OPEN
Compute Project

OCP U.S. SUMMIT 2017

Santa Clara, CA

Flexible & Scalable 48V Solutions Powering Tomorrow's Data Centers

Sean Gold
Maxim Integrated
3/9/2017

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Rack Architectures are Changing from 12V to 48V

Why a New Rack Power Architecture is Needed

Data Centers are Focused on Reducing Energy Consumption

- 2% of Global Electricity use
  - Equivalent Electricity Usage of Italy
- US data centers forecasted to consume 140B KWhrs by 2020
- Rack Power is One of the Largest OpEx Consumers in Data Centers

1

CPU & Memory Consume Most Power in Rack

- CPU & Memory Represent ~80% of Total Server Power
- CPU Power & Dynamic Requirements Continue to Increase

2

New 48V Rack Power Architecture

- Google Introduced a 48V Rack Power Architecture at 2016 OCP Summit to Replace 12V Racks
- Requires New High Efficiency 48V to PoL Regulator for CPU & Memory

3

Racks are Moving from Typically 8kW Today to 20kW by 2020 Timeframe

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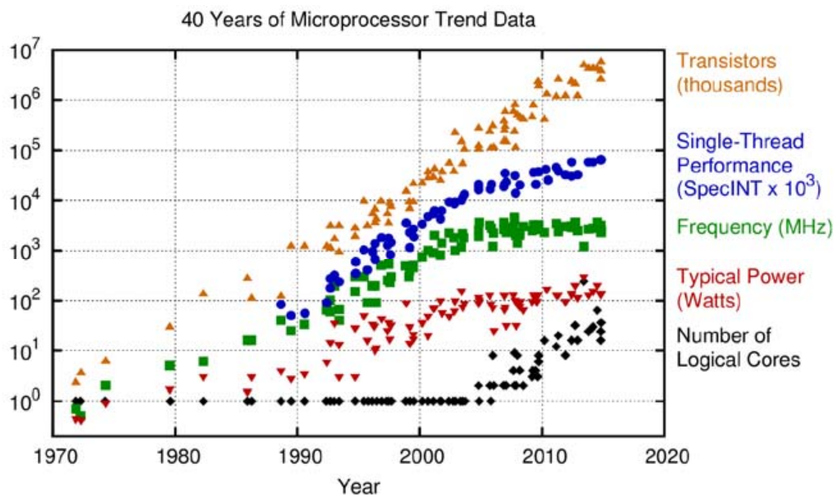
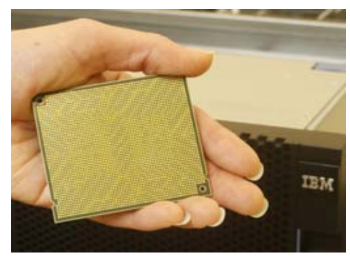
High Performance Silicon Trends

CPUs, GPUs & FPGAs



FPGA Accelerators add 100W +



Open Power P8 with NV Link

GPUs 300W+

Artificial Intelligence, Machine Learning, Big Data, Autonomous Cars & Cloud Computing Driving Rack Power to 20kW+

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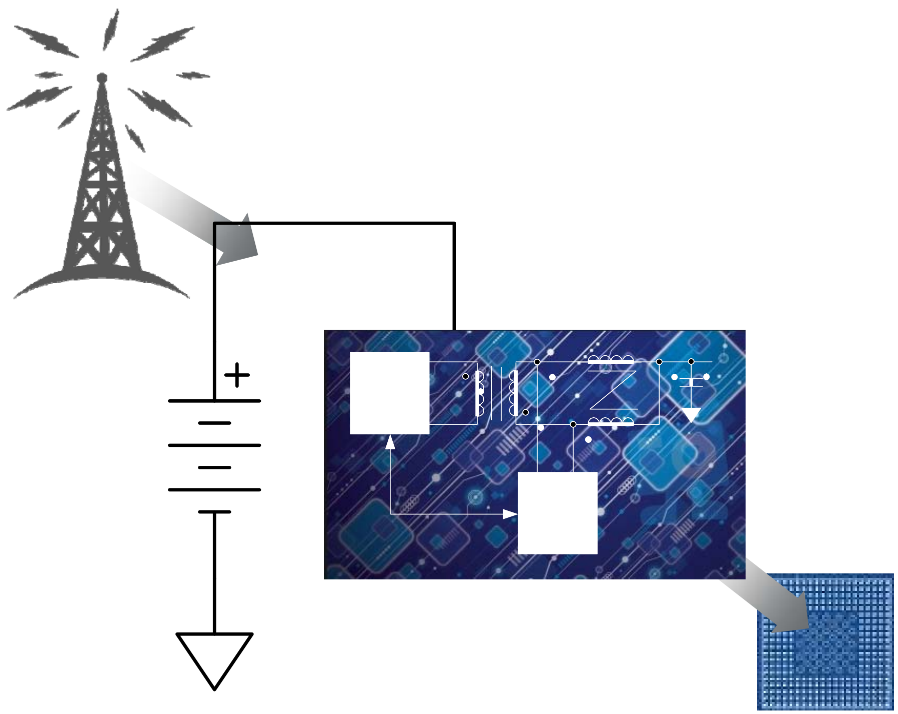
48V to Pol DC/DC Regulator

