

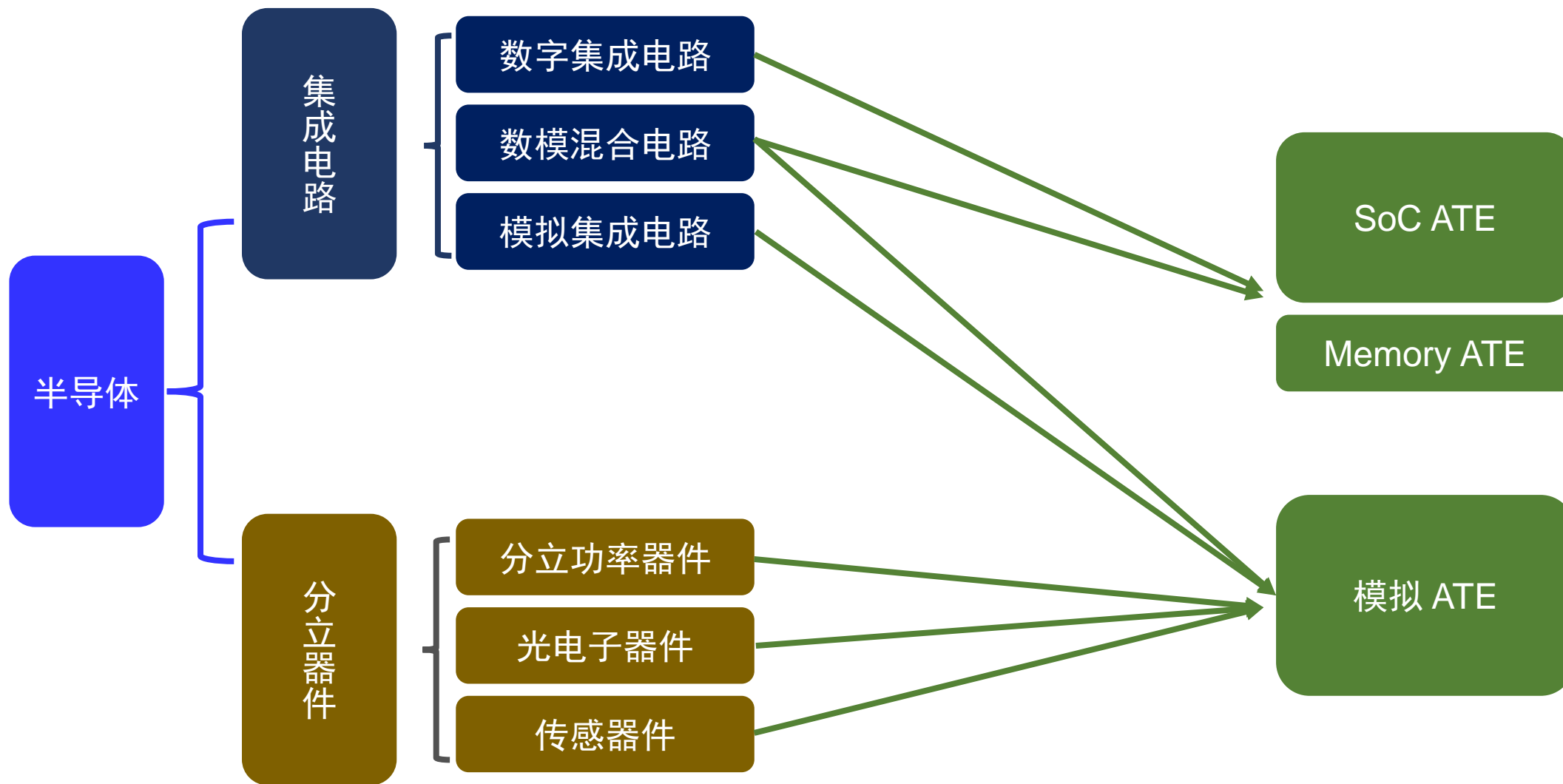
工业测试设备电源的关键技术和解决方案

Roy.tu @
monolithicpower.com

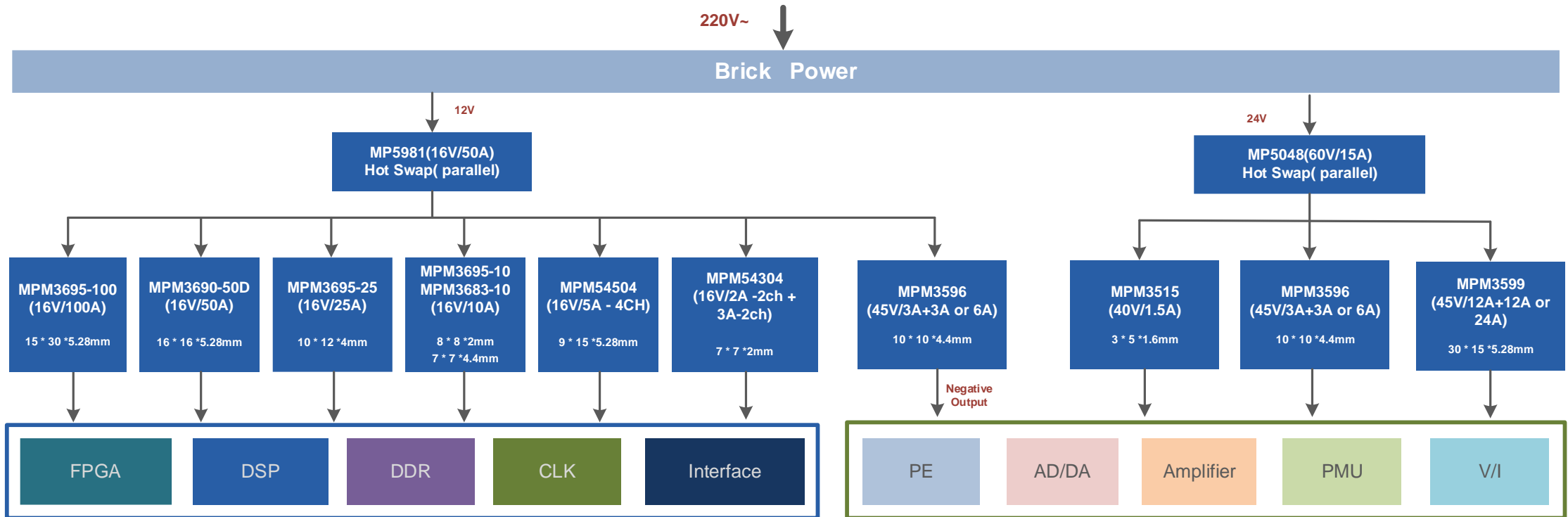
2022/7

- 工业测试设备架构和电源需求综述
 - a. 测试设备构架
 - b. 测试设备中电源架构
- 工业测试设备电源设计的关键点
 - a. 出色的纹波噪声控制
 - b. 高效的损耗控制和热处理
 - c. 体积更加紧凑的方案设计
 - d. 更短的开发周期和更高的可靠性
- MPS电源模块产品介绍
- 工业测试设备电源设计实际案例

