

5G时代高性能电源解决方案

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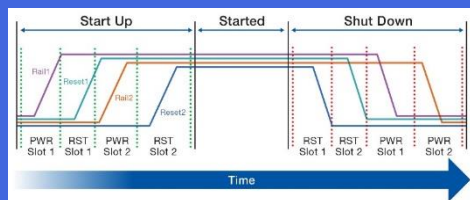
- 5G时代电源的新挑战
 - 更短的开发周期
 - 更小的方案尺寸
 - 解决系统以及电源的散热问题
 - 抑制EMI噪声
 - 高速ADC/DAC的低噪声供电
 - FPGA等复杂电源时序管理以及系统集成
- MPS的电源模块是什么？
- 如何使用MPS电源模块解决复杂新挑战？
- MPS的电源模块产品以及应用

5G时代电源的新挑战

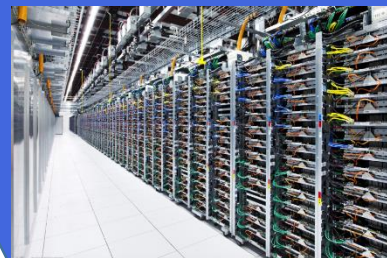
越来越短的开发周期



复杂的多路电源
轨系统



更紧凑的设计
更高的功率密度

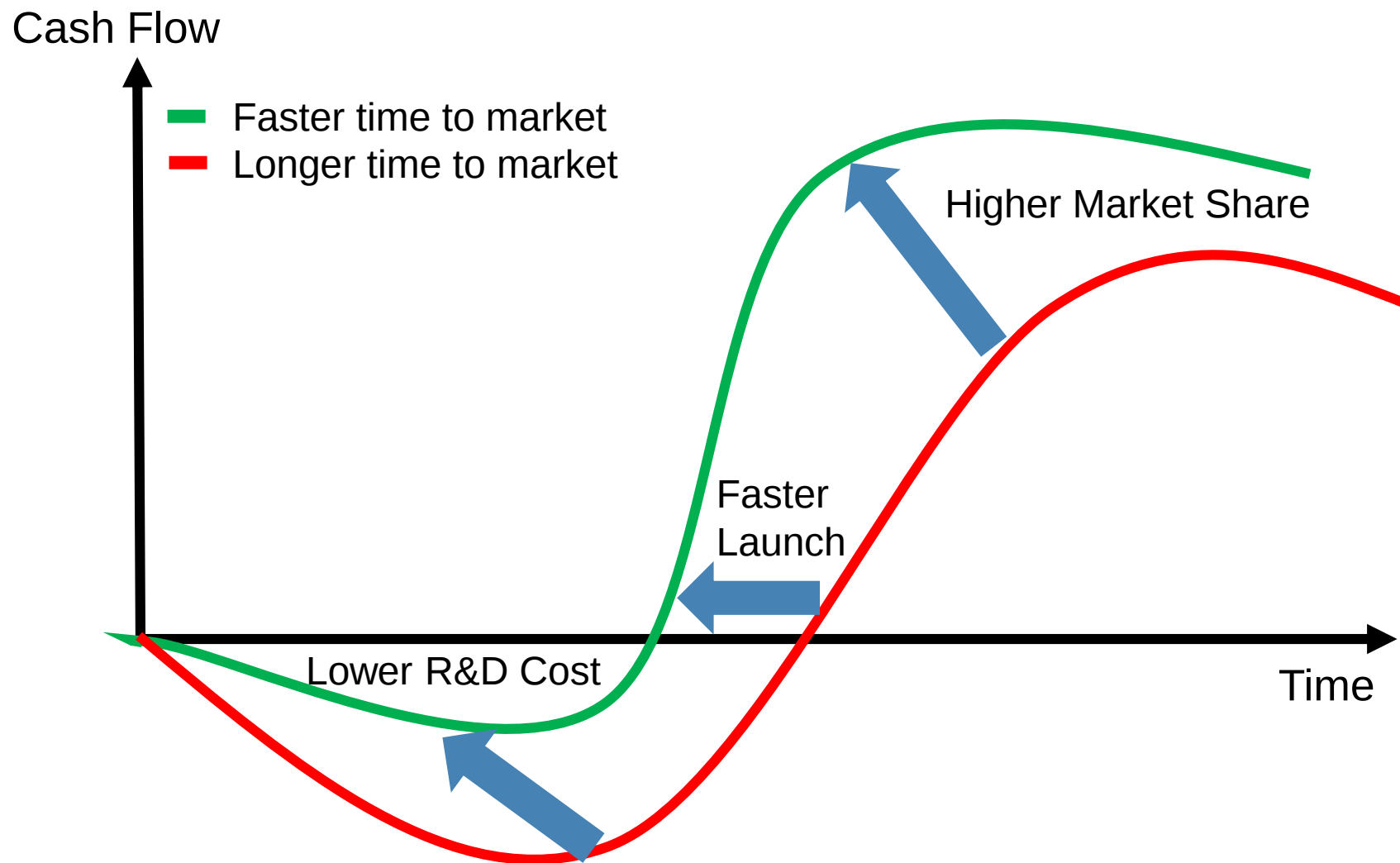


严格的EMI标准

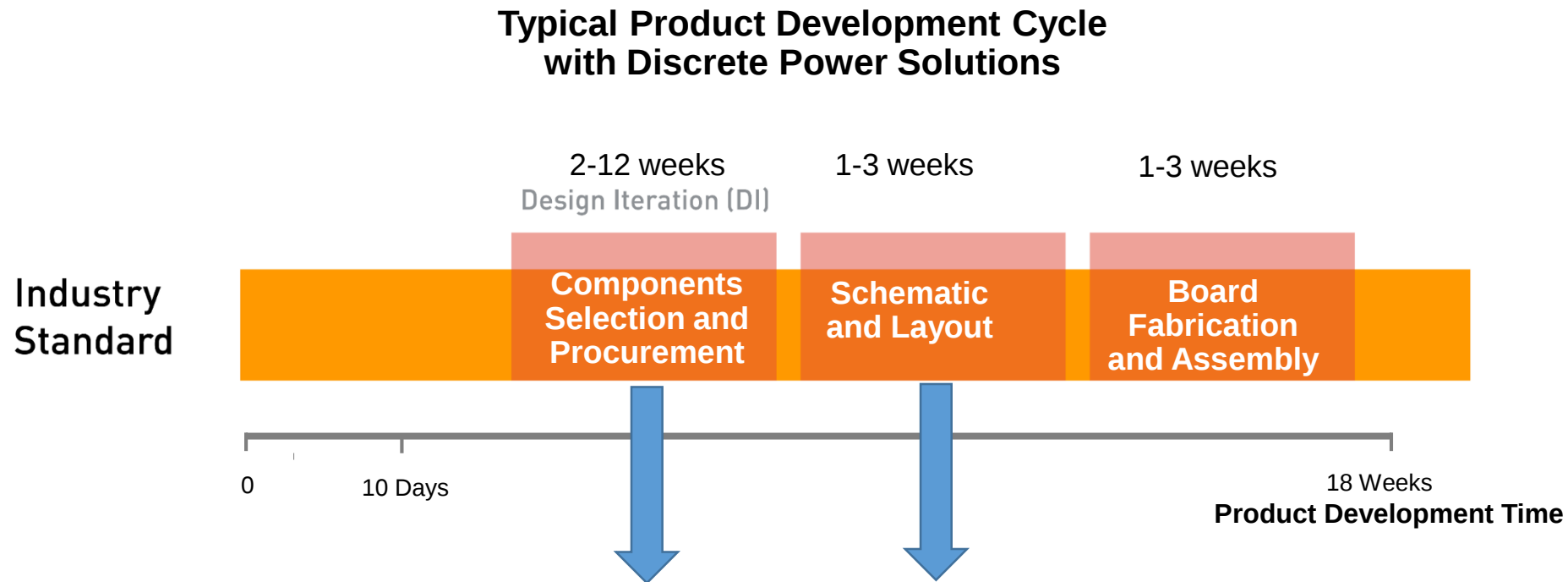


缩短开发周期 – 实现快速上市的关键

新产品现金流曲线

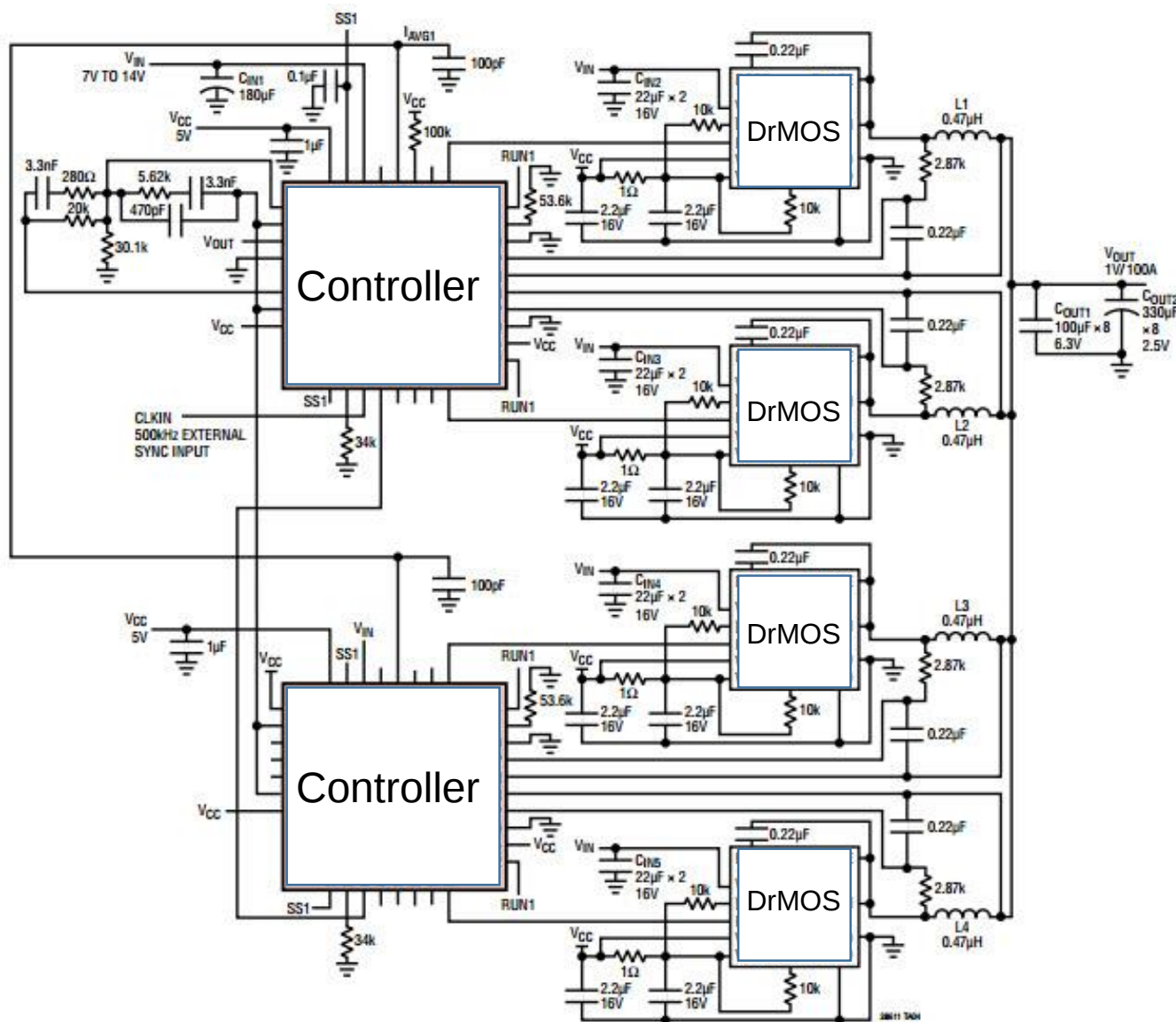


开发验证分立电源方案往往需要18周以上的周期



- 需要优化挑器件，包括芯片，电感等
- 需要根据电感/电容选择合适的环路补偿
- 复杂的原理图以及PCB布线
- PCB布线的风险，有可能需要多次制板验证

输出100A的分立电源方案举例

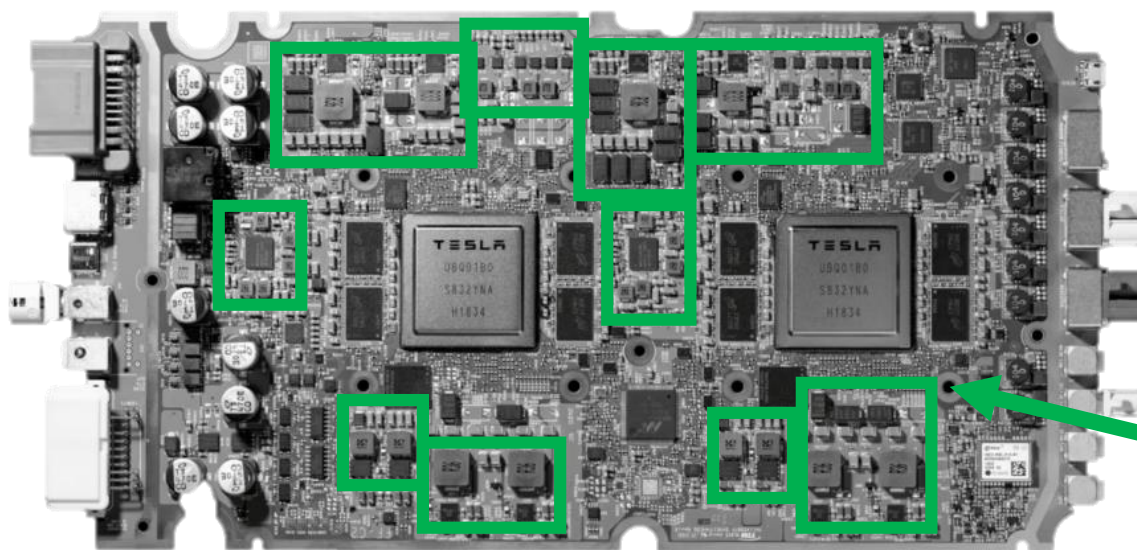


100A分立方案（Controller+DrMOS）典型应用图

- 5颗芯片：
 - 控制器+DrMOSx4
- 4颗电感
- 复杂的电路设计：
 - 电流采样电路
 - 解耦滤波电路
 - 环路补偿电路
 - 多相交错电路
 -

紧凑的系统设计限制了电源占板面积

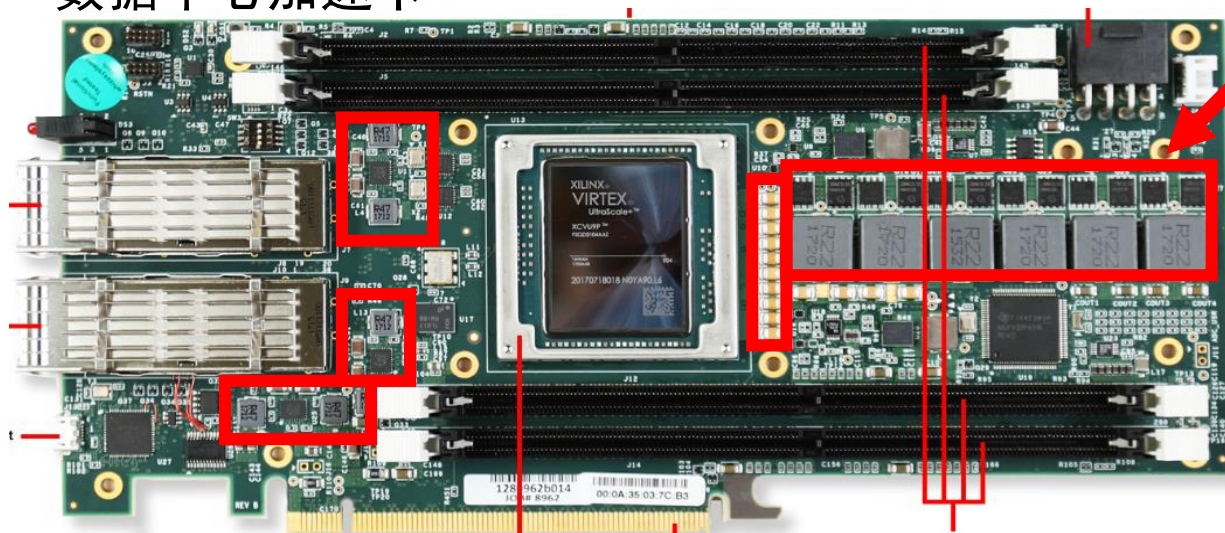
自动驾驶处理器主板



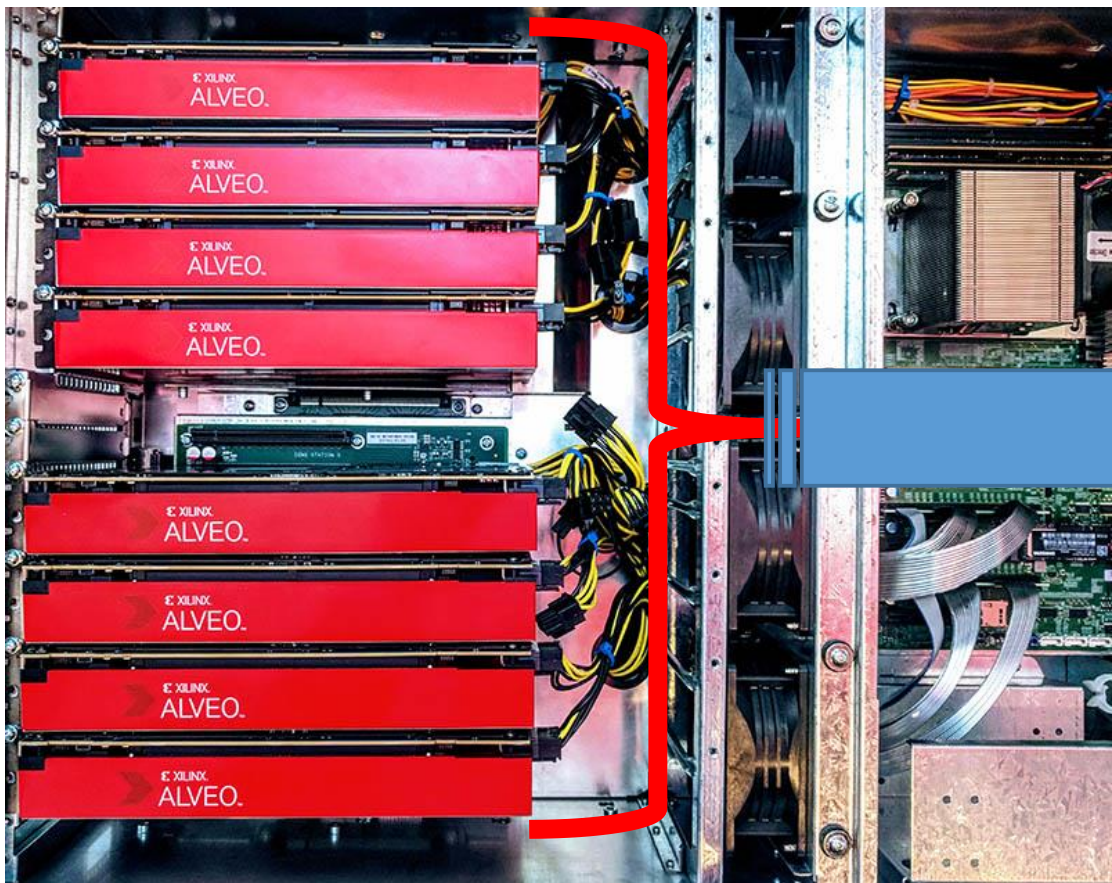
高密度板设计

电源方案往往占据了主板很大的面积

数据中心加速卡



高功率密度对系统散热提出更多的挑战



- 高密度系统设计
- 有限的风速
- 70°C以上的环境温度
- 电源功耗以及散热变的格外重要

EMI标准

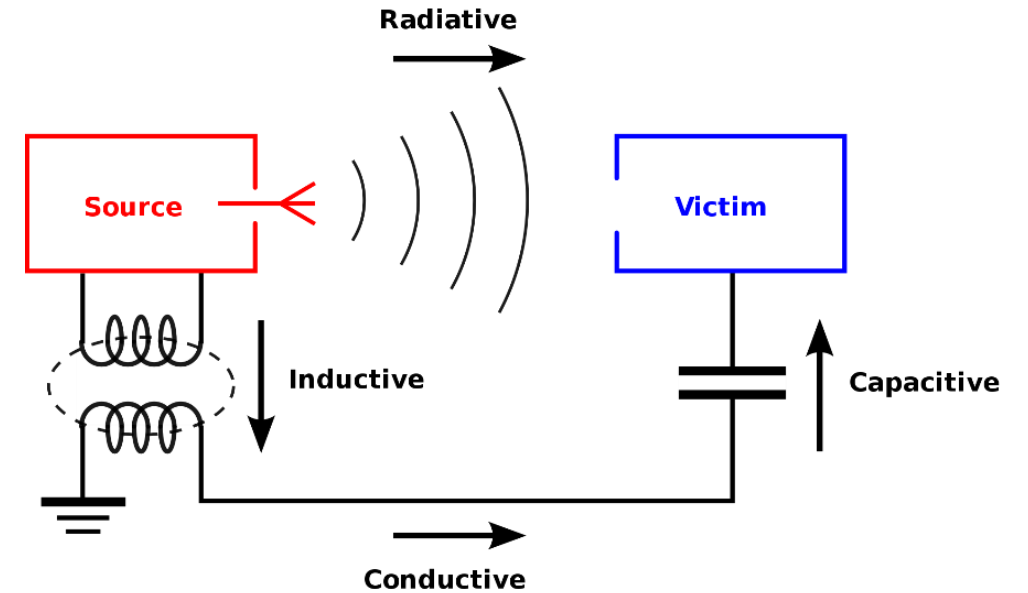
Numerous EMI standards

Conducted Emissions			
	Frequency (MHz)	Quasi-Peak Limit (dBu)	Average Limit
Class A	0.15 - 0.5	79	
Class B	0.1 - 0.5		