Challenges & Requirements

- Eliminate a Conversion Step
  - > Direct 48V to PoL DC/DC
- Scalable Output Voltage & Current
  - > CPUs, Memory, GPUs, FPGAs and ASICS
- High Efficiency 48V to 1V
- Cost-Effective

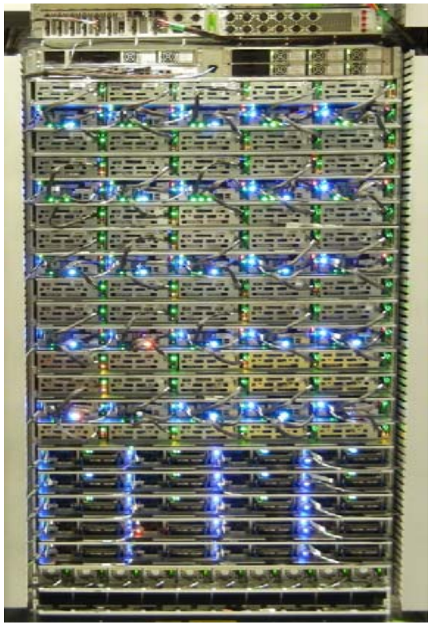


48V OCP Rack

Performance & Features

- Energy Savings Achieved
  > Greater than 20% Less Conversion Losses
  > 16x Less Power Distribution Losses
    - Connectors, Cables, Board
  > Upstream Conversion & Distribution Savings
- Characteristics of Ideal 48V Solution
  > Fast Dynamic Response
  > High Efficiency
  > Scalable & Flexible

48V OCP Rack



Conversion to 48V is Economical for Racks Greater than 12kW

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Maxim Technology & Architecture Advantage

Scalable Single Stage Quick PWM Converter with Proprietary Magnetics & Power Stages

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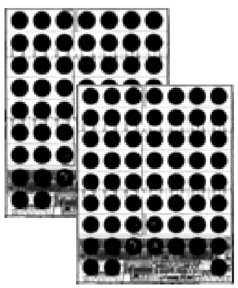
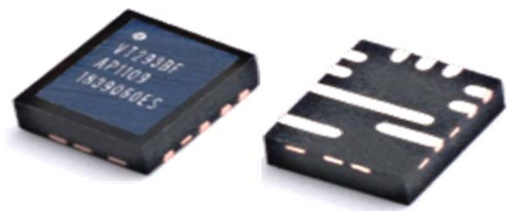
Maxim's Unique Solutions Solve Customer Challenges

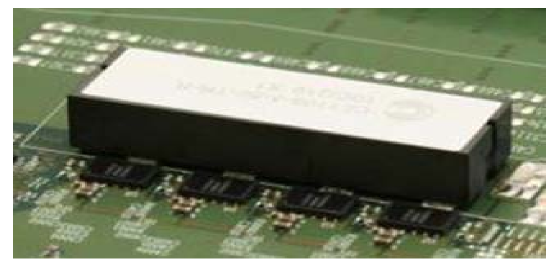
Monolithic Integration



Optimized Power Packaging



Integrated Magnetics



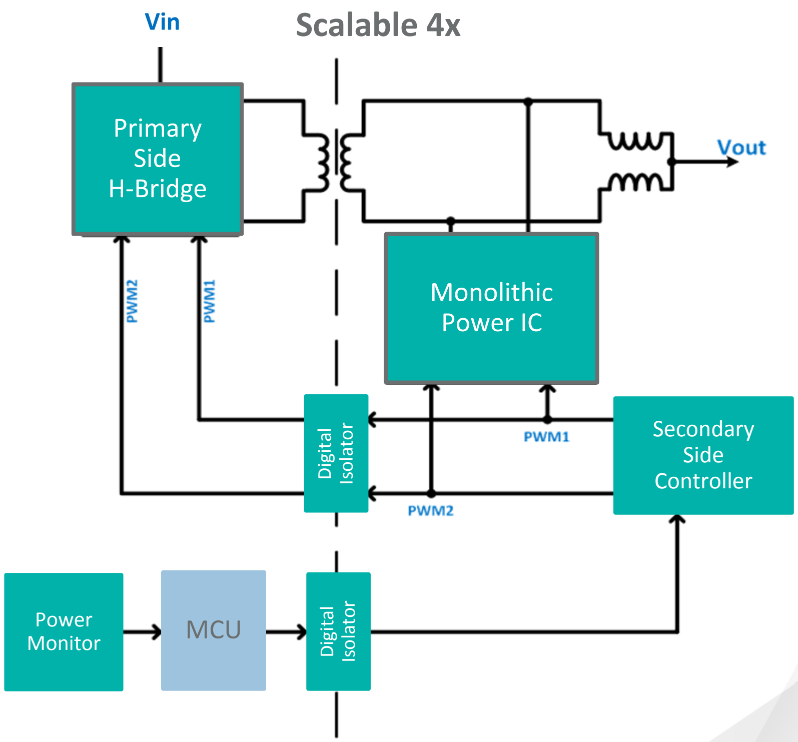
Leveraging Maxim Expertize for 48V Solutions

- 15+ years of Server Power Experience
  > Significant Market Share over Multiple Generations of Server CPU/Memory Power Products at 12V
  > Intimate Understanding of Server Systems & CPU Requirements
- Leveraging Same Core Technology to Implement 48V Solutions
  > Existing 12V Products Leverage Process, Package & Magnetics Expertize
  > Reduce Risk with Maxim’s System & Technology Experience
  > Combination of Unique Technologies Provides Best TCO @ 48V