Following-Process 测试设备分类



测试单板系统框图



工业测试设备电源设计的关键1

出色的纹波噪声控制

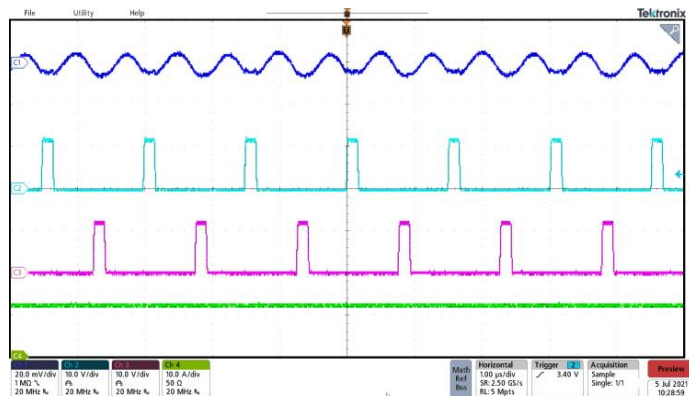
输出电压纹波噪声分析

输出电压噪声

稳态纹波

杂散噪声

跳变纹波



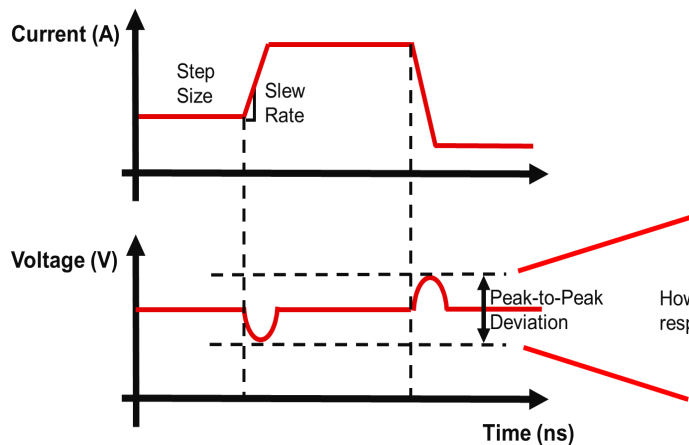
输出电容

开关频率

开关相数

走线设计

紧凑布局

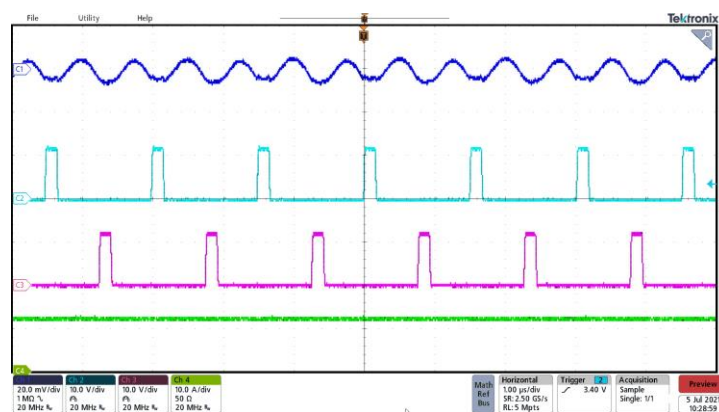
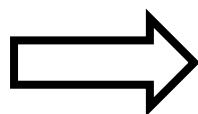
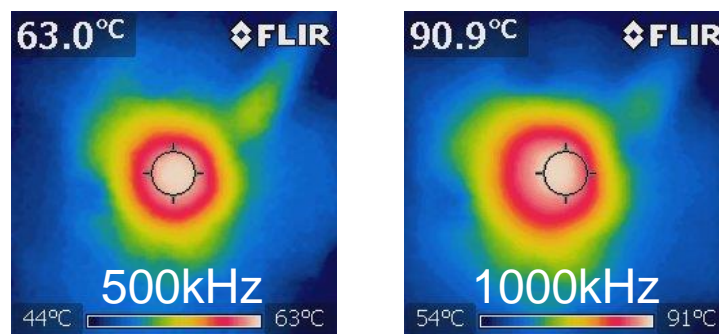
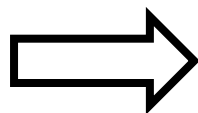
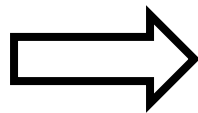


输出电容

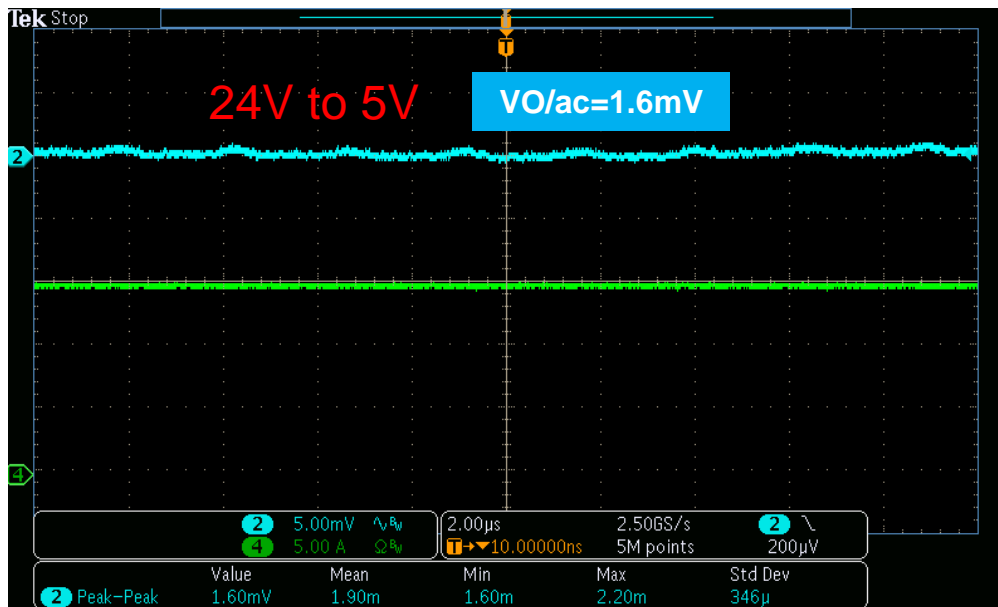
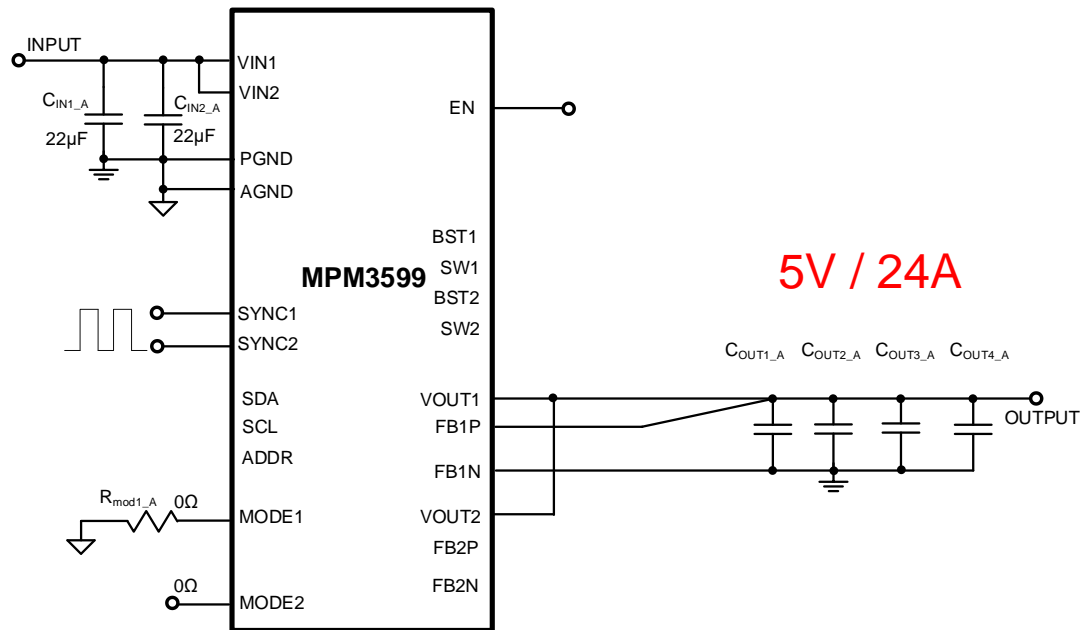
控制策略