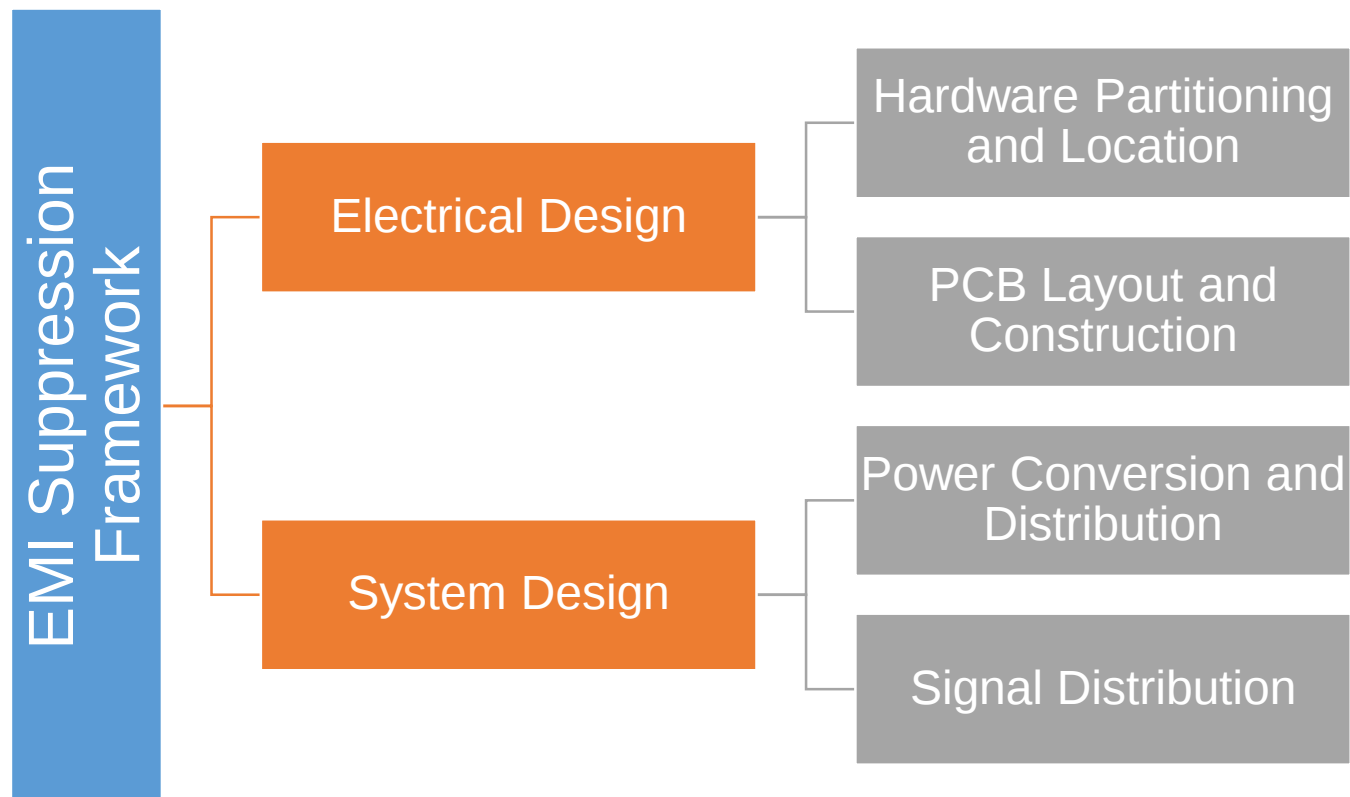
General Radiated Emission			
	Frequency	Field Strength Limit (uV/m)	
Class A	0.1 - 30	90	
Class B	0.1 - 30	150	
	30 - 100	210	
	100 - 300	300	
	300 - 1000	100	
	1000 - 3000	150	
	3000 - 10000	200	
	10000 - 30000	500	

Req't		Standard	Description
CE101	Conducted	EN50081-1	Generic emissions standard for residential, commercial and light industrial environments.
CE102	Conducted	EN50081-2	Generic emissions standard for industrial environment
CE106	Conducted	EN55022	Limits and methods of measurement of radio disturbance characteristics of information technology equipment (Also known as CISPR-22)
CS101	Conducted	EN55011	Industrial, scientific and medical (ISM) radio frequency equipment - Radio disturbance characteristics - Limits and methods of measurement (Also known as CISPR-11)
CS103	Conducted	EN55013	Limits and methods of measurement of radio disturbance
CS103	Conducted	EN55014-1	
CS104	Conducted	EN55015	
CS105	Conducted		
CS109	Conducted		
CS114	Conducted	EN61000-3-2	
CS115	Conducted		
CS116	Conducted	EN61000-3-3	
RE101	Radiated Emissions, Magnetic Field	EN61000-4-2	Electrostatic Discharge
RE102	Radiated Emissions, Electric Field	EN61000-4-3	Radiated Susceptibility Test
RE103	Radiated Emissions, Antenna Spur	EN61000-4-4	Electrical Fast Transient/Burst Test
RS101	Radiated Susceptibility, Magnetic Field	EN61000-4-5	Surge Test
RS103	Radiated Susceptibility, Electric Field	EN61000-4-6	Conducted Immunity Test
RS105	Radiated Susceptibility, Transient	EN61000-4-8	Power Frequency Magnetic Test
		EN61000-4-11	Voltage Dips and Interruptions Test
		EN61000-6-1	Immunity for residential, commercial and light-industrial environments
		EN61000-6-2	Immunity for industrial environments
		EN61547	Equipment for general lighting purposes — EMC immunity requirements
		EN12016	Electromagnetic compatibility — Product family standard for lifts, escalators and passenger conveyors — Immunity

- 严格的EMI测试标准
- EMI的调试比较复杂
- 往往需要多个版本PCB修改以及调试

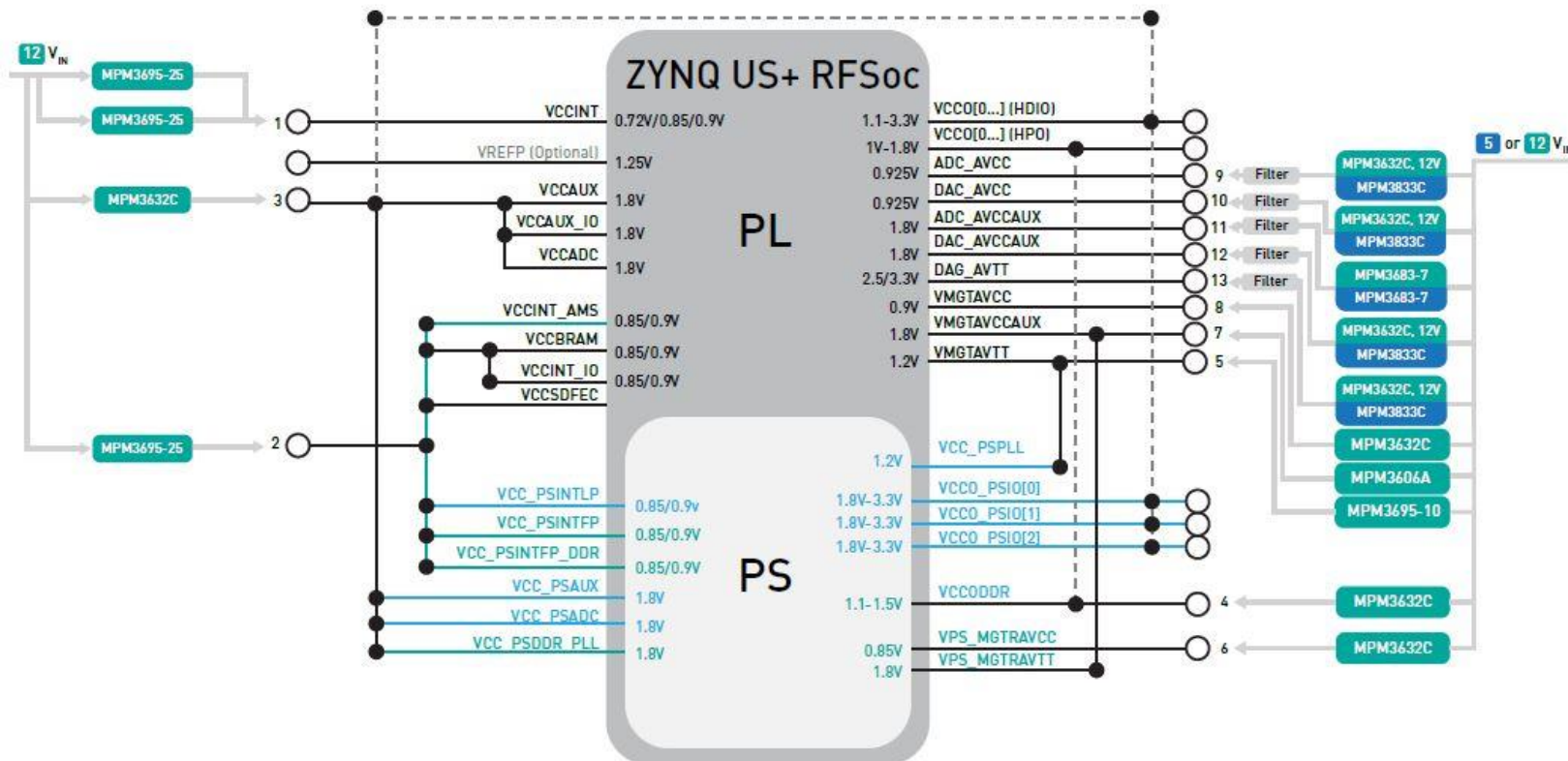


复杂的EMI调试过程



- **EMI抑制很困难EMI**
- **往往导致项目推迟，以及增加的成本**
- **往往需要多次PCB优化布局走线**

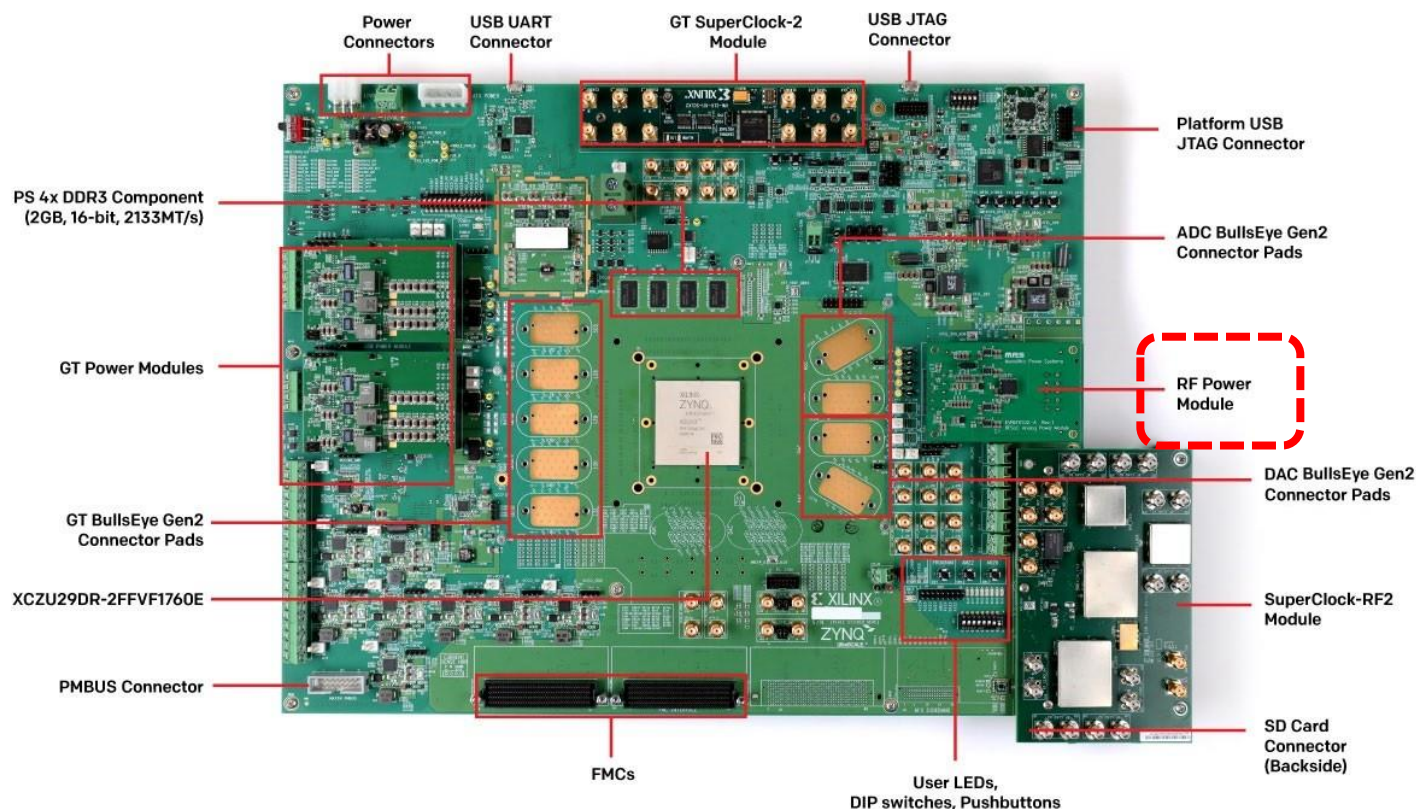
FPGA/ASIC复杂的电源设计要求



- 电源轨数多
- 需要严格的启动/关机时序
- 电压精度要求高
- 动态响应速度快
- 低噪声
- 效率，散热，占板面积

RFSoc中高速ADC/DAC的供电要求

Example: Zynq UltraScale+ RFSoc ZCU1275

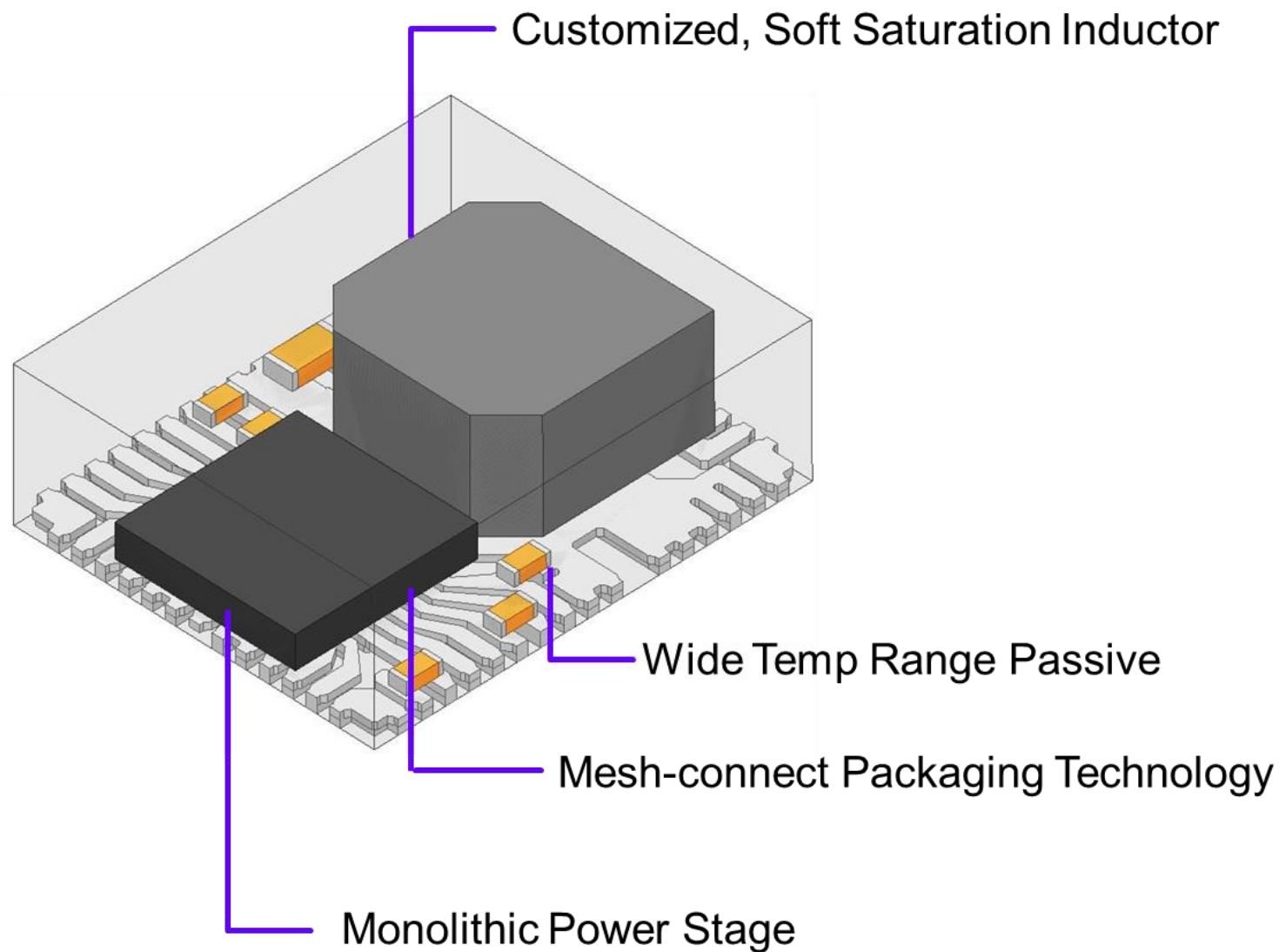


- 射频单元 12-bit 2GSPS ADCs 以及14-bit 6.4GSPS DACs供电电源模块
- 超低纹波: $<1\text{mV}$
- 效率要求: $12\text{V} \rightarrow 3.3\text{V}/8\text{A}$, 93%
- 动态纹波要求: 0-4A, $\text{di}/\text{dt}=100\text{A}/\mu\text{S}$, $<+/-2\%$

