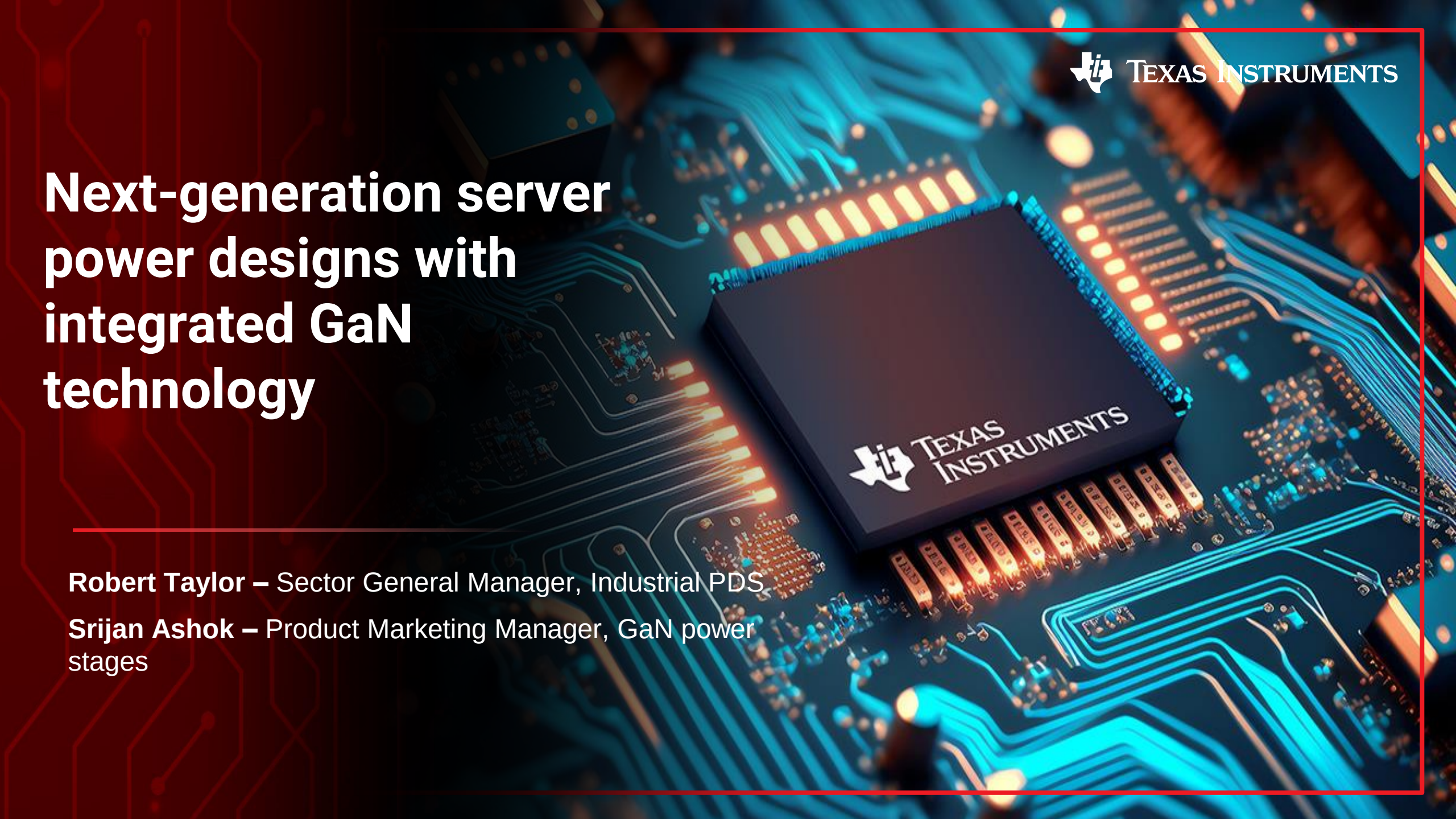
Next-generation server power designs with integrated GaN technology



Robert Taylor – Sector General Manager, Industrial PDS

Srijan Ashok – Product Marketing Manager, GaN power stages

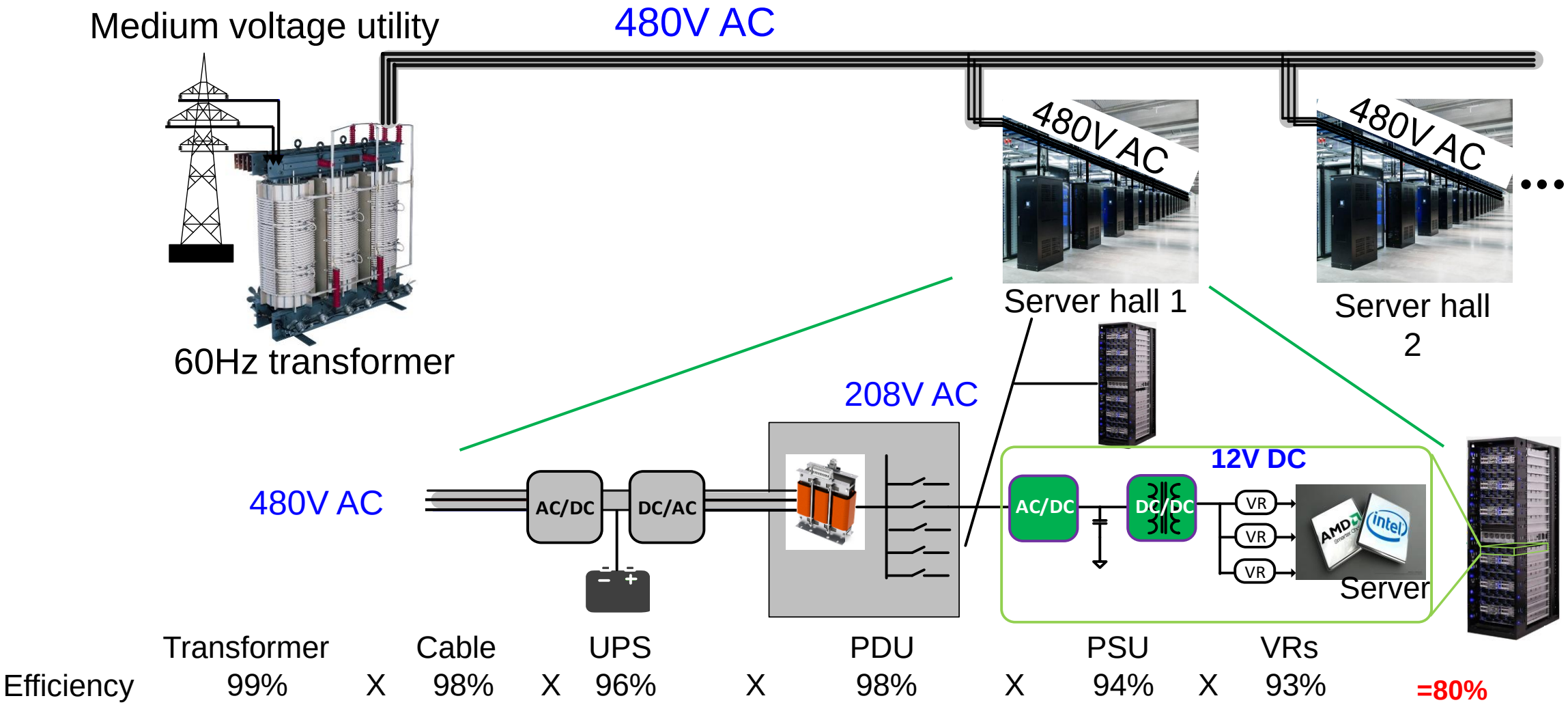
Agenda

- Server power system evolution
- TI GaN portfolio optimized for server power
- Server subsystem deep dive ➔ reference designs and solutions to key technical challenges
  - Power supply unit (PSU)
  - Battery backup unit (BBU)
  - Intermediate bus converter (IBC)
- Q&A

Please feel free to share your questions on “chat”. We will also have 10 mins of Live Q&A towards the end of the presentation

Evolution of server power

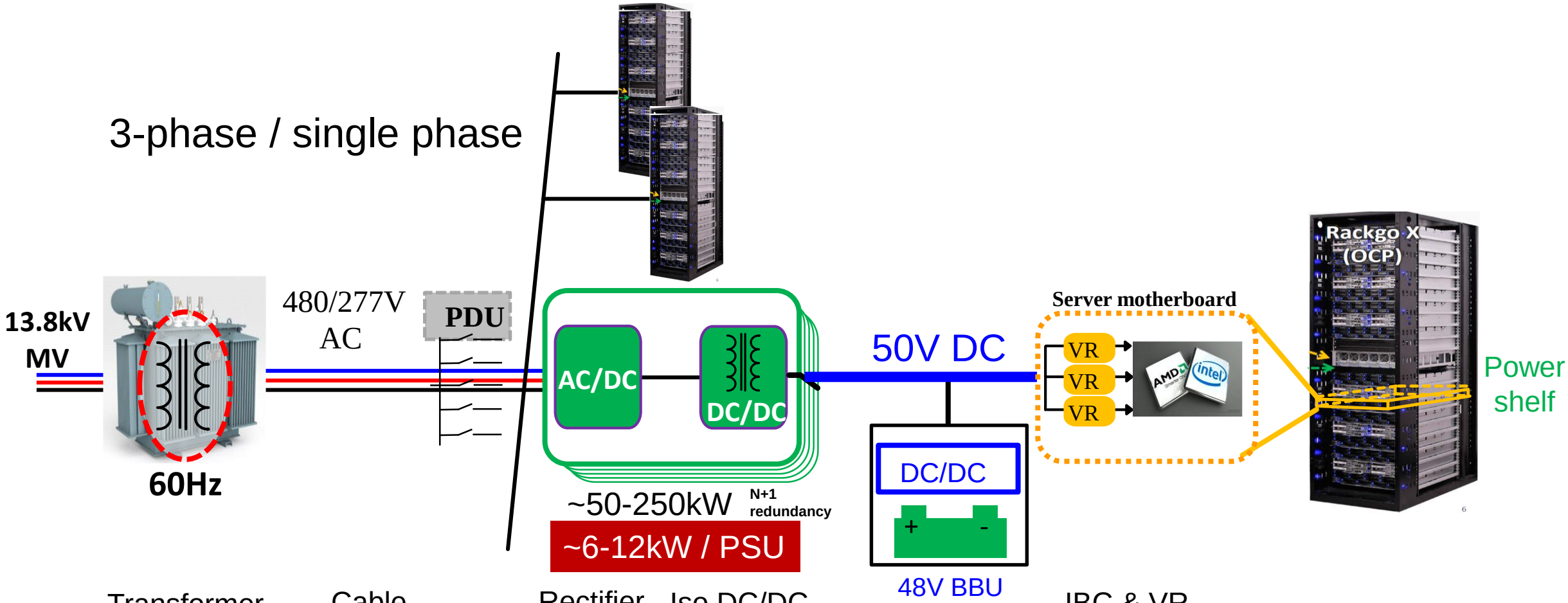
Generation 1: 12V data center power architecture



	Transformer		Cable		UPS		PDU		PSU		VRs		
Efficiency	99%	X	98%	X	96%	X	98%	X	94%	X	93%		=80%

