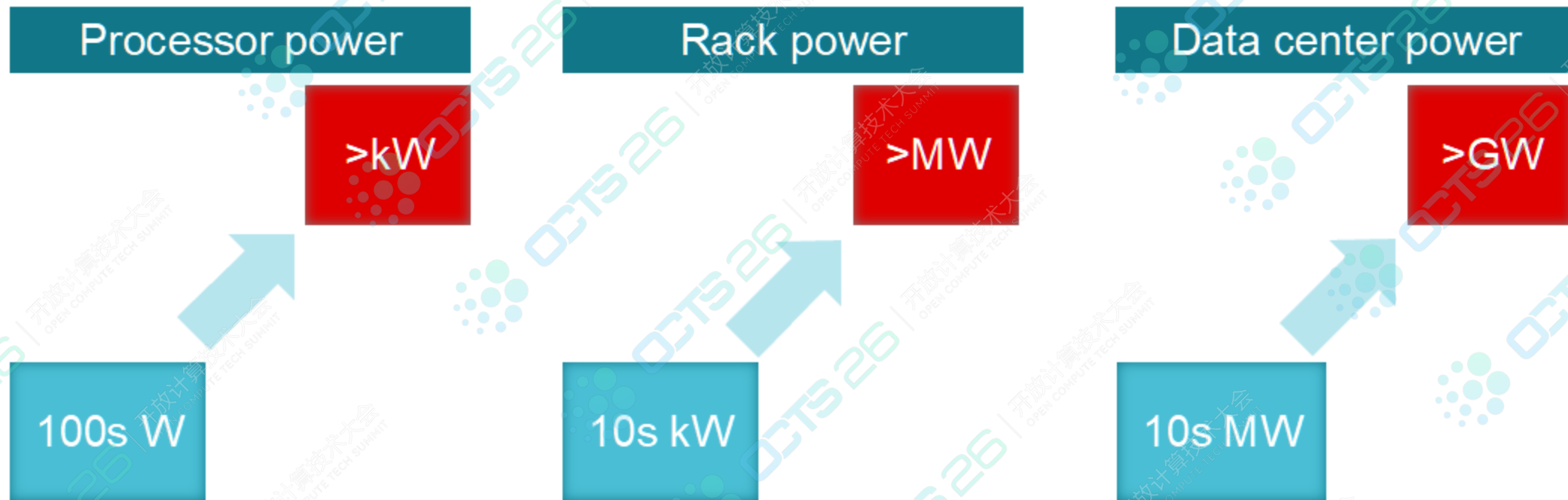


Powering AI Data Centers: TI's Innovations in 800VDC Architecture

Desheng Guo, System engineer
Texas Instruments

Why is data center power demand increasing?

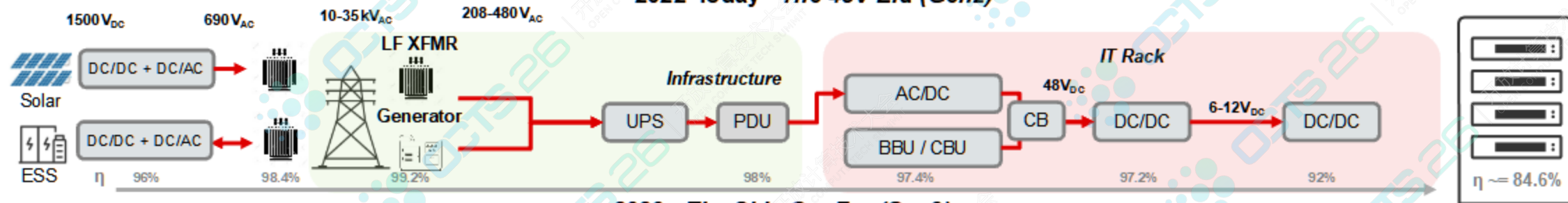


Key point: Computing power density is increasing dramatically

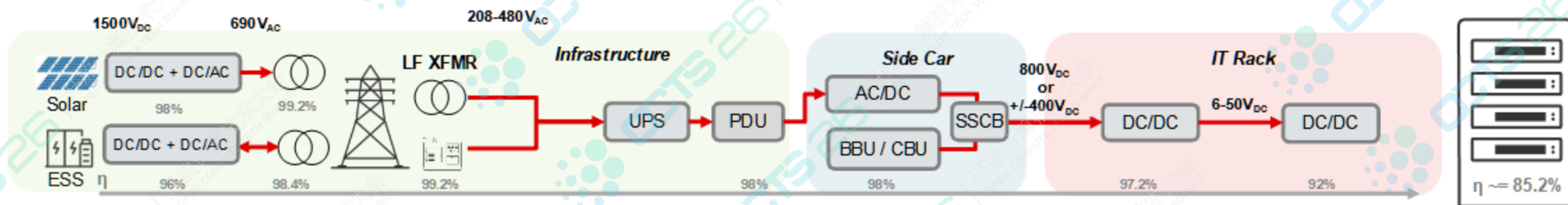
Grid to Gate Evolution

UPS: Uninterruptible Power Supply
PDU: Power Distribution Unit
SSCB: Solid State Circuit Breaker
SST: Solid State Transformer

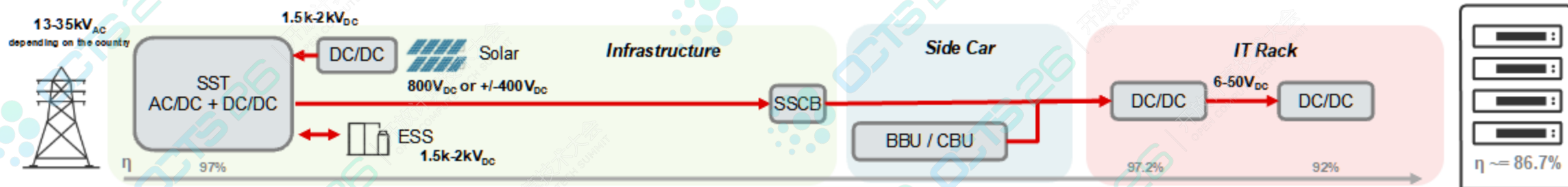
2022-Today – The 48V Era (Gen2)



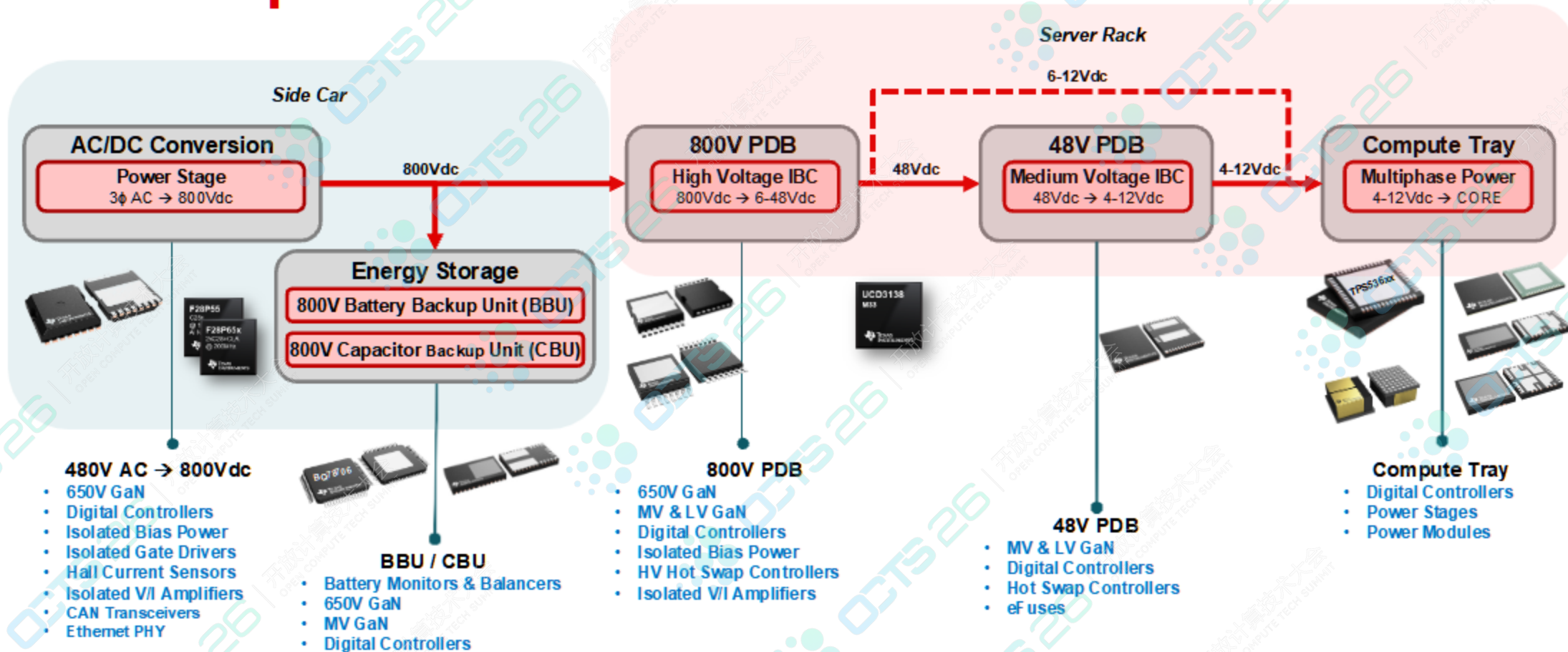
2026 – The Side Car Era (Gen3)