Scalable Single Stage Quick PWM Converter with Integrated Magnetics & Power

Technology Building Blocks

- Optimized for Efficiency
  - > Monolithic Power Stage with 2 Phases per IC
  - > Integrated Loss-less Current Sensing
  - > Energy Recovery
- Best-in-class transient response
  - > Advanced ISO-Quick PWM Control Architecture
  - > Proprietary Coupled Inductor Technology
- Supports Isolated or Non-Isolated Options



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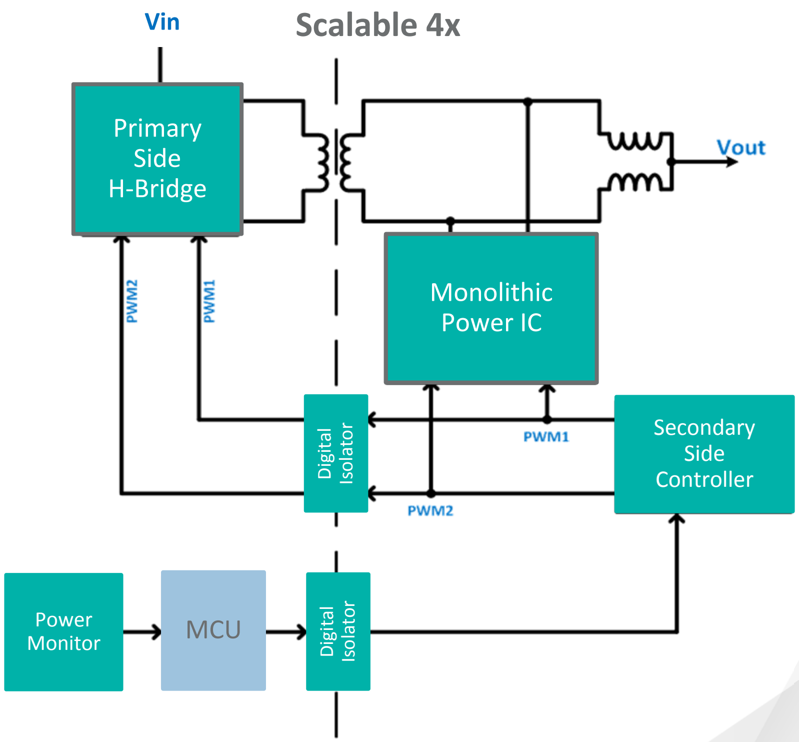
Scalable Single Stage Quick PWM Converter with Integrated Magnetics & Power

- Primary Side HV: 60V ≥ Vin ≥ 40V
- Transformer Ratio 6:1, 10V Secondary
  - > Multiphase System up to 8 Phases
  - > High Load Current per Transformer Stage
- Secondary Side Controller
  - > Drive Up to 4 Scalable Transformer Stages
- Secondary Side Power Stage
  - > Synchronous Rectifier
- Optional Isolator
  - > Primary to Secondary Isolation: 600V – Noise Relief
  - > Fast Response – Sub 15ns Transit Delay



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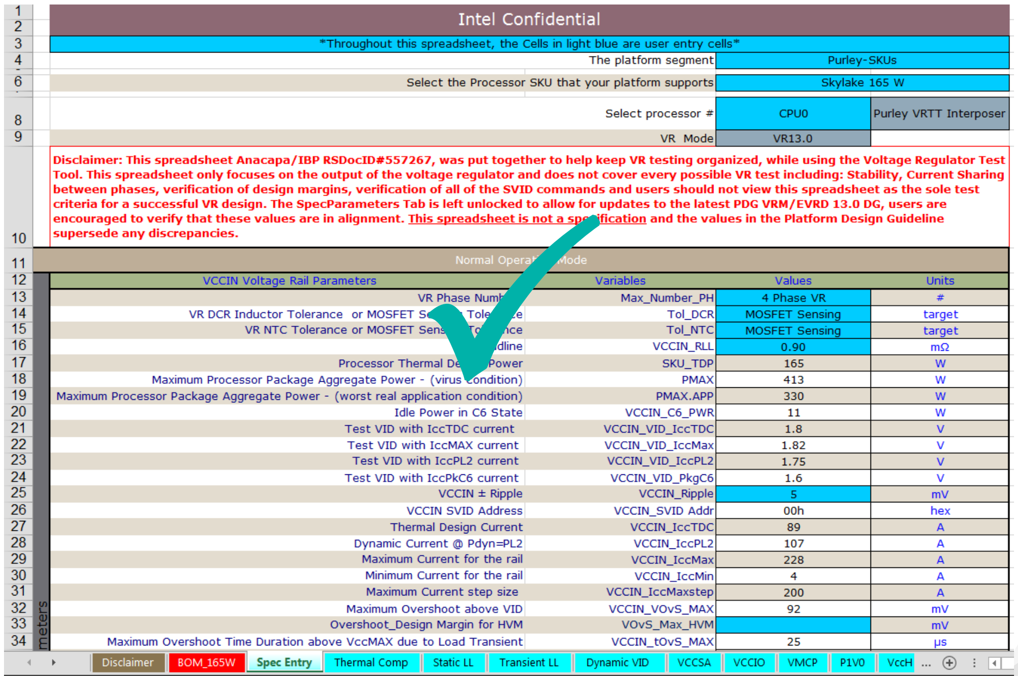
Scalability & Flexibility of Maxim Solution