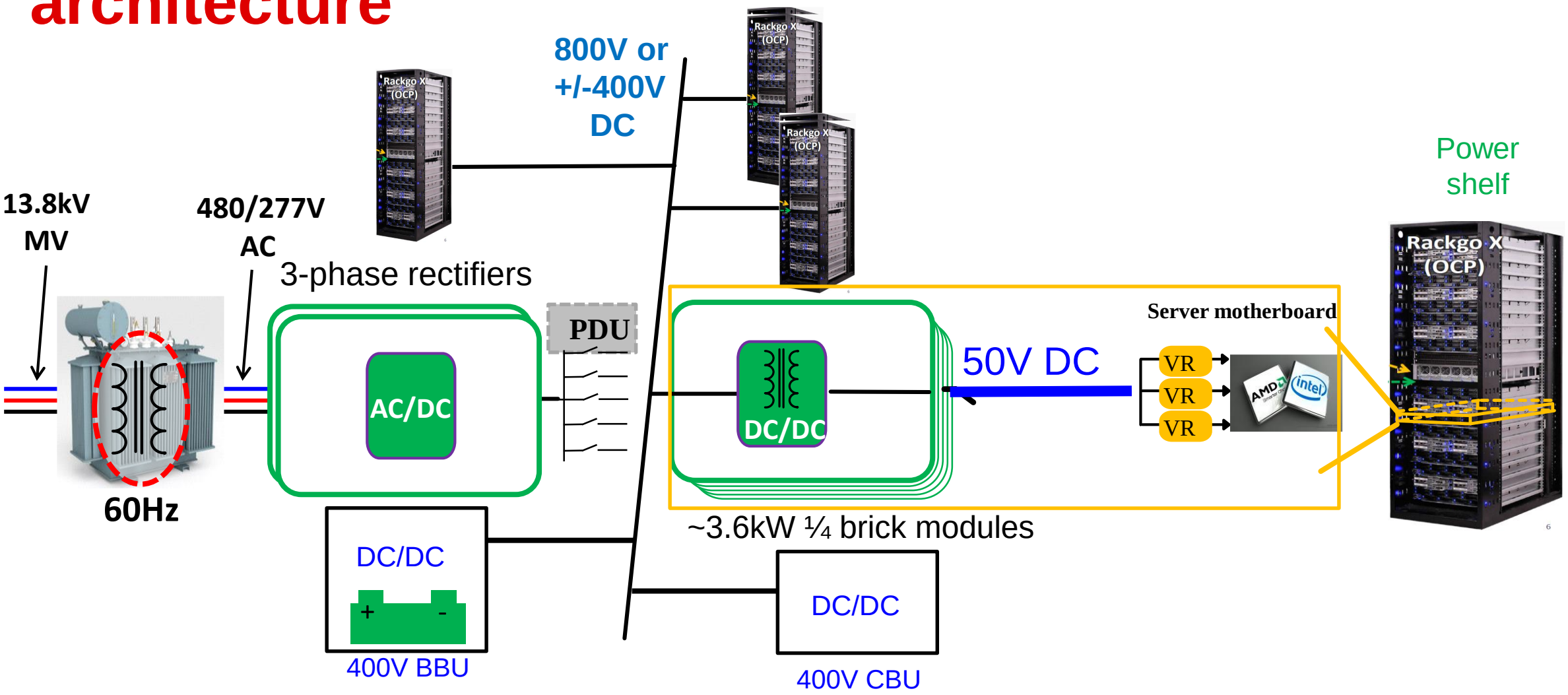
Redundant power conversion stages

Generation 2: 48V data center power architecture



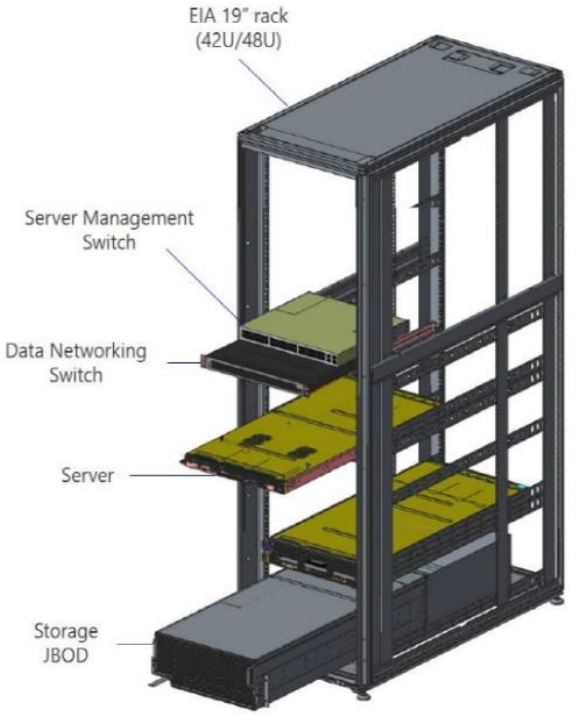
	Transformer	Cable	Rectifier	Iso DC/DC	IBC & VR	
Efficiency	99%	98%	99%	98%	90%	≈ 85%

Generation 3: DC distribution data center power architecture



Server PSU market trends

1990s – Now: Traditional rack servers (CRPS): Gen 1

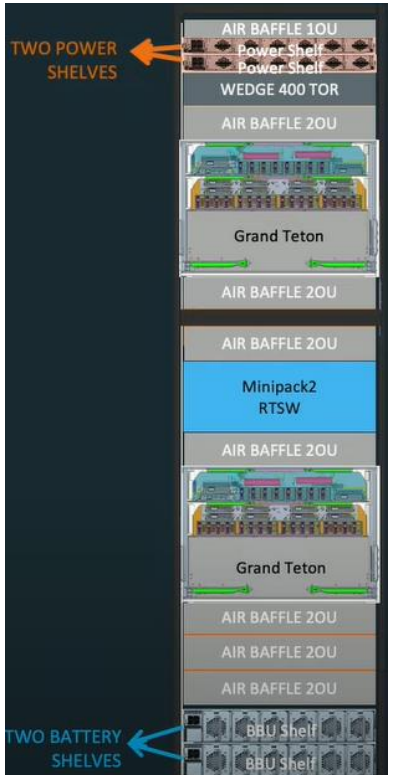


800~3.2kW per PSU
10-15kW per rack
2 PSUs/Motherboard
2023 ~13.7M PSUs
2028 ~16.7M PSUs

2012s – Now: Cloud Gen2:

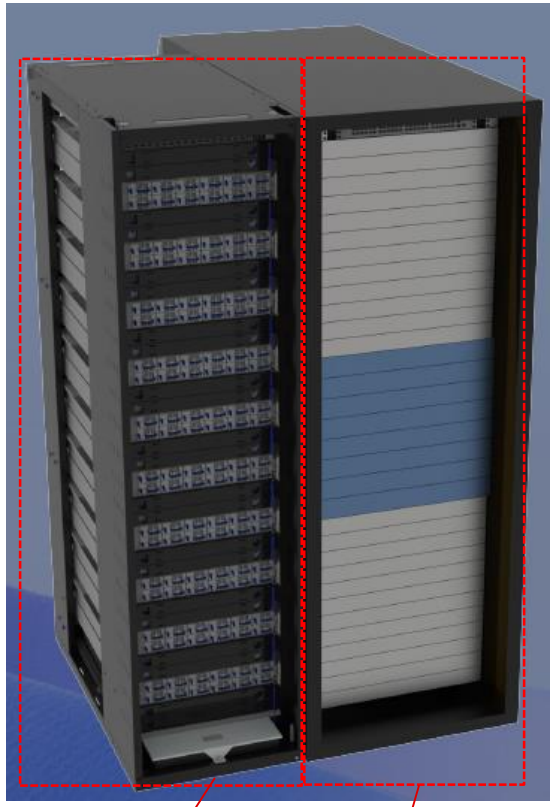
3.3kW per power shelf (x2)
12-18kW per rack
5+1 PSUs + BBU
2023 ~2.5M PSUs
2028 ~3.7M PSUs

2016s – 2027: Cloud/AI Gen 2.5:



2-4 power shelves per rack
44kW to 152kW per rack
12 to 24 PSUs + BBU
2023 ~1.1M PSUs
2028 ~8.8M PSUs

2027 to: Gen 3
+/-400V Bus

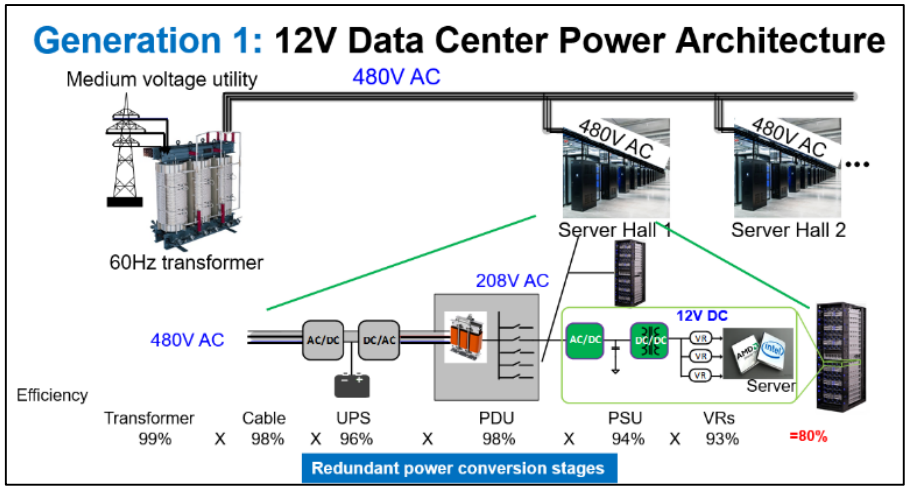


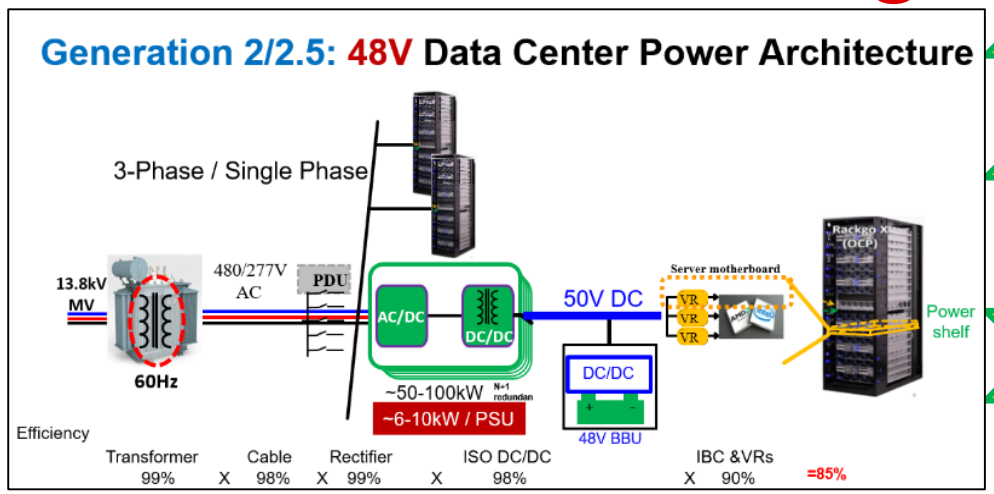
Rectifier rack

IT rack

References:
https://www.opencompute.org/wiki/Open_Rack/SpecsAndDesigns#RACK_Standards
https://www.163.com/dy/article/HJ5DNAGT0511C4M6.html; https://opencompute.dozuki.com/c/OCP_Open_Rack_V2

Server PSU market trends and challenges





Efficiency

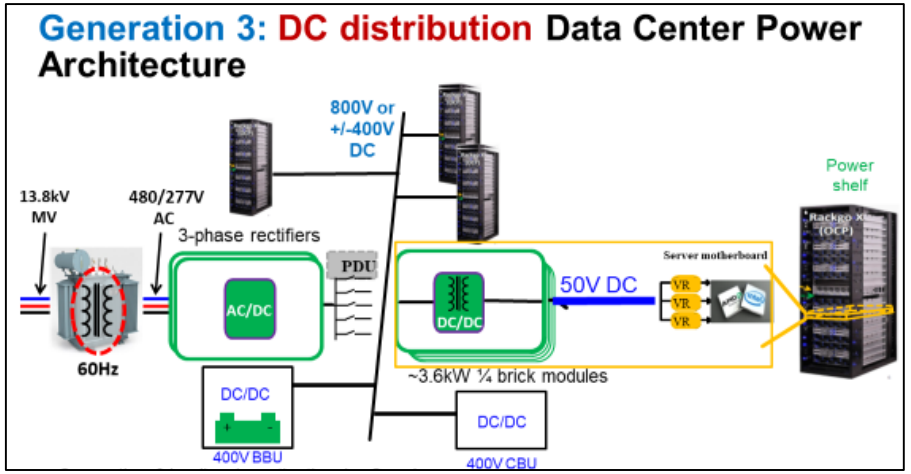
Power consumption

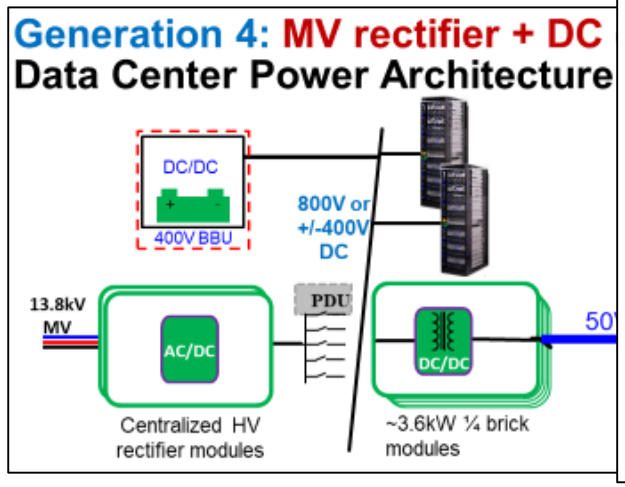
Size

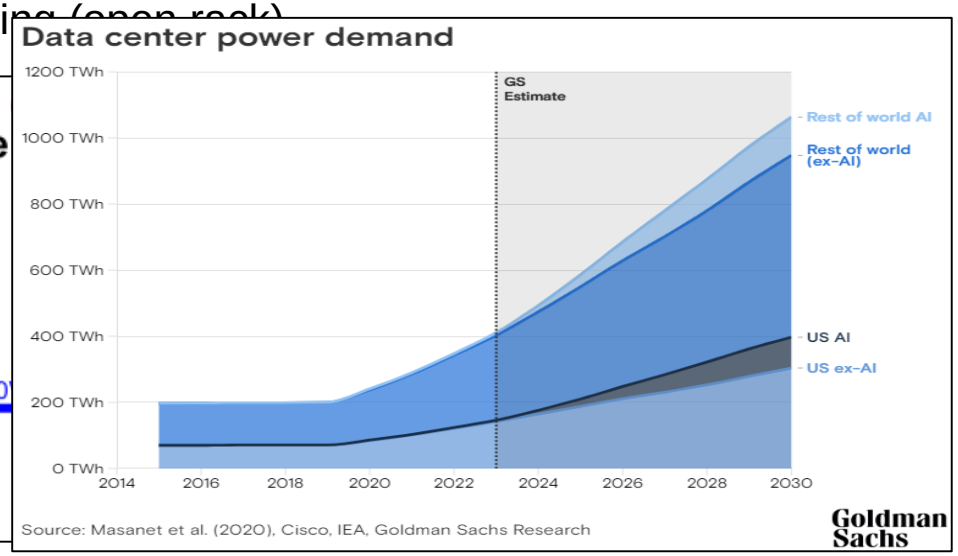
Power density

1990s – Now: Traditional rack servers (CRPS)