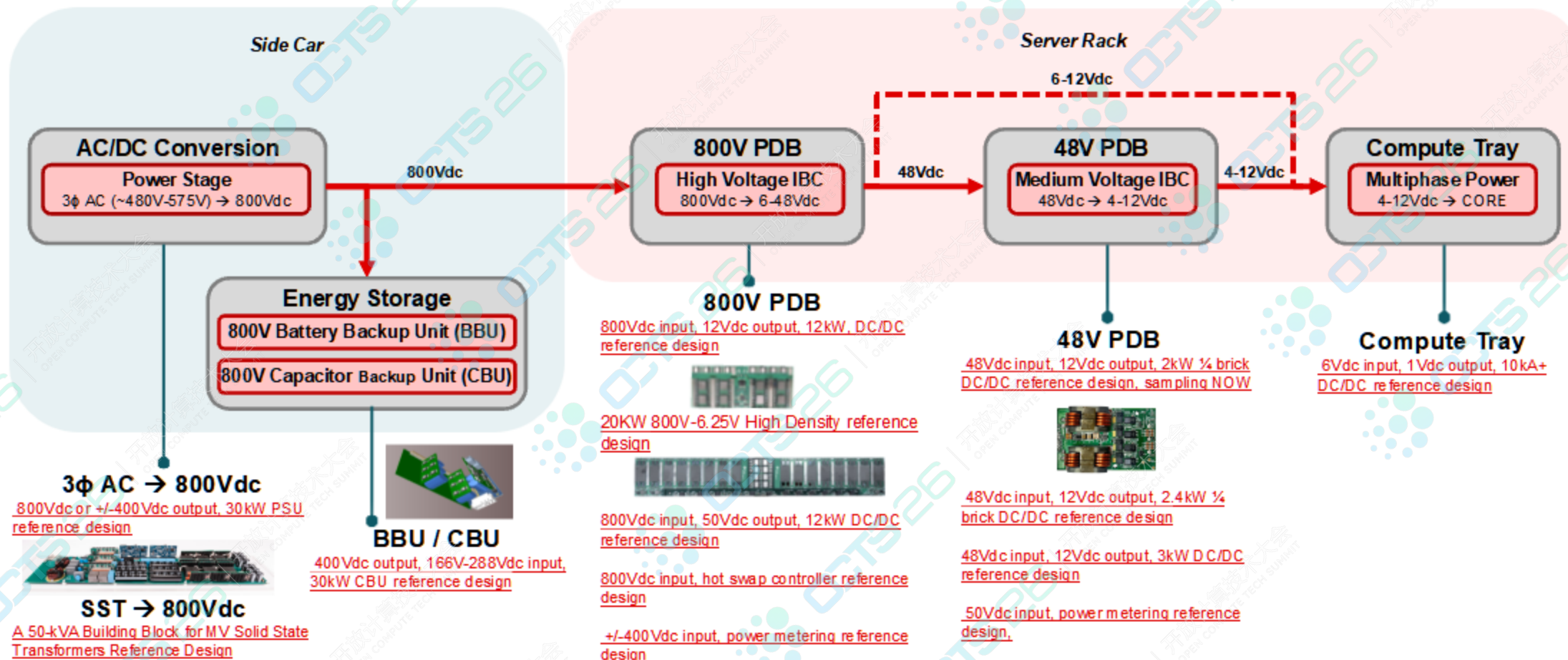
2027+ – The SST and DC Distribution Era (Gen4)



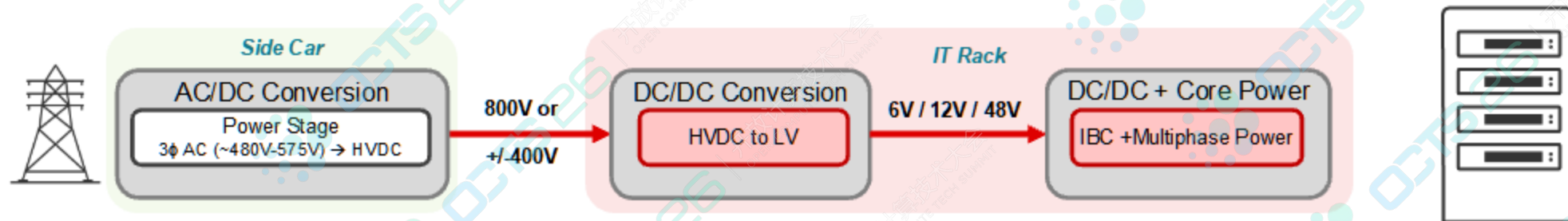
800V AIDC power with ACDC sidecar



TI reference designs in 800V AI/DC sidecar architecture

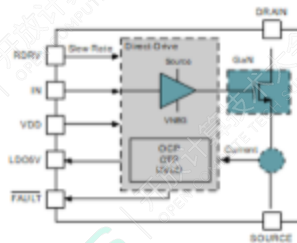
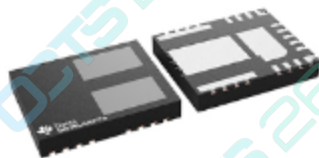


TI GaN in high-voltage DC architecture



TI technology advantages

- World-class GaN and Si processes
- Package Innovation
- Advanced driver IP



HVDC: 800V to 48/12/6V

- 650V GaN power stages
- 100V, 40V integrated GaN SRs
- 25V Monolithic Integrated SRs
- Digital controllers: UCD / C2K

IBC: 48V to 4-12V

- 100V GaN power stages
- 40V, 25V integrated GaN SRs
- Digital controllers: UCD / C2K

TI GaN Benefits

- Integrated driver with reduced switching loss
- Integrated protection with reliable gate control
- Advanced features (zero voltage/current sense) to improve system efficiency
- Thermally enhanced packages