电源模块稳态纹波分析

- 更多输出电容可以有效减小输出电压纹波；
- 更多输出电容增加设计成本，占用更大布板面积；
- 增加开关频率也可以有效减小输出电压纹波；
- 过高开关频率会增加开关损耗
- 增加输出相数可以直接减小输出电压纹波；
- 多相设计IC会更复杂，同时均流设计也需要考虑



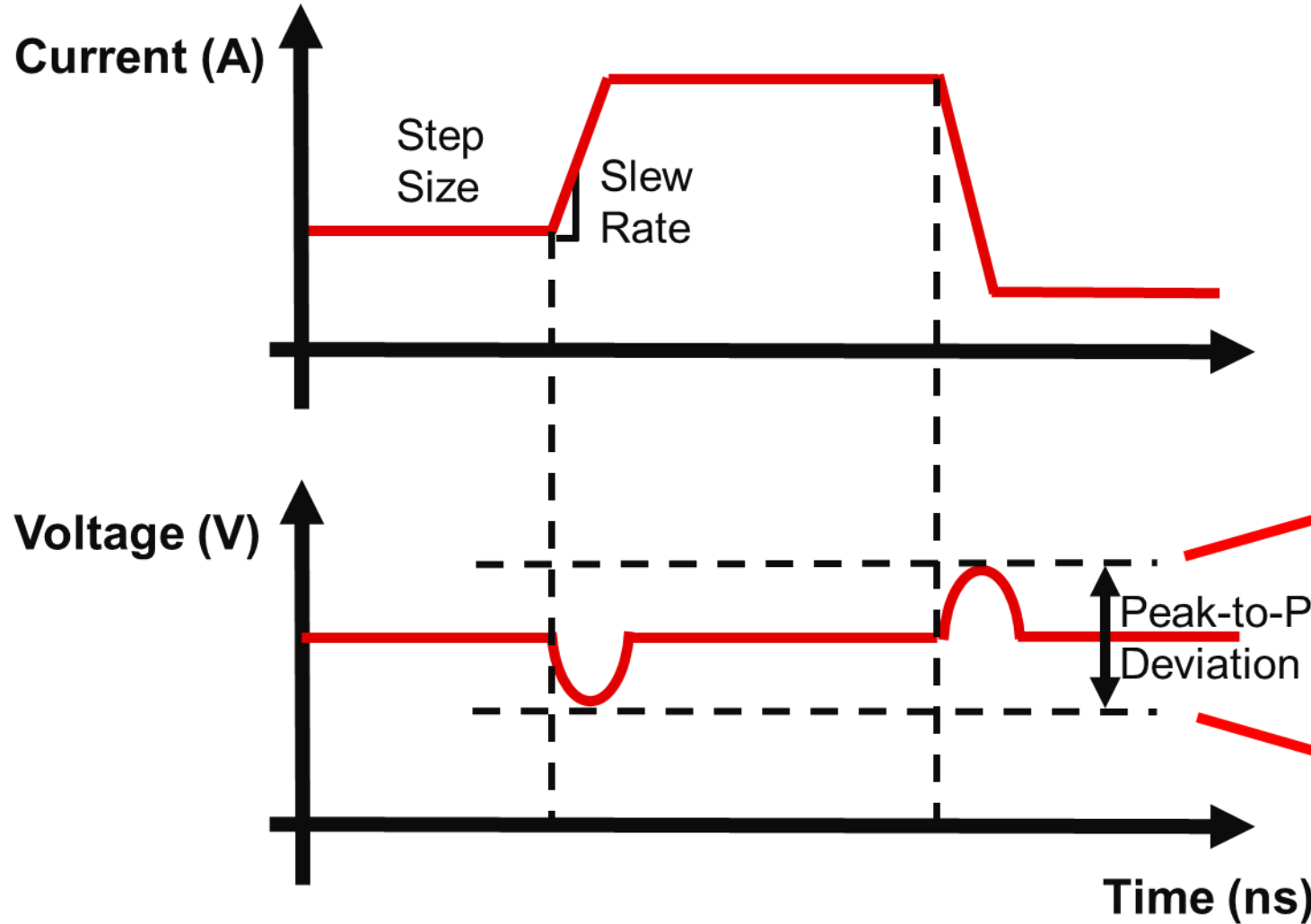
MPM3599 45V/24A多相电源模块有效减小输出纹波



20x22µF
Total 440µF

典型ATE 24V母线供电
输出电压稳态纹波小于2mV

FPGA/ASIC 负载的动态纹波需求



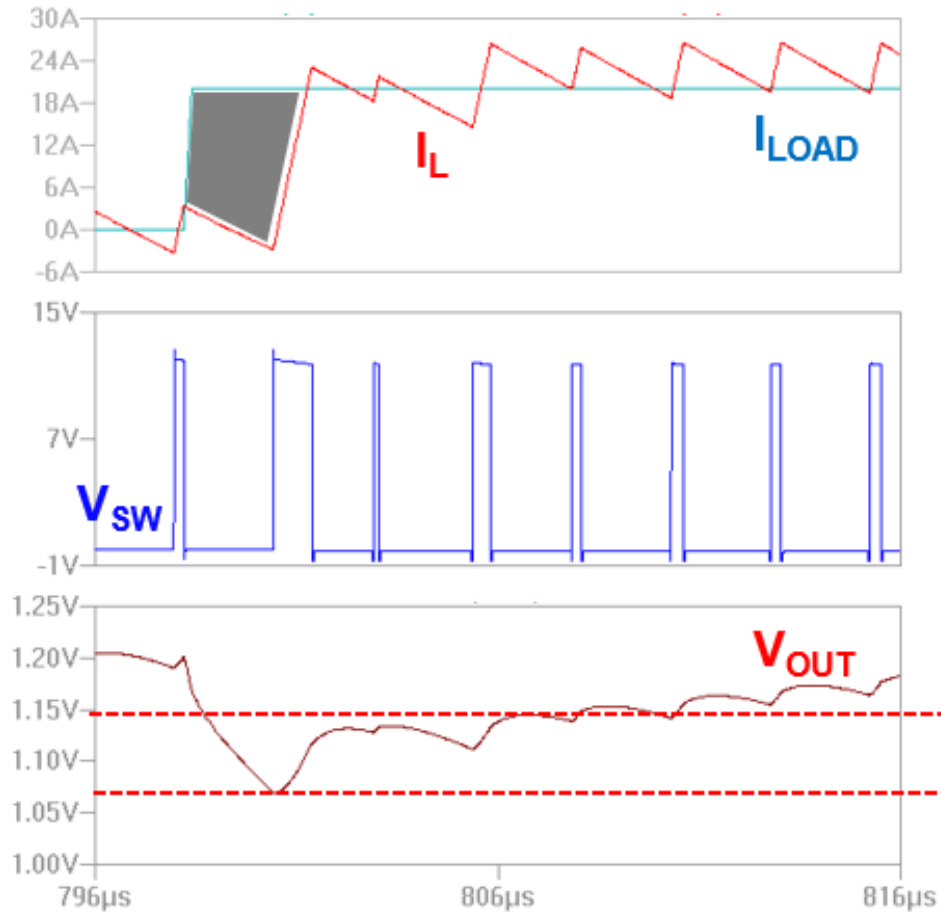
FPGA Core Power Requirements:

- V_{OUT} : 1V
- I_{OUT} : 20A