2016 – 2027: Cloud/AI computing (open rack)



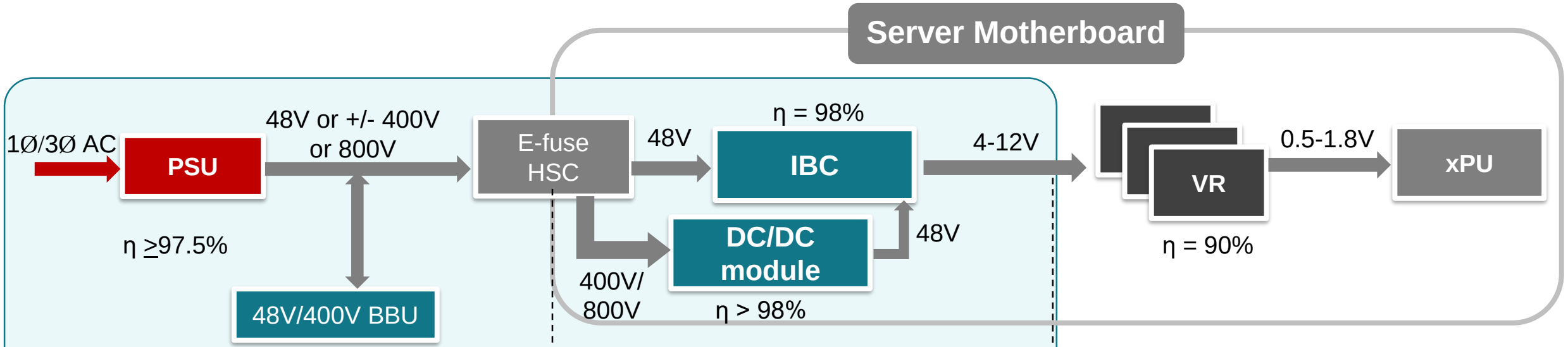




2027 onwards

TI GaN portfolio

TI solutions from Grid to Gate– Gen 2 & 3 architectures



PSU(AC/DC + DC/DC)* + *BBU: (DC/DC)

- 650V GaN integrated power blocks
- 100/170V GaN integrated SRs/ HBs
- Digital controllers: UCD and C2K
- Analog controllers: LM51770, LM5171
- Packages with Thermal enhancements
- Advanced protection / monitoring features; OCP, OTP, ZVD, current sense

IBC: 48V to 4-12V
DC/DC Module: 400/800V to 48V

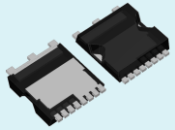
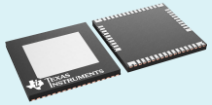
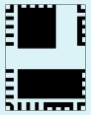
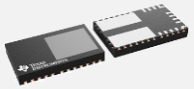
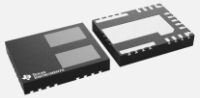
- 650V GaN integrated power blocks
- 100/170V GaN integrated SRs/ HBs
- 40V monolithic SRs
- Digital controllers: UCD and C2K

Multiphase VR

- Monolithic High Current,
- High Frequency Power Stage
- Integrated Power Module

TI-GaN

New GaN power stages for server design

	Integrated high-voltage devices			Integrated mid-voltage devices	
Part #	**LMG3650R0xx**	**LMG352xR0xx**	**LMG265x**	**LMG3100R0xx**	**LMG2100R0xx**
V_{DS-Max}	650V	650V	650V	100V	100V
Rdson	25mΩ,35mΩ, 70 mΩ	26mΩ, 50 mΩ	100mΩ, 140mΩ, 230mΩ	1.7mΩ, 4.4mΩ	2.6mΩ, 4.4mΩ
RTM	All variants- Apr '25 (sampling now)	All variants released	100, 230mΩ- released 140mΩ- Mar '25	All variants released	All variants released
Device type	Integrated driver with FET	Integrated driver with FET	Integrated Half bridge driver with 2 FETs, level shifter and bootstrap	Integrated driver with FET	Integrated Half bridge driver with 2 FETs, level shifter and bootstrap
Features	Integrated low Coss with OCP, SCP, OTP, UVLO, **Fault-reporting**		Integrated HB with OCP, SCP, OTP, UVLO, **Fault-reporting**	Integrated Single FET with UVLO	Integrated HB FETs with UVLO
Package	TOLL 	QFN 	QFN 	QFN 	QFN 
Thermal pad location	Bottom side cooled	Top side cooled	Bottom side cooled	Top side cooled	Top side cooled

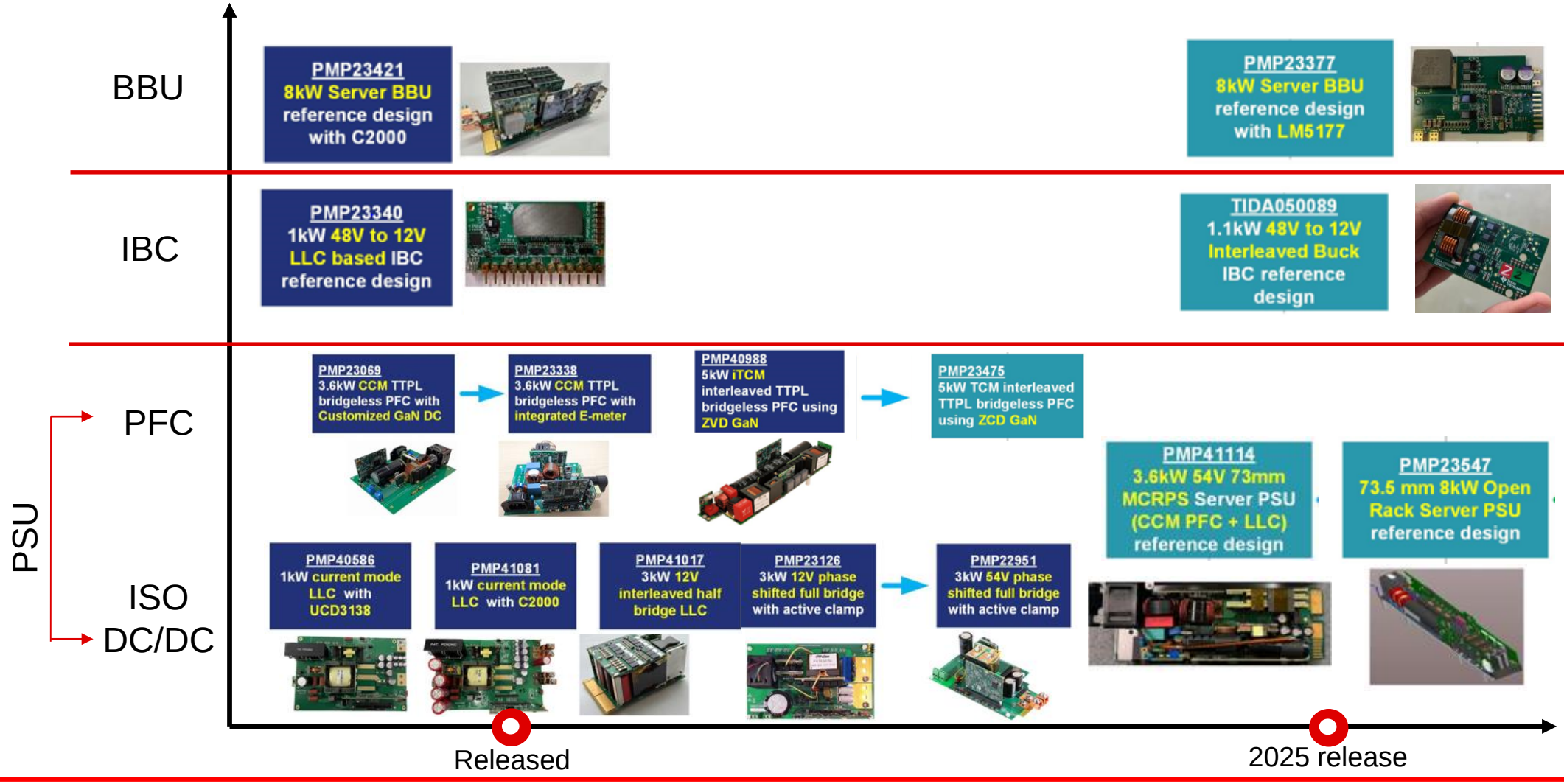
Server subsystems

Reference designs & solutions to key technical challenges

Server PSU, BBU and IBC reference designs

Status

- ≤2024 release
- 2025 designs

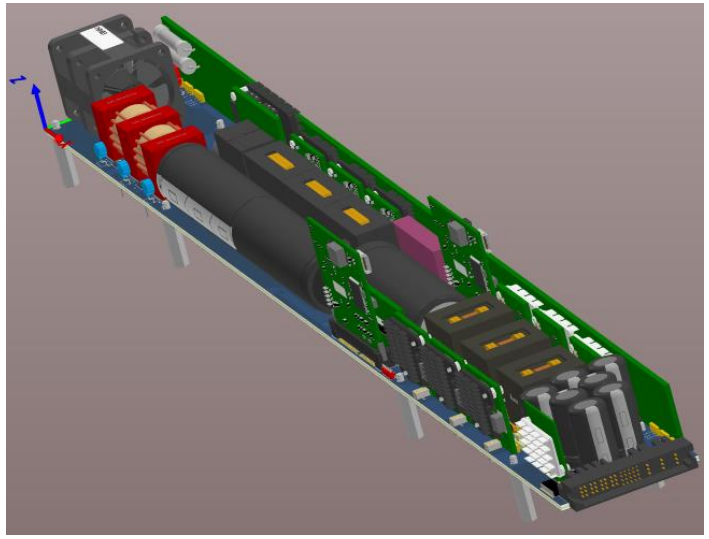


Server PSU

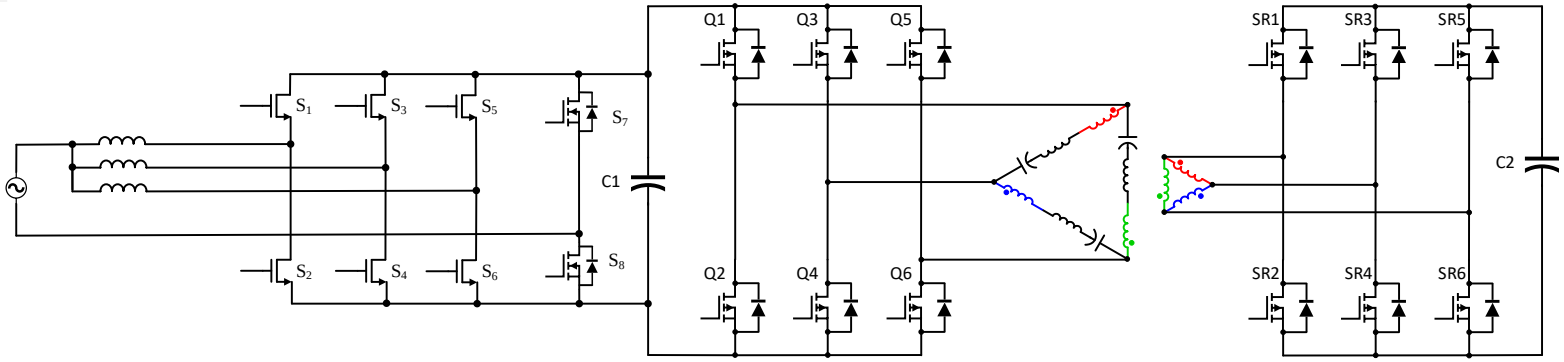
PMP23547 8 kW AI server PSU

Features

- Peak efficiency 97.5% with fan
- Δ-Δ connected 3 phase LLC
  - 200 kHz – 1.5 MHz
  - Reduced resonant tank currents
  - In/output current cancellation
- 3 phase totem pole PFC
  - ZVS across line and load
  - 70 kHz – 1.2MHz
- 700mm x 68mm x 32mm



Parameter	Specification
AC input voltage	180V to 305V
Output voltage	48V
Output power	8kW
Switching frequency	70kHz – 1.2MHz
Topologies	TCM totem pole PFC 3 phase LLC
Key devices	LMG3526R030 LMG3100R017 TMS320F280039C TMS320F28P550SJ



PMP41114 3.6kW 54V Titanium mCRPS server PSU

Features

- Completed **system level reference design** for Server PSU
- **3.6kW 54Vout, 185mm x 73.5mm x 40mm**
- **80 Plus Titanium efficiency**
- **CCM TTPL PFC + FB LLC + ACF Flyback (GaN in all stages)**
- Ultra **compact (70mm x 25mm x 40mm) LLC module** with PCB windings
- Fully functioning demo with OCP mCRPS

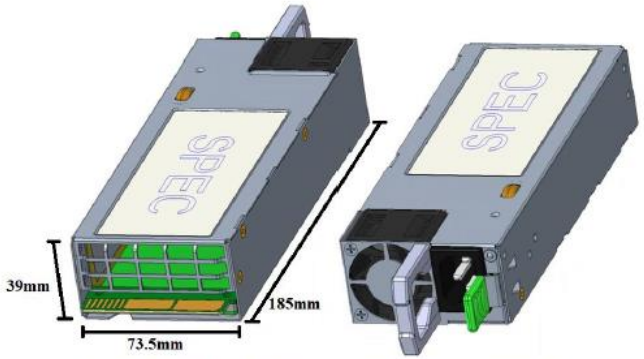
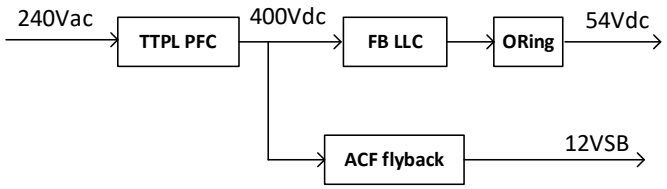