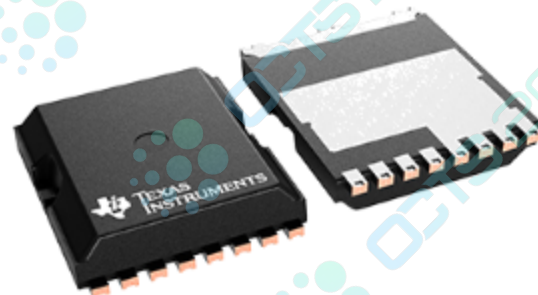
Multiphase VR

- Monolithic high current, high frequency power stage
- Integrated power module

LMG365x: 650V industrial GaN with integrated driver

Features

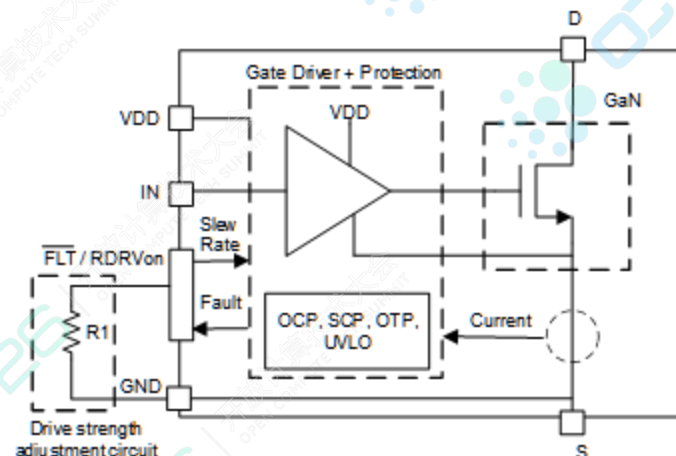
- Package: TOLL 10x15mm
- 25, 35, 70 m Ω typical $R_{DS(on)}$ Drain to Source at 25° C
- Abs Max junction temperature T_{Jmax} : 175° C
- Integrated GaN Gate Driver
 - TI Direct-Driver technology
 - >200 V/ns FET hold off
 - Single V_{dd} unregulated supply
- External resistor sets drive strength
 - 8 turn on slew rates, 10 V/ns to 80 V/ns adjustability
 - 4 turn off slew rates, 10 V/ns to full speed adjustability
 - No compromise in gate-drive inductance
- Fault monitoring and protection
 - <100ns Over-current protection
 - <300ns Short circuit protection
 - Over-temperature protection
 - UVLO protection
- Advanced versions (on Pin 7)
 - LDO5V
 - Zero-voltage detection
 - Zero-current detection



Applications

- Uninterruptible power supplies
- High power server PSUs
- HVAC
- Portable power supplies
- Solar inverters
- Motor drives

Functional Block Diagram & Package



LMG366x: 650V industrial GaN with integrated driver

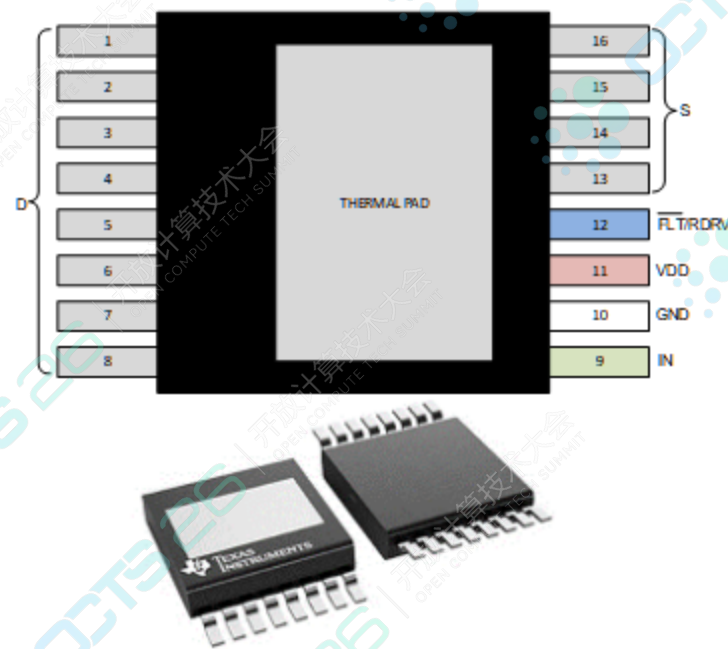
Features

- Package: **TOLT** 10 mm x 15.4 mm
- **15, 25, 40 mΩ** typical $R_{DS(on)}$ Drain to Source at 25 ° C
- Abs Max junction temperature $T_{J,max}$: **175 ° C**
- Integrated GaN Gate Driver
 - >200 V/ns CMTI and 1.7 MHz switching frequency
 - Only single V_{dd} unregulated supply needed
- Fault monitoring and protection
 - Over-current protection
 - Short circuit protection
 - Over-temperature protection
 - UVLO protection
- External resistor sets drive strength
 - 8 turn on slew rates, 10 V/ns to 150 V/ns adjustability
 - No compromise in gate-drive inductance
- Advanced versions (on PIN 10):
 - LDO5V
 - Zero-voltage detection
 - Zero-current detection

Applications

- Server PSU and Telecom rectifiers
- Solar inverters and industrial motor drives
- Uninterruptable power supplies

Package & Pin-out (Co-layout with Discrete FETs)



LMG367x: 650V STOLT GaN FET w/ integrated driver

Features

- 10, 15, 25m Ω typical $R_{DS(on)}$ at 25° C
- **Package: Slim TOLT** (9.9mm x 12.5mm)
- Abs Max junction temperature $T_{J,max}$: 175° C
- Integrated GaN Gate Driver
 - >200 V/ns CMTI and 1.7 MHz switching frequency
 - Only a single V_{dd} unregulated supply needed
- Fault monitoring and protection
 - Over-current protection
 - Short circuit protection
 - Over-temperature protection
 - UVLO protection
- External resistor sets drive strength
 - 8 turn on slew rates, 10 V/ns to 150 V/ns adjustability
 - No compromise in gate-drive inductance
- High surge-event peak transient V_{DS} (800 V)

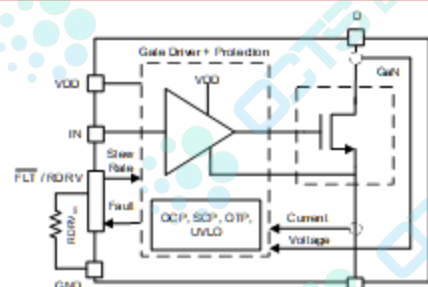
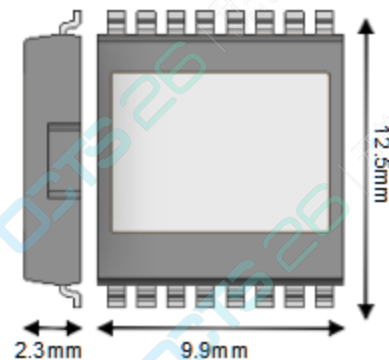
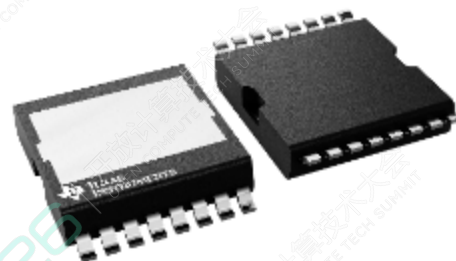
Applications

- Server and telecom PSU
- Solar inverters
- Industrial motor drives
- Uninterruptable power supplies

Benefits

- **STOLT package**
 - Better BLR performance than QFN and TOLL
 - Smaller footprint than standard TOLT

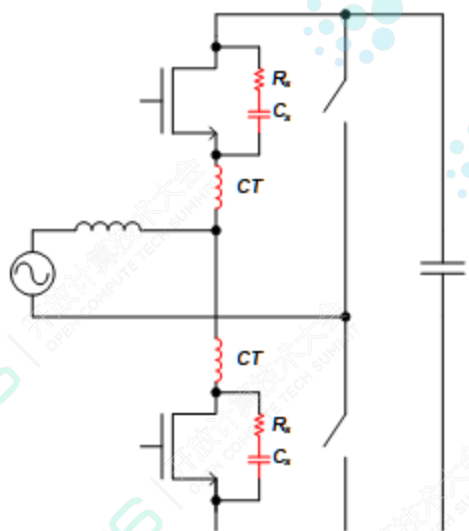
Package, Pinout, and Function Diagram



ZVS detection challenges

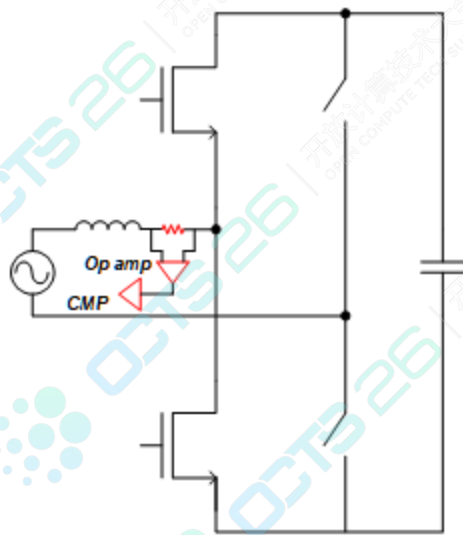
External Detection Circuit vs Integrated ZVD / ZCD