- Load Step: 0A-12.5A, $di/dt=50A/\mu S$
- Peak to Peak Deviation: $<+/-3\%$

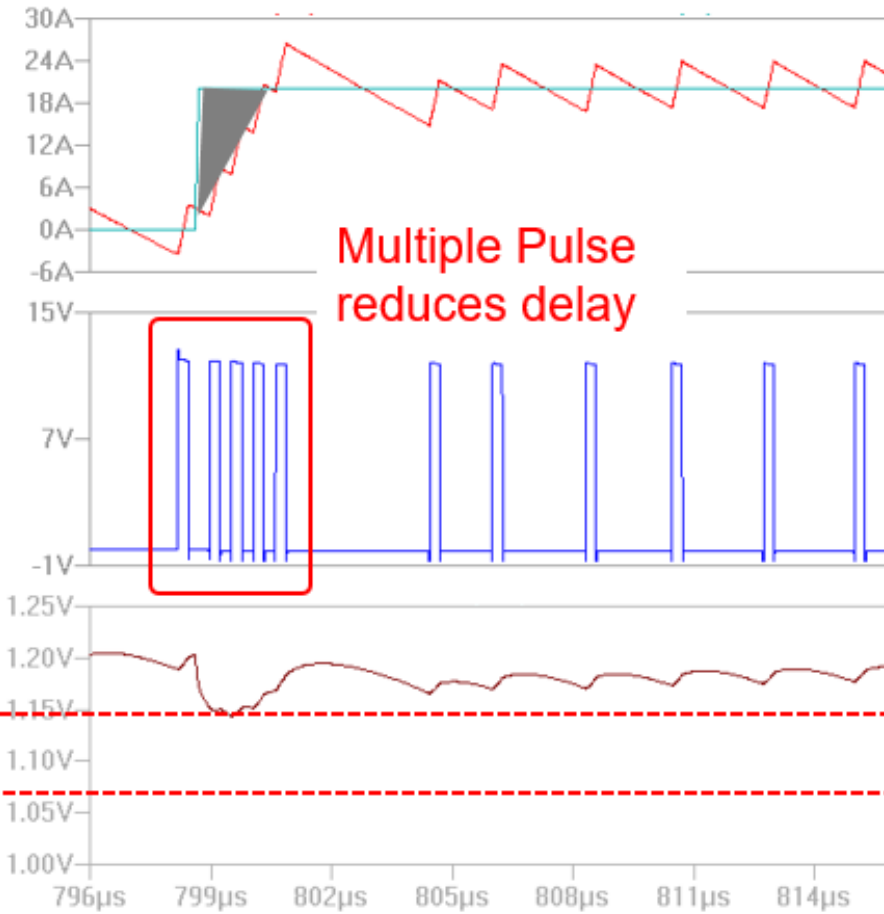
How fast the control loop response to a voltage drop

电源模块的控制策略满足快速动态响应

Current-mode Control



Constant-On-Time Control

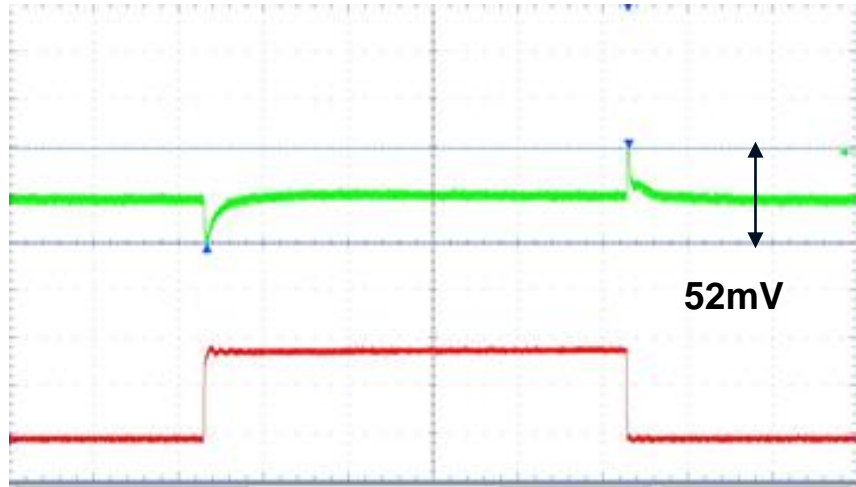


MPM3690-50D – 50A 电源模块可以节省70%输出电容

MPM3690-50D

12V_{IN}, 1V_{OUT}, 0-12.5A Step, 800kHz

V_{OUT(AC)}
30mV/DIV



Output Capacitor Needed:

1x220 μ F + 1x470 μ F

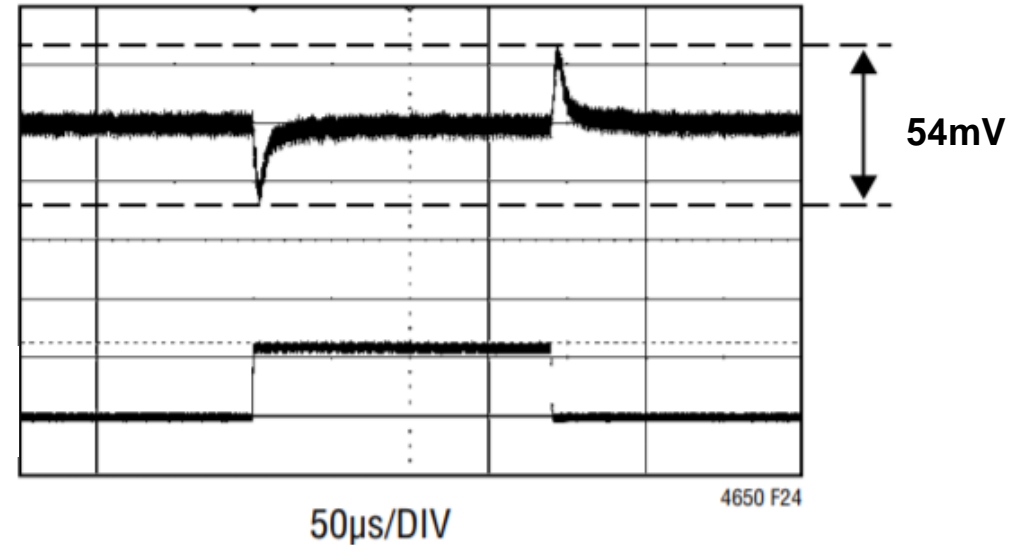
Total 690 μ F

Others – Current Mode Control

12V_{IN}, 1V_{OUT}, 0-12.5A Step, 500kHz

V_{OUT(AC)}
20mV/DIV

Load Step
10A/DIV



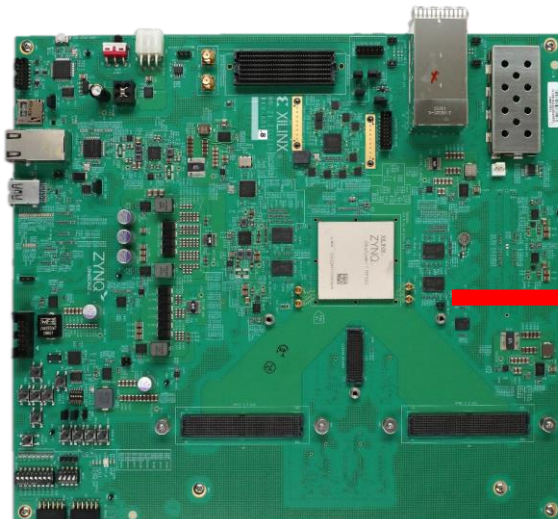
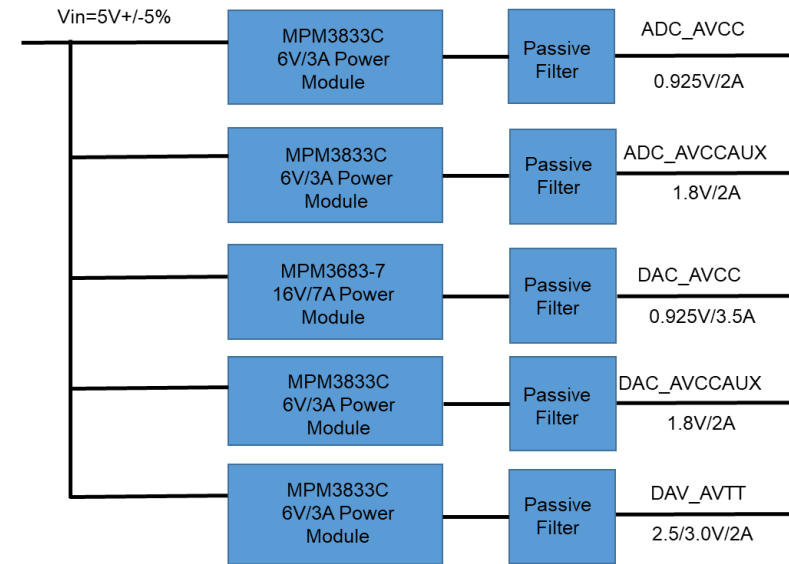
Output Capacitor Needed:

3x220 μ F + 2x470 μ F

Total 1400 μ F

MPS低噪声解决方案- EVREF0102

- MPS Solution – EVREF0102
 - Ultra-low noise - <1mV Ripple
 - High Efficiency
 - Fast Transient
- Now on board Xilinx ZCU216 Gen3 board powering:
 - 16x 14-bit 2.5GSPS ADCs
 - 16x 14-bit 10.0GSPS DACs



Xilinx Zynq US+ RFSoc ZCU216 Development kit

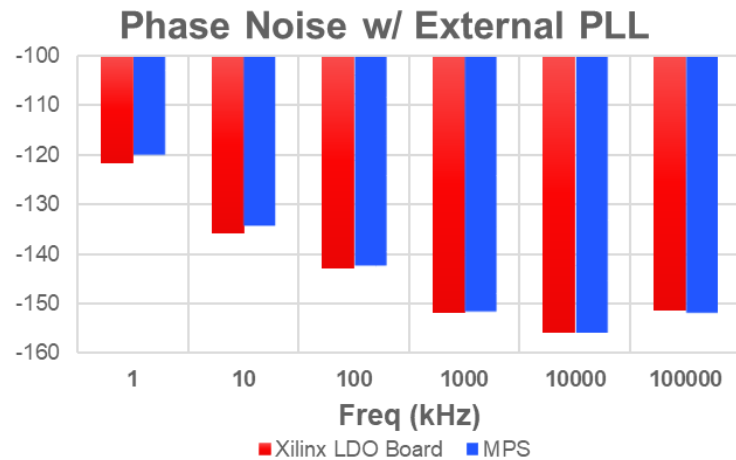
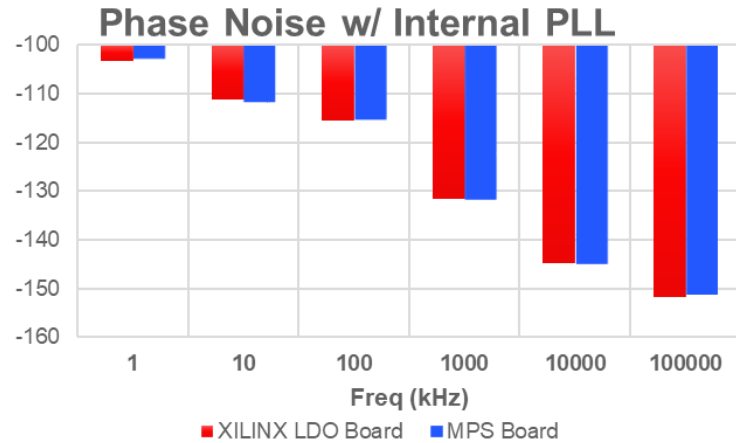
EVREF0102