Figure 2-2 185mm by 73.5mm in width form factor outline



OPEN Compute Project

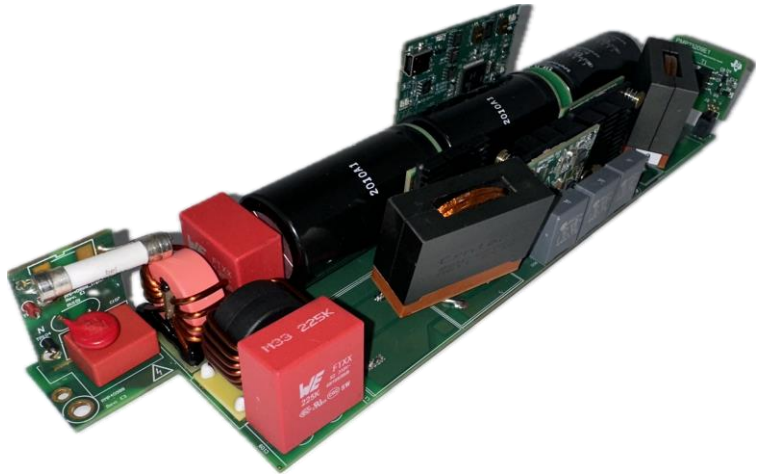
Modular Hardware System-
Common Redundant Power Supply
(M-CRPS) Base Specification

Parameter	Specification
Input voltage range	$90V_{AC}$ ~ $264V_{AC}$, 47Hz ~ 63Hz
Output voltage	54 VDC +/- 0.2V
Rated power	3.6kW /67A
Over power	115% >20s @200Vac 155% >15ms @240Vac 165% >100us @240Vac
Dynamic loading	54V -/+8% @100% 1A/us 54V -/+5% @50% 1A/us
Current sharing	<2%@100% load
ORing	54V DC keep in regulation @ 1+1 redundant, 1 set fault to shortage
IC	PFC: • F280023, LMG3522 LLC • F280039C, LMG3650, LMG3100, ACF: • UCC28782, LMG2610

PMP23475 Variable-frequency, ZVS, 5-kW, GaN-based, totem-pole PFC reference design

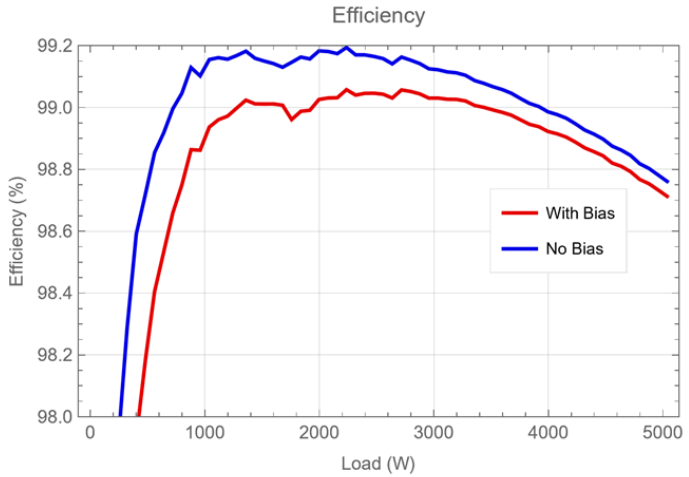
Features

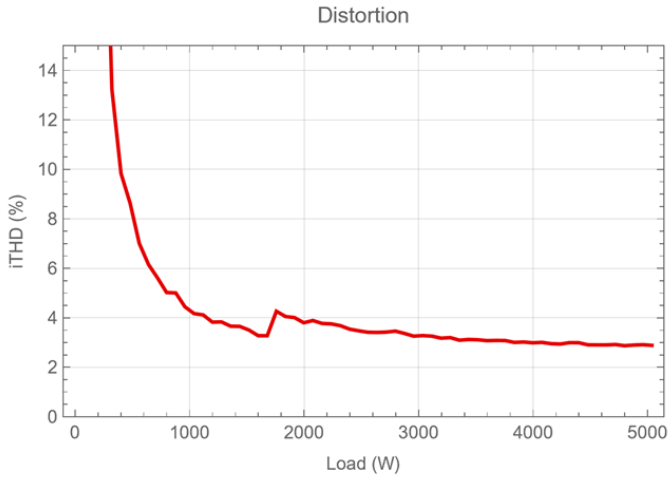
- Efficiency greater than 99.1 %
- Full load iTHD < 4 %.
- Full ZVS across line and load
- No additional current sensing for ZCD control
- Novel feedforward algorithm for ZVS and iTHD



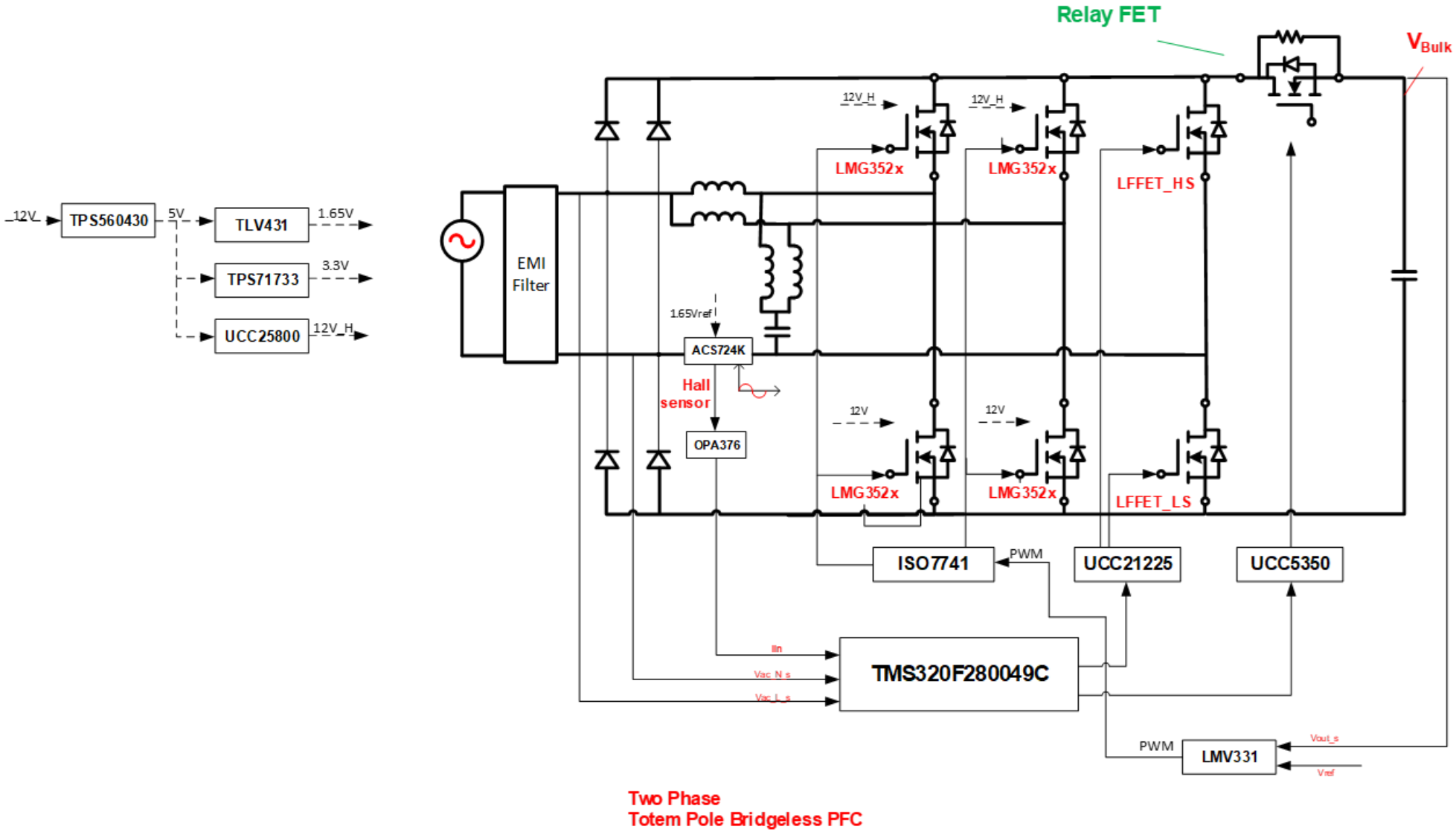
Parameter	Specification
AC Input voltage	180 V to 264 V
Output voltage	400 V
Output Power	5 kW
Switching frequency	70 kHz – 1.2 MHz
Topology	TCM Totem Pole PFC
IC	LMG3526R030 TMS320F280039C

Commit: 388ab6febb986e7d7d185850daf13dda9e5cf42a , $V_{ac,rms}$ = 229.5 V



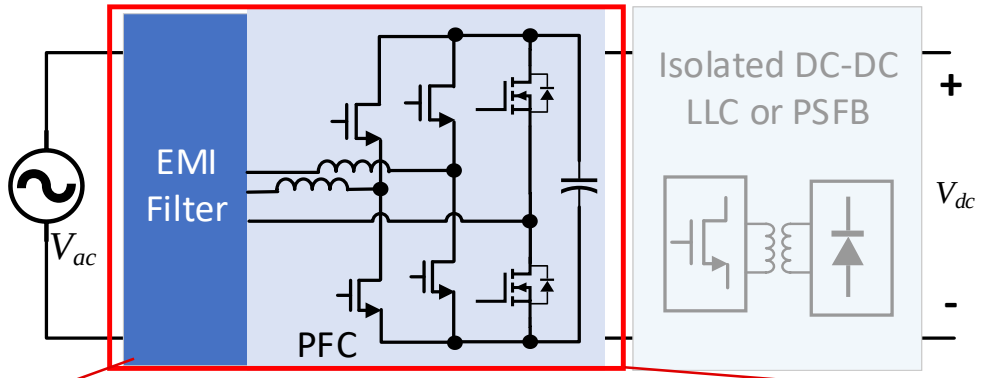


Block diagram with key TI parts



Two Phase
Totem Pole Bridgeless PFC

Improving efficiency / density trade-off with iTCM

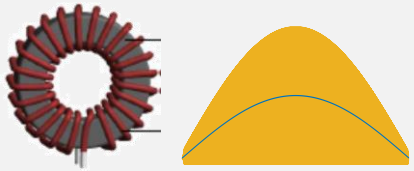


Totem-pole PFC + WBG devices

CCM PFC

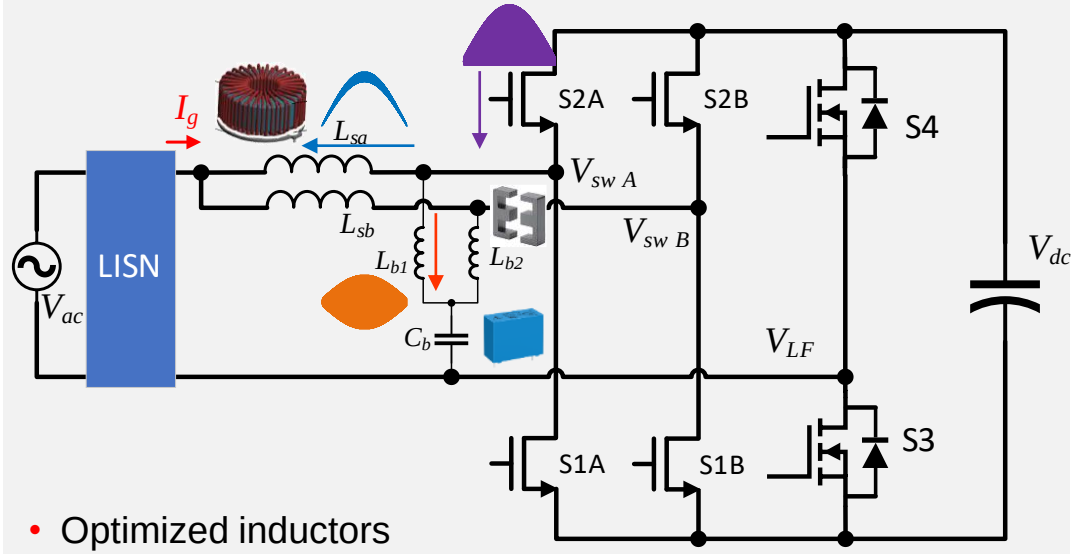
- Hard switching
- Larger passive component
- Power density / loss trade-off
- Frequency limited
- Requires WBG devices