Current Transformer (CT) Method



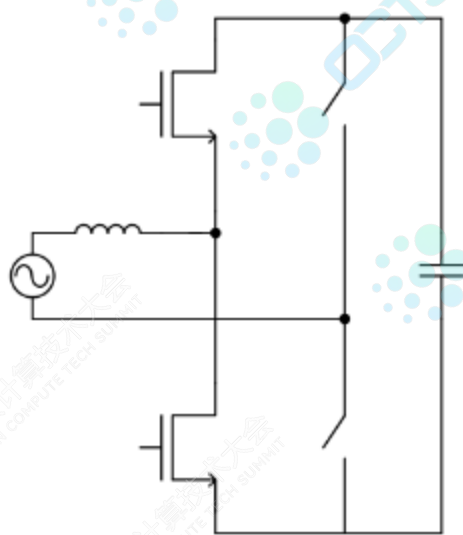
- 2x current transformers
- 2x comparators
- Clamping circuits: 2x high voltage capacitors, 2x resistors
- Low efficiency due to CT and snubber circuit losses

Shunt Resistor Method



- 1x shunt resistor
- 1x high-bandwidth op-amp
- 1x fast comparator
- Low efficiency due to shunt loss

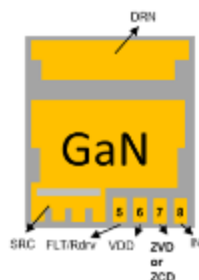
Integrated ZVD / ZCD with GaN



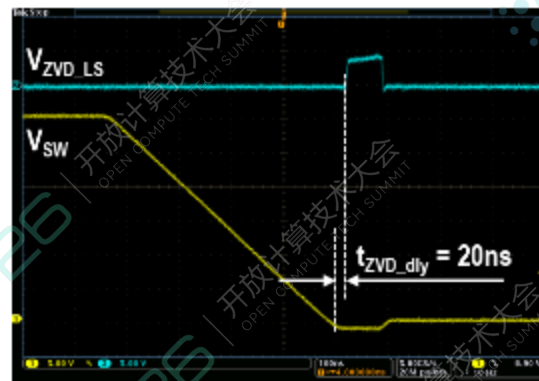
- 1x channel in Isolator

➤ Integrated ZVS detection option does **not introduce sensing loss**, but it can **simplify system design, minimize footprint size, and lower cost.**

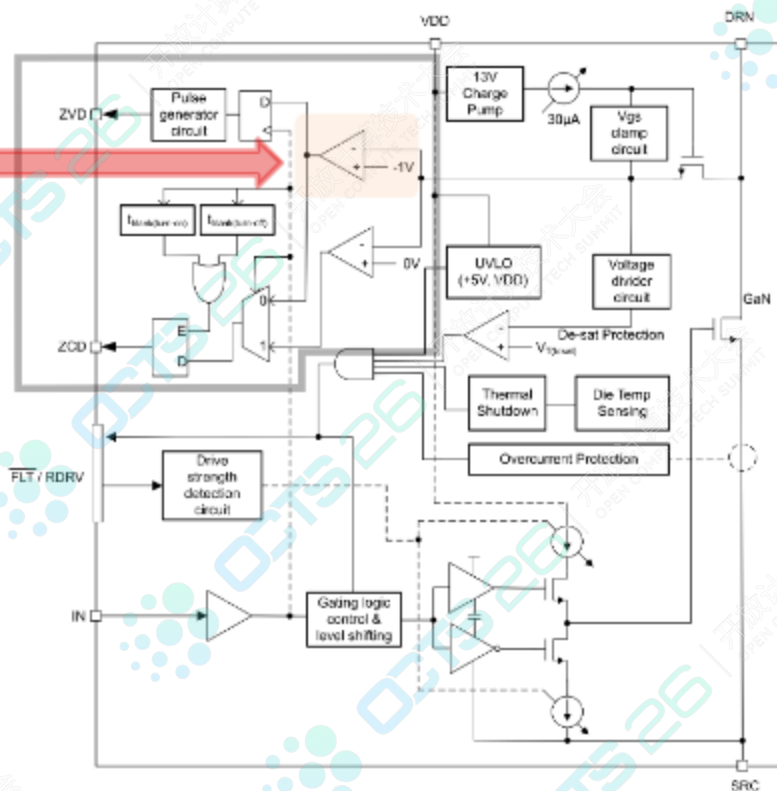
TI GaN with integrated ZVD



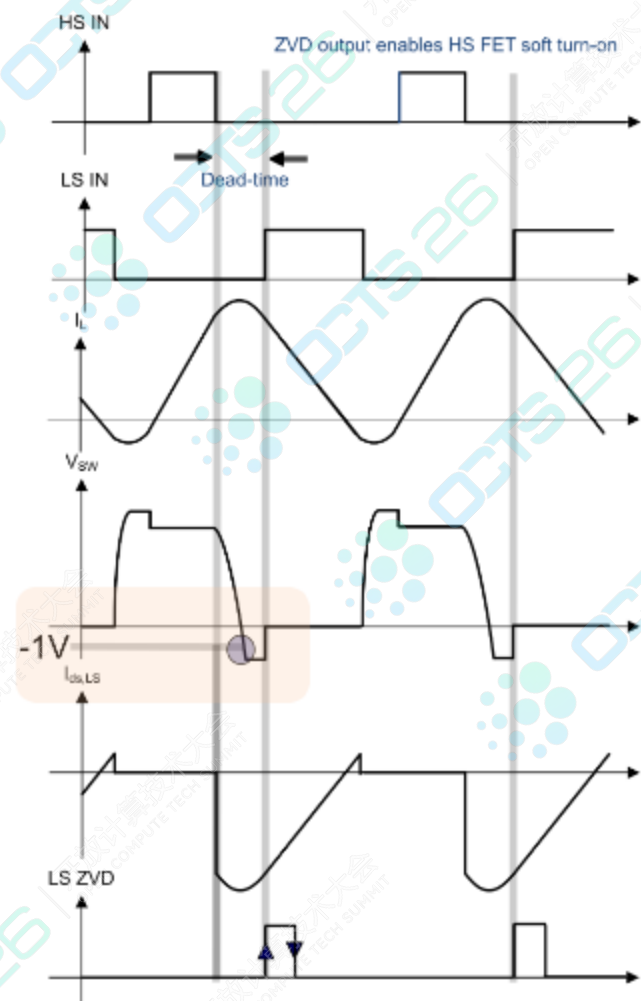
ZVD pulse in sync with PWM



Experimental waveforms - ZVD



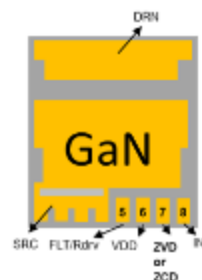
Logic block diagram of ZVD



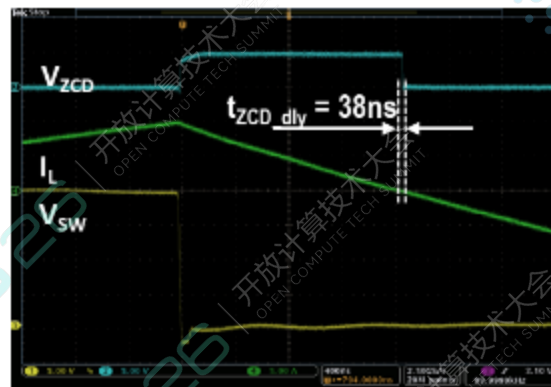
ZVD pin out illustration waveforms (TCM Buck)