Available for
Evaluation

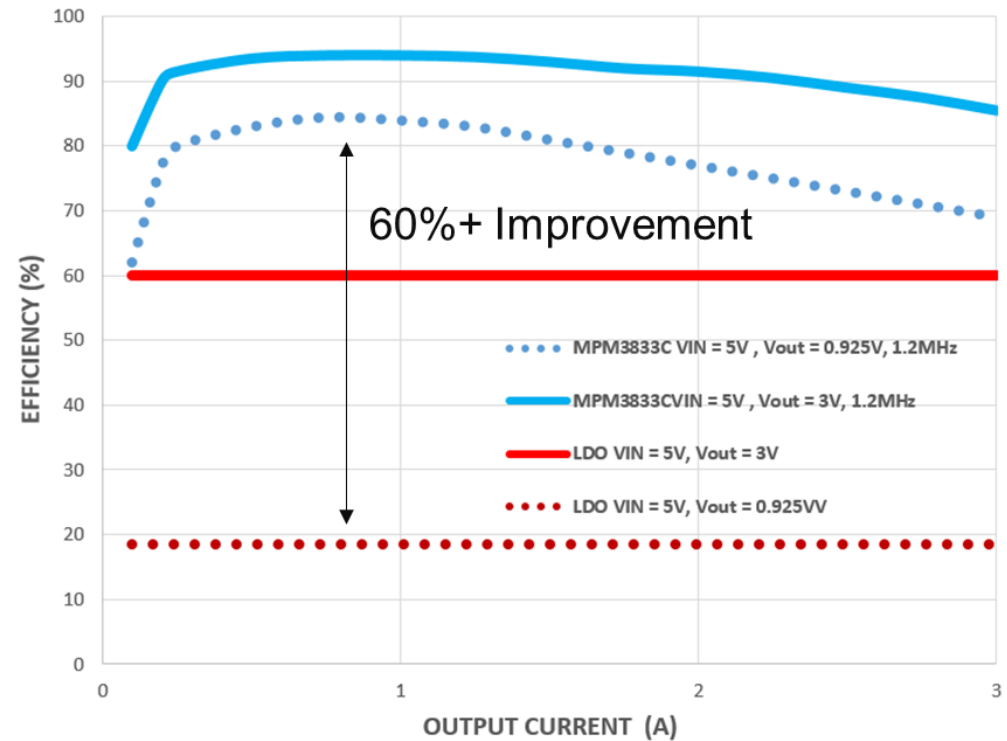
模块方案和LDO方案的噪声比较

Noise Comparison



Test performed at Xilinx lab on RF
12-bit 2GSPS ADCs and 14-bit 6.4GSPS DACs

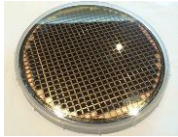
Efficiency Comparison:



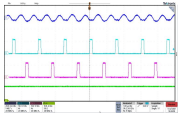
工业测试设备电源设计的关键2

高效的损耗控制和热处理

MPS模块的损耗控制



- MPS独有的大电流工艺减小功率器件导通阻抗



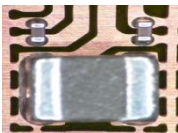
- 多相开关拓扑有效减小开关损耗



- 倒装封装工艺减小封装引线带来的线路阻抗



- 定制电感设计优化电感的交直流损耗

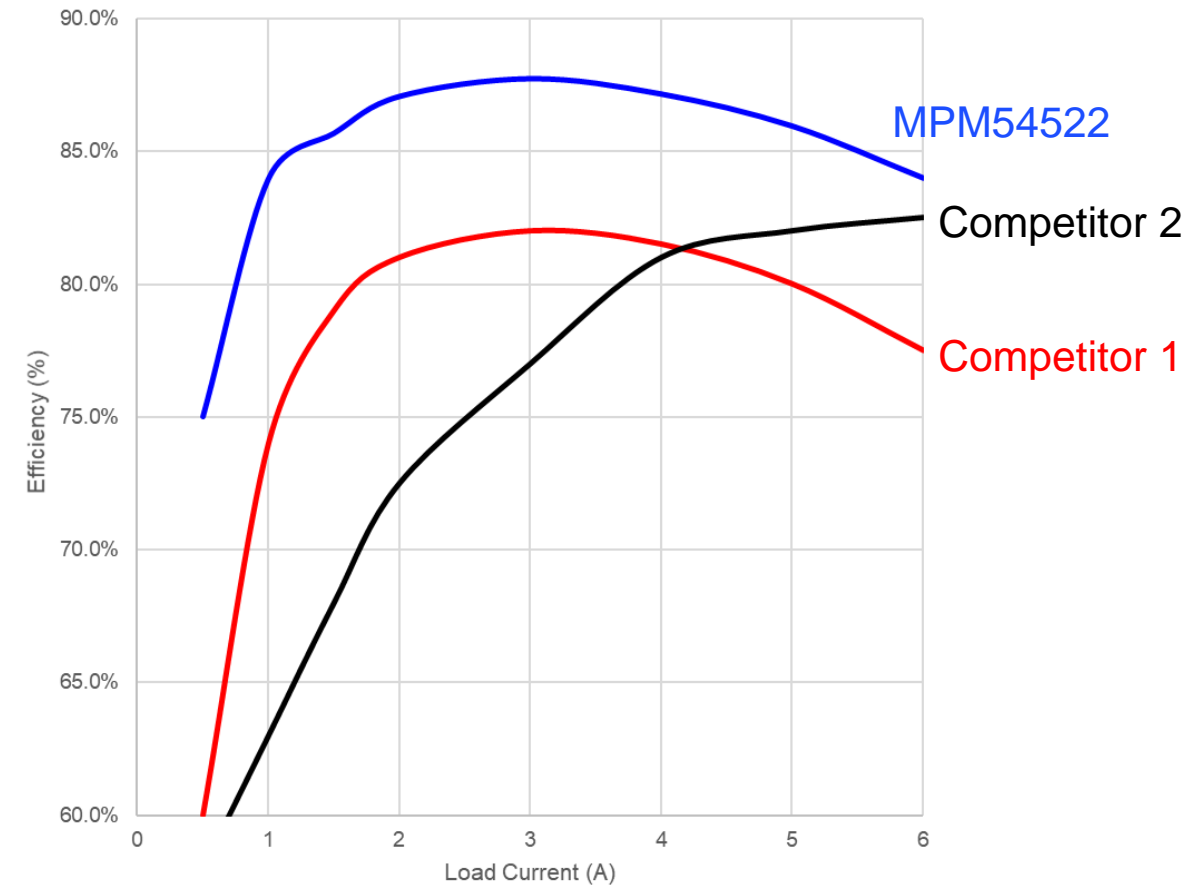


- 针对客户应用的负载范围合理选择电感值

MPM54522 vs. Competitions

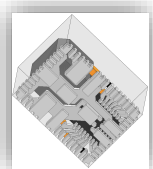
	MPM54522	Competitor 1	Competitor 2
Vin Range	2.85V-16V	4.5V-15V	4.5V-17V
Vout Range	0.3V-3.8V	0.5V-5.5V	0.5V-5.5V
Iout	2x6A	2x6A	2x9A
Module Size	5.5x6mm	5.5x8mm	11.9x16mm
Area	33mm ²	44mm ²	190mm ²
Height	2.9mm	1.8mm	3.51mm
I2C	Yes	No	Yes
Telemetry	Yes	No	Yes