TCM/CRM PFC



- Soft switching
- Higher density **or** efficiency
- Large ripple, high peak current and larger DM EMI
- Complexed control / higher THD

iTCM* totem-pole PFC



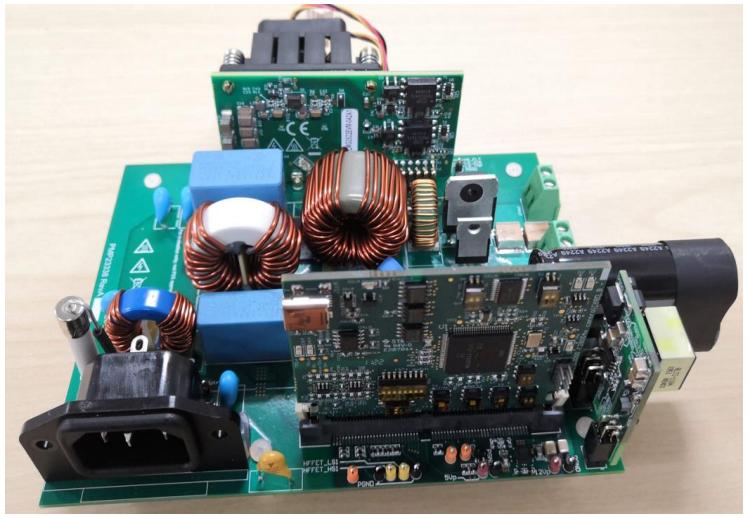
- Optimized inductors
  - HF inductor (ferrite) - no high peak currents
  - LF inductor (powder iron) - no large ripple
- Lowest DM EMI as HF ripple bypasses LISN
  - Reduces EMI filter size, Ls forms part of DM filter
- Increased magnetics component count, but each component smaller and easier to fit in 1U design
- Cb need to be X-cap rated and is rms current limited

*10kV SiC-based bidirectional soft-switching single-phase AC/DC converter concept for medium-voltage Solid-State Transformers https://ieeexplore.ieee.org/document/7972488

PMP23338 high power density TTPL bridgeless PFC design

Features

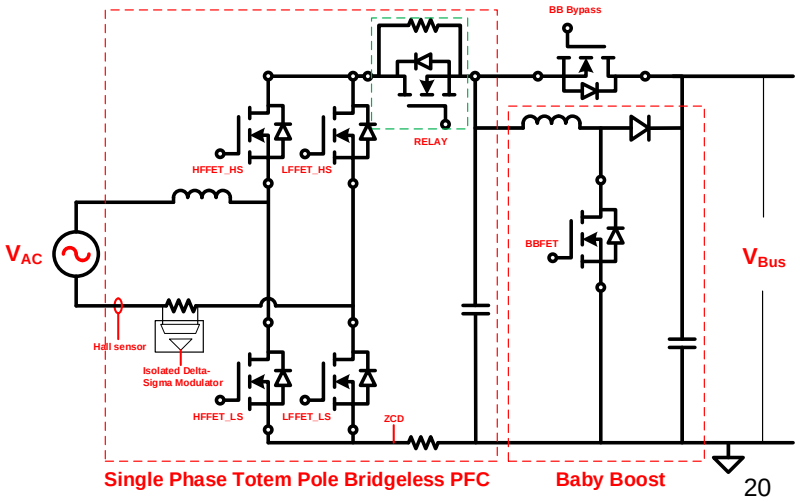
- >180W/in³ power density
- Single current sensor for both PFC control and e-metering
- Integrated e-meter function with <0.5% accuracy
- Peak efficiency of 98.93%
- Includes baby boost to extend holdup time and reduce Bulk Cap
- Re-rush current control when AC comes back from dropout
- Extreme low THD
- Meet the M-CRPS spec



Parameter	Specification
Input voltage	85-265 VAC
Output voltage	385VDC
Output power	3.6kW
Topology	Totem-pole PFC
IC	LMG3522R30, AMC1306, TMS320F28003x, TMCS1133, UCC27712, TPSM863252, UCC21220

2 current sensing options:

- *Hall-effect current sensor*
- *Isolated Delta-Sigma modulator*



For test report, design files, and more:
www.ti.com/tool/PMP23338

To order the EVM online-
https://www.ti.com/tool/PFC23338EVM-107

PMP23338 e-meter test results

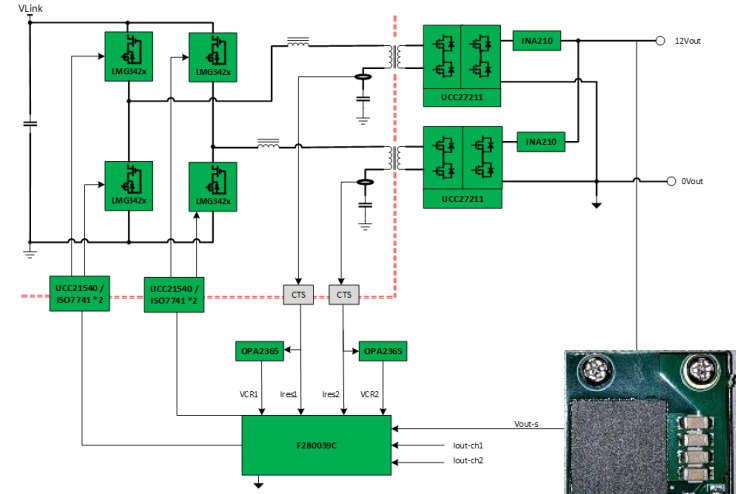
	Pin(W)					
Vin(V)	meter	PMP23338	abs(error)(W)	error spec (W)	error(%)	error spec(%)
	27.28	27.18	0.1	5		
	58.55	58.51	0.04	1.25		
	124.99	125.2	0.21	1.25		
	246.4	246.9	0.5	2.46	0.20	1
	499.2	500.3	1.1	4.99	0.22	1
	754	755.5	1.5	7.54	0.20	1
	1021.5	1023.5	2	10.22	0.20	1
	1269.1	1271.1	2	12.69	0.16	1
115	1507.1	1509.2	2.1	15.07	0.14	1
	26.36	26.32	0.04	5		
	57.34	57.45	0.11	1.25		
	122.47	122.71	0.24	1.25		
	493.9	494.4	0.5	4.94	0.10	1
	1007.9	1009.3	1.4	10.08	0.14	1
	1512.2	1514.6	2.4	15.12	0.16	1
	2018.4	2021.6	3.2	20.18	0.16	1
	2526.3	2530.7	4.4	25.26	0.17	1
230	3037.4	3042.1	4.7	30.374	0.15	1

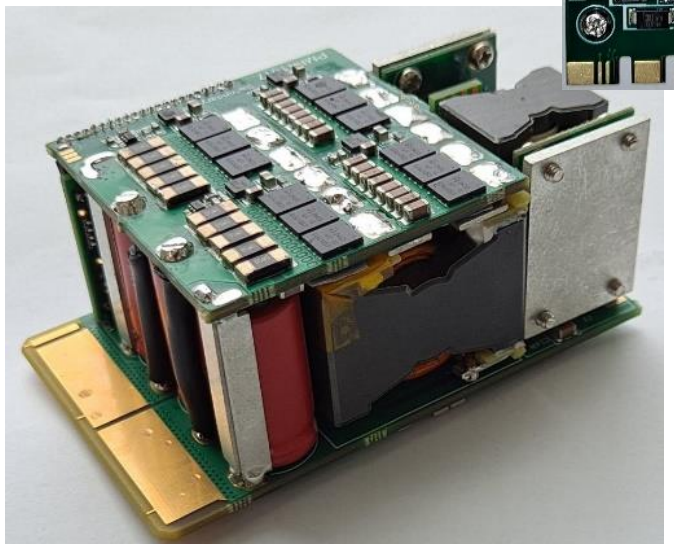
(>125W – Max load/Peak Power)		
Accuracy (50W - 125W load)	+/-1.25W	
Accuracy (<50W load)	+/-5W	
System polling rate	1 sample/ second	10 samples / second

PMP41017 3kW interleaved half-bridge LLC converter

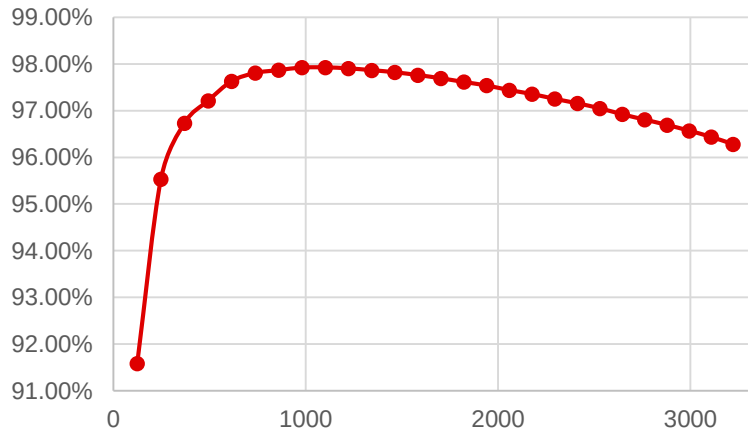
Features

- 3kW two phase interleaved LLC design
- GaN-based high efficiency of **~98.0% (peak)**
- Low ripple current on the output E-cap
- CRPS standard form factor:
  - **W64mm x H35mm x L70mm**
- High power density of **313 W/in^3**
- Output voltage in +/-5% regulation with 50% 2.5A/uS load transient





Parameter	Specification
Input voltage	350V to 450V
Output voltage	12V
Output current	260A
Switching frequency	100kHz
Topology	Interleaved half-bridge LLC
IC	TMS320F280039C LMG342x



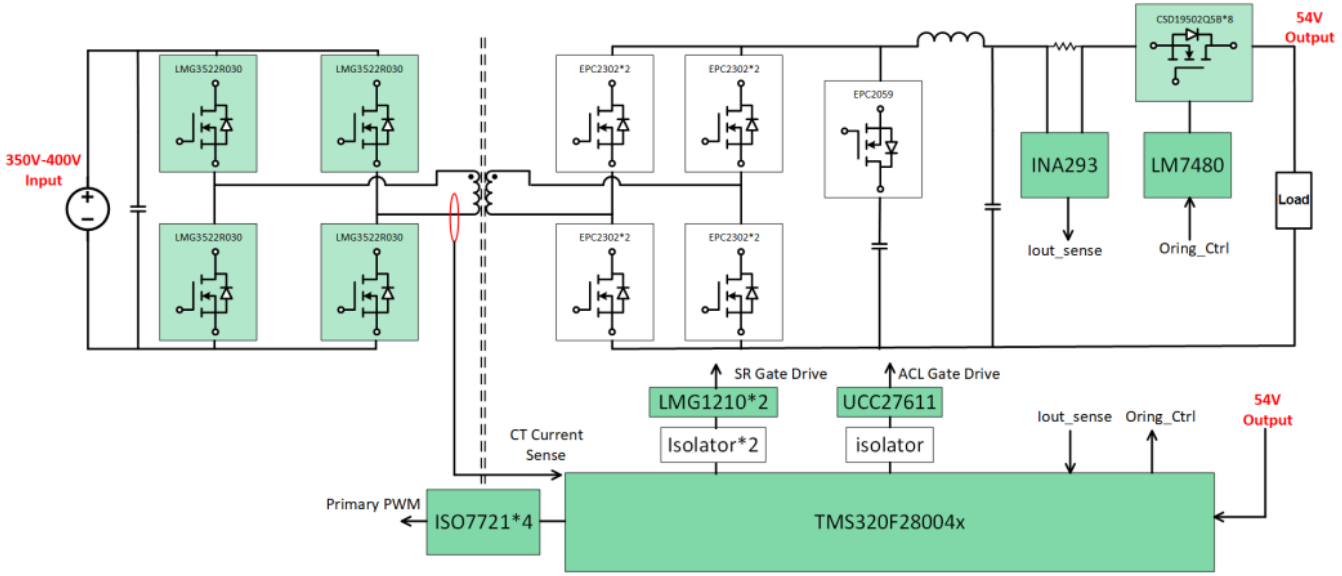
For test report, design files, and more:
https://www.ti.com/tool/PMP41017

PMP22951 54V 3kW phase-shifted full bridge with active clamp

Features

- Peak current mode control for fast transient response
- Peak efficiency of 97.45% at 385V input
- Active clamp for minimizing voltage stress on SR MOSFETs enabling use of better FoM devices
- All GaN solutions enabling better efficiency at light-medium loads while eliminating reverse recovery loss in secondary

Parameter	Specification
Input voltage	350V – 400V
Output voltage	54 V
Output current	56 A max
Switching frequency	140 kHz



PSFB With Active Clamp Block Diagram

For test report, design files, and more:
https://www.ti.com/tool/PMP22951

Intermediate bus converter (IBC)

PMP23340 1/8 brick, 1.1kW medium voltage GaN module

Features

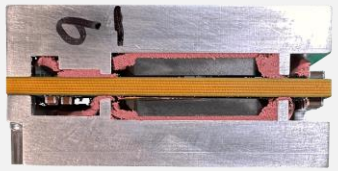
System specifications:

- Output: 10-15V
- DC input: 40-60V (48V nominal)
- Sw. frequency: **1MHz**
- Topology: Full bridge open loop LLC
- Form factor: **22.9mm x 58.4mm**
- Protections: OCP, OTP, OVP and UVLO
- Peak efficiency: **97.7%**