- Scalability & Flexibility:
  > Simply Add More Stages to Increase Power Level

  > No Tuning Required – Change Output Voltage and Current with No Design Changes

  > Multiple Magnetics Options Available

  > Meets all Intel Specifications



Intel Confidential

Throughout this spreadsheet, the Cells in light blue are user entry cells

The platform segment		Purley-SKUs	
Select the Processor SKU that your platform supports		Skylake 165 W	
Select processor #		CPU0	Purley VRTT Interposer
VR Mode		VR13.0	

Disclaimer: This spreadsheet Anacapa/IBP RSDocID#557267, was put together to help keep VR testing organized, while using the Voltage Regulator Test Tool. This spreadsheet only focuses on the output of the voltage regulator and does not cover every possible VR test including: Stability, Current Sharing between phases, verification of design margins, verification of all of the SVID commands and users should not view this spreadsheet as the sole test criteria for a successful VR design. The SpecParameters Tab is left unlocked to allow for updates to the latest PDG VRM/EVRD 13.0 DG, users are encouraged to verify that these values are in alignment. This spreadsheet is not a spe ification and the values in the Platform Design Guideline supersede any discrepancies.

Normal Operat Mode

VCCIN Voltage Rail Parameters	Variables	Values	Units
VR Phase Numb	Max_Number_PH	4 Phase VR	#
VR DCR Inductor Tolerance or MOSFET Se Tole e	Tol_DCR	MOSFET Sensing	target
VR NTC Tolerance or MOSFET Sens To nce	Tol_NTC	MOSFET Sensing	target
dline	VCCIN_RLL	0.90	mΩ
Processor Thermal De Power	SKU_TDP	165	W
Maximum Processor Package Aggregate Power - (virus condition)	PMAX	413	W
Maximum Processor Package Aggregate Power - (worst real application condition)	PMAX.APP	330	W
Idle Power in C6 State	VCCIN_C6_PWR	11	W
Test VID with IccTDC current	VCCIN_VID_IccTDC	1.8	V
Test VID with IccMAX current	VCCIN_VID_IccMax	1.82	V
Test VID with IccPL2 current	VCCIN_VID_IccPL2	1.75	V
Test VID with IccPkC6 current	VCCIN_VID_PkgC6	1.6	V
VCCIN ± Ripple	VCCIN_Ripple	5	mV
VCCIN SVID Address	VCCIN_SVID Addr	00h	hex
Thermal Design Current	VCCIN_IccTDC	89	A
Dynamic Current @ Pdyn=PL2	VCCIN_IccPL2	107	A
Maximum Current for the rail	VCCIN_IccMax	228	A
Minimum Current for the rail	VCCIN_IccMin	4	A
Maximum Current step size	VCCIN_IccMaxstep	200	A
Maximum Overshoot above VID	VCCIN_VOvS_MAX	92	mV
Overshoot_Design Margin for HVM	VOvS_Max_HVM		mV
Maximum Overshoot Time Duration above VccMAX due to Load Transient	VCCIN_tOvS_MAX	25	µs

Disclaimer | BOM_165W | Spec Entry | Thermal Comp | Static LL | Transient LL | Dynamic VID | VCCSA | VCCIO | VMCP | P1V0 | VccH