- ZVD pulse (fixed width) output indicates ZVS is achieved when turning on

TI GaN with Integrated ZCD

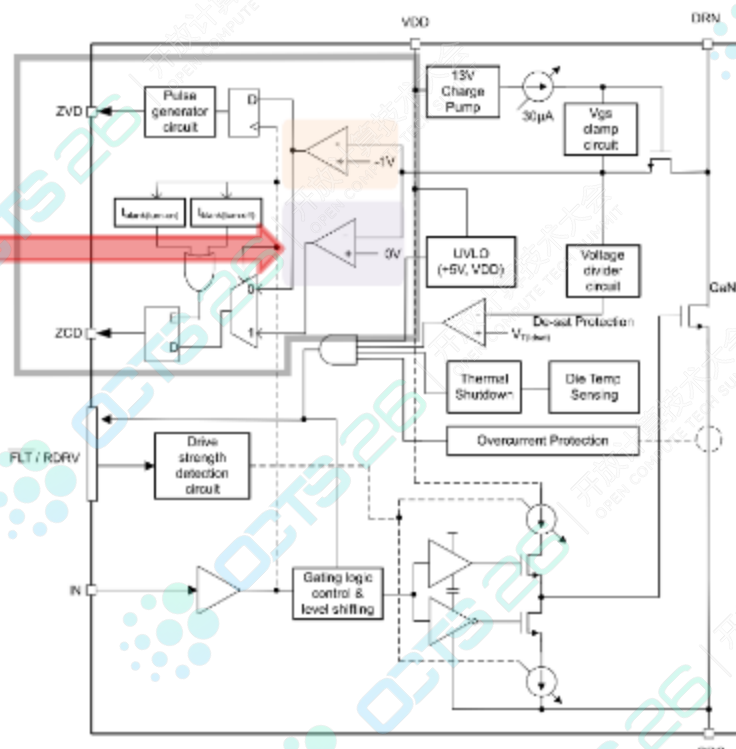


ZCD pulse generation

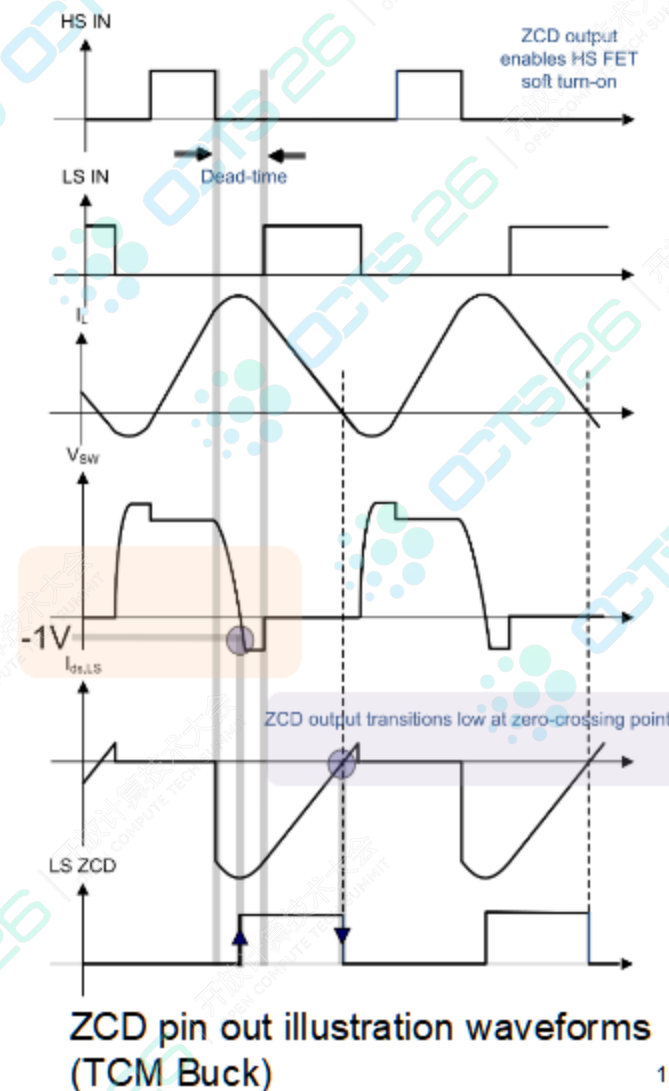


Experimental waveforms - ZCD

- Positive edge: Indicates ZVS is achieved in device
- Negative edge: Indicates Zero Current crossing point
- Asynchronous ZCD out signal

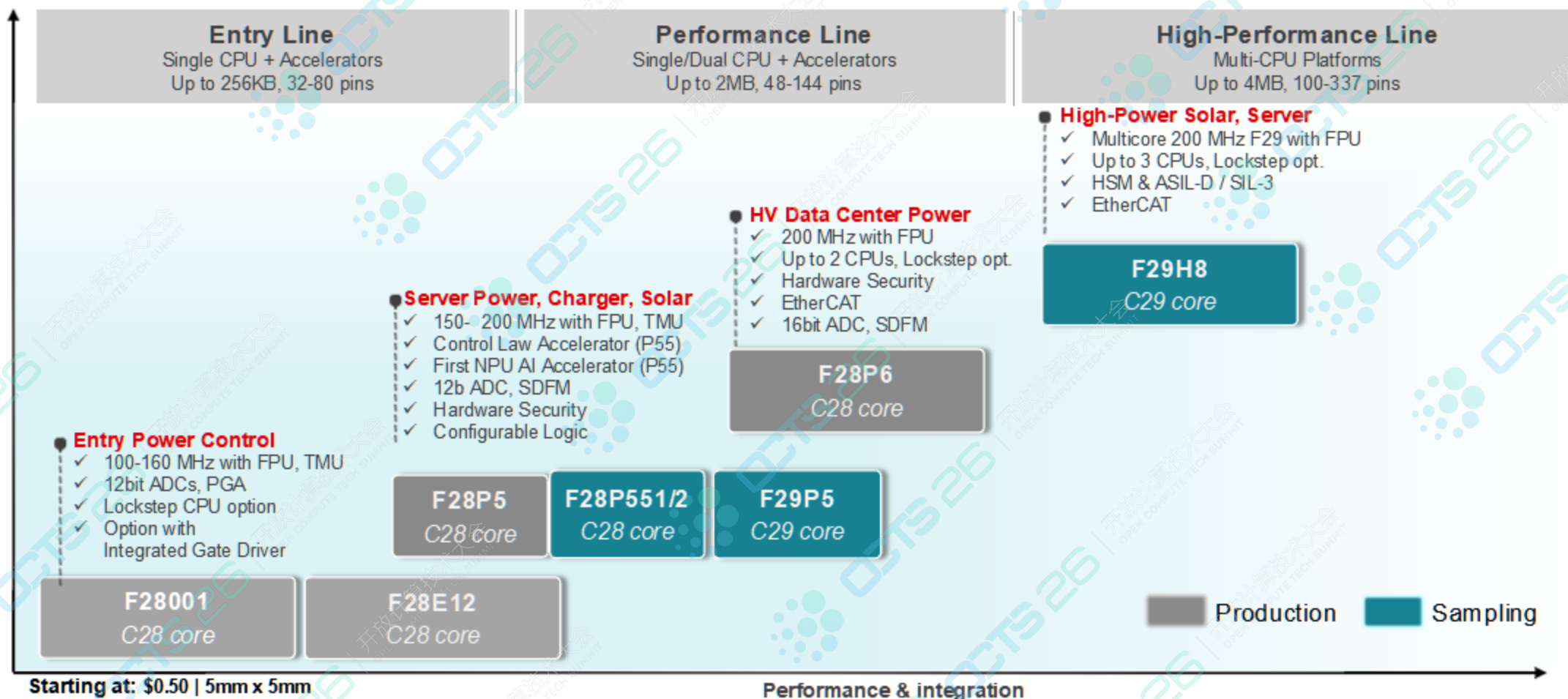


Logic block diagram of ZCD

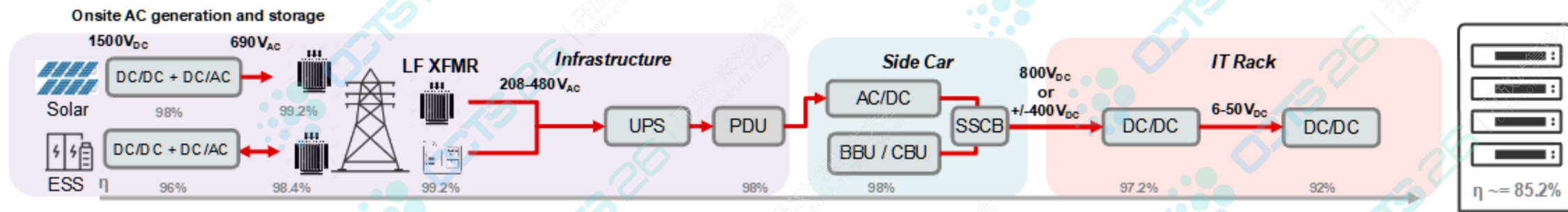


ZCD pin out illustration waveforms (TCM Buck)