Efficiency vs. Load
12V_{IN}, Single Channel, 1.2V_{OUT}

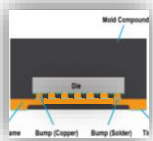


MPM54522 has 7-10% higher Efficiency

MPS电源模块常规热设计



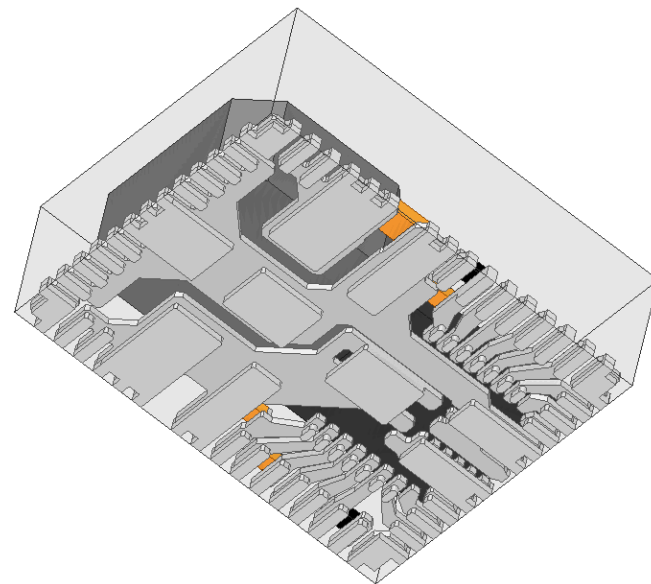
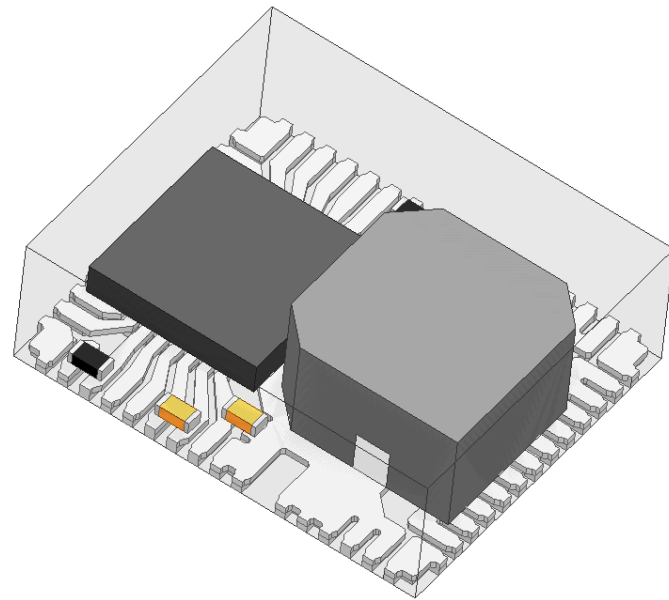
- 优化模块设计，减小功耗



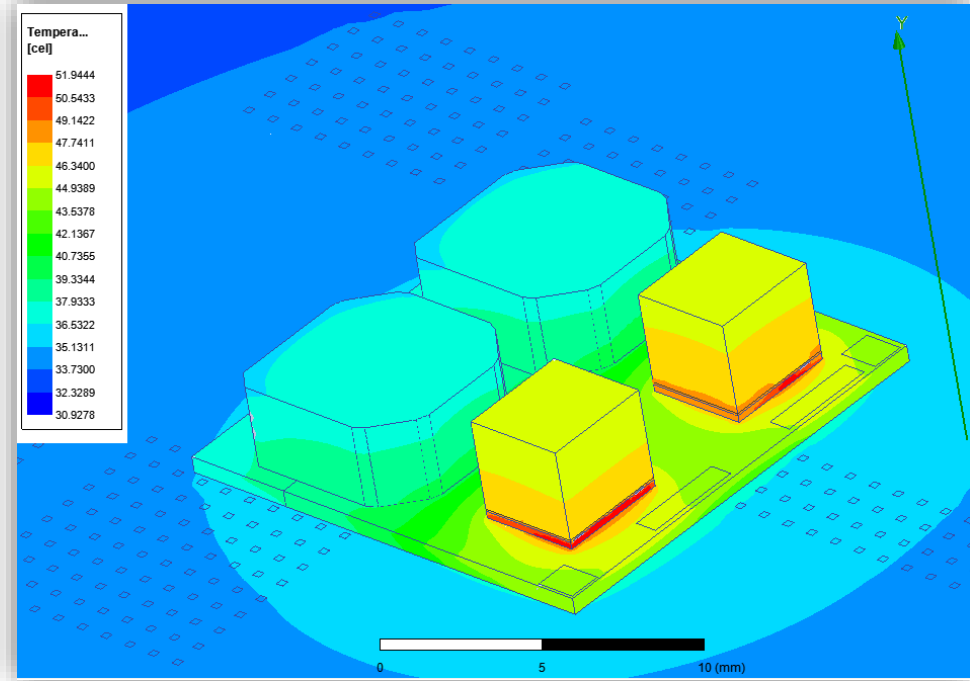
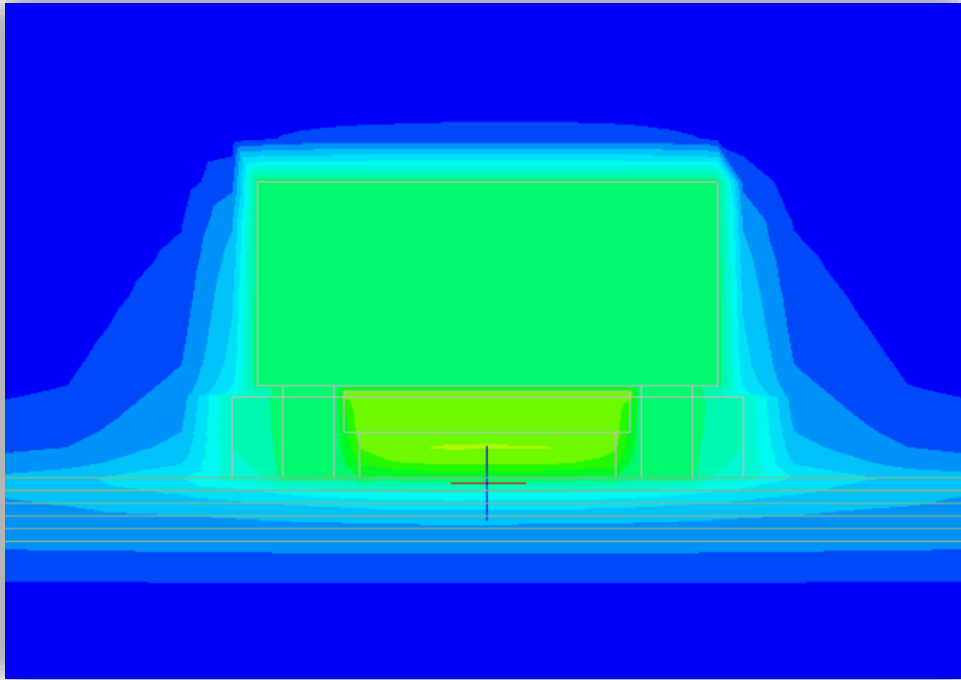
- 芯片倒装工艺降低了热阻