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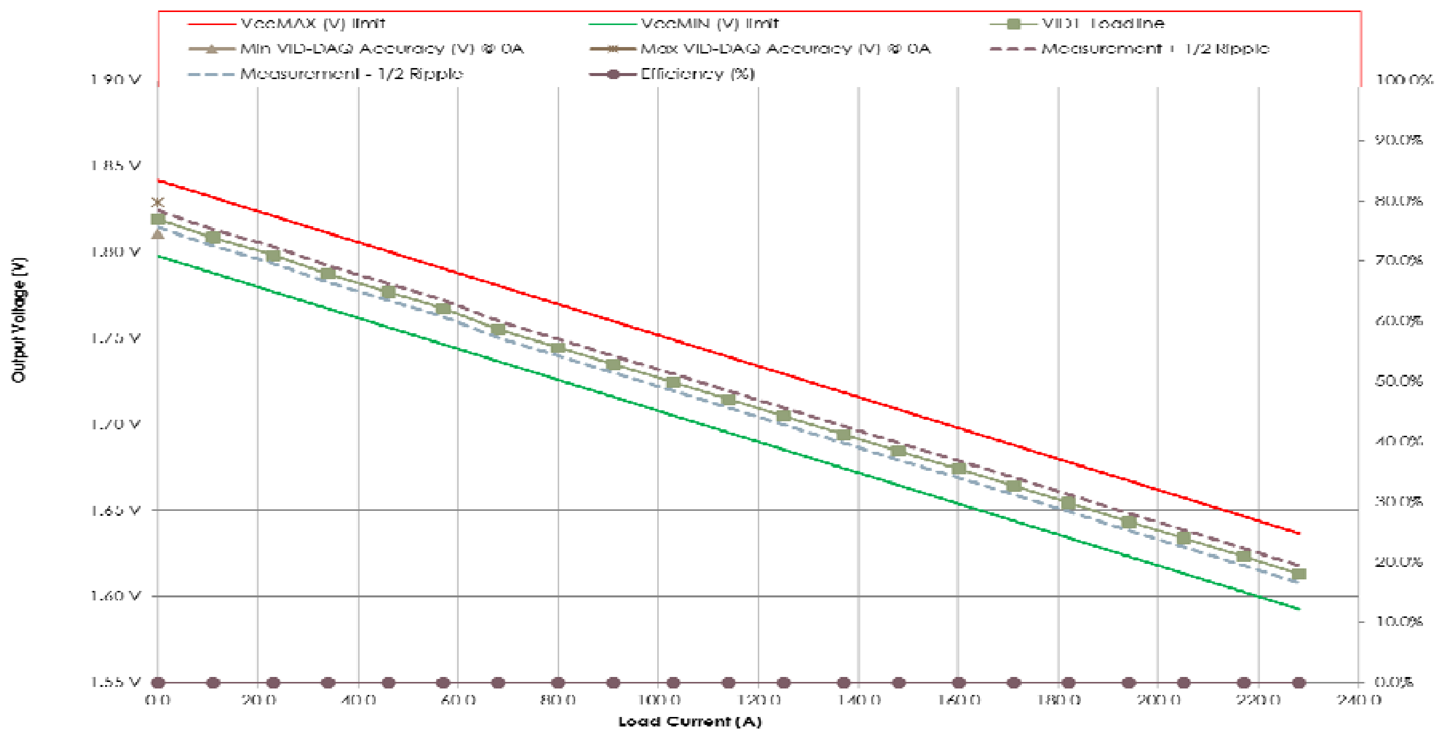
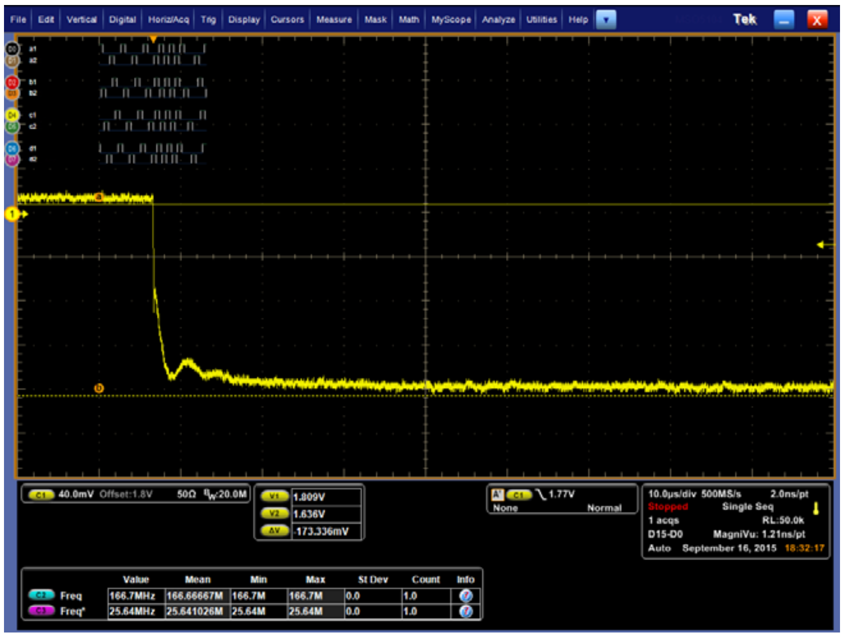
Regulator Performance