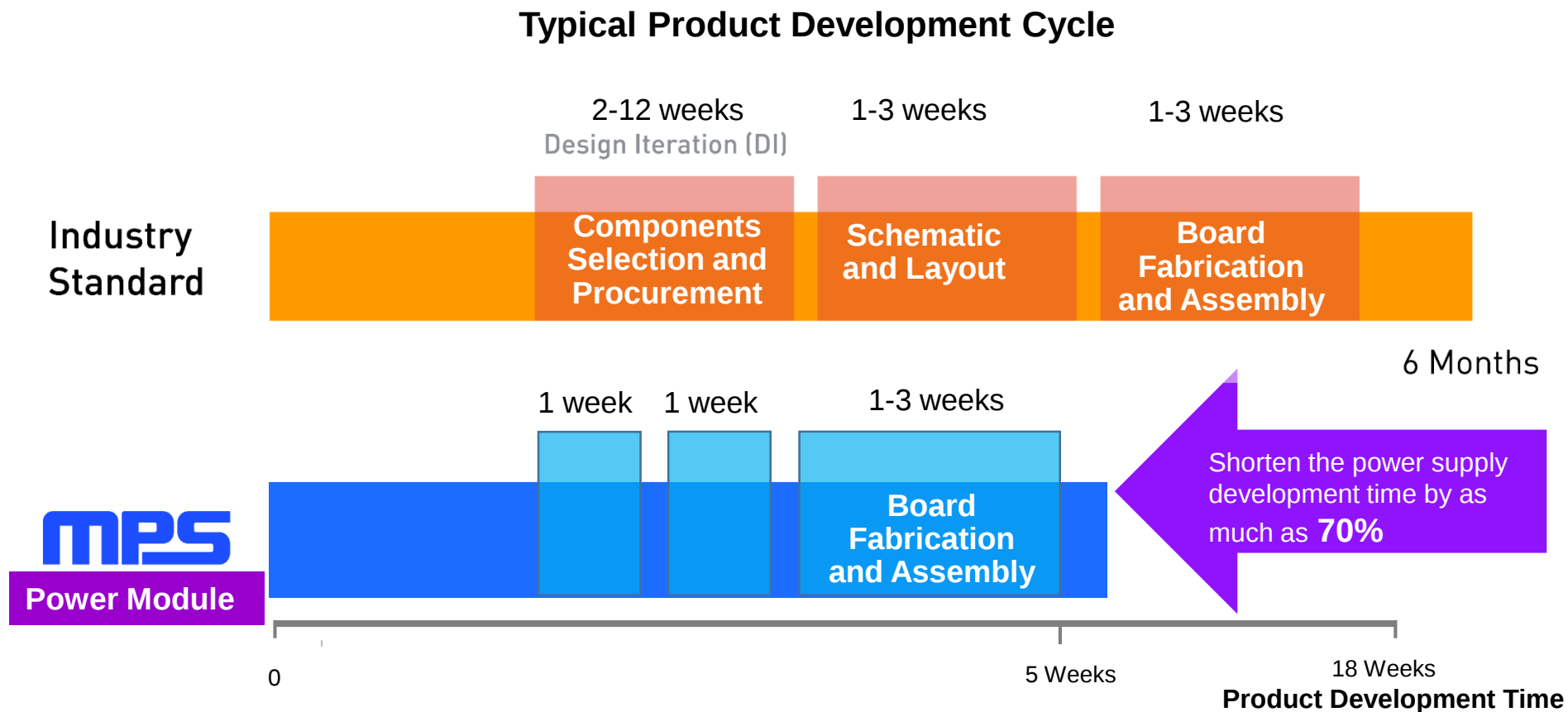
小总结 - 5G时代电源的新挑战

- 更短的开发周期
- 更小的方案尺寸
- 解决系统以及电源的散热问题
- 抑制EMI噪声
- 高速ADC/DAC的低噪声供电
- FPGA等复杂电源时序管理以及系统集成

MPS电源模块是什么？



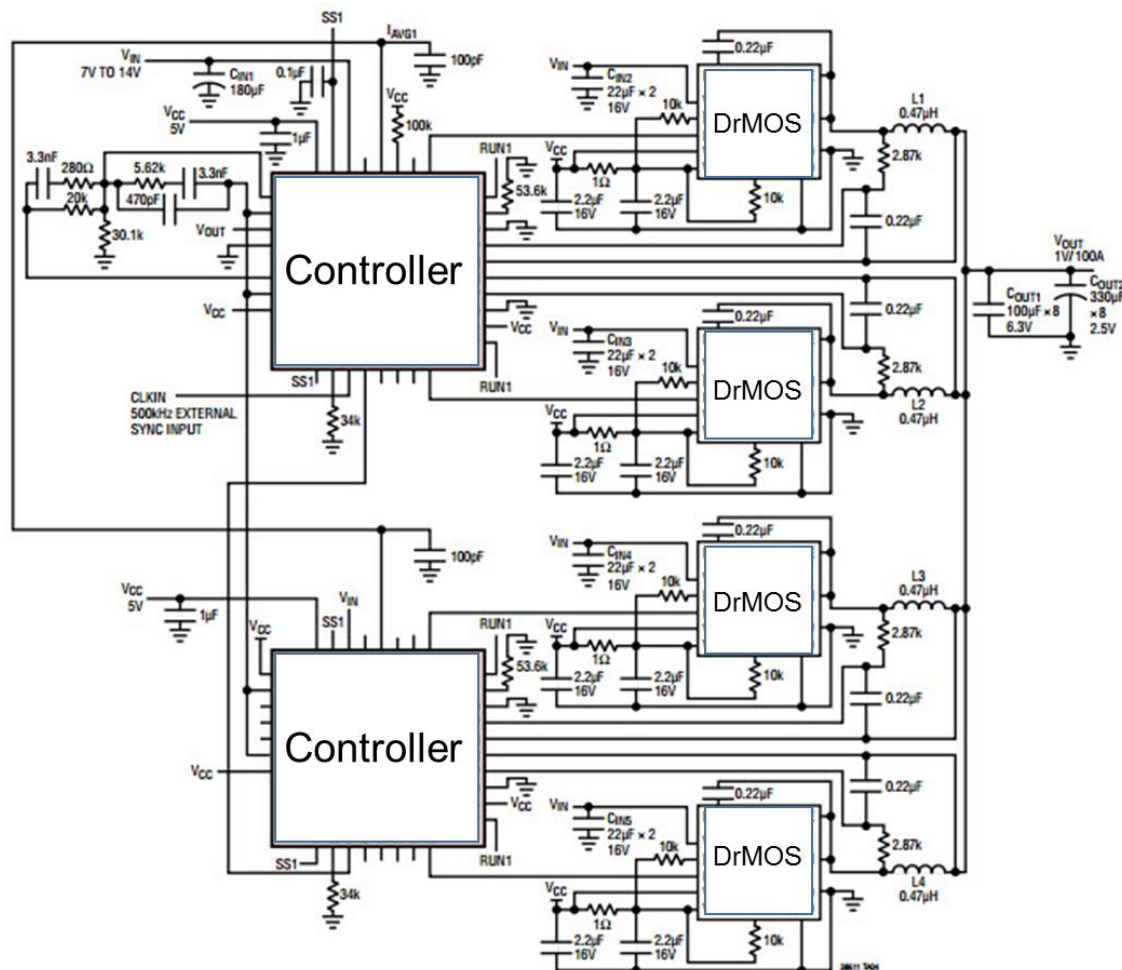
电源模块极大的缩短的开发周期



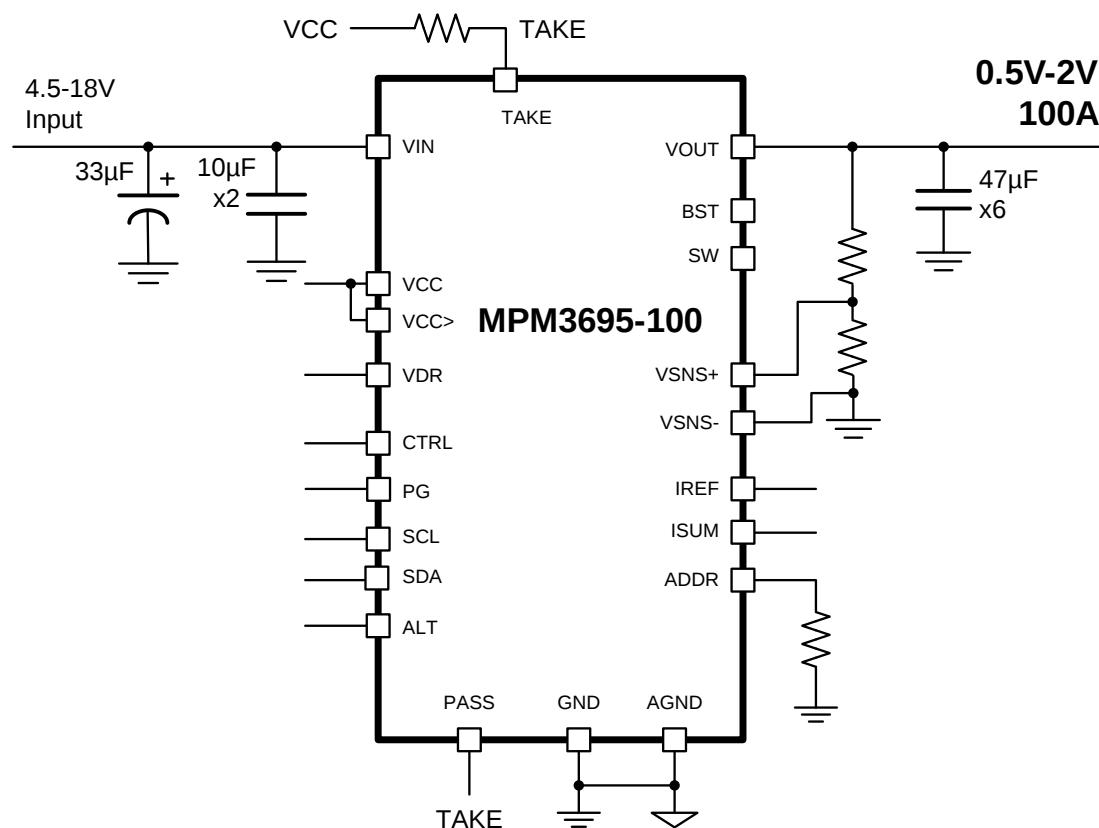
- 电源模块提供了高集成度的方案
- 优化的性能
- 大大简化的原理图和PCB布板
- 极少的外围元器件

电源模块简化了设计的复杂度 – 100A设计举例

100A分立方案（Controller+DrMOS）典型应用图

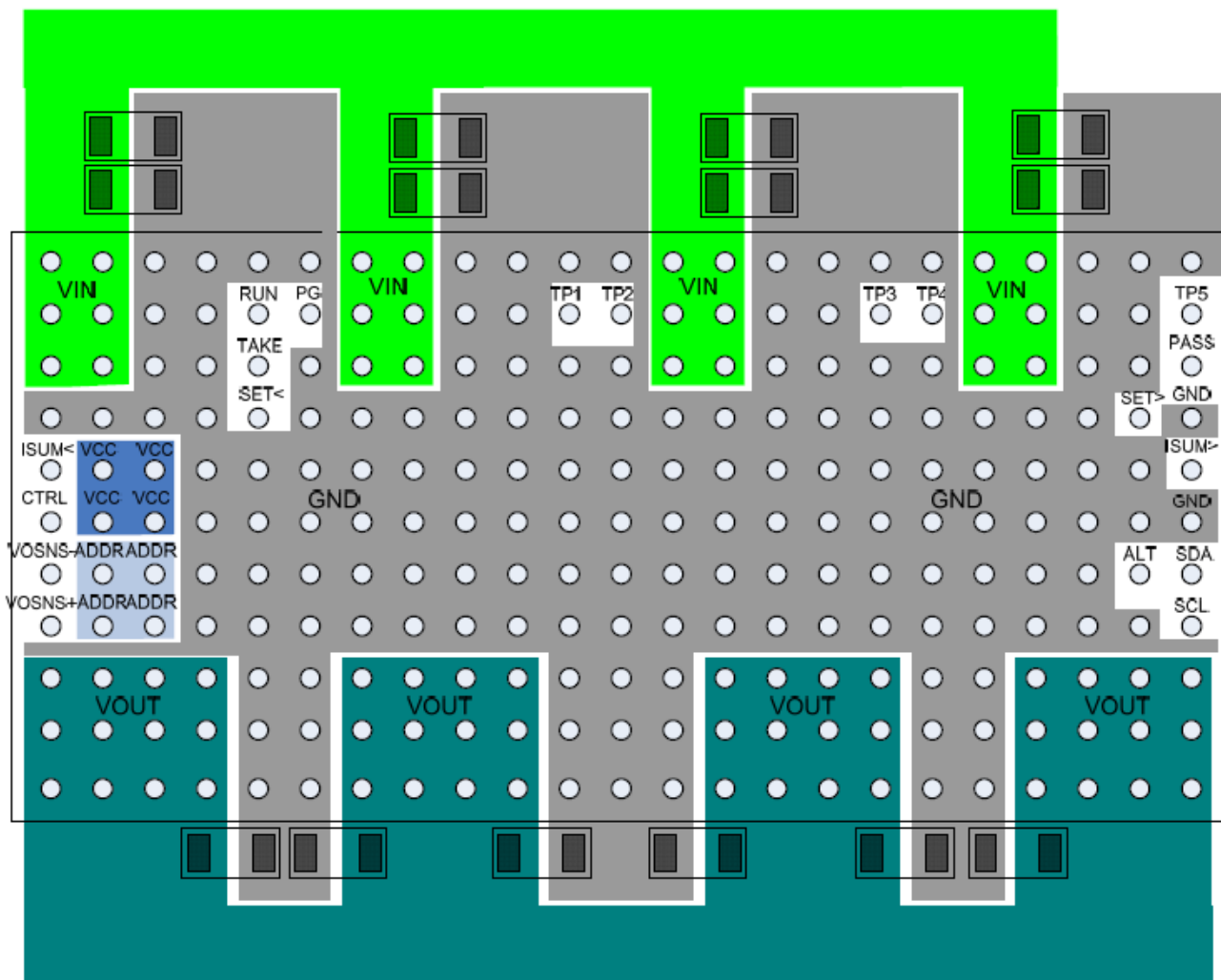


MPS 100A模块典型应用图



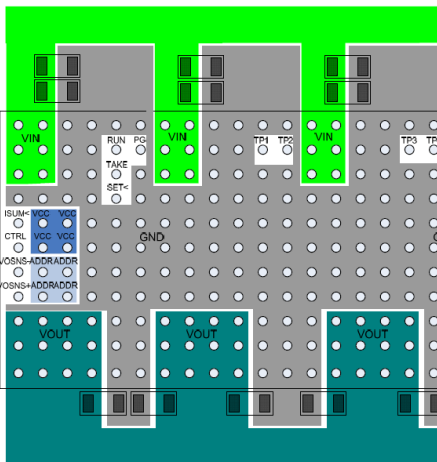
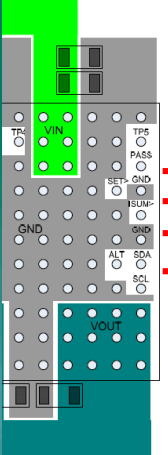
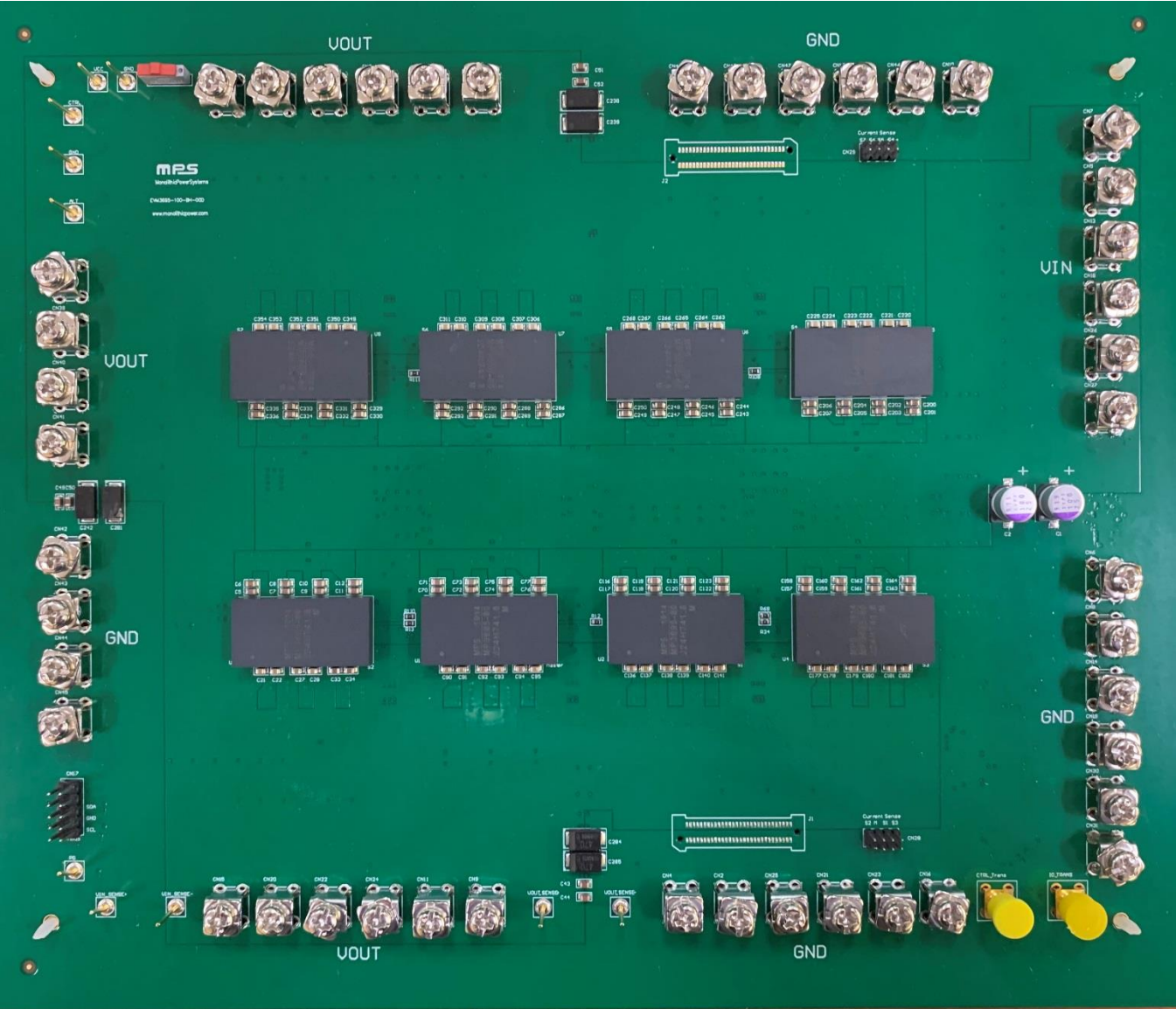
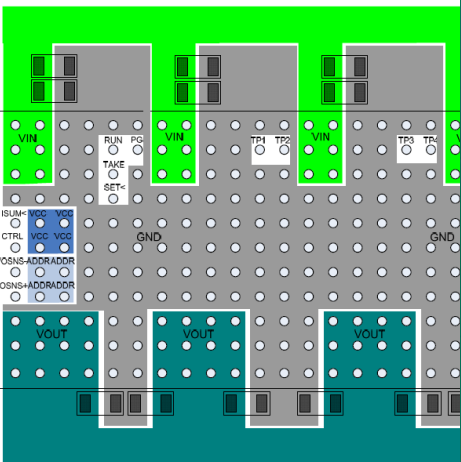
电源模块简化了PCB布板的风险以及复杂度 – 100A设计举例