Typical application

- Enterprise and Telecom Server 48-12V conversion

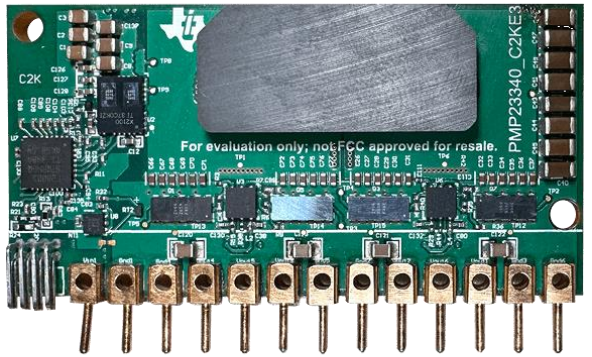
Tools & resources

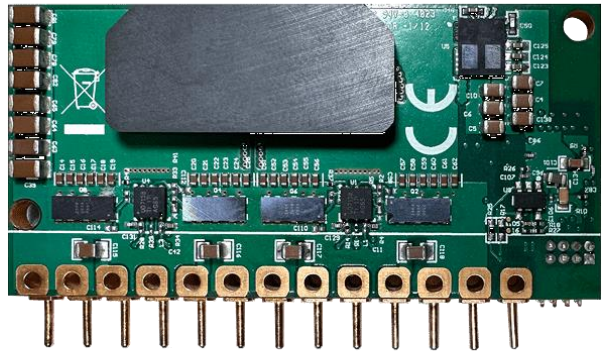


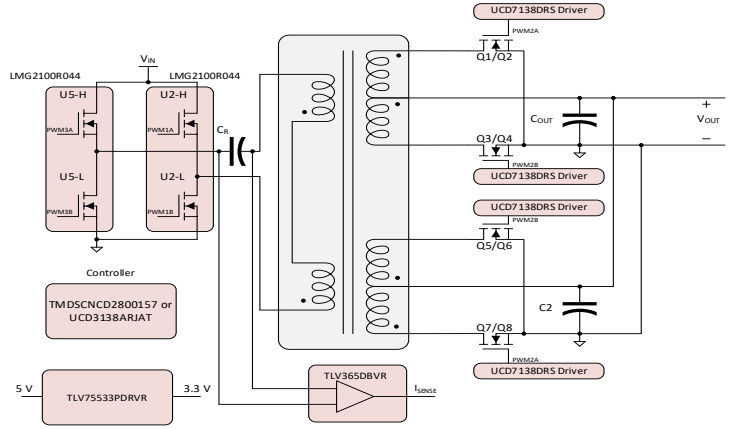
- **Design files:** Schematics, BOM, Gerber, GUI for parameter management for the controller
- **Device datasheets:**
  - LMG2100R044
  - UCD3138
  - F2800157

Benefits

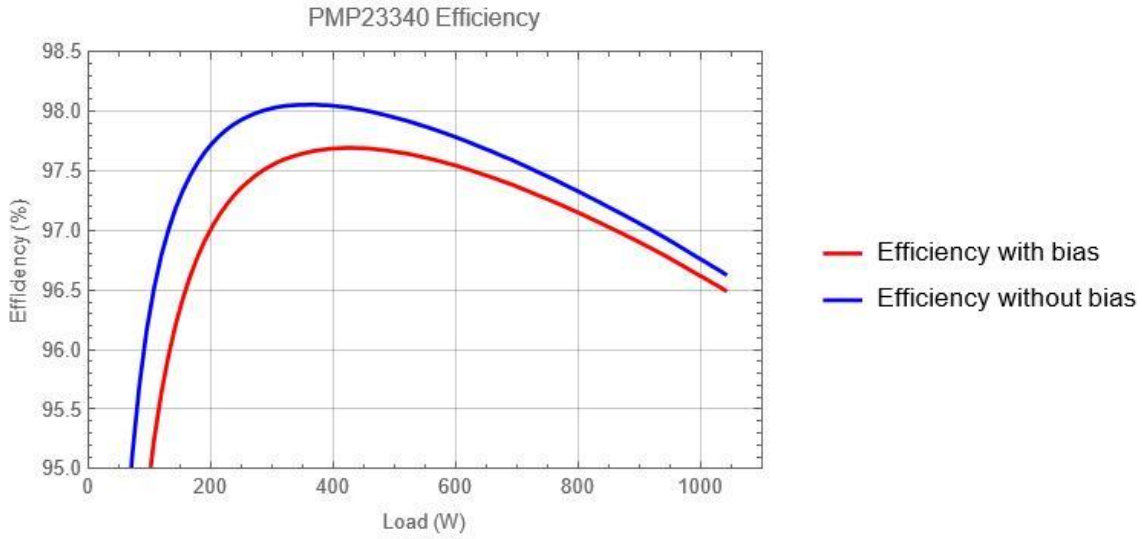
- High power density **>1.4kW/in^3** with a high peak and full load efficiency (~96.5%)
- Integrated half bridge GaN based design at high switching frequency enables planar transformer design increasing power density
- 2 versions available : with UCD3138 and C2000 microcontroller (F2800157)

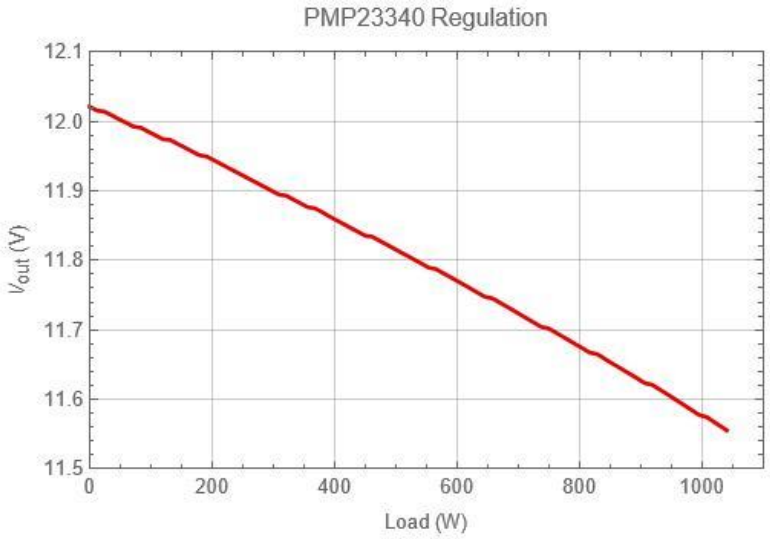


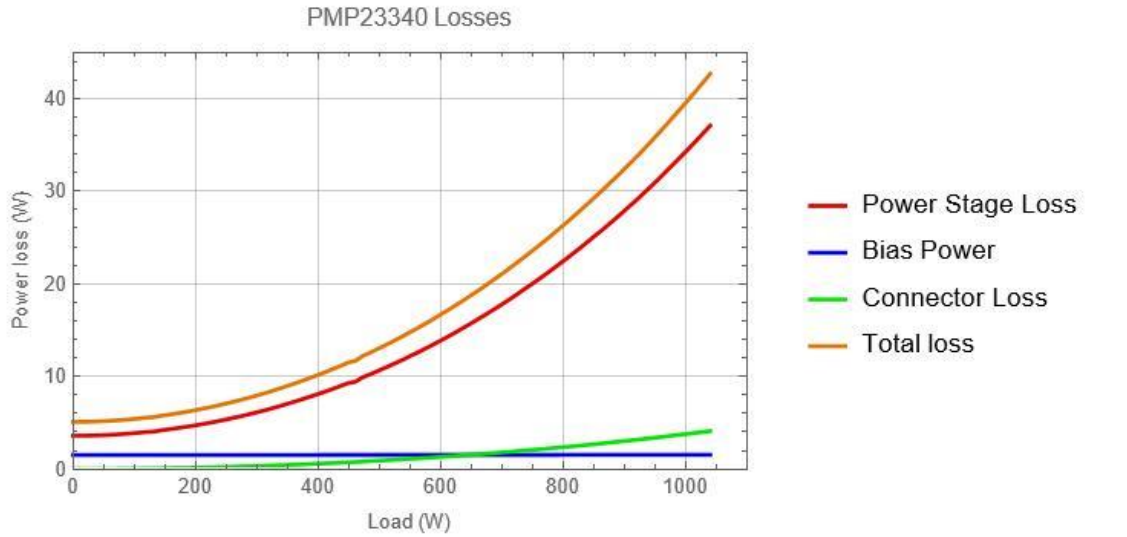




Efficiency & loss data – measured data







Bias power includes:
- Microprocessor power
- Gate drive loss

Efficiency curves do not include connector losses

TIDA050089-v1 2 phase bidirectional power converter, 1/4 brick, 1.1kW medium-voltage GaN

Features

System specifications:

- Output: 12V
- DC Input: 40-60V (48V nominal)
- Sw. frequency: **200kHz**
- Topology: 2 Phase Interleaved Buck (48-12V) & 2 Phase Interleaved Boost (12-48V)
- Form Factor: **36.8mm x 58.4mm x ~18mm**
- Protections: OCP, OTP, OVP and UVLO
- Peak Efficiency: **~98%**

Typical application

- Enterprise and Telecom Server 48-12V conversion

Tools & resources

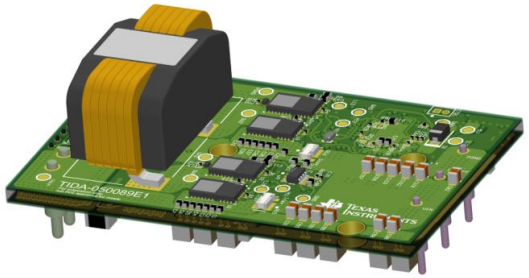
Design files: Schematics, BOM, Gerber, GUI for parameter management for the controller

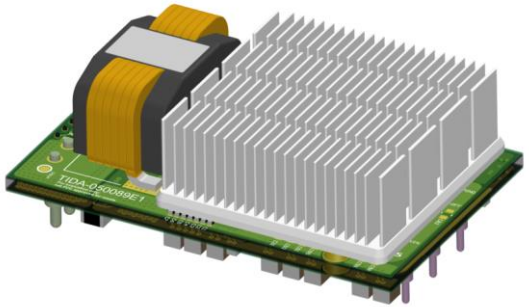
Device datasheets:

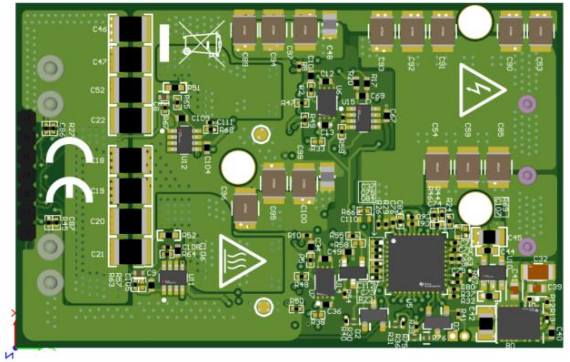
- LMG3100R017 x 4
- UCD3138A x1

Benefits

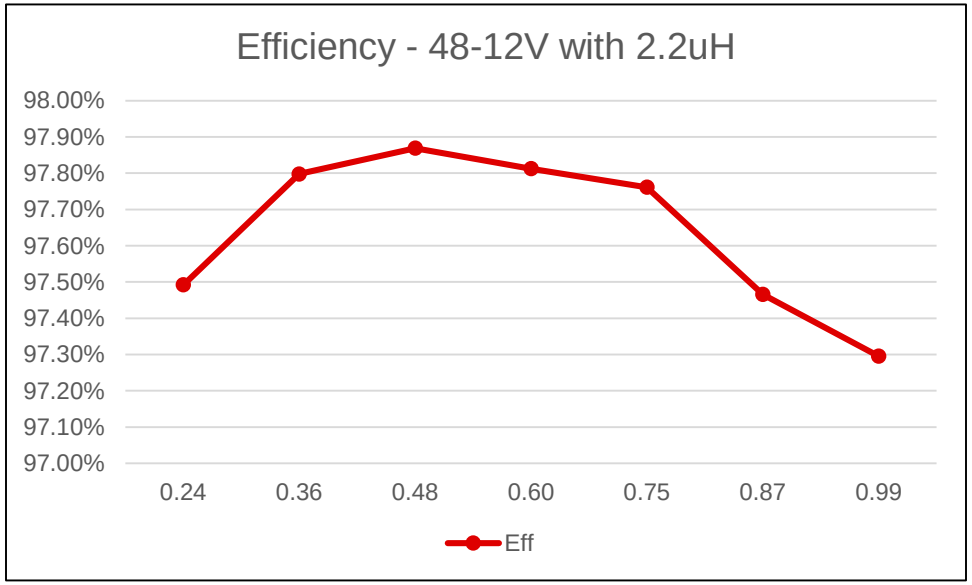
- High power density with a high peak and full load efficiency of ~97%+
- Transformer-less regulated topology with high peak and full load efficiency
- Easy to implement in a chip down design