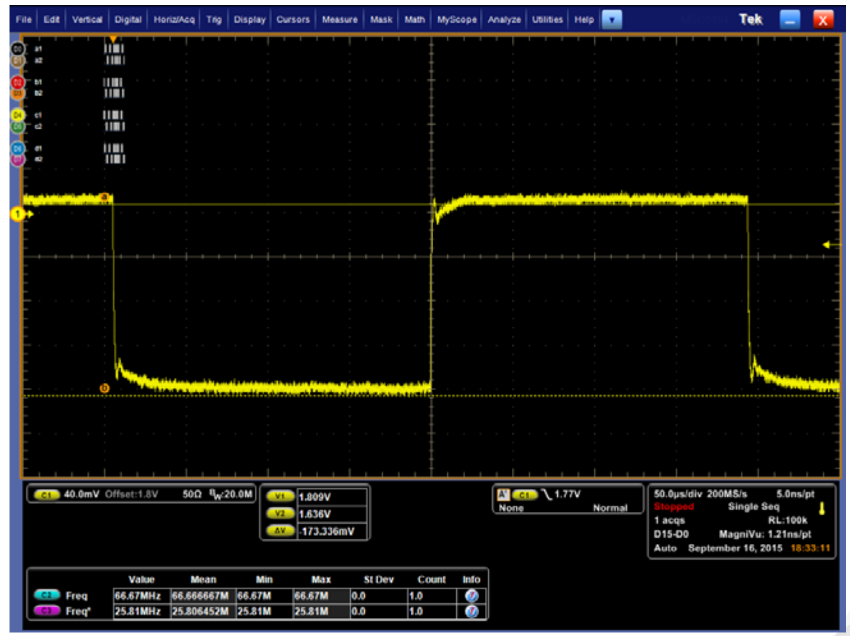
Transformer Load Line: V_{OUT} = 1.80V



Transient Response: 10A – 197A – 10A

CH1: V_{OUT}, 40mV/DIV





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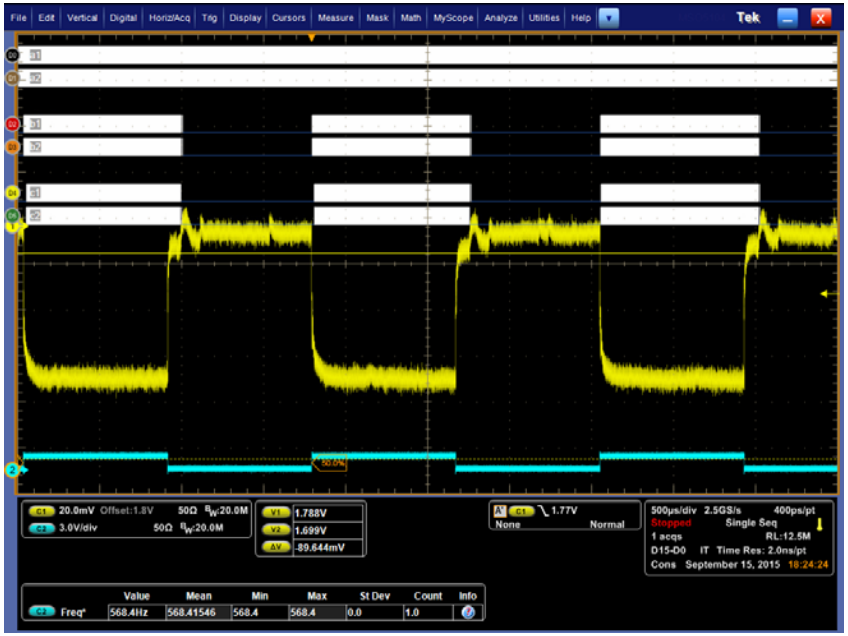
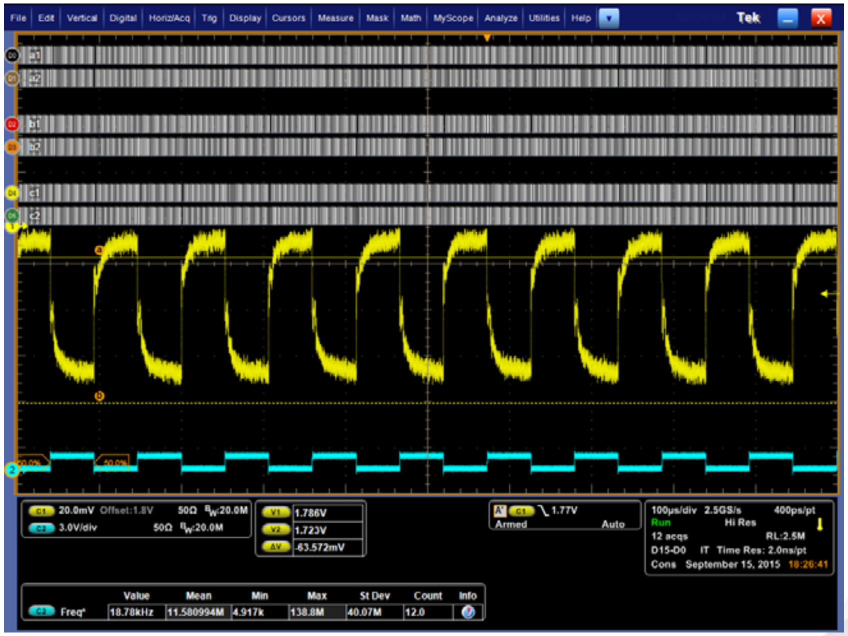
Auto Phase Shedding: 6A to 63A @ Variable Load Repetition Rate

CH1: V_{OUT}, 20mV/DIV; CH2: I_{LOAD}





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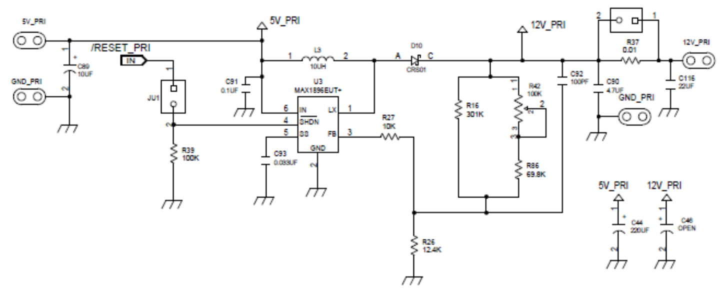
Dynamic VID Transition: 1.5V to 1.8V, I_{LOAD} = 10A

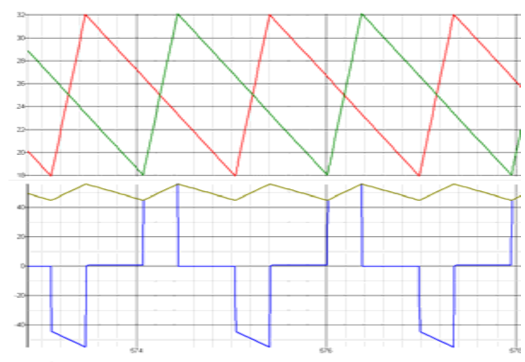
CH1: V_{OUT}, 60mV/DIV; CH2: ALERT 90mV/DIV, CH3: SKIPB 2V/DIV, CH4 SKIPDC 2V/DIV