实例: MPM3695-100, 带PMBus, 可并联的100A电源模块, 15x30x5.3mm BGA封装

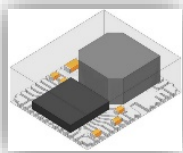


- 模块集成了控制器，功率 MOSFET，电感以及滤波电容
- 外围仅需输入输出电容
- 及其简单的PCB布线
- 优化的模块管脚分布

需要更大的电流？ 400A？ 800A？



电源模块为什么可以做的那么小？



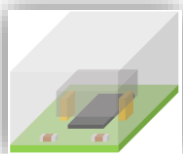
1. 单晶圆的功率+控制减小了芯片的面积



2. 倒装的封装工艺减小了芯片的占板面积

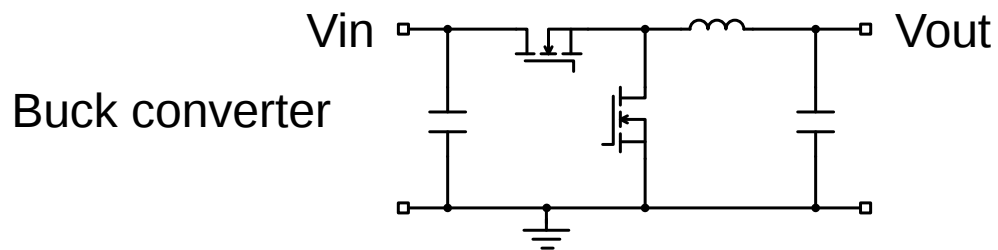


3. 提高开关频率减小电感体积

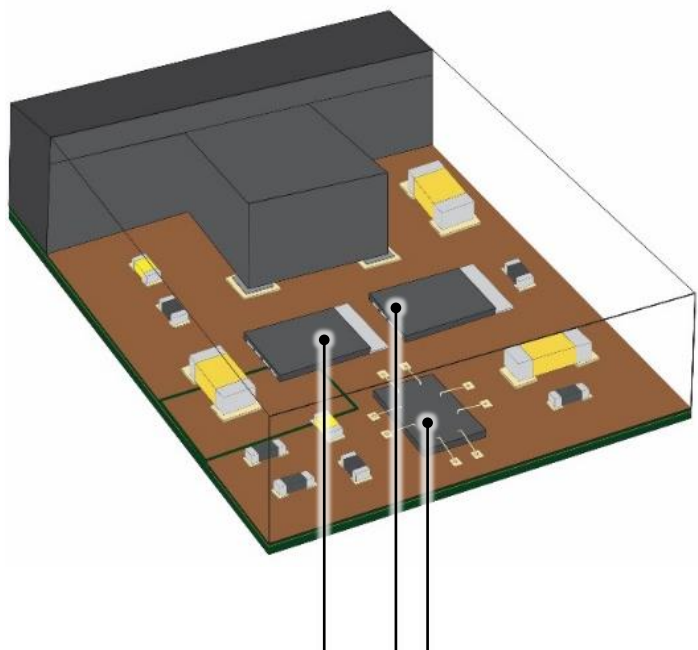


4. 电感/芯片的3D封装进一步提高功率密度

单晶圆的功率+控制级减小了芯片的面积

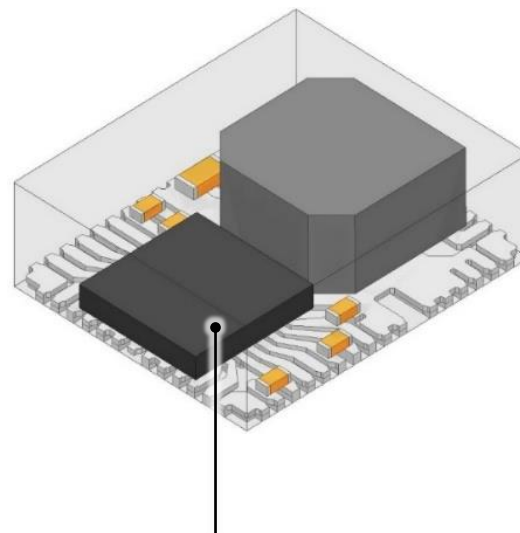


❑ 传统的模块设计方案



分立的上管，下管，控制器限制了进一步缩小模块面积

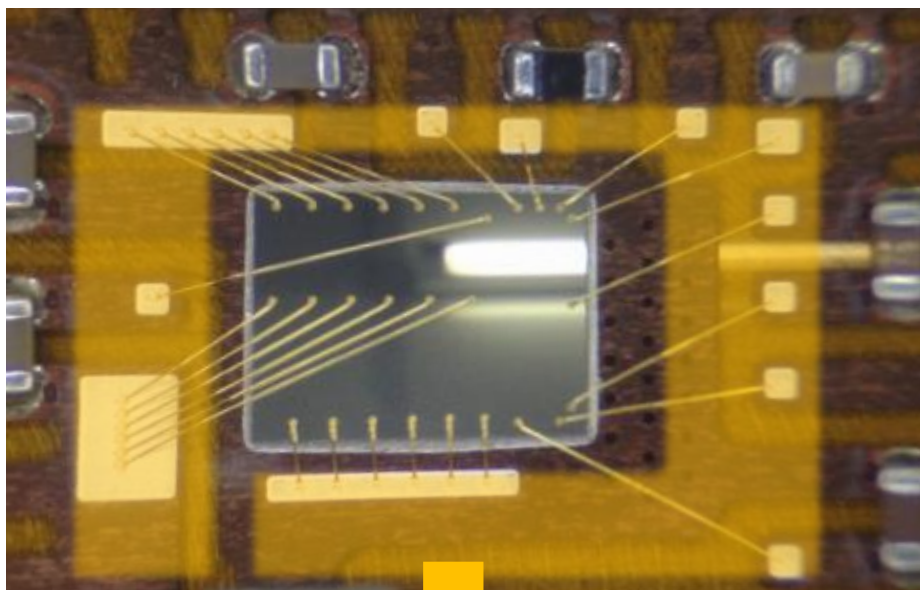
❑ MPS 单晶圆功率+控制



MPS将上管，下管以及控制器集成在一片晶圆上，减少50%的芯片面积以及成本

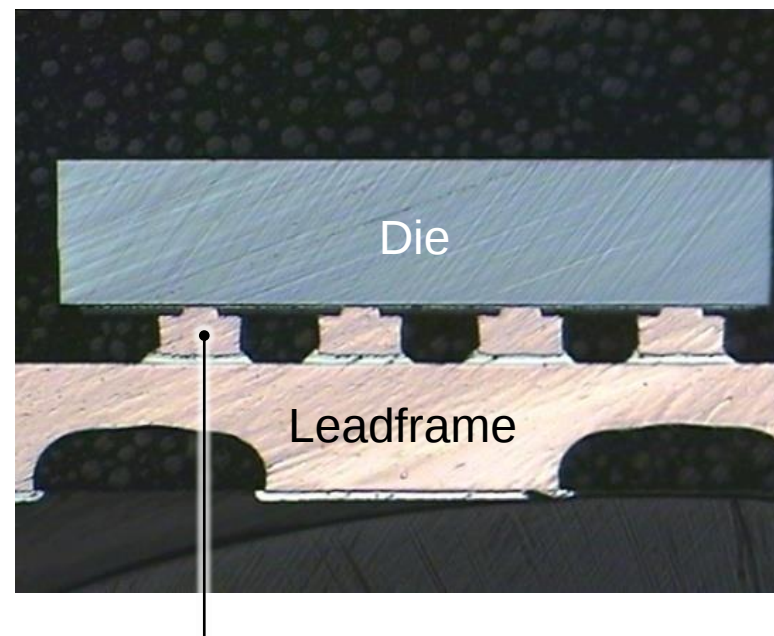
芯片倒装工艺减小了封装带来的多余占板面积

❑ Conventional Design – wire bond



Area increased by using bond wire interconnects

❑ MPS Flip-Chip Solution



Copper pillar directly connects die and lead frame

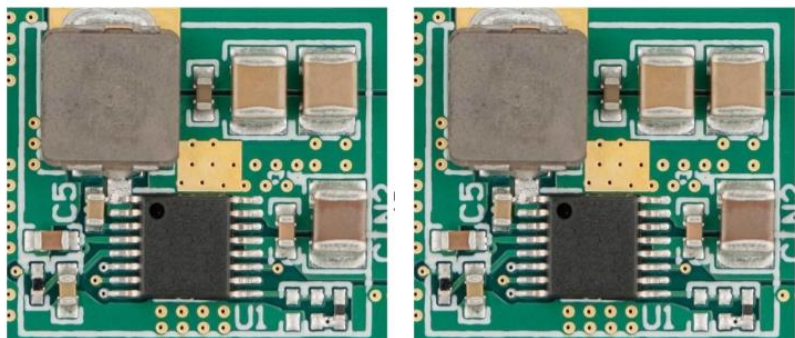
提高开关频率减小电感体积

芯片的先进制成，低FOM, 单晶圆功率级，倒装工艺减小了芯片的寄生参数，这使MPS可以进一步提高开关频率来减小电感体积。

❑ Conventional Design

24V->5V/3A, 3.3V/3A

Operate @ 300kHz

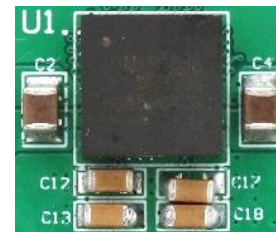


Total area: 510mm²

❑ MPS High-Frequency Solution

24V->5V/3A, 3.3V/3A

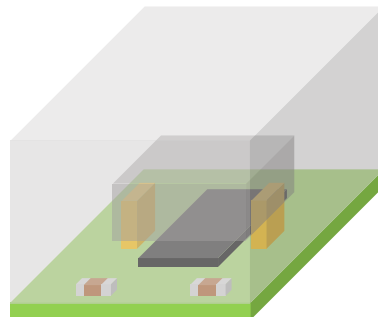
Operate @ 800kHz – 2MHz



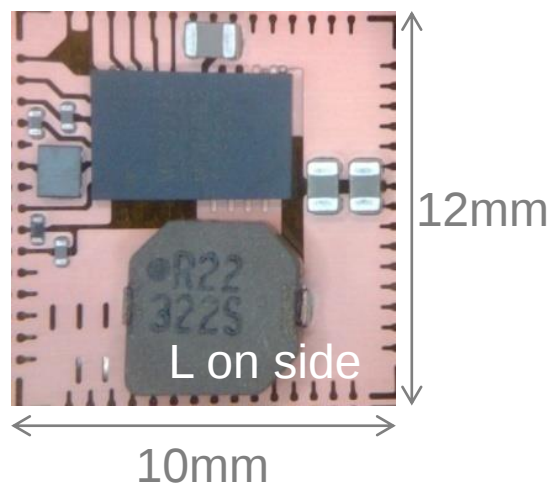
Total area: 225mm²

电感/芯片的3D封装形式提高了功率密度

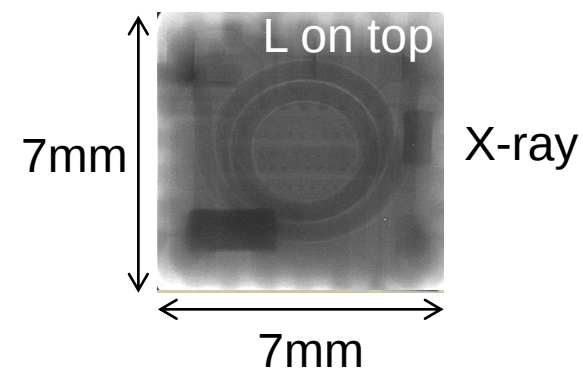
3D packaging is to stack inductor to the IC and substrate to reduce size by half



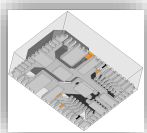
❑ Conventional Design



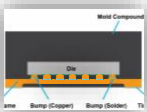
❑ MPS 3D Packaging Solution



MPS电源模块的散热设计



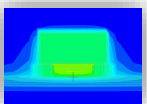
优化模块设计，减小功耗



芯片倒装工艺降低了热阻



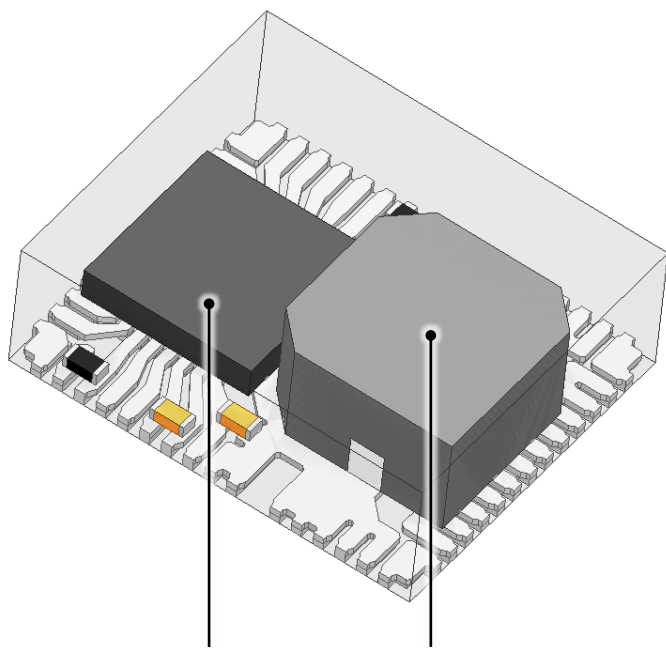
低高度的模块设计可以和主芯片共用散热器



3D封装帮助散热更加均匀

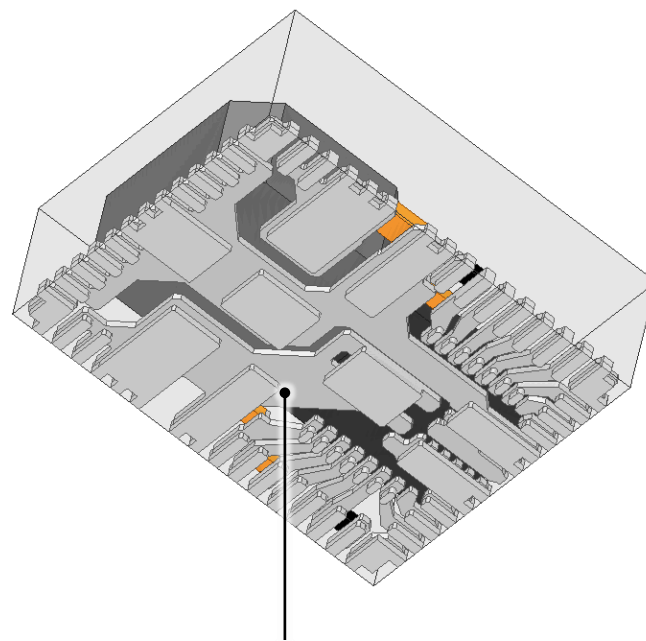
优化模块基板以及电感设计降低功耗

- 1) 定制、优化的电感设计 – DC/AC损耗
- 2) 引线框架以及BT基板采用厚铜，降低接触电阻
- 3) 优化的基板的布线设计
- 4) 90nm BCD制成可以减少 30% FOM



Monolithic die

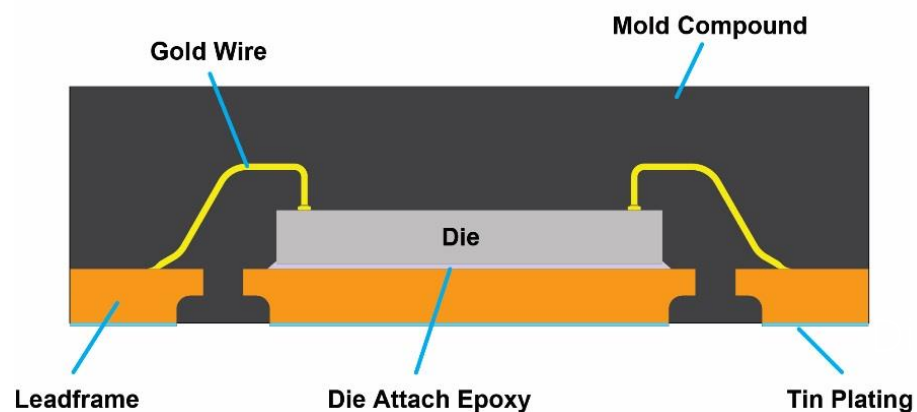
Customized inductor



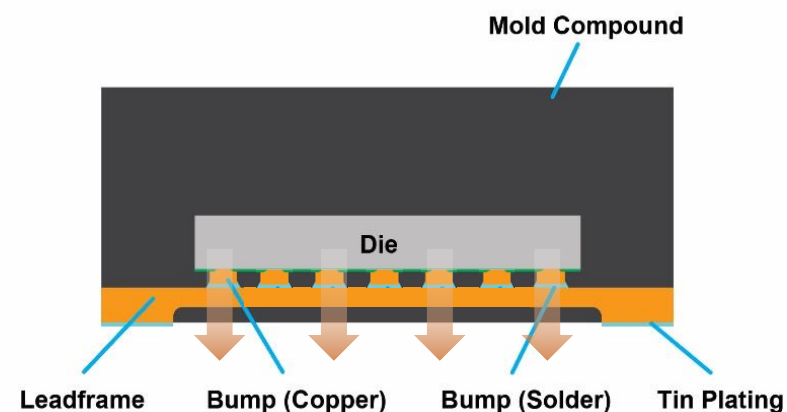
Thick copper lead frame

倒装工艺降低了模块热阻

❑ Conventional Design

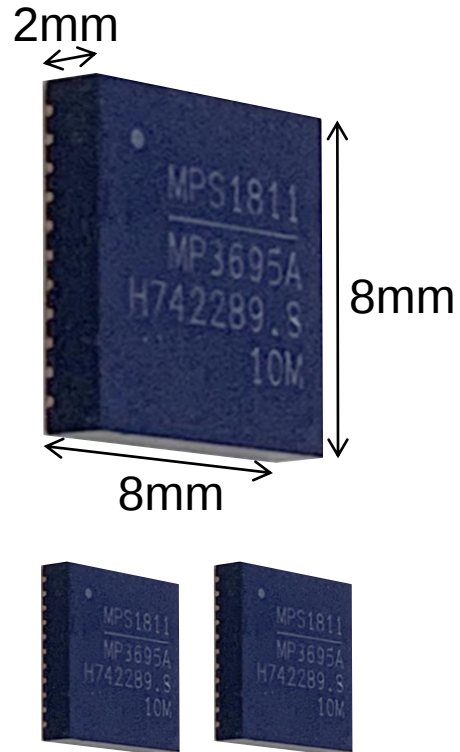


❑ MPS Flip-Chip Solution



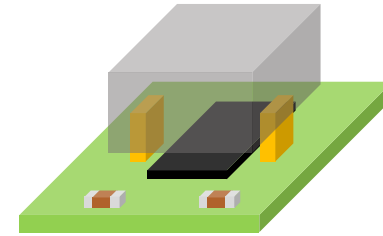
Heat directly spreads from bump to board

3. 低高度模块可以与主芯片共用散热器

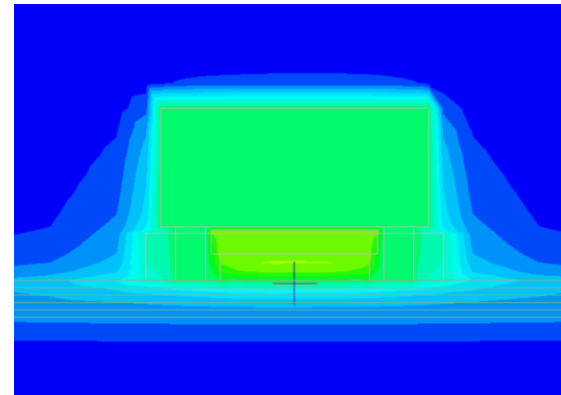


MPM3695A-10 10A thickness
of 2 mm parallel to 60A

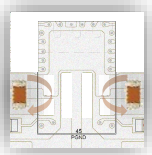
4. 3D 封装可以使得模块散热更加均匀



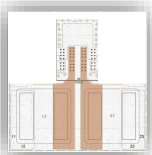
Inductor legs to help
distribute heat evenly



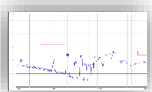
MPS电源模块降低了EMI设计难度



1. 集成的对称输入电容有效的反相抵消了“热环路”电磁场



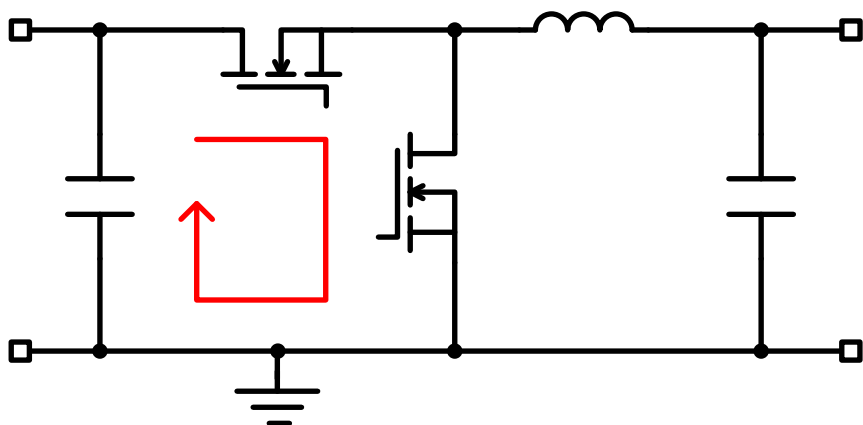
2. 优化SW节点设计减小EMI辐射



3. 可编程的频谱展开，抖频， dv/dt 速度可以进一步降低EMI噪声源以及分布

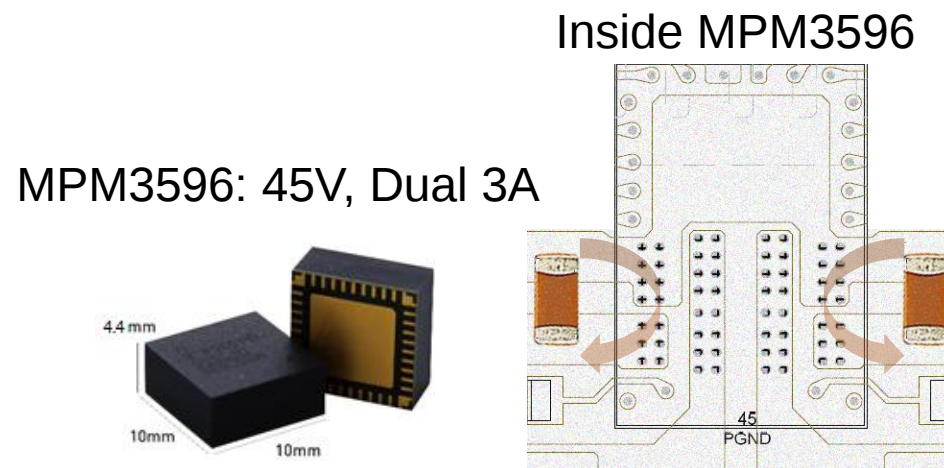
集成的对称输入电容有效的反相抵消了“热环路”移入的噪声

❑ Hot Loop in a Buck



Strong noise generated from **hot loop** due to pulsating current in **HS FET**, **LS FET**, and **input capacitors**