Digital power real-time controllers



Embedded processing solutions for datacenters



AI Server Power

(OPEN COMPUTE PROJECT)

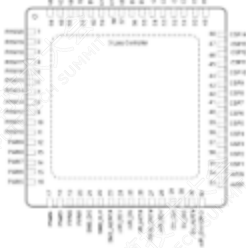
Cloud/AI/Datacenter Server Rack with High Power

	UPS	AC/DC	BBU	CBU	DC/DC	SST* Next Gen.	SSCB	CDU	PDU/ PDB
Trends	Multi-stage design, Security	20kW+	48V -> 400/800V	New Design	48V -> 800V, CAN Interface	New Design	New Design	New Design	New Design
MCU's	F28P65x	F28P55x / F28P65x	F28P65x	F28P65x	F28P55x	F28P65x F29H85x	AM13Ex	AM13Ex	F28P55x, AM13Ex
Reference Designs	✓ 3-Phase T-type Inverter ✓ 3-Phase ANPC inverter	✓ 3-Phase Vienna Rectifier PFC ✓ 3-Phase LLC	✓ 4-Switch Buck-Boost		✓ 1 kW LLC 1/8 Brick ✓ 2 kW 4-Phase Interleaved Buck 1/4 Brick	✓ 50KVA building block for Medium Voltage SST			

Multiphase processor power

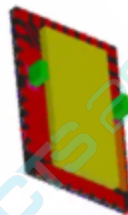
Providing Timely & Efficient Enterprise Power Solutions
~2 Billion Multi-phase Controller + Power Stage Chipsets since 2017
Continuous Portfolio, Teams, Capacity & Investment Growth

Controllers



- Scalable Phase count & Loop count
- Digital Control Loop (DDCAP+)
- Higher switching Frequency
- Full featured diagnostics / telemetry

Power Stages



- Monolithic Solutions
- Best-in-class efficiency
- Highest Power Density
- All in Thermal enhanced package

Power Stage Modules



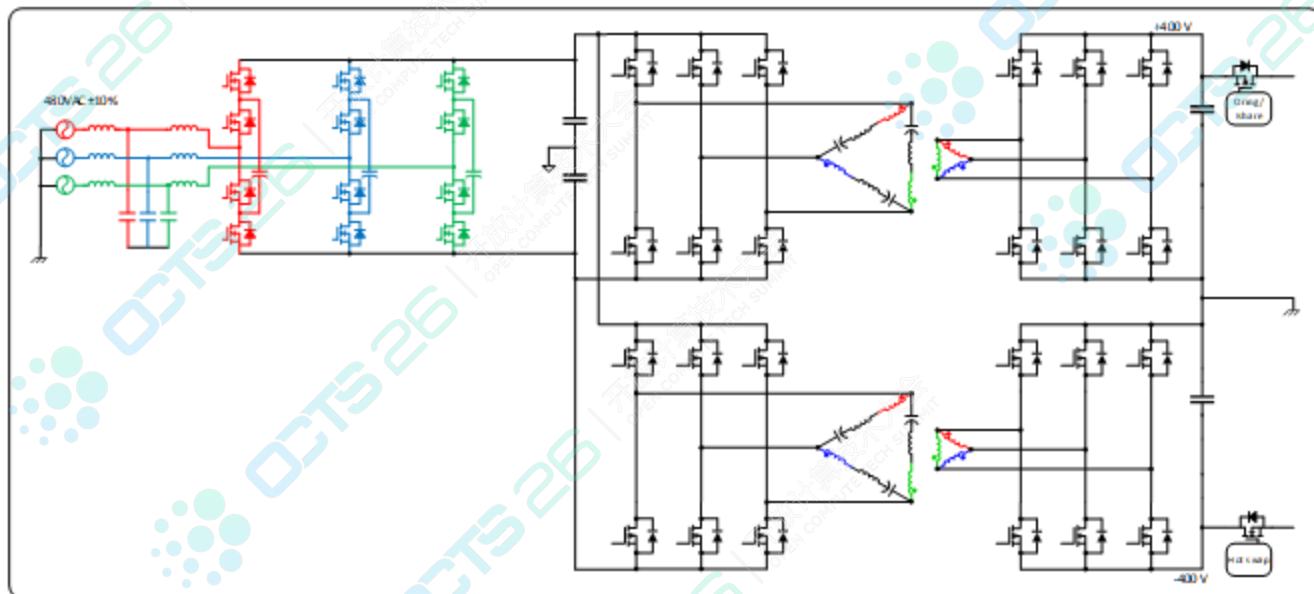
- Highest system efficiency
- Smallest area (including height)
- High Peak & Fast transient response
- Common footprint options available

PMP23630 30 kW AI Server PSU key features

Features

- Peak Efficiency 98.5 % with fan
- 3-level flying capacitor PFC
 - 65 kHz/phase
 - 130 kHz conversion frequency
- Δ - Δ Connected 3 Phase LLC
 - 100 kHz – 1.5 MHz
 - Reduced resonant tank currents
 - In/output current cancellation
 - Hybrid Hysteretic Control (HHC)
- 800 mm x 160 mm x 32 mm

Parameter	Specification
AC Input voltage (line-line 3 phase AC)	480 V +/- 10%
Output voltage	+/- 400 V +/- 10%
Output Power	30 kW
Peak Power	48 kW/50 ms



DC-DC reference design for 30kW 400V CBU

Features

- Peak Efficiency 98 % with fan
- Bidirectional 2SWs converter
- 6 phases interleaving
 - Higher power capability
 - Fast response
- Dimensions W x H x D (mm)
 - CBU : 82mm x 179mm x 855mm
 - DCDC: 76 mm x 172 mm x 120 mm