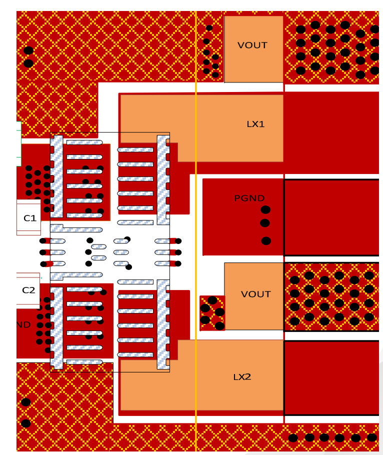
Design Support

Full Design & Verification Support



- **Complete Reference Designs**
- **SIMPLIS Models**
- **PCB Layout Support**
  > From Concept to Gerber Out





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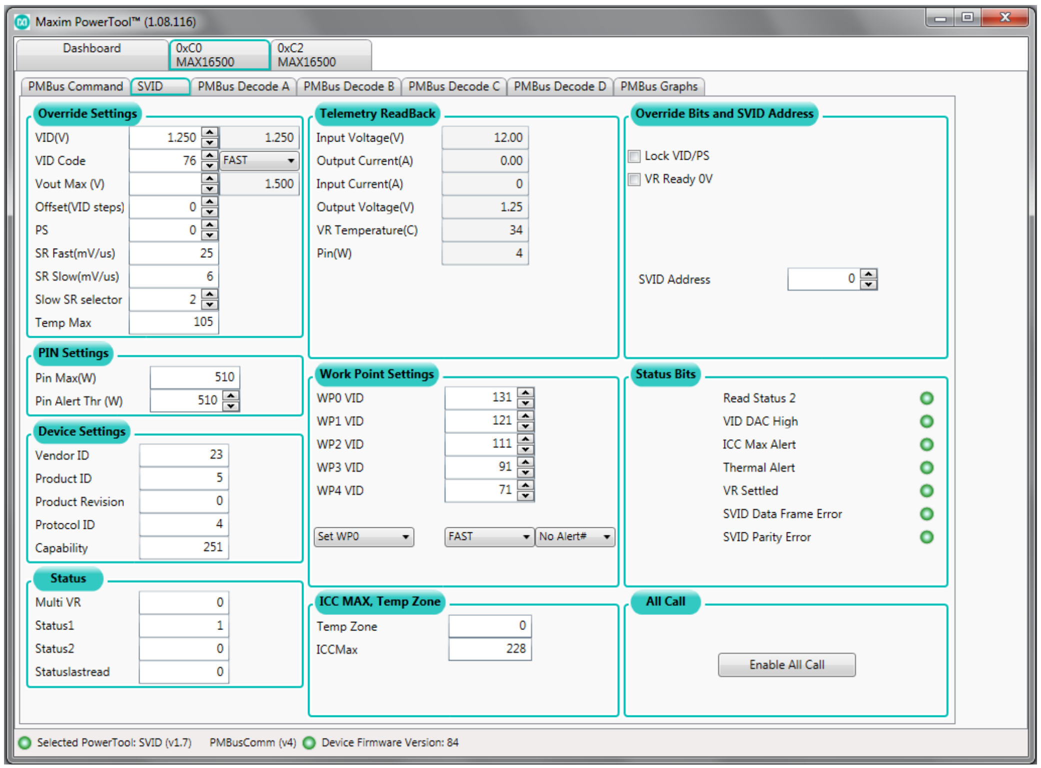
Full Design & Verification Support

- **Verification**
- **Characterization**
- **Thermal Evaluation**

Easy-to-Use GUI

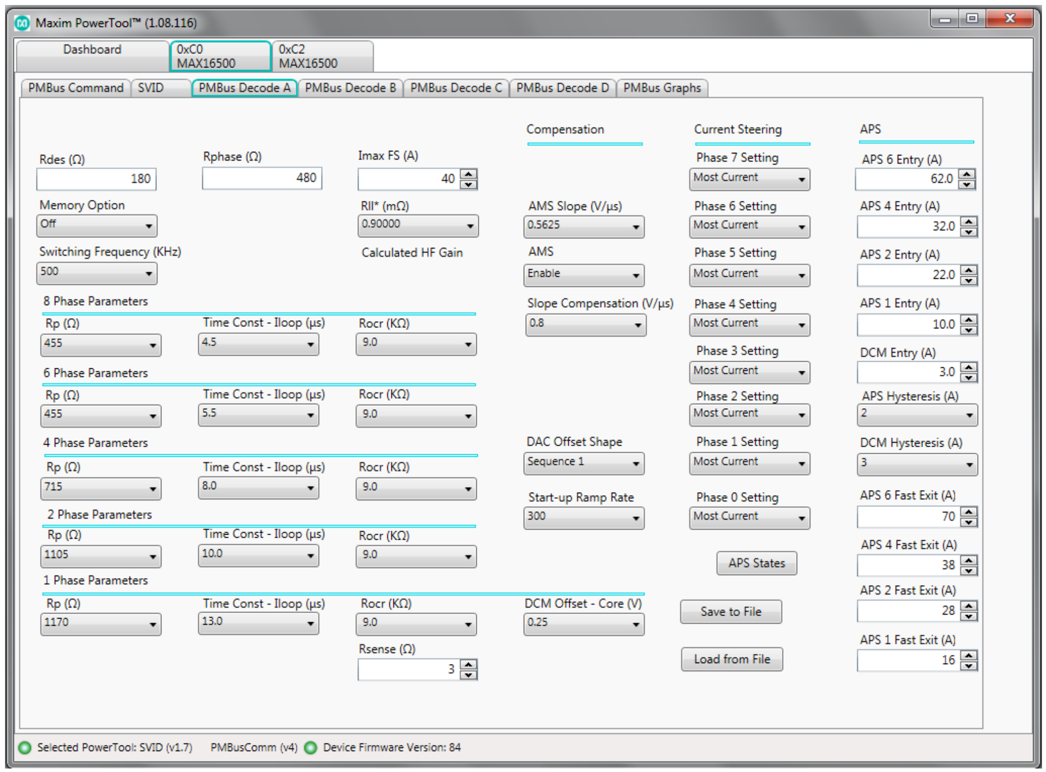
GUI makes it easy for the user to monitor, control, and measure the parameters of interest.