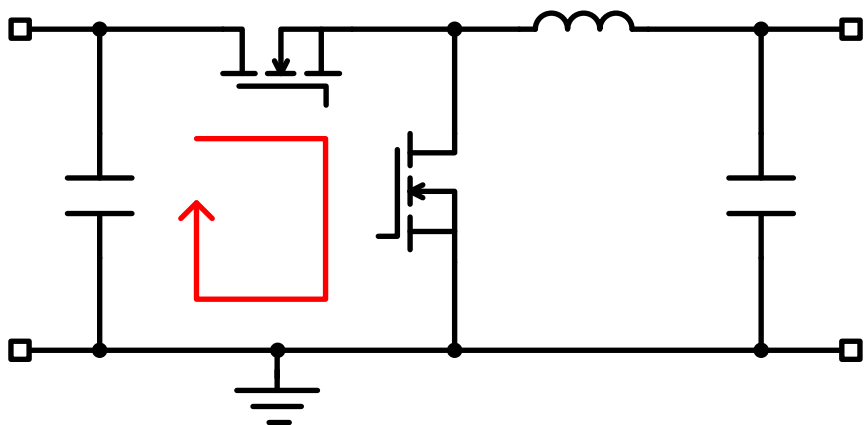
❑ MPS Noise-Cancelling Caps



Field generated in the hot loop are **cancelled** by opposite current direction from two sides

减小SW面积，基板集成接地层，减少EMI辐射

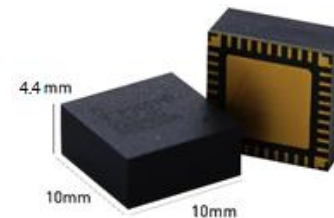
❑ Hot Loop in a Buck



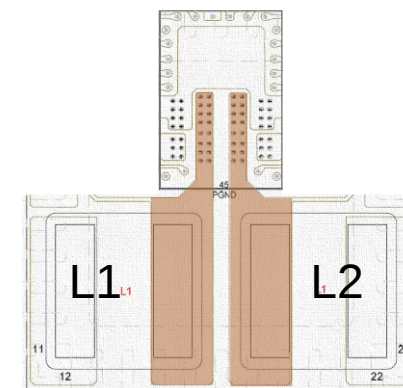
Strong noise generated from **hot loop** due to pulsating current in **HS FET**, **LS FET**, and **input capacitors**

❑ Reduced SW Area

MPM3596: 45V, 3A



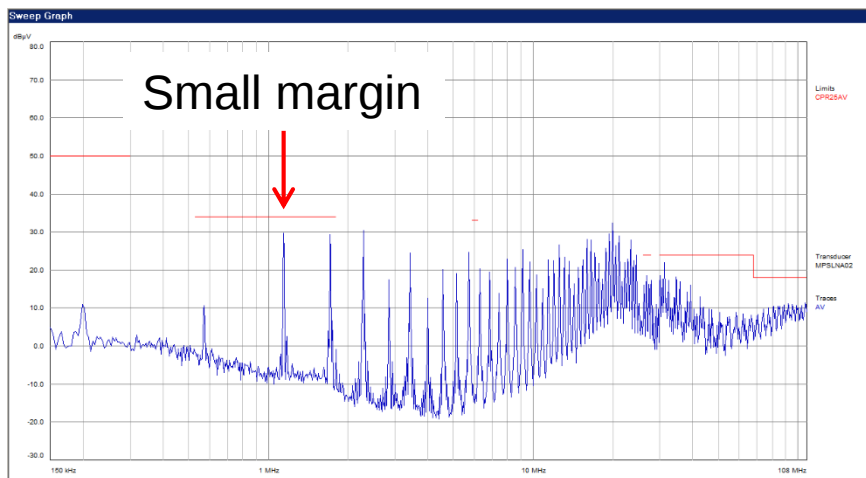
Inside MPM3596



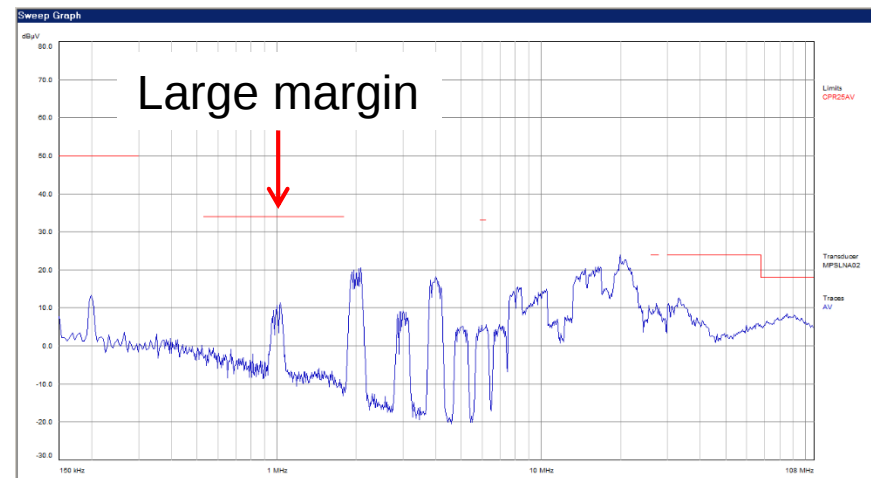
Limit the area of switching node to reduce EMI emission

频谱展开可以进一步降低EMI噪声

❑ Conventional Switching



❑ MPS Solution with Frequency Spectrum



- 1) Spread frequency spectrum: allow part to switch in a frequency range instead of a single frequency point; the range is adjustable around a fixed value
- 2) dv/dt can also be adjusted to meet EMI requirement

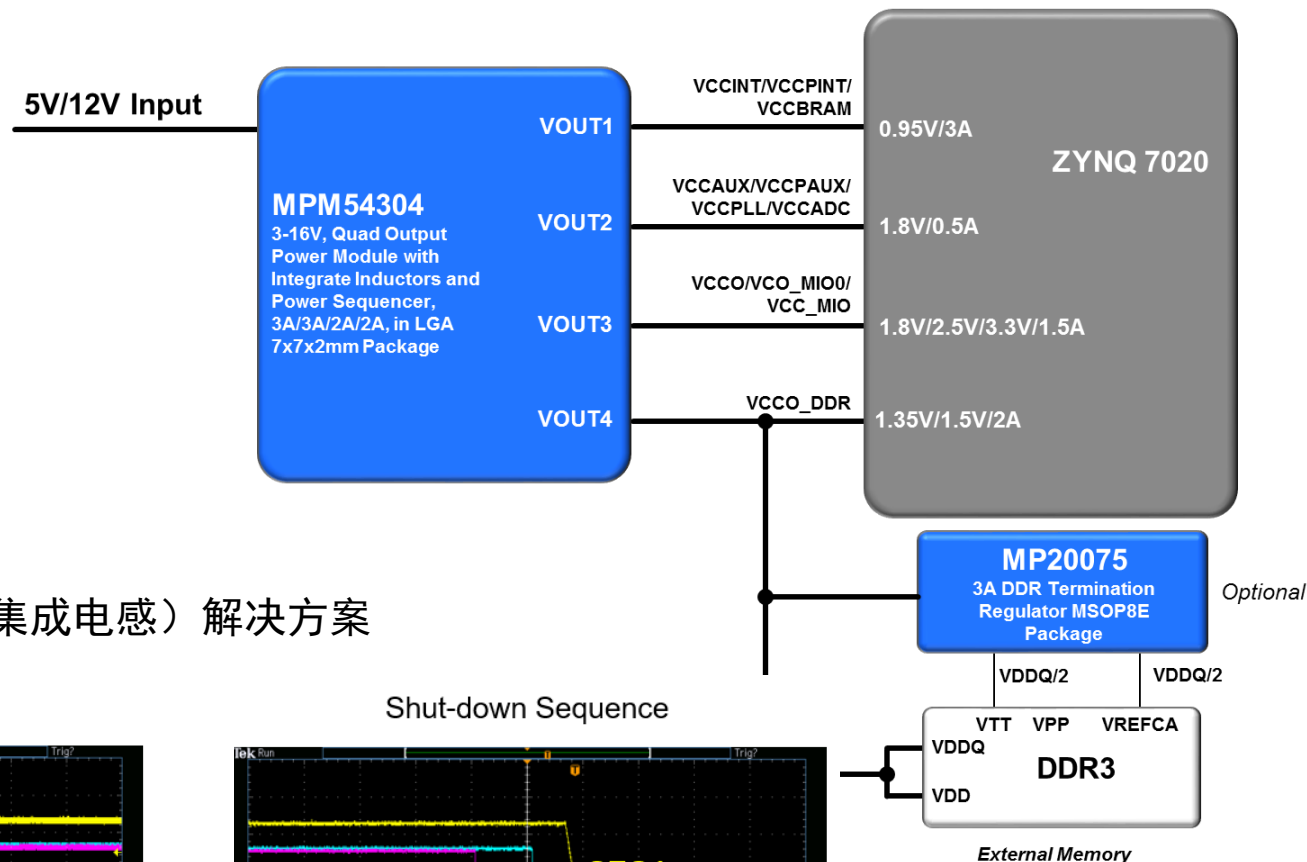
电源模块解决FPGA的供电问题 – 多路电源轨以及电源管理

- 更小尺寸的单路输出电源模块

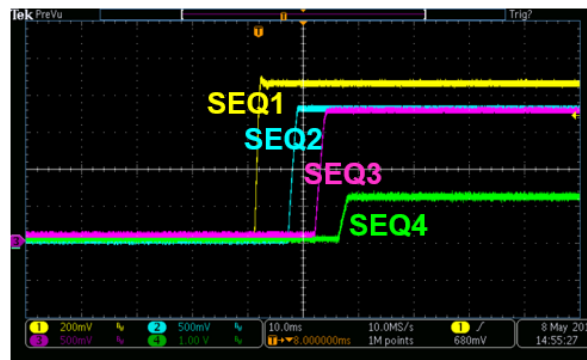
- 3A: MPM3632C 3x5x1.6mm
- 5A: MPM3650 4x6x1.6mm
- 8A: MPM3683-7: 7x7x4mm
- 20A: MPM3695-25: 10x12x4mm

- 集成了电源管理功能的4路输出电源模块

- MPM54304: 2x3A + 2x2A
 - 适用于ZYNQ/Spartan/Artix/Cyclone的单芯片（集成电感）解决方案
- MPM54504: 4x5A
- MPM82504: 4x25A



Start-up Sequence

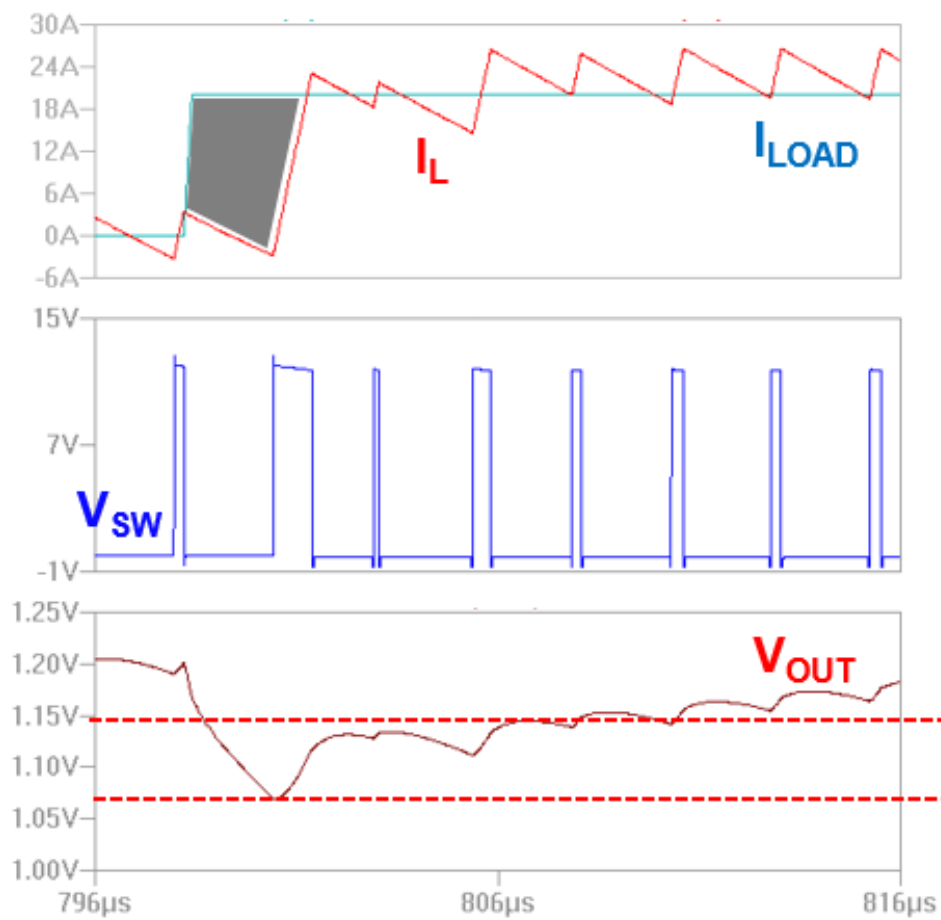


Shut-down Sequence

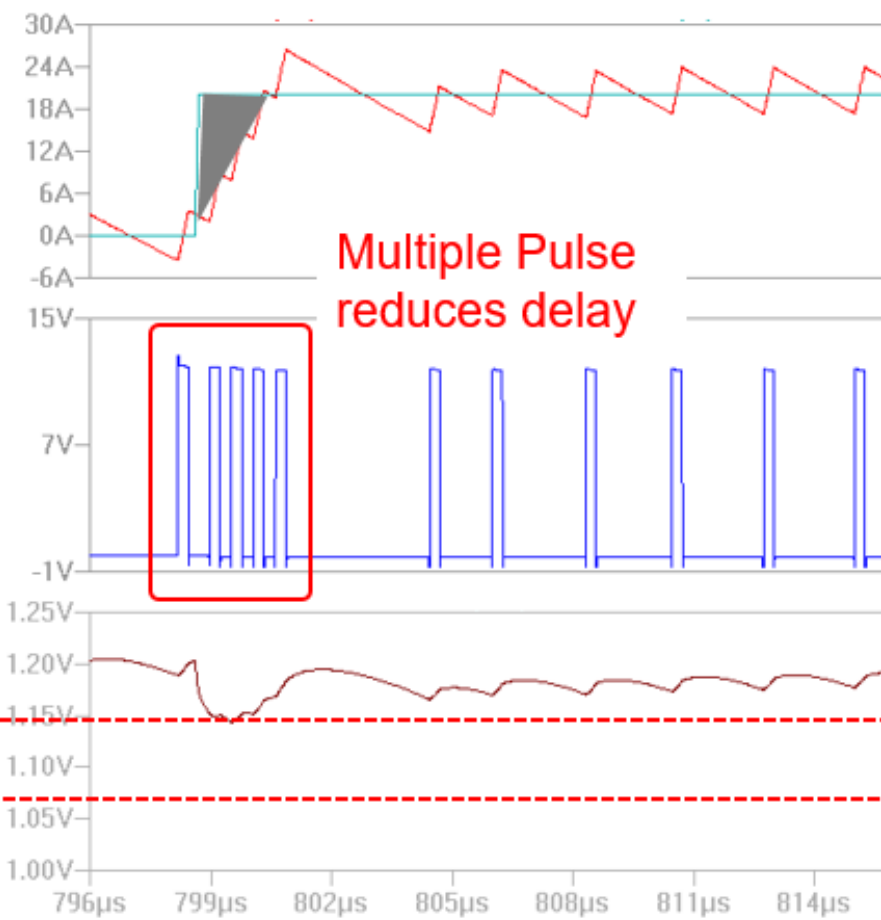


电源模块解决FPGA的供电问题 – 快速动态响应以及电压精度

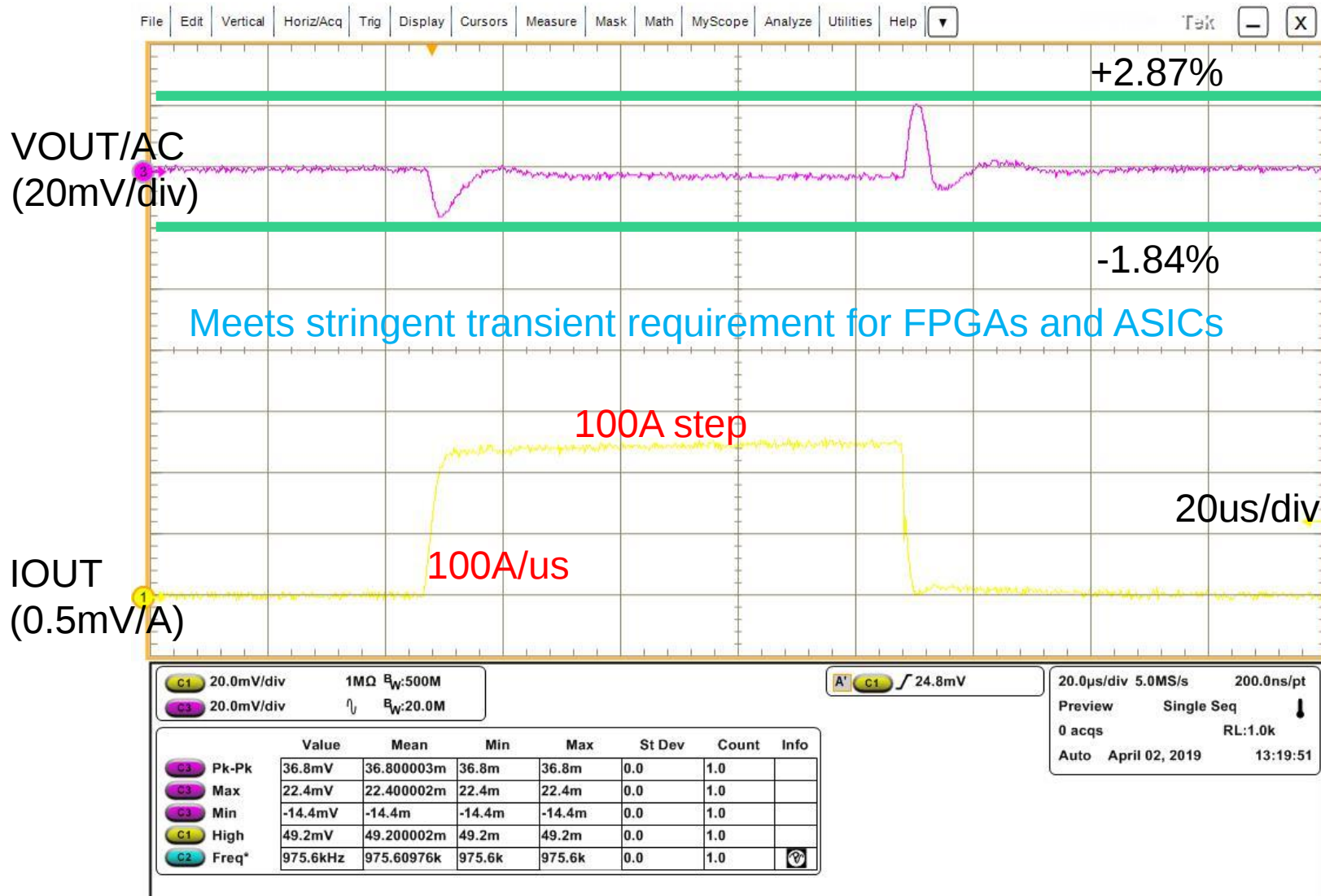
Current-mode Control



Constant-On-Time Control



用2xMPM3695-100实现100A/uS的负载跳变



Parameter	Value
Number of power modules	2
Maximum output current	200A
Ceramic output capacitor	47uFx16 per module 6.3V 0805
SP-Cap output capacitor	220uFx8 total
Input voltage	12V
Output voltage	0.78V