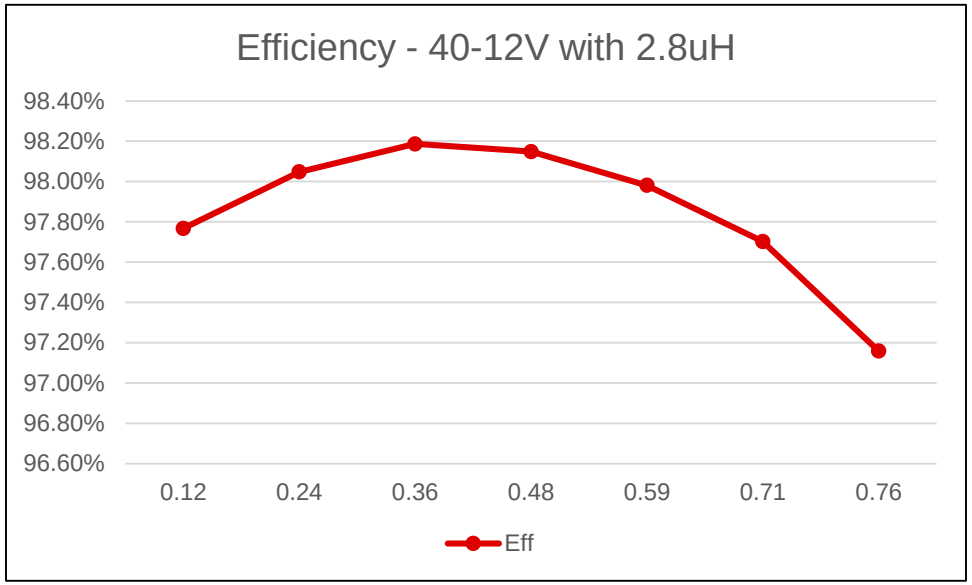


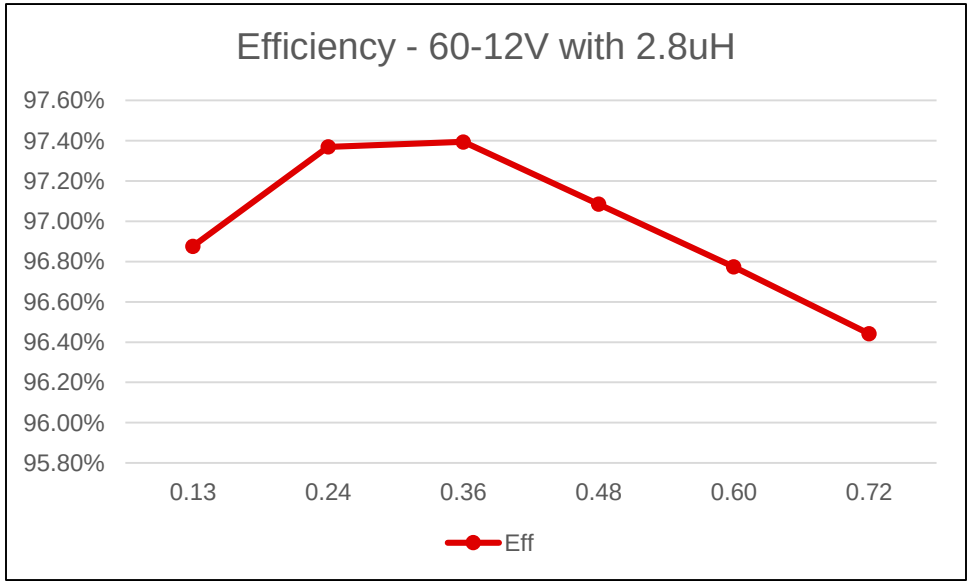




Efficiency – TIDA-050089







~98% peak eff. at 48Vin
>98% peak eff. at 40Vin
>97.4% peak eff at 60Vin

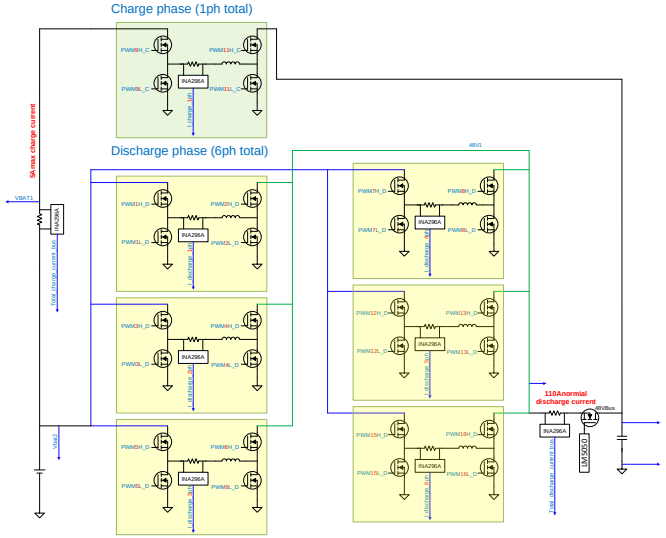
Battery backup unit (BBU)

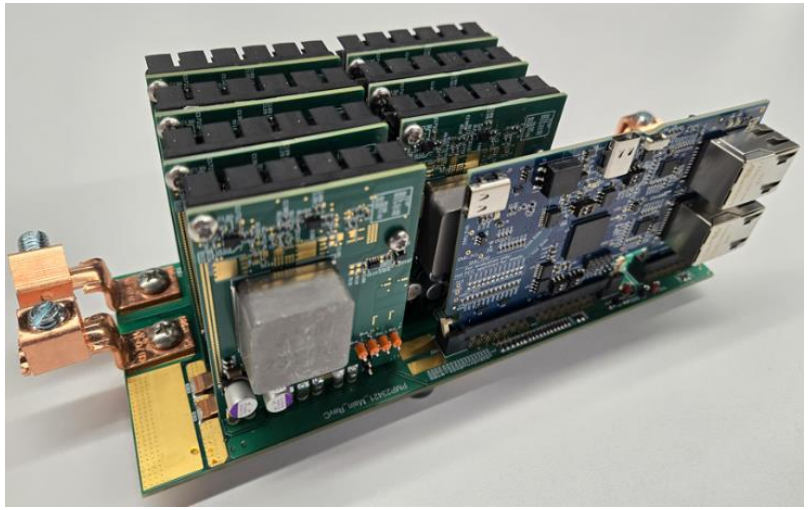
PMP23421 multi-phase 4-switch buck-boost DC/DC converter

Features

- Fully digital controlled
- 6 discharge phases with 8.1kW total discharge power. 1 charge phase
- Peak current mode control, fast load transient
- Multi-mode operation: buck, buck/boost, boost
- Current balancing
- 99% peak efficiency
- Meet Open Rack Base Version 3 (OCP-V3) 50V BBU specification

Parameter	Specification
Input voltage (battery)	28.6V – 54.6V
Output voltage (DC bus)	50V
Output power	8.1kW
Switching frequency	300KHz
IC	TMS320F28P65x, LMG3100, UCC33420, INA296, TLV71333, TLV365, ISO6521





For test report, design files, and more:
www.ti.com/tool/pmp23421

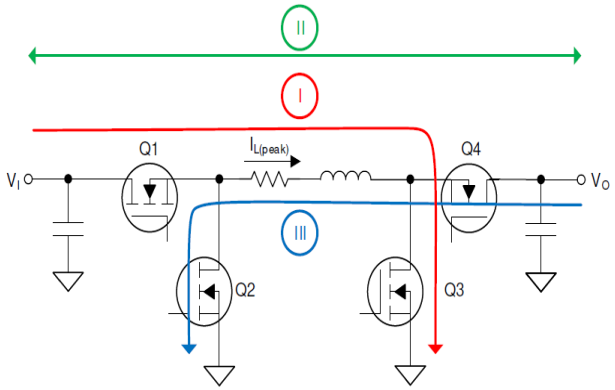
PMP23377B 4-SWs buck-boost by LM5177 + LMG3100

Features

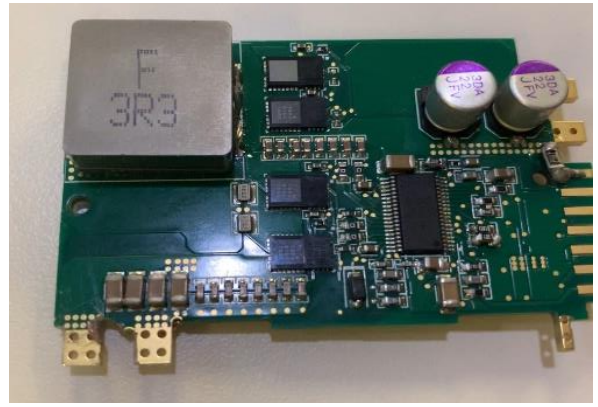
- Target 36V~56V Vi, 50V Vout, 4-Switch buck boost converter by LM5177 for bi-directional BBU(Target to ORV3)
- Peak efficiency >98.5% by using LMG3100 GaN power stages
- Power capability : 1200W each board, total 5 PCS in parallel could achieve power to 6000W

Parameter	Specification
Input / output voltage	36V~56V / 50V
Output current	Maximum: 24A
Output power	1200W
Board dimensions	L x W : 55.8 mm x 37.1mm Thickness : 16mm
IC	LM5177
Inductor	3.3uH molding choke
Switches	LMG3100 x 4

Schematics



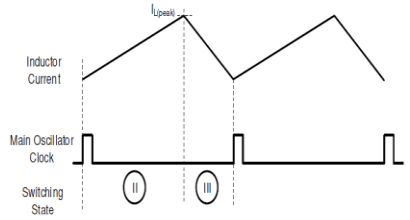
Placement



3 convert modes configure by LM5177

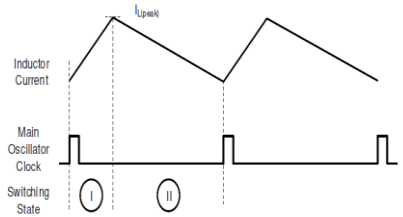
Switch	State I	State II	State III
Q1	ON	ON	OFF
Q2	OFF	OFF	ON
Q3	ON	OFF	OFF
Q4	OFF	ON	ON

Buck mode



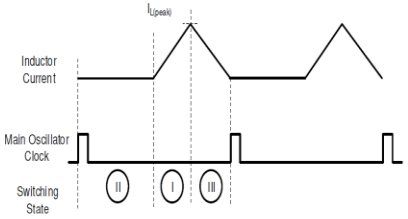
State II → III → Repeat…

Boost mode



State I → II → Repeat…

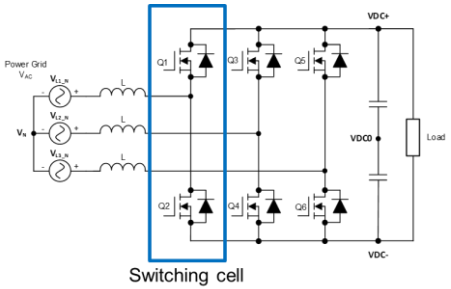
Buck-boost mode



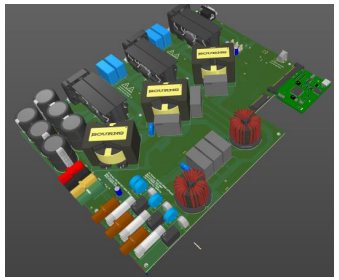
State II → I → III → Repeat…

Generation 3 rectifier designs

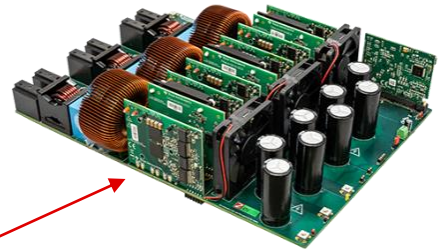
Key 3-Φ rectifier reference design for Gen 3 server



Switching cell

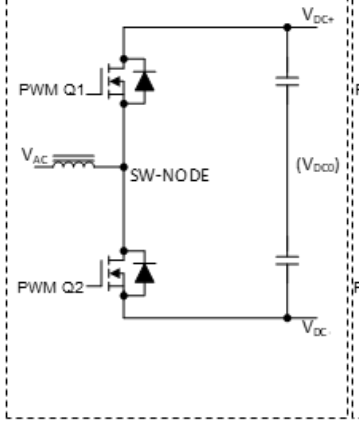
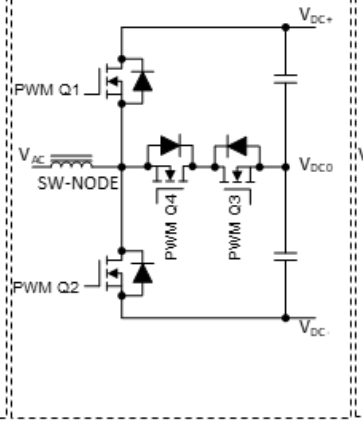
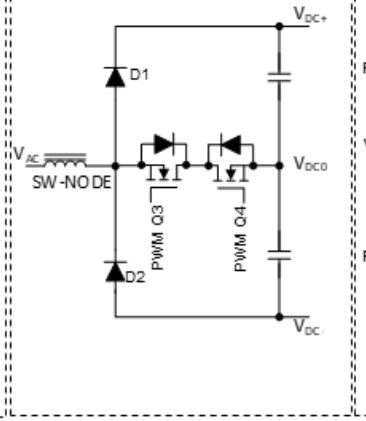
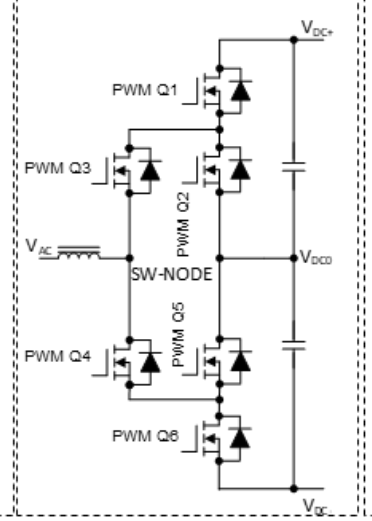
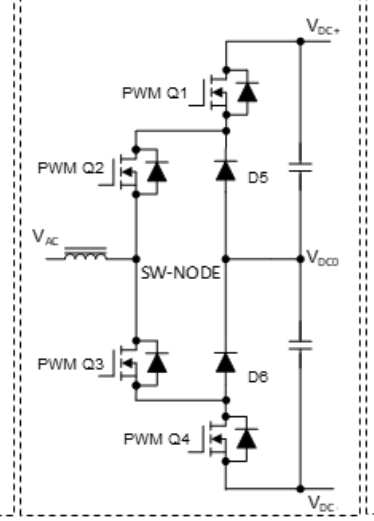
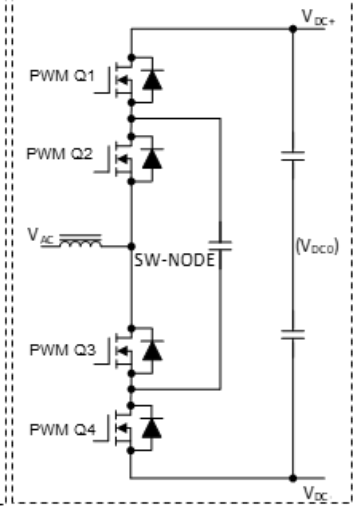