SVID Parameters

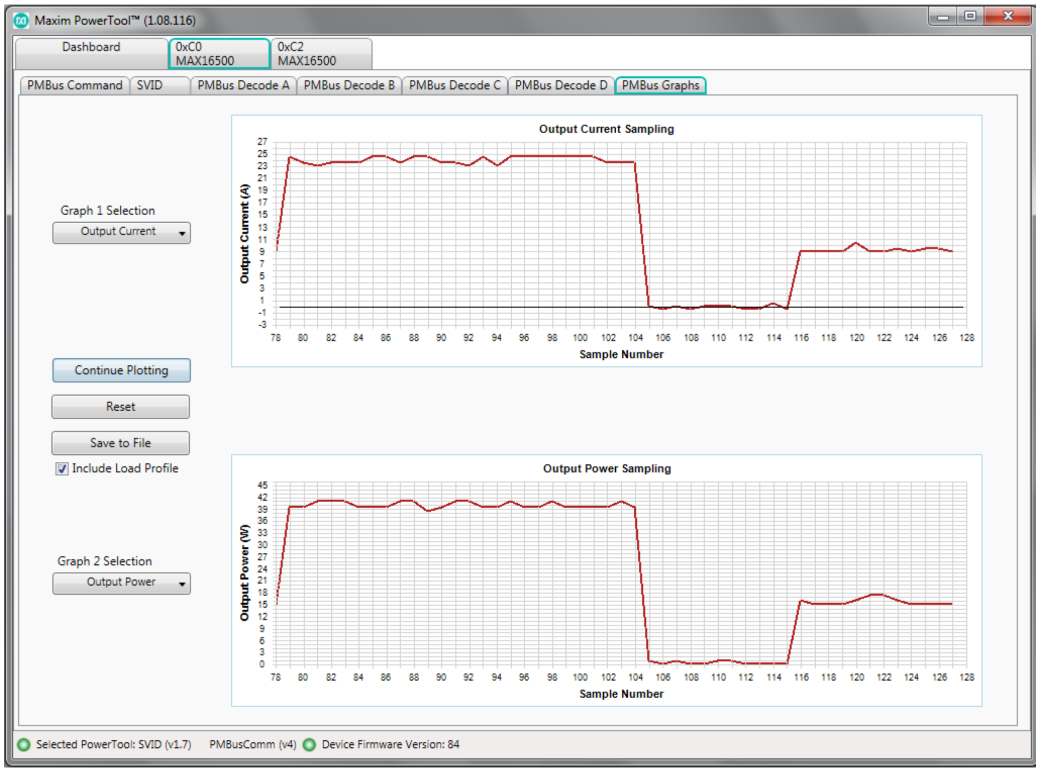
Easy-to-Use GUI

GUI makes it easy for the user to monitor, control, and measure the parameters of interest.



PM Bus Parameters

Easy-to-Use GUI



Plotting feature allows monitoring telemetry parameters in real time or record the data for analysis.

48V TCO Advantage

12V to 48V Rack TCO Assumptions

Open Compute Rack			
Server Lifetime (Years)		4	
Hours Per Day		24	
Days per Year		365	
Cost of Energy ($/kWhr)		$0.10	
	Year	**2017**	**2019**
Efficiency & Distribution Delta		2%	3%
CPU Power (W)		100 x 2	160 x 2
Memory Power (W)		30 x 4	80 x 4
Total Server Power (W)		400	800
# of Servers per Rack		20	25
Rack Power (kW)		8	20
Data Center PUE		1.1	1.05

48V TCO Savings Summary

48V TCO Cost Savings Summary (4 years)		
Rack Architecture	Open Compute	
Year	**2017**	**2019**
Rack Power (kW)	8	20
Lifetime Savings per Server	$15	$128
Payback Period (Years)	4.7	1.1
100K Server Savings	$0.7M	$12M

Full Payback in 1.1 Years

Hyper-Scale Data Centers

48V Rack Architecture Driving Compute Density

Data Center Trends

- New Applications Driving need for Higher Power Compute Nodes
  - 200W+ CPUs with 100W+ Accelerators and 300W GPUs
  - 10kW Racks Today, 25kW Tomorrow

Our Solutions

- Two Decades of 12V Server Power Technology Leadership
- 48V to PoL Technology for High Power Rack Density
  - Passes all Intel's Skylake Tests
  - Supports all CPUs, Memory, GPUs, FPGAs & ASICs
  - Best in Class Efficiency

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