小总结 – MPS电源模块应对新挑战之道

- 更短的开发周期
 - 更高的集成度，简化了原理图和PCB布线，以及可靠性认证周期
- 更小的方案尺寸
 - 单晶圆的功率+控制；更高的频率；倒装工艺；3D模块封装
- 解决系统以及电源的散热问题
 - 先进的芯片制成；优化的模块设计降低损耗；更小的热阻
- 抑制EMI噪声
 - 集成对称的输入电容；可编程的频谱展开；更小的SW面积
- FPGA等复杂电源时序管理以及系统集成
 - 更小体积的单路电路；业界第一款多路输出带电源管理的模块系列；COT控制提高负载动态响应速度
- 高速ADC/DAC的低噪声供电

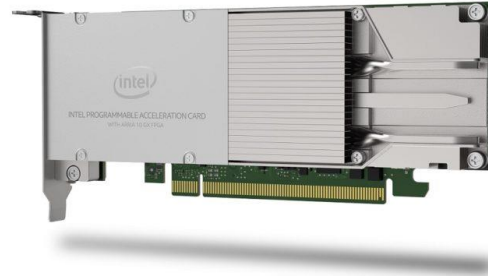
MPS电源模块产品系列 – 降压

I_{OUT} Max V_{IN}	0.6A	1.2A	2A	3A	4-6A	7-8A	10A	20A-25A	30A-50A	100A
Wide VIN ($\leq 75V$)	MPM3570E 10x10x4.4mm			MPM3530 10x12x4mm					Blue - Released Gray- Sampling Orange – Sampling Soon	
High Voltage ($\leq 45V$)	MPM3506A 3x5x1.6mm	MPM3510A MPM3515 3x5x1.6mm	MPM3593 I2C 6x8x1.6mm MPM3520E 10x10x4mm	mEZD74003L 11x15x4mm MPM3596 2x3A, PMBus 10x10x4mm	MPM3596 PMBus, Parallel 10x10x4mm MPM3550E 12x12x4mm					
Medium Voltage ($\leq 24V$)	MPM3606/A 3x5x1.6mm	MPM3610/A 3x5x1.6mm	MPM3620/A 3x5x1.6mm	MPM3632C MPM3630 3x5x1.6mm MPM54304 2x3A+2x2A, I2C 7x7x2mm	MPM3650 4x6x2mm MPM54504 4x5A, I2C	MPM3683-7 7x7x4mm	MPM3695-10 PMBus, Parallel 8x8x2mm	MPM3695-25 PMBus, Parallel 10x12x4mm MPM82504 4x25A, PMBus 15x30x5.3mm		MPM3690-100 PMBus, Parallel 15x30x5.3mm
Low Input ($\leq 6V$)	MPM3804 2x2x0.9mm MPM3805 3x2.5x0.9mm	MPM3811 2x2x1.6mm MPM38111 2x1A 4x4x1.6mm	MPM3822C 2.5x3.5x1.6mm MPM38222 2x2A 4x4x1.6mm	MPM3833C 2.5x3.5x1.6mm MPM3830 3x5x1.6mm	MPM3860 4x6x1.6mm MPM3840 3x5x1.6mm					

MPS电源模块的应用



5G Wireless



AI Acceleration



Optical Modules



Test Equipment



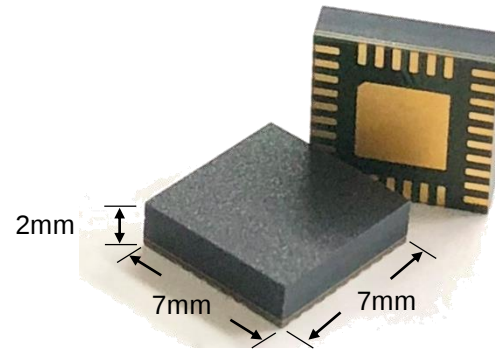
Sensors, Cameras



Industrial

MPM54304 – Industry First PMIC Module

16V, Four Outputs, 3A/3A/2A/2A Module in
7x7x2mm LGA



MPM54304 Introduction

FEATURES

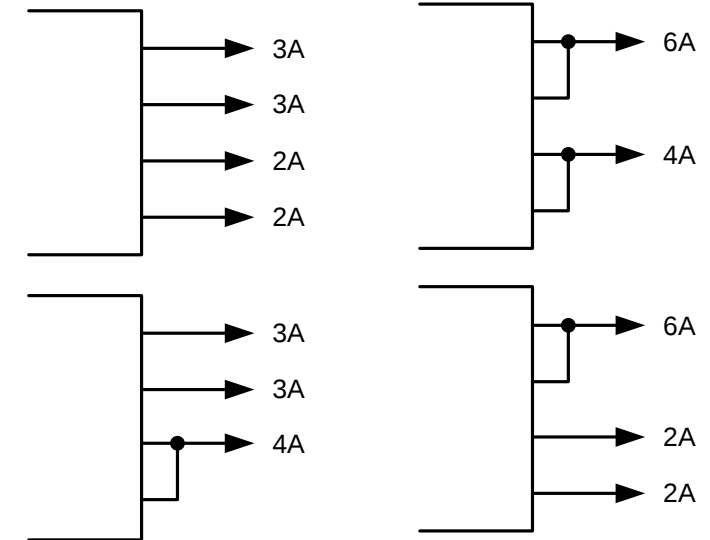
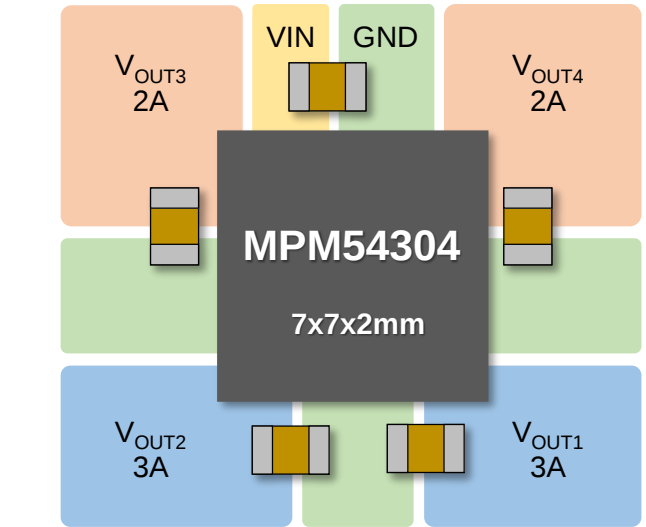
- Input range: 3V-16V;
- Output range: 0.55-5.5V, with 10mV Steps
- Output Current: 3A/3A/2A/2A
- Rails Can be Combined
- Adjustable Power On/Off Sequence
- PG & Enable
- Total Loss allowed: 2.75W
- MTP (3-time) and I2C Function
- QFN package (7x7x2mm)

KEY ADVANTAGES

- **Small Solution Size**
- **Flexible Configuration**
- **Easy Layout**
- **Sequencing & Power Management**

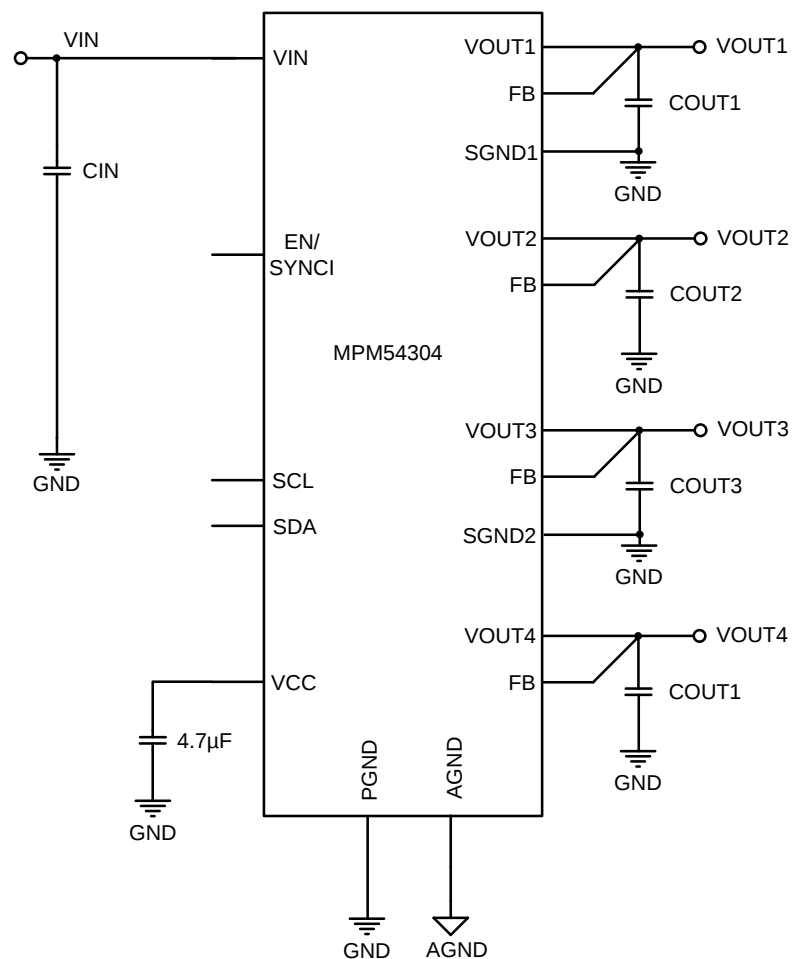
APPLICATIONS

- FPGA/DSP Power Supply
- Single Chip power solutions for ZYNQ-7000 series
- Multi-rail application
- Telecom and Industrial

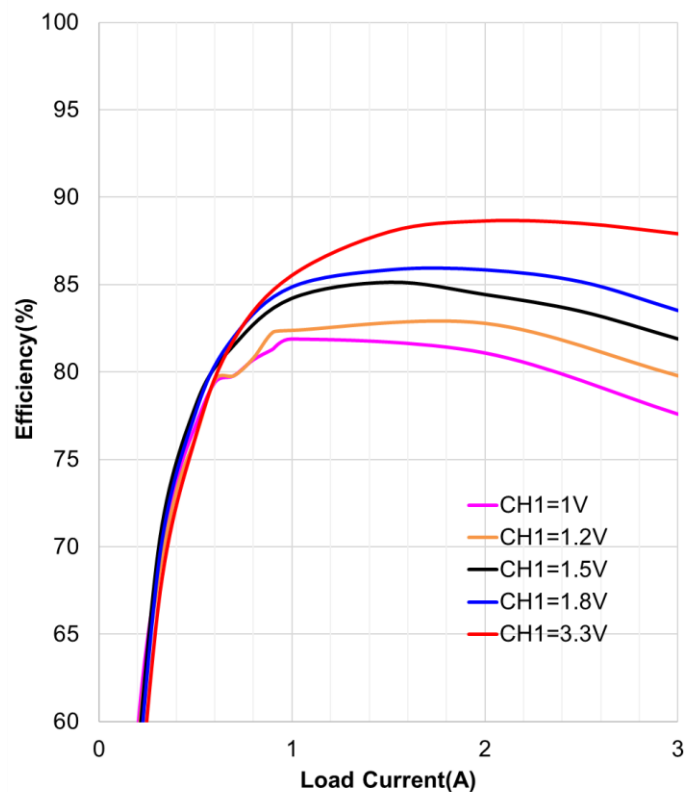


MPM54304 Application Circuit & Efficiency

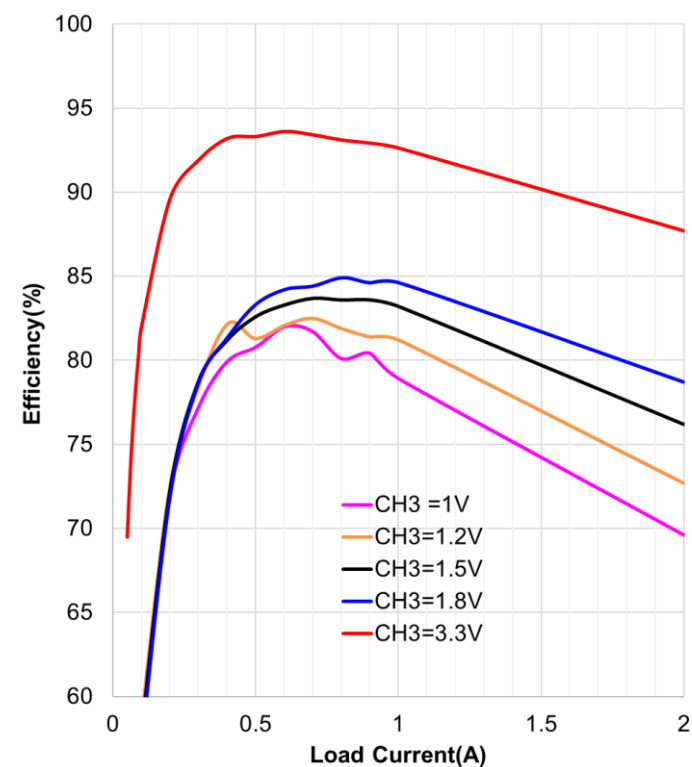
Schematic



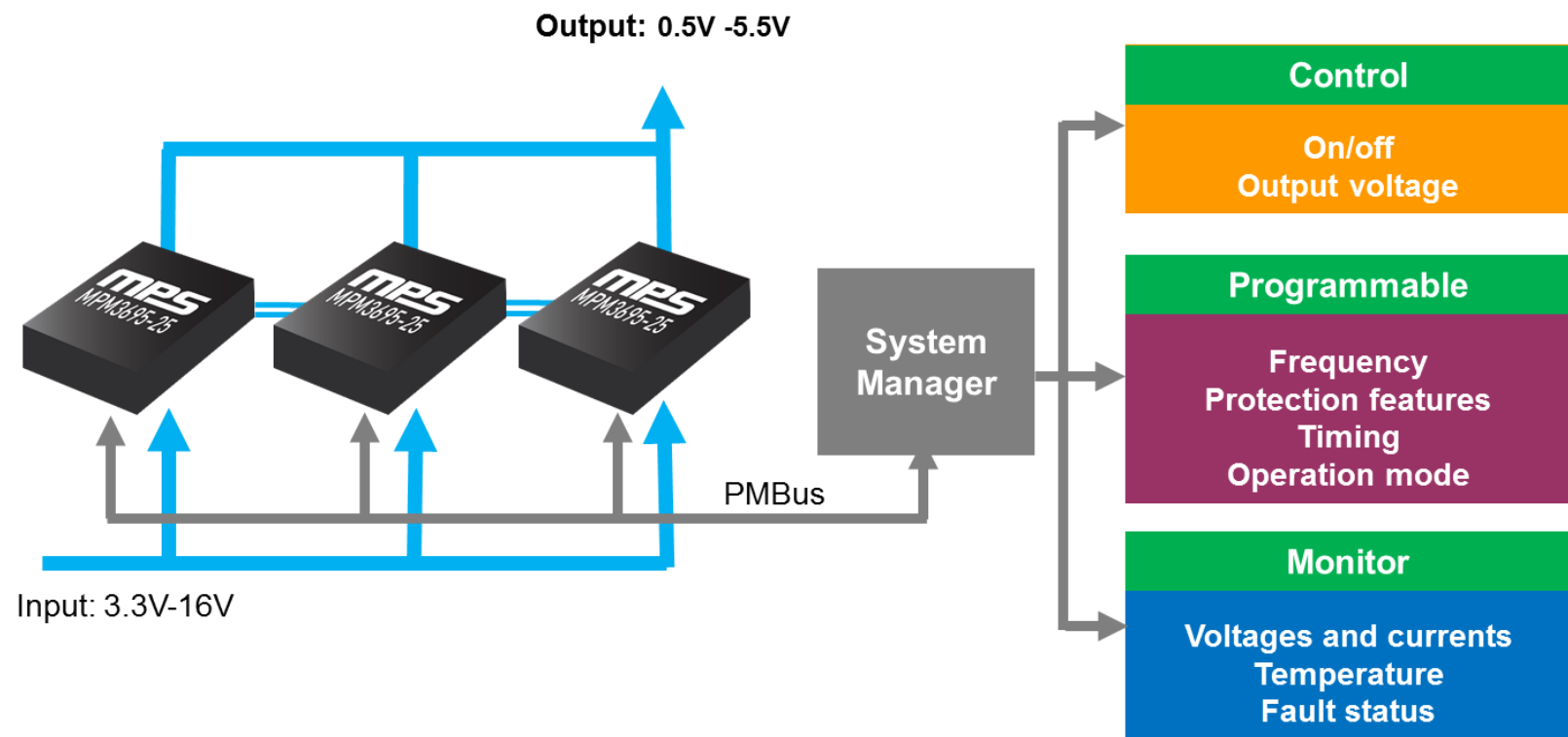
Efficiency VS. Load Current, Vin=12V



Efficiency VS. Load Current, Vin=12V



Intelligent Scalable DC-DC Power Module Family



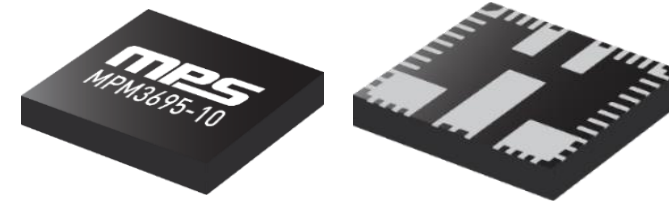
Part Number	IOUT	# of Outputs	Vin Range	Package	Height	I2C	Parallel
MPM3695-10	10A	1	3-16V	8x8mm	2mm	Yes	Yes, up to 2
MPM3695-25	25A	1	3-16V	10x12mm	4mm	Yes	Yes, up to 2
MPM82504	25Ax4	4	3V-16V	15x30mm	5.3mm	Yes	Yes, up to 8
MPM3695-100	100A	1	3V-16V	15x30mm	5.3mm	Yes	Yes, up to 8



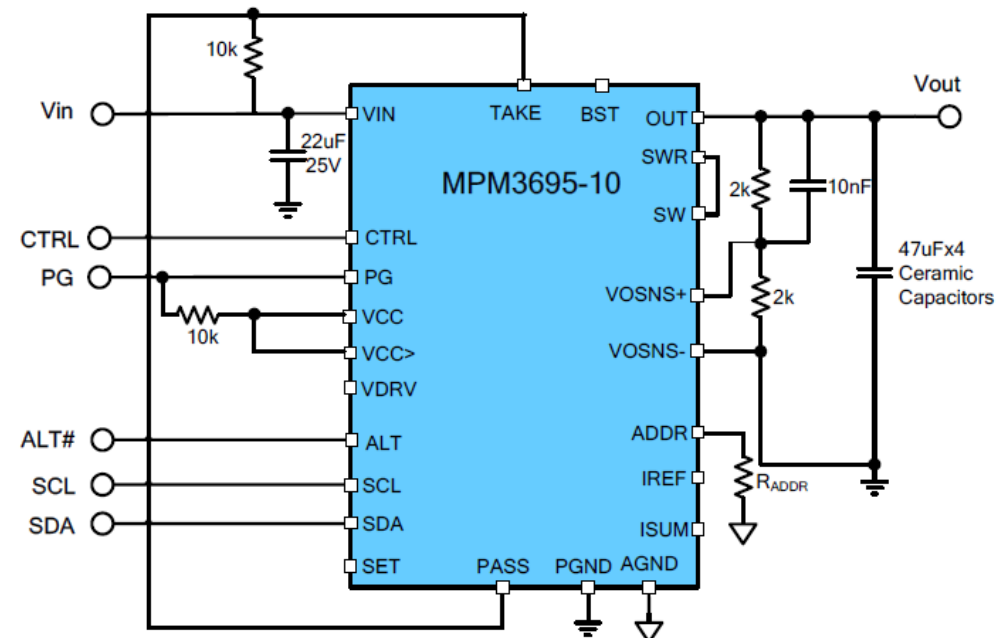
MPM3695-10: 16V, 10A Module, Parallel, PMBus, 2mm Height

FEATURES

- Input voltage range: 3V-16V
- Output voltage range: 0.5V-5.5V
- 10A Continuous Output current
- Parallel up to 2-Phases
- Auto-Compensation, Auto Interleaving
- Voltage Remote Sensing
- Programmable via PMBus and MTP memory
- GUI available
- LGA 8x8x2mm Ultra-thin package