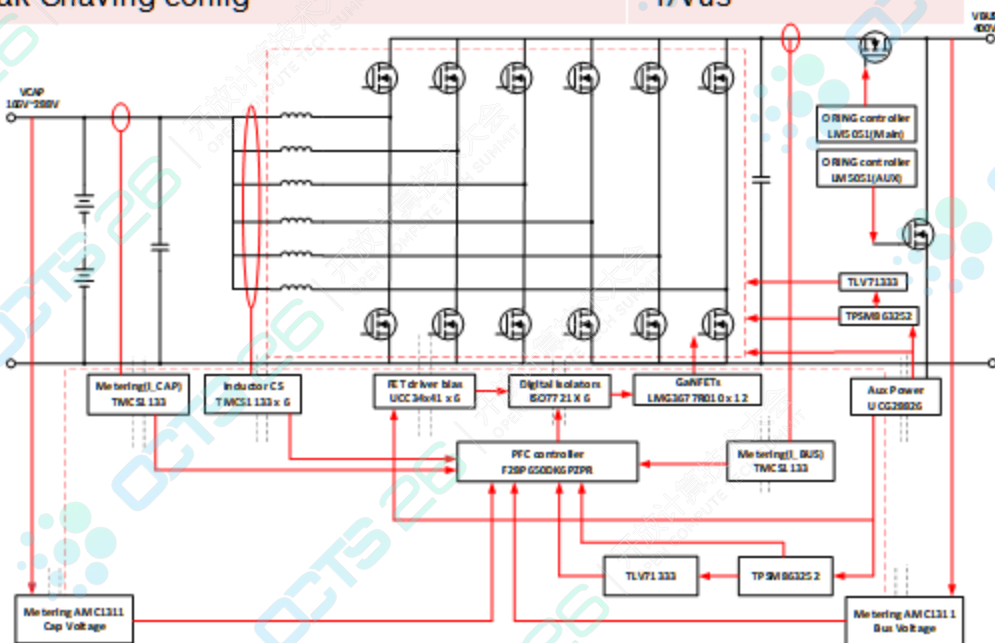
Applications

- High Voltage Datacenter BBU/CBU Shelf for AI Applications

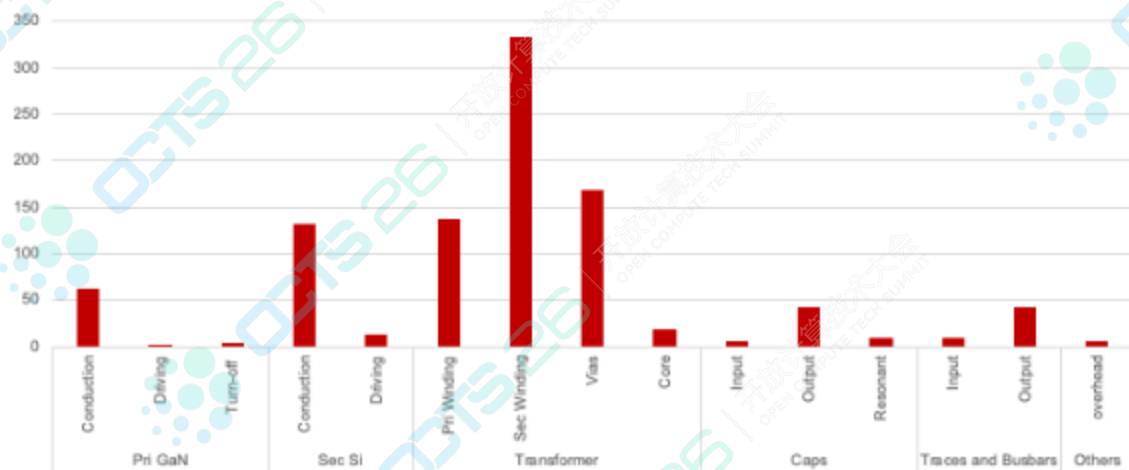
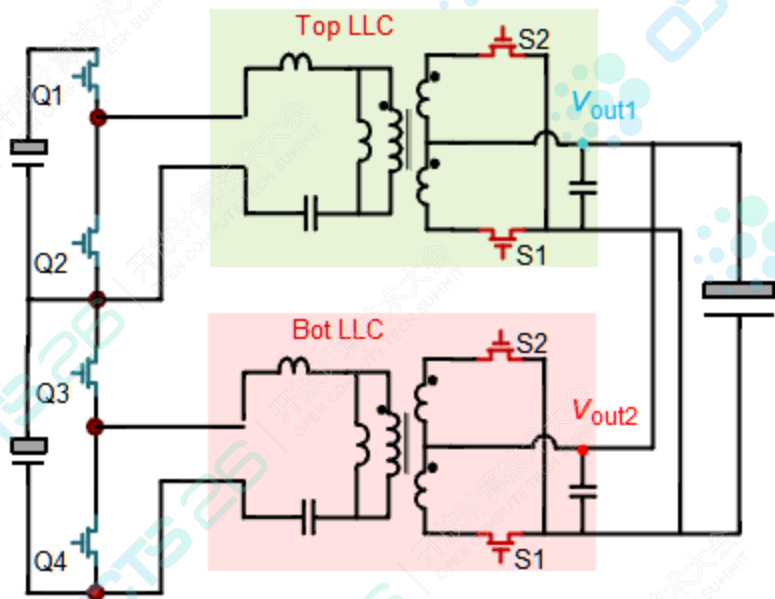
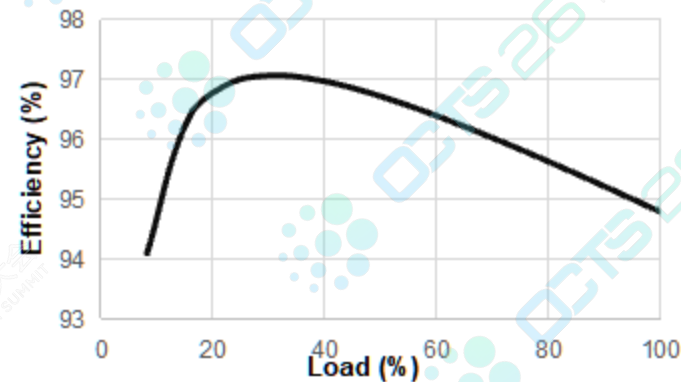
TI Parts

- See subsequent slides

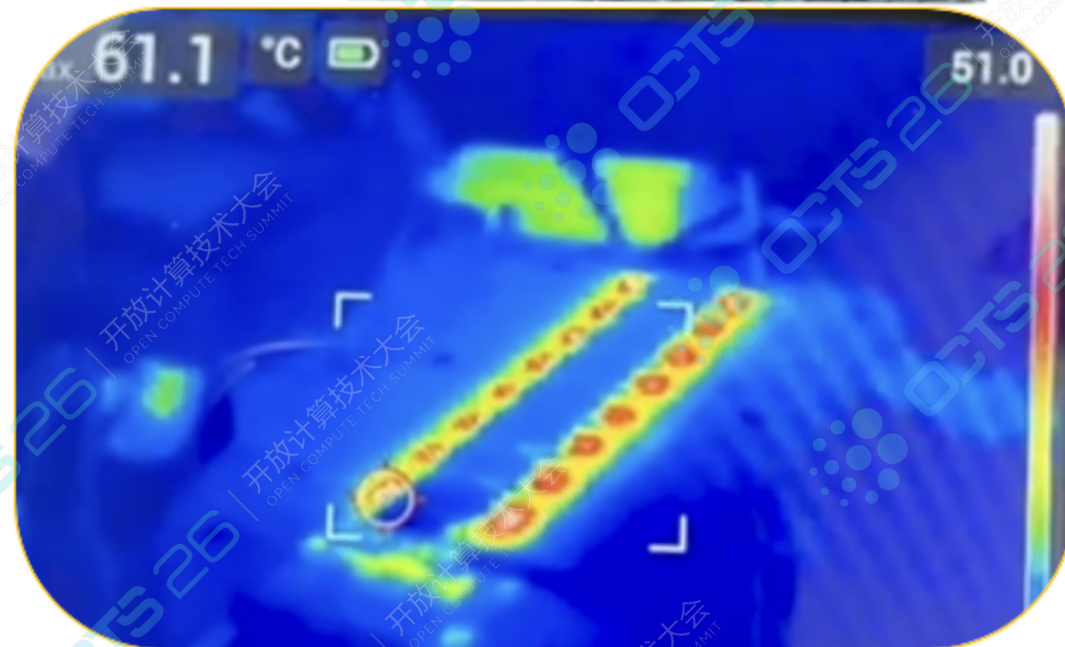
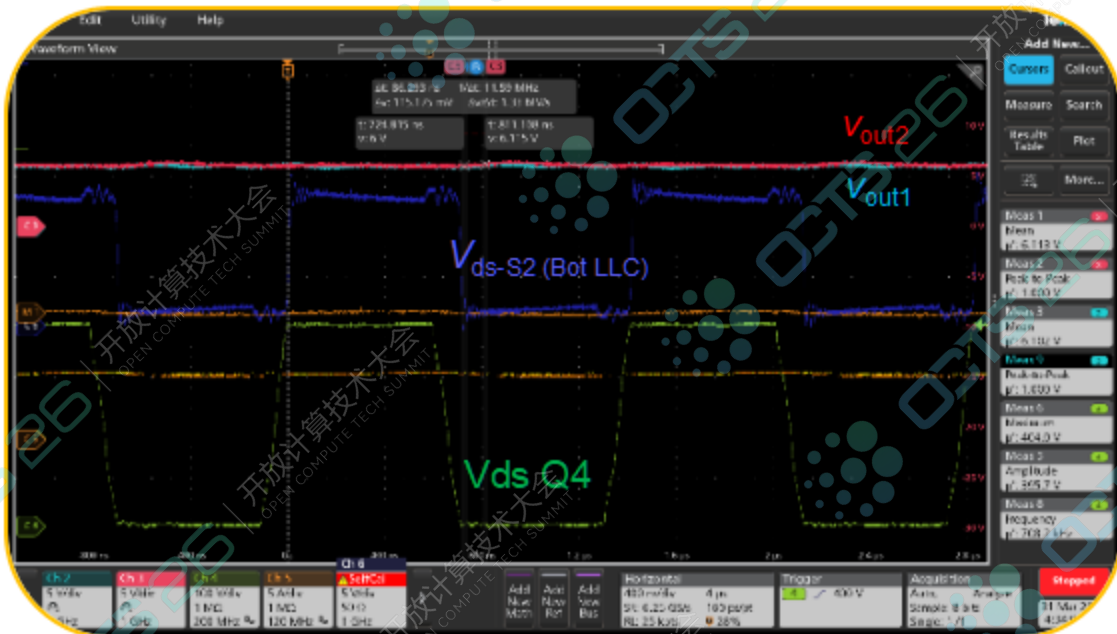
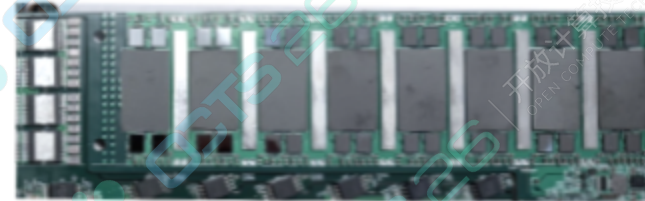
Parameter	Specification
Vcap	166V ~ 288V
Output voltage	400 V +/-10%
Output Power	30 kW
Peak Shaving config	1A/us