TIDA-01606



TIDA-010210
GaN based ANPC rectifier

Cell options:

2L two-level converter	3L three-level T-type	3L Vienna rectifier	3L ANPC	3L neutral-point clamped (NPC)	FC3L flying capacitor
					

Requires two connections to the DC link

Requires three connections to the DC link

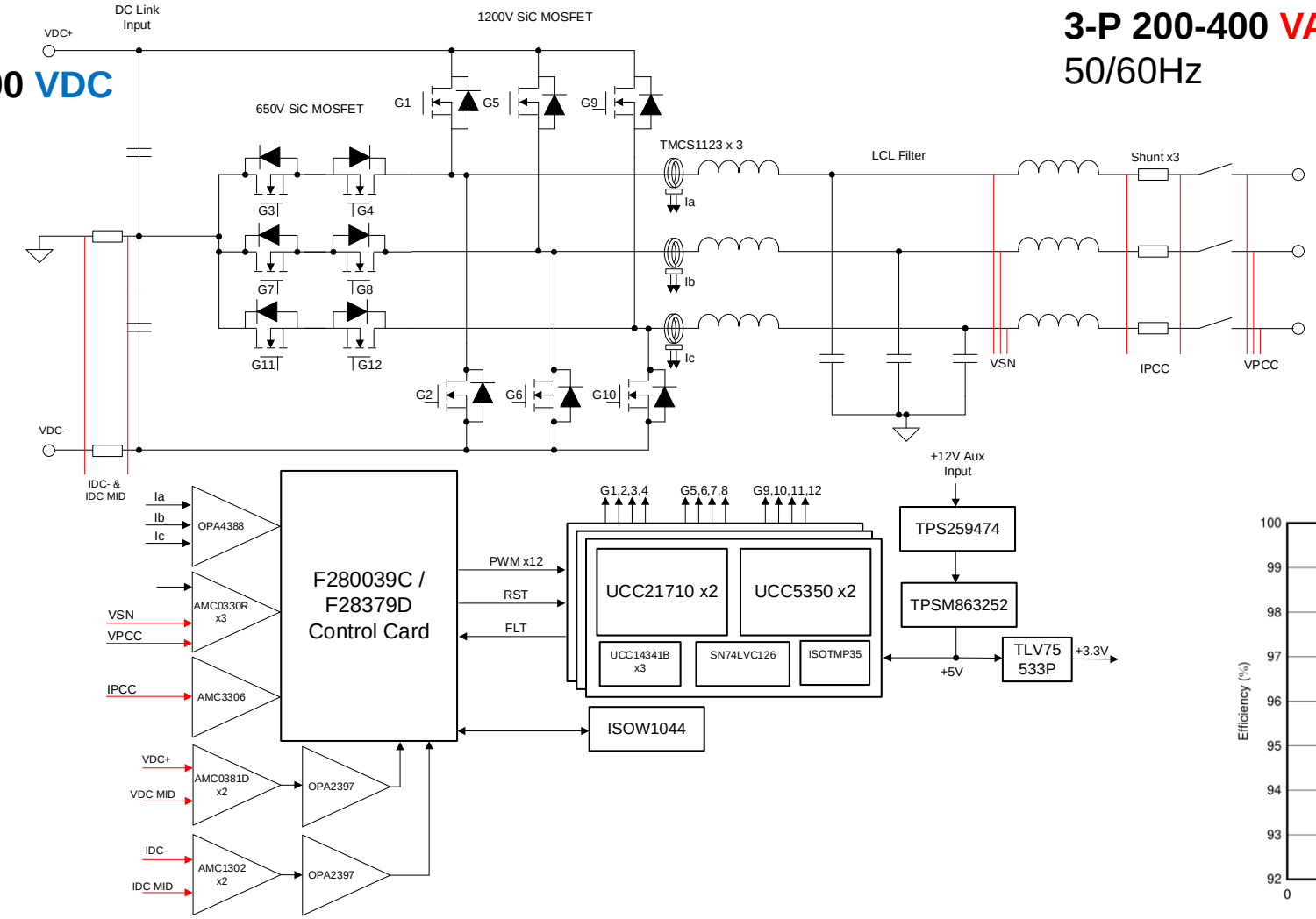
Requires two connections to the DC link

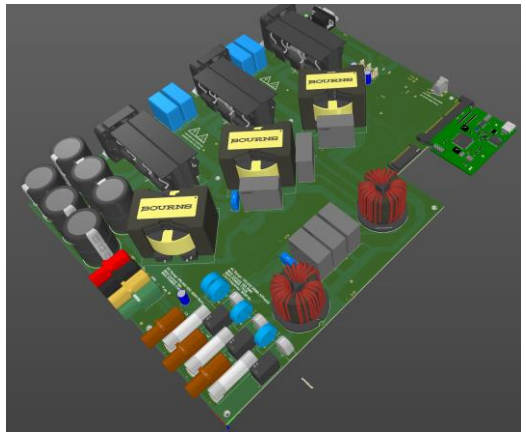
TIDA-01606 11kW T-type/Vienna 3-P, 3-L converter

650-900 VDC

3-P 200-400 VAC
50/60Hz

T-type converter - 75kHz
2-L capable HW (bi-directional)
Vienna capable HW (uni-directional)





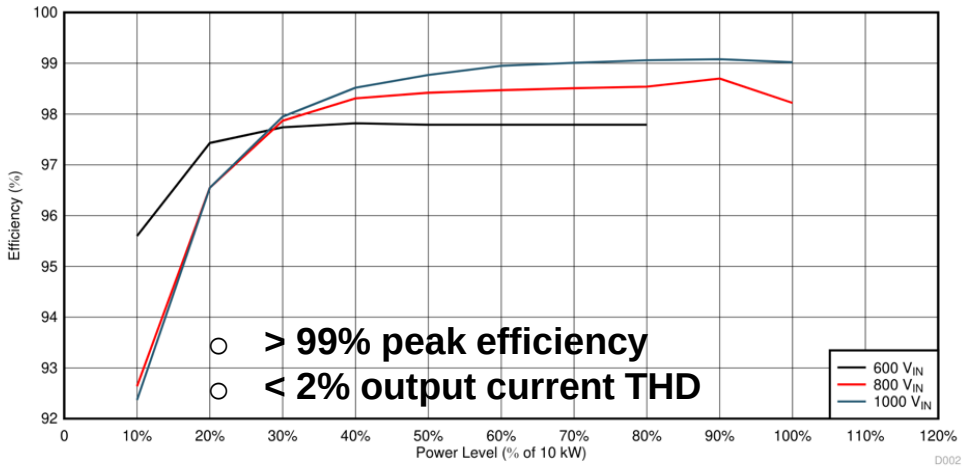


Figure 3-56. Inverter Efficiency

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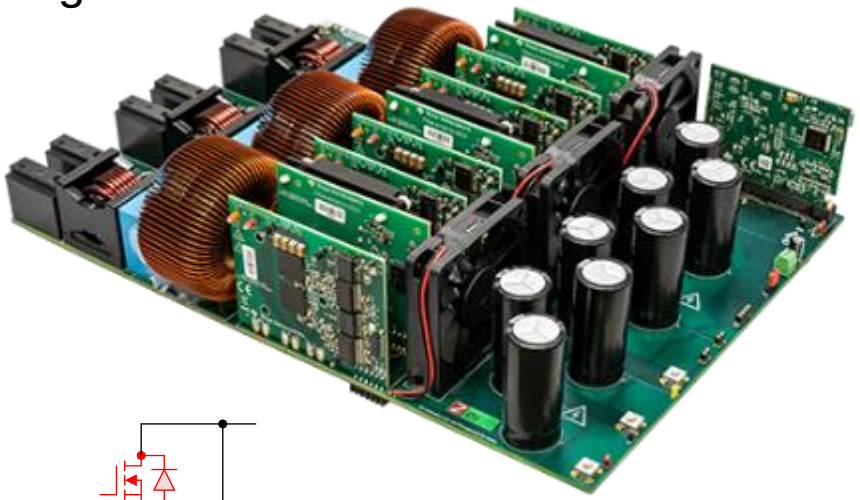
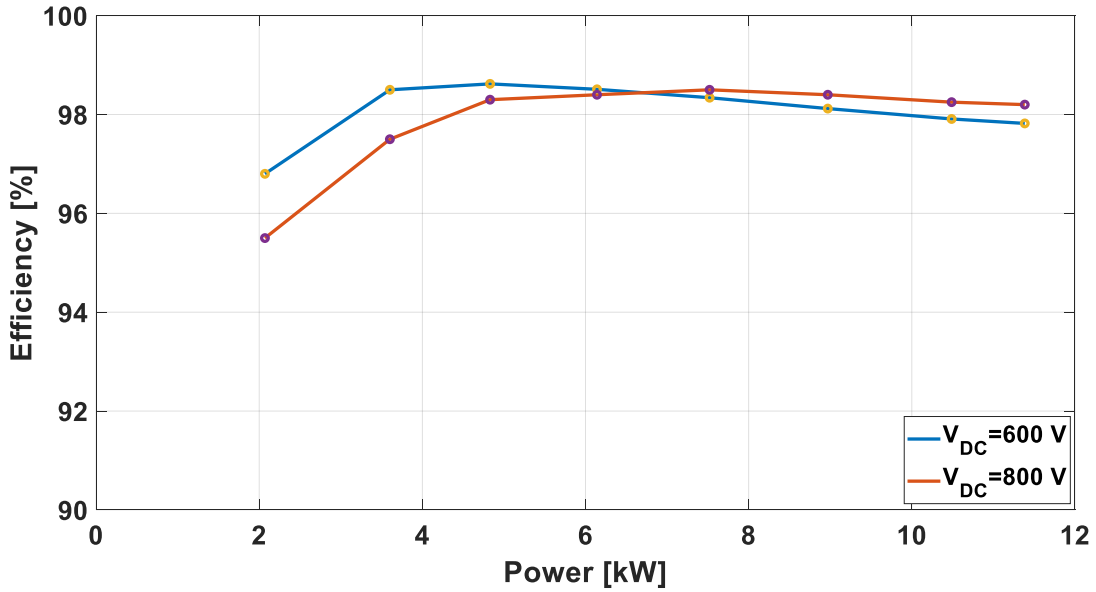
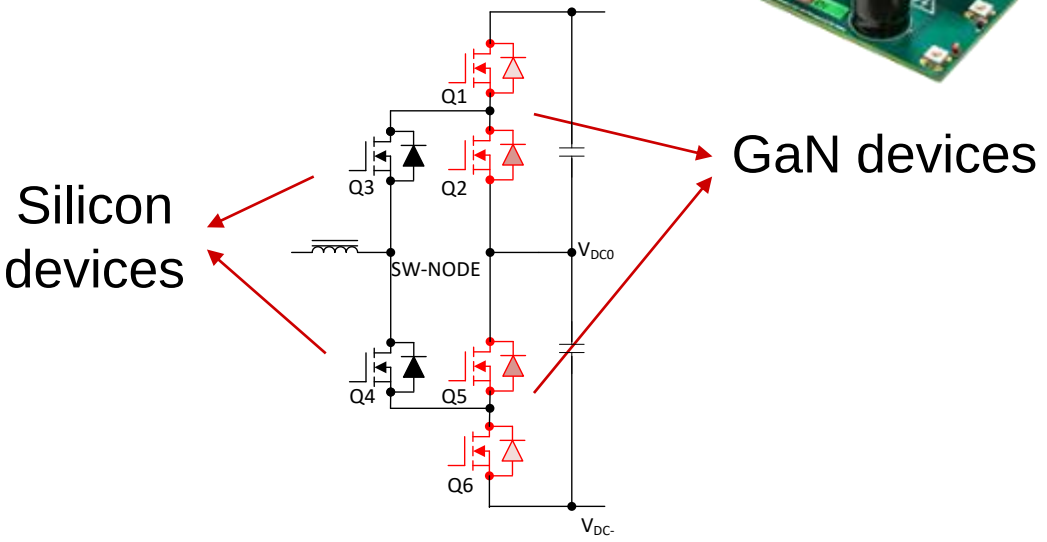
TIDA-010210 – 3-P, 3-L 11kW ANPC

- The 11-kW, bidirectional, three-phase ANPC based GaN reference design includes an 11-kW converter based on GaN devices (100kHz):
  - Low frequency 40mΩ, 600V silicon superjunction MOSFET
  - High-frequency 30mΩ, 600V GaN
- At a higher DC link voltage and low load, efficiency is lower
- At a higher DC link voltage and high load, efficiency is higher







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