LGA 8×8×2mm

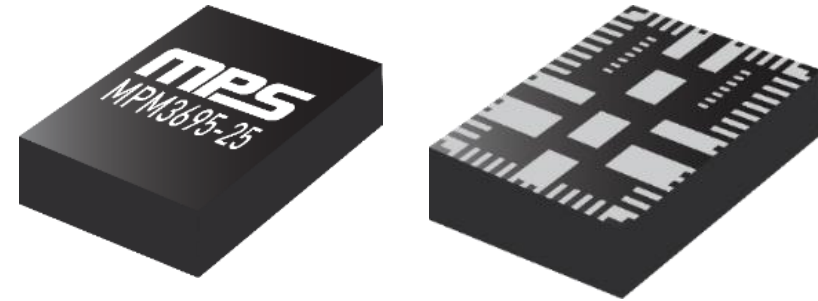


Application circuit for single phase operation at 1.2V output

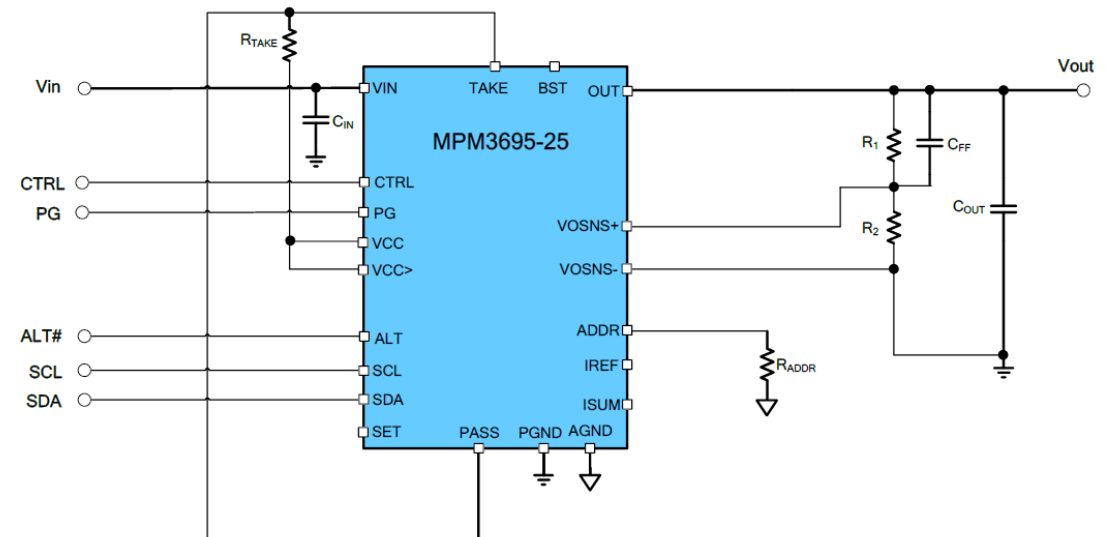
MPM3695-25 Features

FEATURES

- **Parallel for higher current**
- VIN range: 3.3V-16V
- VOUT Range: 0.5V-5.5V
- Continuous 20A
- Differential Remote Voltage Sensing
- **Auto Interleaving, Auto Compensation**
- Readback:
 - VIN, VOUT, IOUT, TEMP, Faults
- Programmable via PMBus:
 - Current Limit, SS, FSW, OCP, UVP, OVP, OTP limit
- GUI available



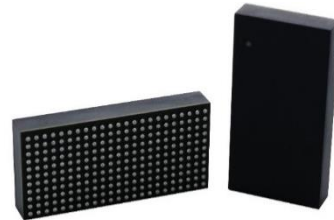
QFN 10×12×4mm



Single Phase Operation

MPM3695-100

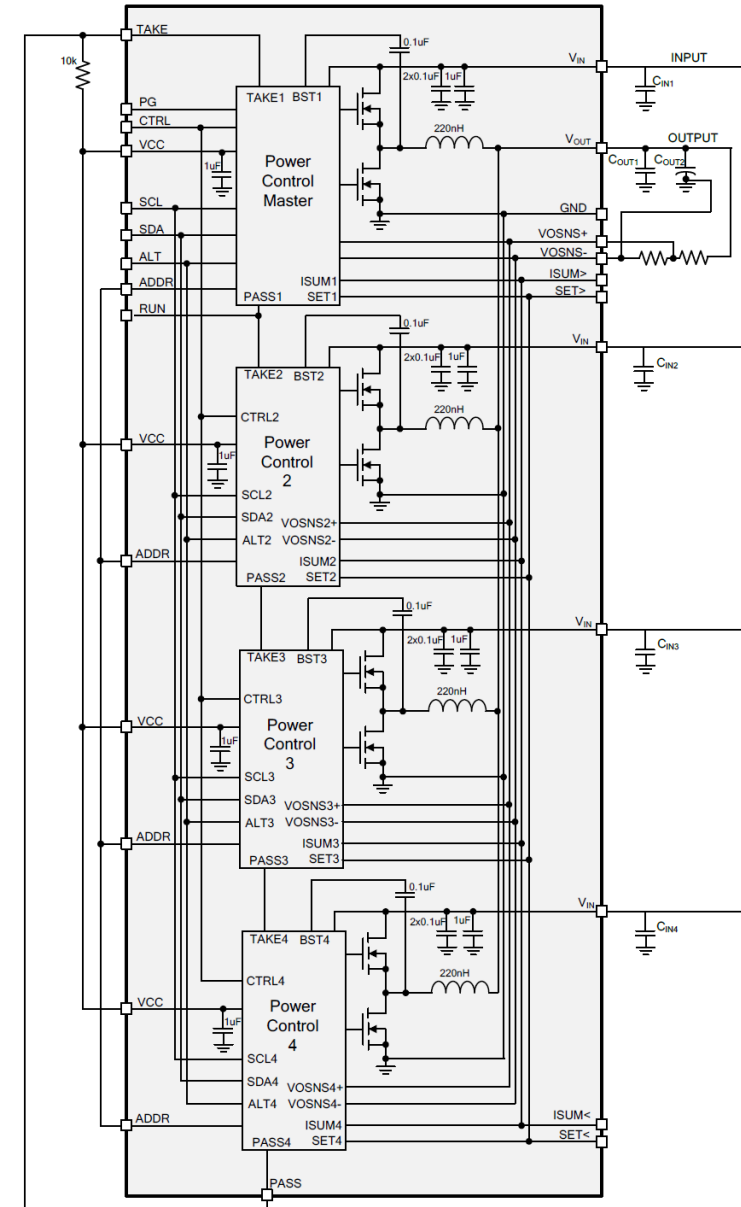
Scalable, 100A Power Module in 15x30x5mm
BGA Package



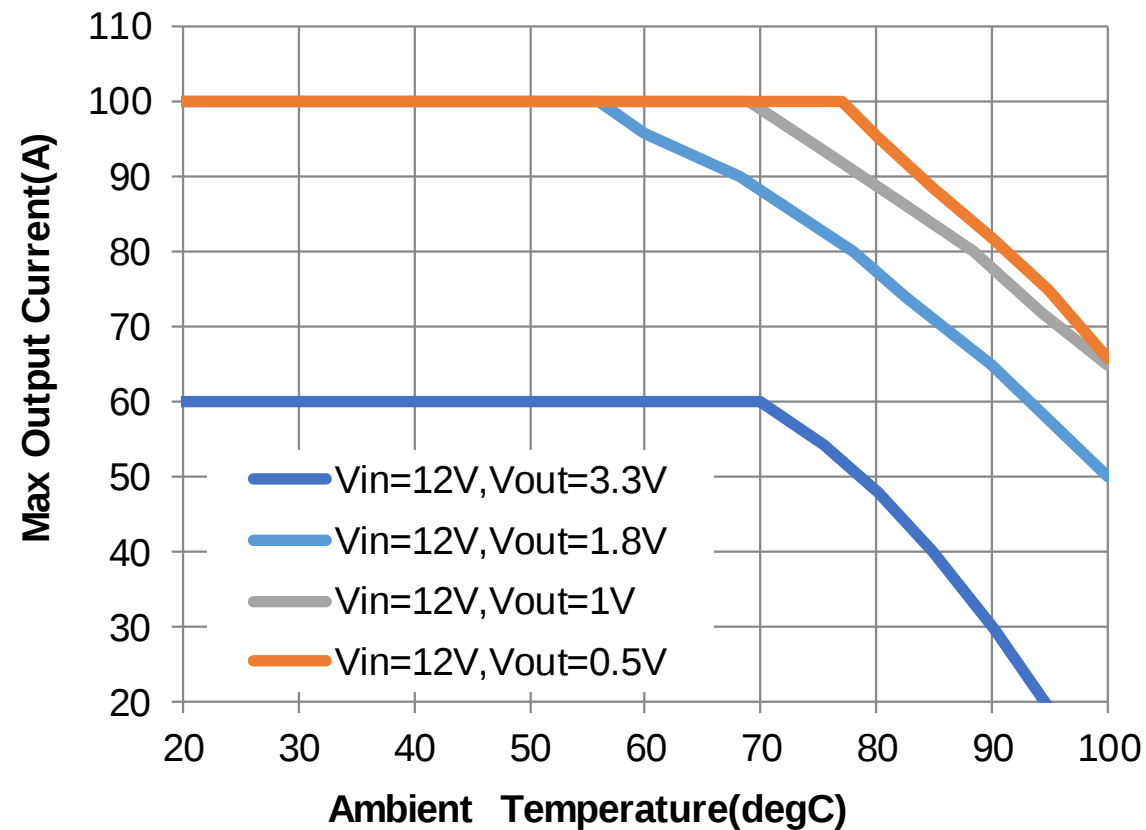
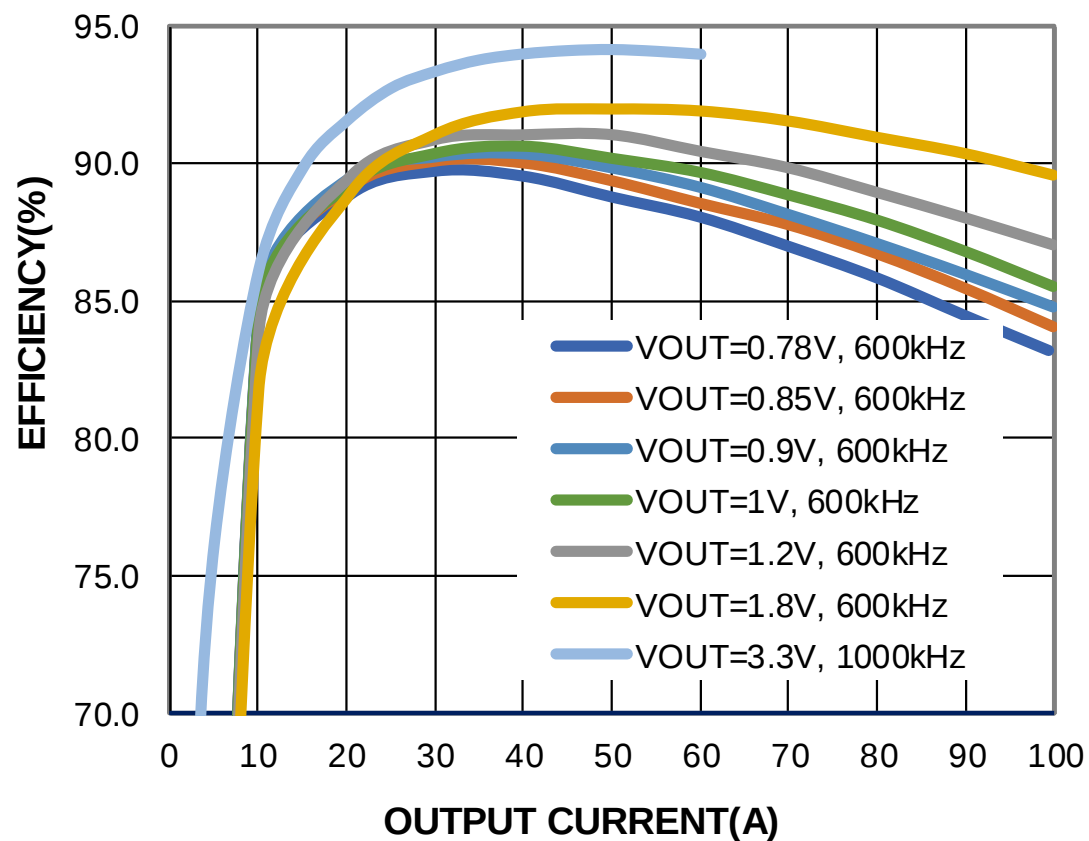
MPM3695-100 – 100A Power Module

FEATURES

- Input range: 4V-16V; output range: 0.5V-3.3V
- Continuous 100A Output Current
 - 60A for 3.3V Output
- Peak 90% at 12V input, 1V output
- Parallel for up to 800A
- Up to 70% footprint reduction compared to discrete solution
- 4-Phase Interleaved in one module
 - Equivalent 3.2MHz Switching Frequency
 - Ultra-fast transient – requires minimized output capacitance
 - <5mV Voltage Ripple with 4x47uF Output Cap only
- PMBus 1.3 Compliant
- BGA packages (15x30x5.2mm, 1.27mm pitch)
- Ease of Use



MPM3695-100 Efficiency & Thermal Derating



Thermal Test

Test Condition:

12V Input

0.85V Output

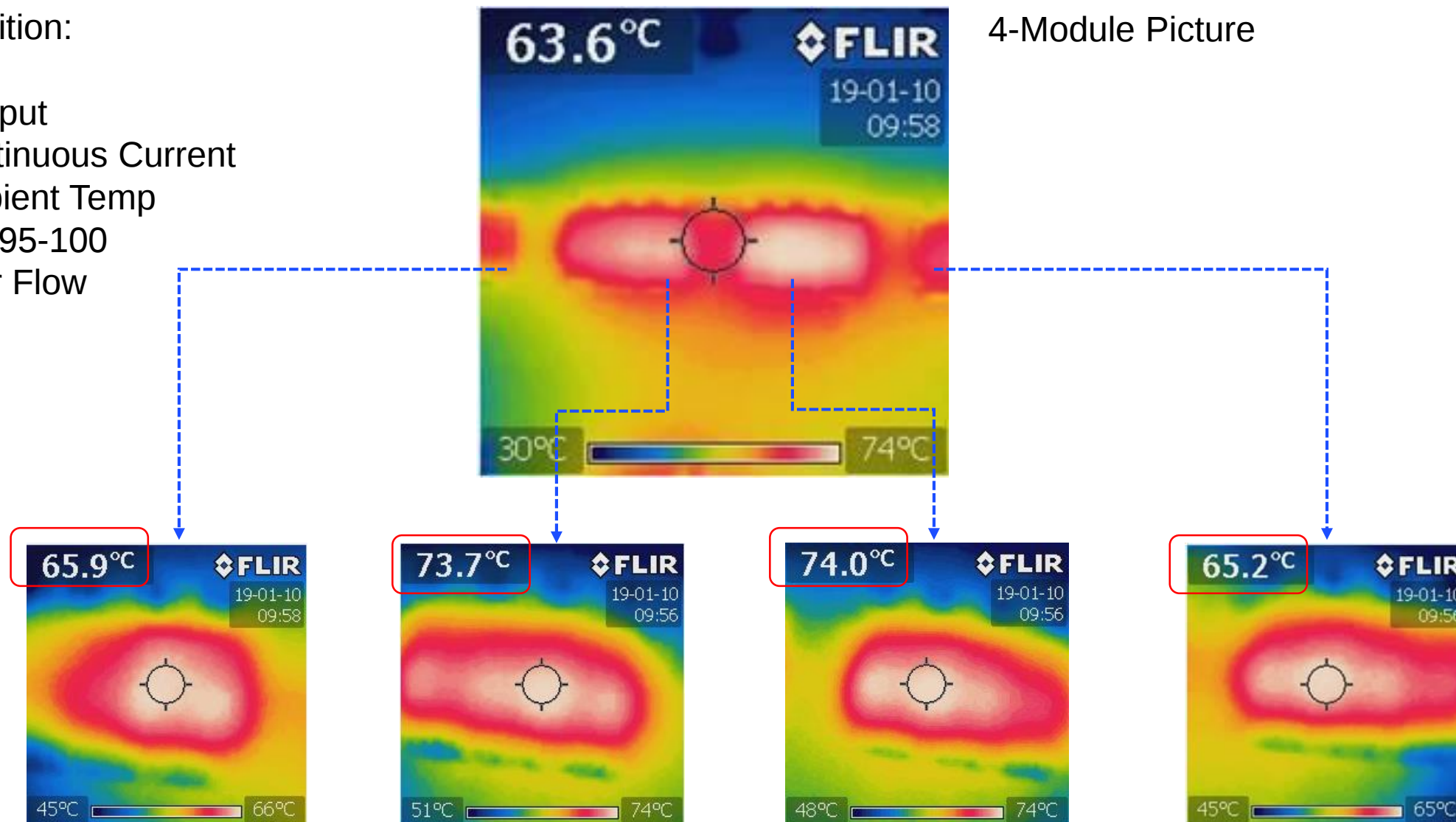
320A Continuous Current

18°C Ambient Temp

4xMPM3695-100

0.5m/S Air Flow

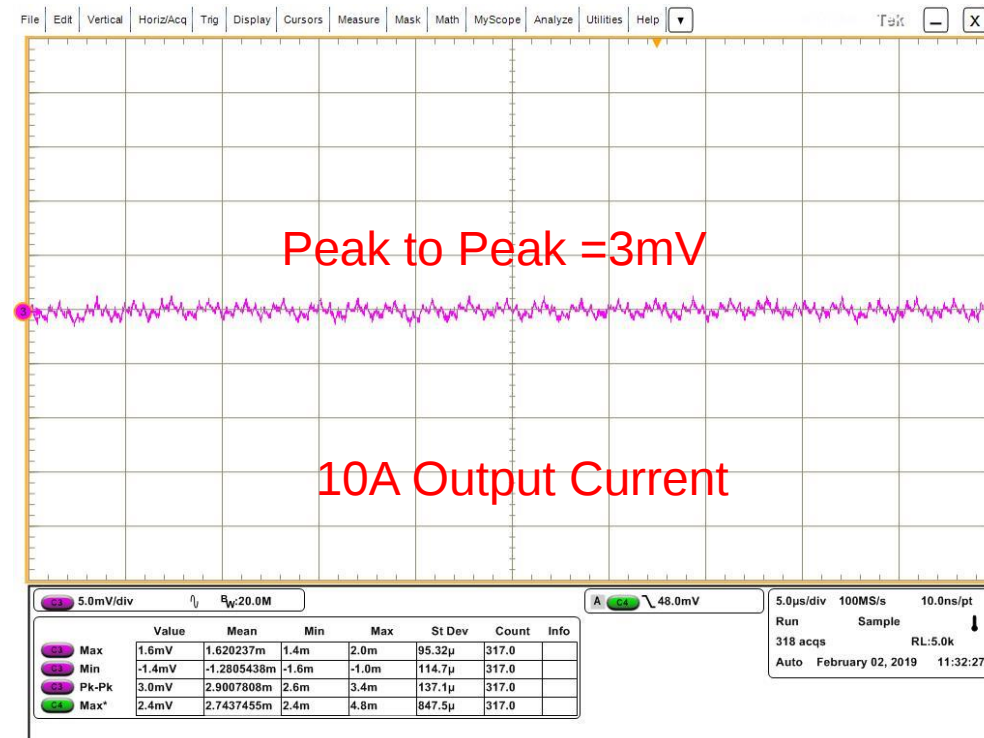
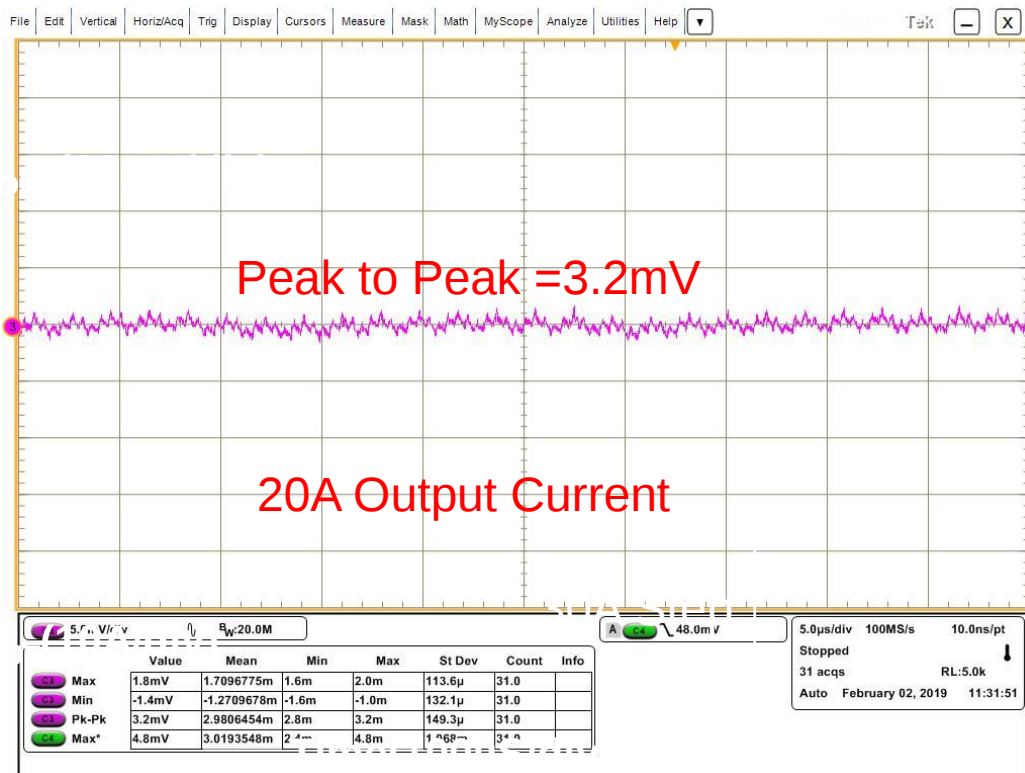
4-Module Picture