800-6V | Simulated Loss Breakdown @ 20KW



800-6V | Full Power Test Results



- V_{ds} Q4 is 400V @ 800V input: voltage balance among stacked LLCs
- Perfect match on the V_{out} for both stacked LLCs
- Even thermal distribution
- Good current sharing across all the 16 parallel output cell

TIDA-050095: 4 phase GaN-based buck, 48-12V 2kW high efficiency design in 1/4th brick size (Chip-Down)

System Specifications:

- Output: 12V
- DC Input: 40-60V (48V nominal)
- Sw. frequency: 200kHz
- Topology: 4 Phase Interleaved Buck (48-12V)
- Form Factor: 36.8mm x 58.4mm x 19mm
- Protections: OCP, OTP, OVP and UVLO
- Efficiency @ 1kW: ~98.1% @48V
- Efficiency @ 2kW: 97.5% @ 48V

Typical application

- Enterprise Server and Telecom 48-12V conversion

Tools & resources

- **Design files:** Schematics, BOM and design files
- **Device datasheets:**
 - [LMG3100R017 x 8](#)
 - [UCD3138A x1](#)

Benefits

- High power density with a high peak and full load efficiency of ~97.5%+
- Transformer-less regulated topology with high peak and full load efficiency
- Easy to implement in a chip down design



Orthographic View

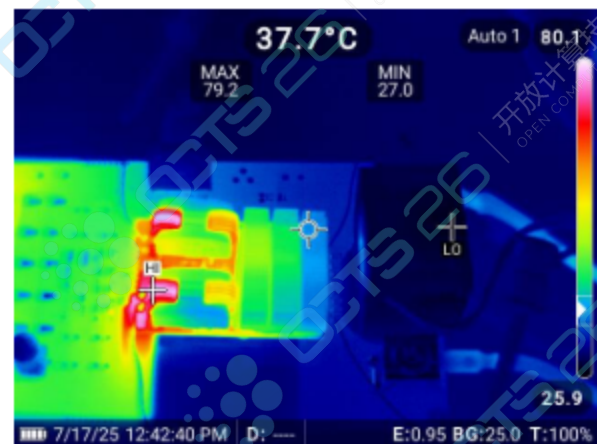
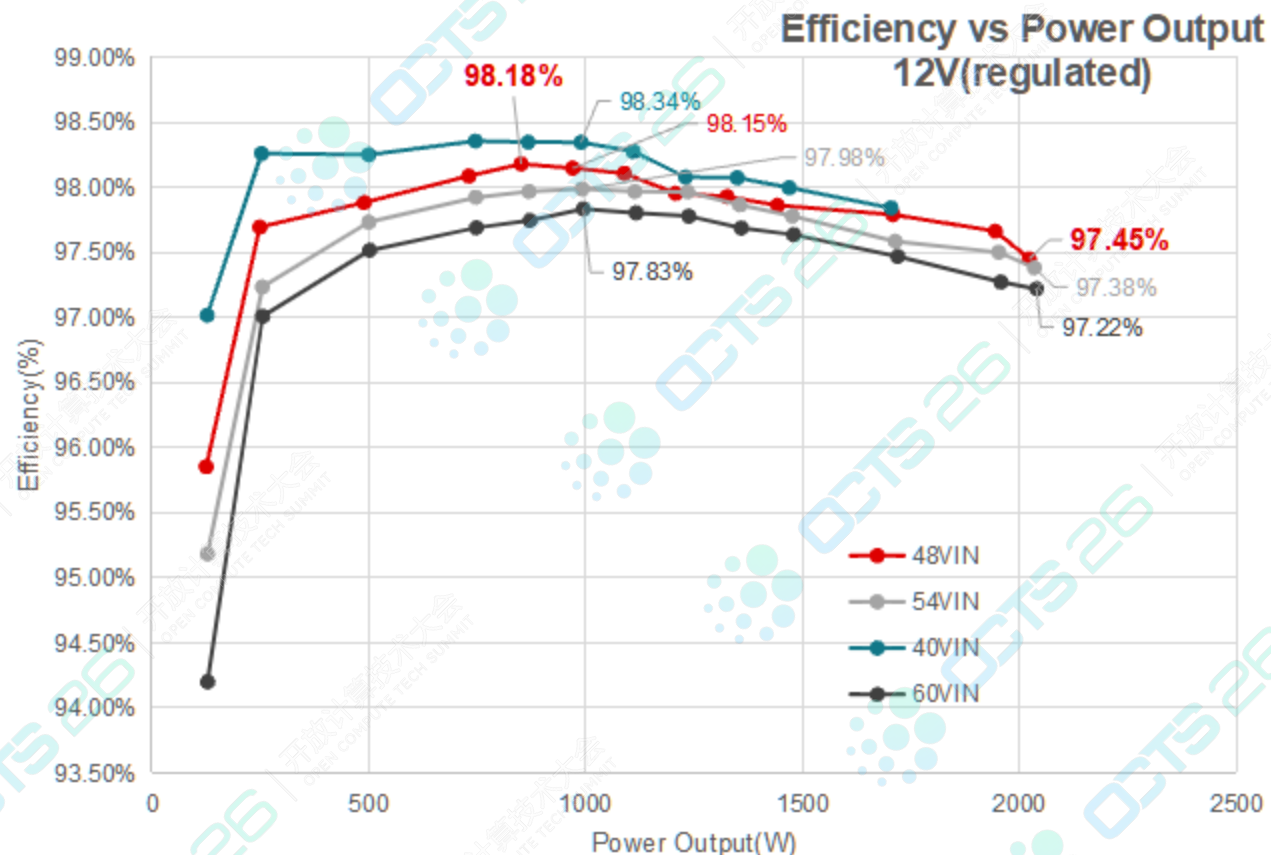


Top View



Bottom View

Efficiency and Thermals



Thermals 48VIN@2kW

Current Status:

- Optimized efficiency to achieve **98.1%+** peak and **97.5%** at full load.
- Implementing regulation and testing transient response

Next Steps:

- Use LMG3105R017 and LMG3105R011 to increase mid-load efficiency to **98.5%+** and full-load to **98%+**
- Implement protection features

Thanks