Steady State Ripple – Single Phase

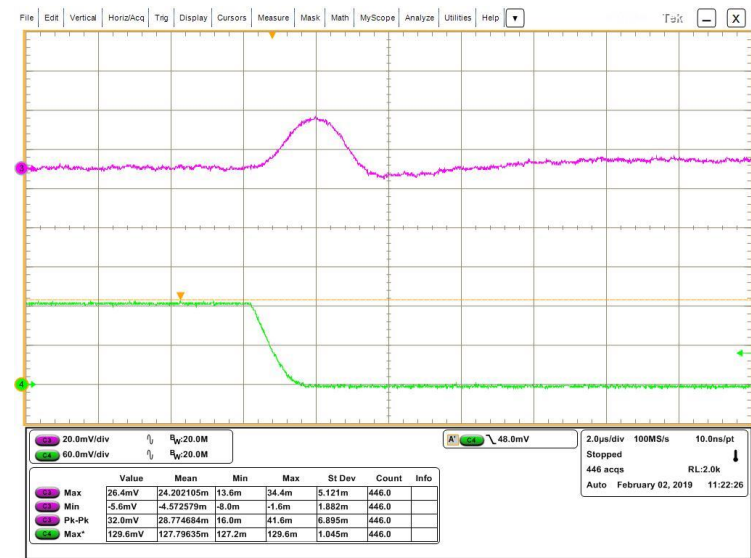
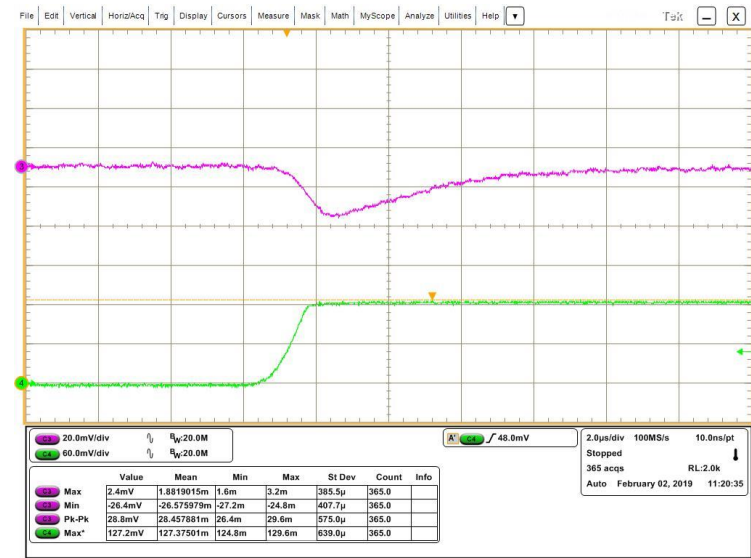
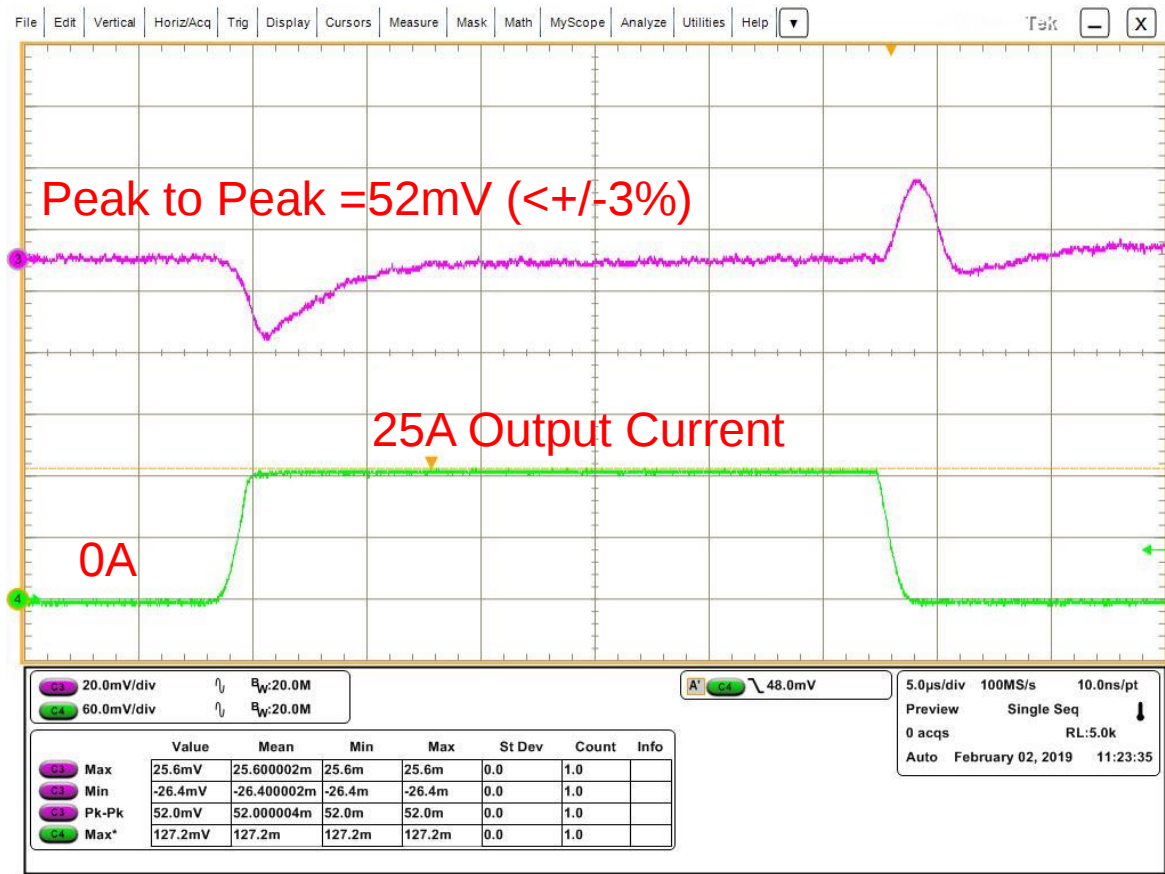
12V Input, 1V Output,
COUT = 6x47 μ F + 1x220 μ F SP-CAP

Achieves >70% output capacitance reduction compared to competing power modules



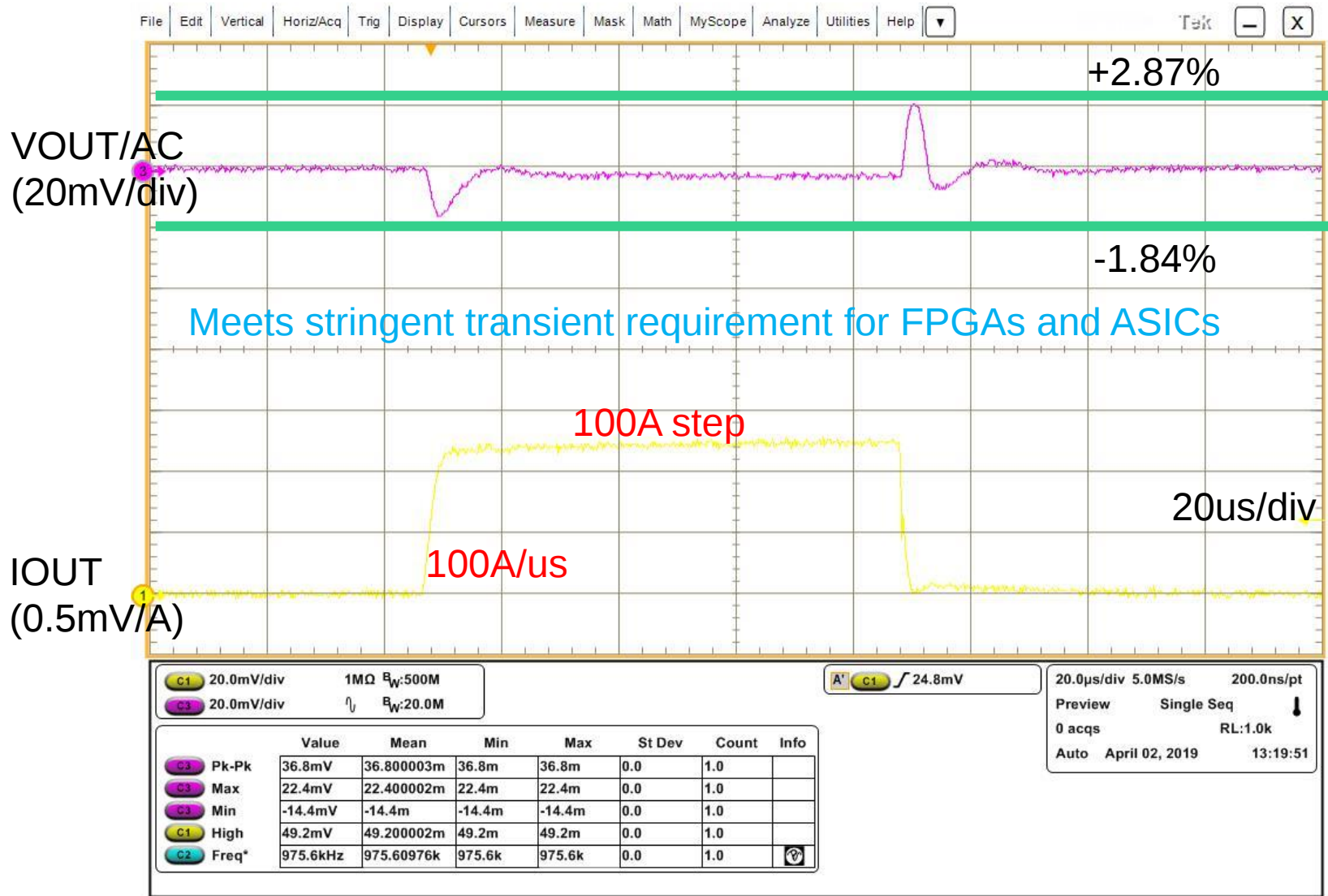
Load Transient Performance – Single Phase

12V Input, 1V Output, 0A-25A Step (25%), 10A/us
COUT = 6x47μF + 1x220μF SP-CAP



Achieves >70% output capacitance reduction compared to competing power modules

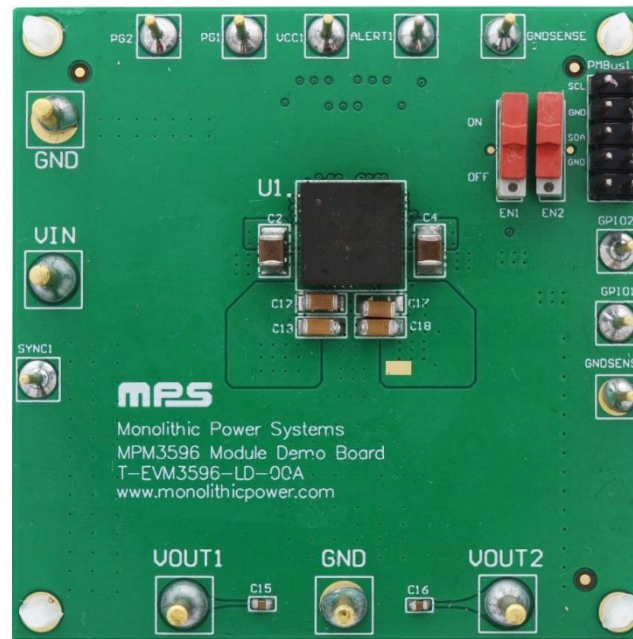
100A Transient in 1 Micro Second – 2xMPM3695-100



Parameter	Value
Number of power modules	2
Maximum output current	200A
Ceramic output capacitor	47uFx16 per module 6.3V 0805
SP-Cap output capacitor	220uFx8 total
Input voltage	12V
Output voltage	0.78V

MPM3596 Introduction

45V, Dual 3A, Single 6A, Scalable, Digital
Power Module in 10x10x4.4mm LGA

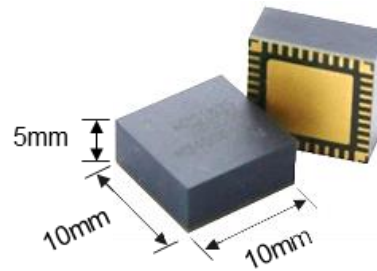
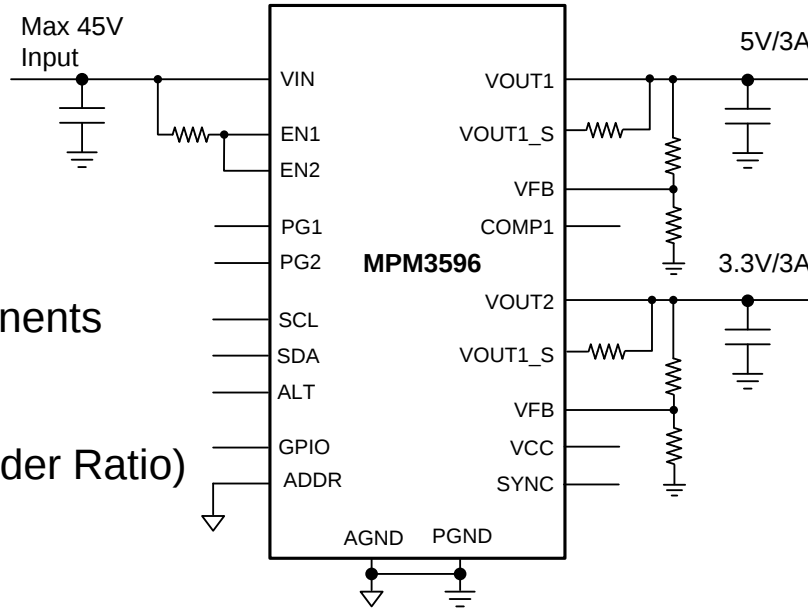


MPM3596 Introduction

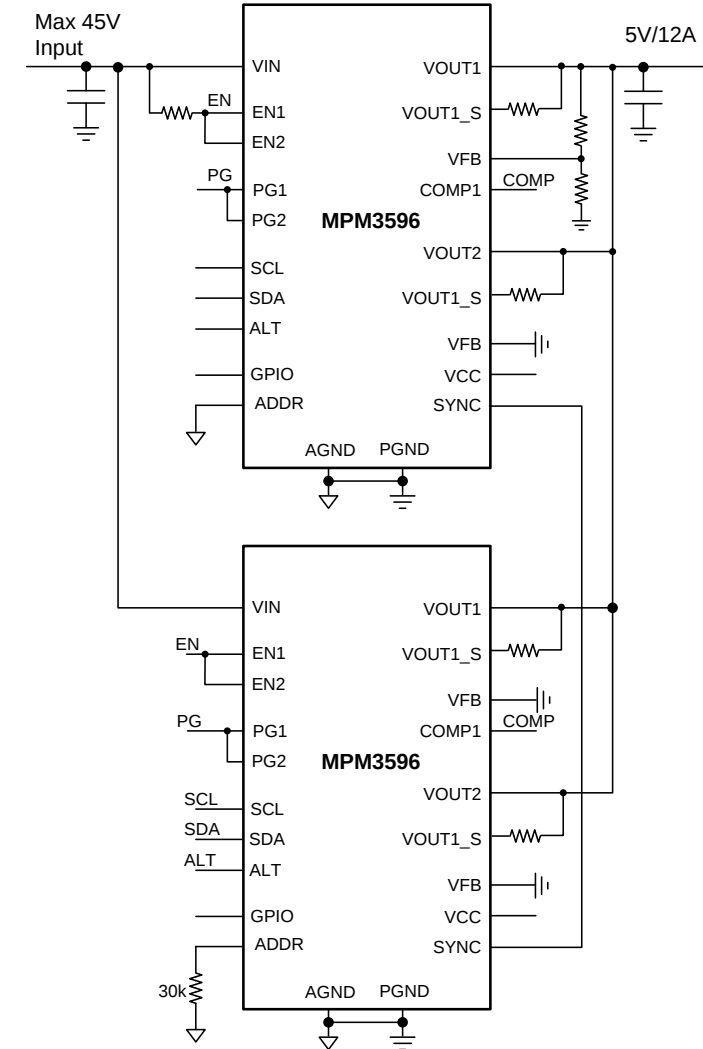
FEATURES

- Wide V_{IN} Range: 3.5V-45V
- V_{OUT} Range: 0.4V-24V
- Dual 3A, Single 6A
 - Parallel up to 36A
- LGA 10x10x4.4mm
- Small Solution Size, Minimum Ext Components
- Telemetry Read-back
 - V_{IN} , V_{OUT} , I_{OUT} , Temp
- Change V_{OUT} on-the-fly (Step: $1.5\text{mV} \times \text{Divider Ratio}$)
- Low EMI
 - Dual Side Input Capacitors
 - Dithering /Frequency Spread Spectrum
- $\pm 1\%$ V_{OUT} Over Temp
- Peak Current Mode Control
- External Clock Synchronization
- Programmable MTP Registers including
 - Switching Frequency
 - Protection Threshold & Responses
 - PWM/PFM
- OTP, OVP, UVP, OCP
- GPIO can be programmed as ADC input

Application Circuit: Dual Output



Application Circuit: Paralleling

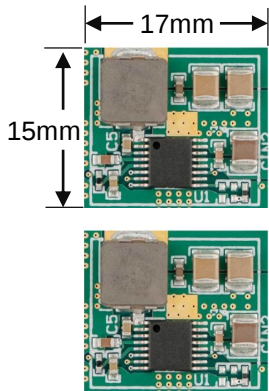


MPM3596 Advantages

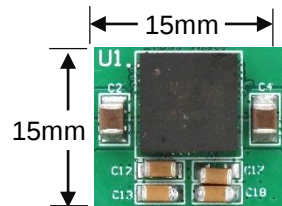
Small Size, High Power Density

- Monolithic Power Stage
- High F_{SW} to Reduce Passive
- Customized Magnetic Design

24V_{IN}->3.3V/3A & 5V/3A



Discrete Solution
510mm²



MPM3596 Solution
<225mm²

Ease of Use, Parallelable

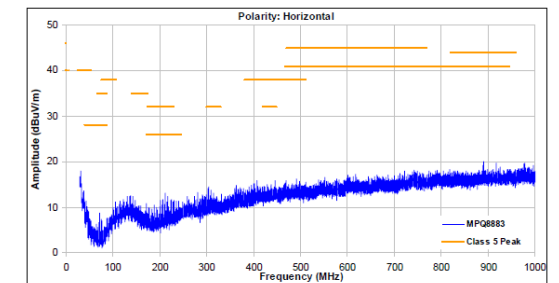
- Simple Schematic, Simple Layout
- Parallel up to 36A
- Programmability & Monitor



Great EMI Performances

- Double Side Input Cap
- Adjustable Switching Speed
- Spread Frequency Spectrum

CISPR25 Class 5 RE



Thank You!