- 低高度的模块设计可以和主芯片共用散热器



MPS电源模块特殊的热设计1



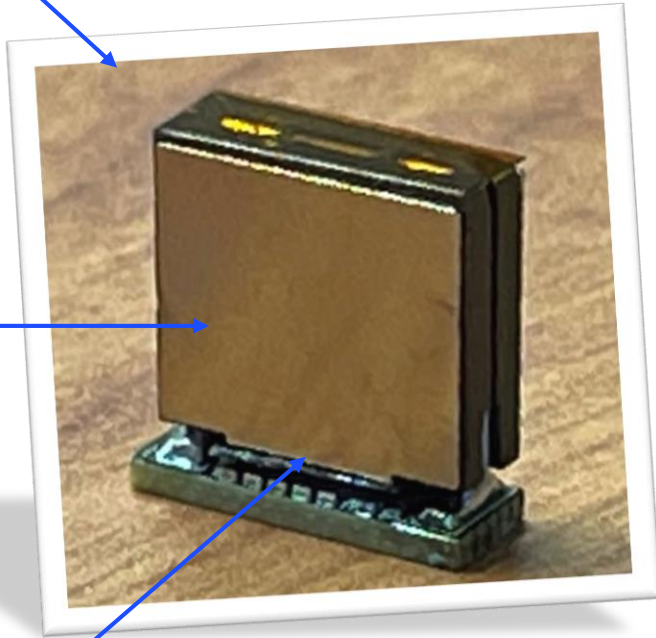
针对发热晶圆和器件，通过内置散热器或者3D封装实现热平衡

MPS电源模块特殊的热设计2

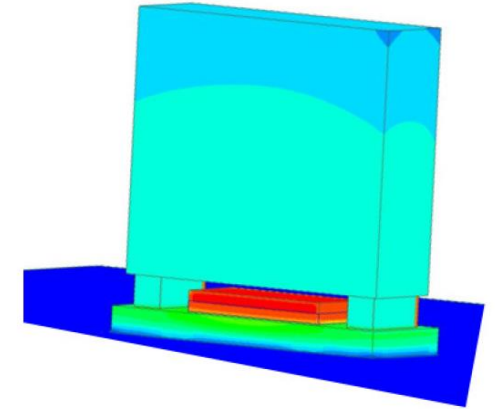
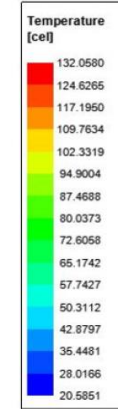
Customized Low Loss Inductor, or TLVR inductor

Copper Band surrounding the inductor brings the heat to the side and top

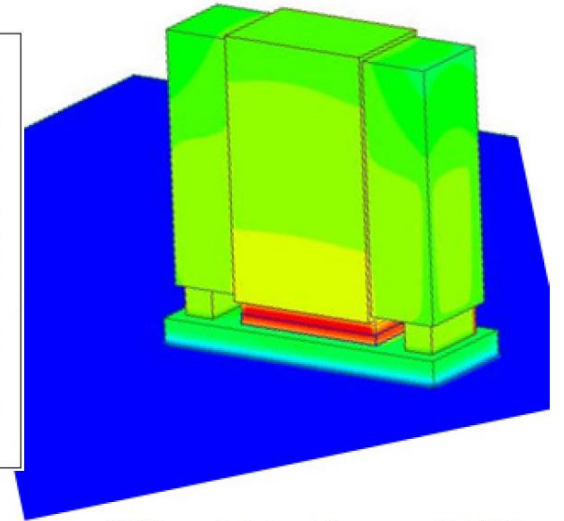
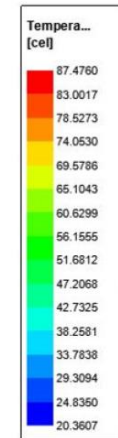
TIM Interface touches DrMOS & Inductor Band



IC和电感均衡化散热设计



Without metal ring Tj, max = 132.07C

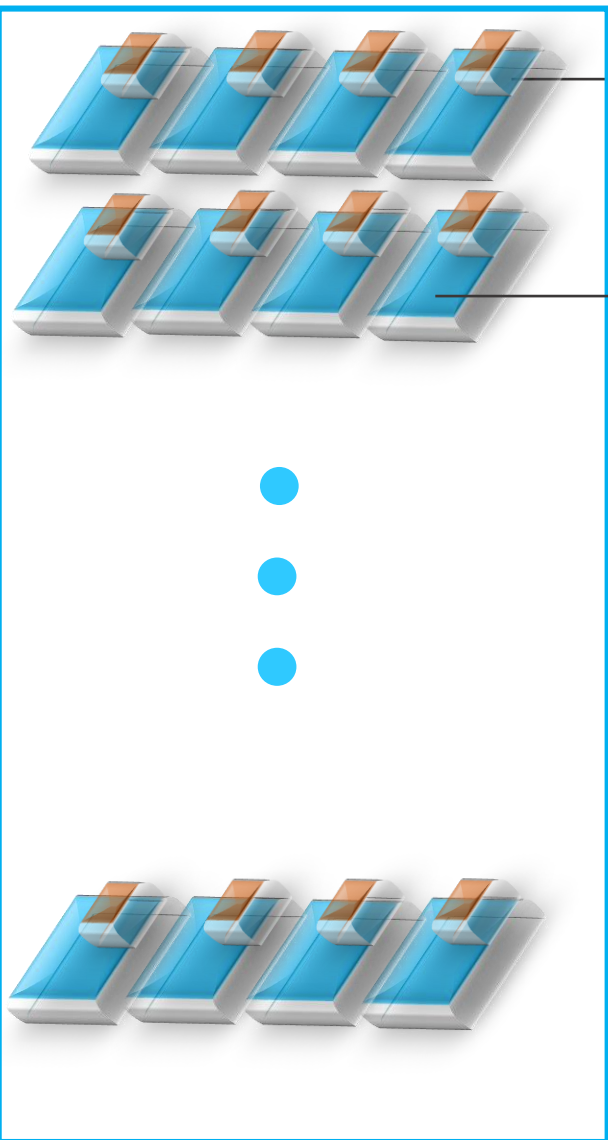


With metal ring Tj, max = 87.48C

工业测试设备电源设计的关键3

体积更加紧凑的方案设计

某型工业测试设备介绍



供电板，用于产生多通道不同规格电压供DUT使用

背板，用于FPGA主控、通讯、校准信号采集等

测试机主要升级目标：更多测试通道，更高测试效率，更低测试成本

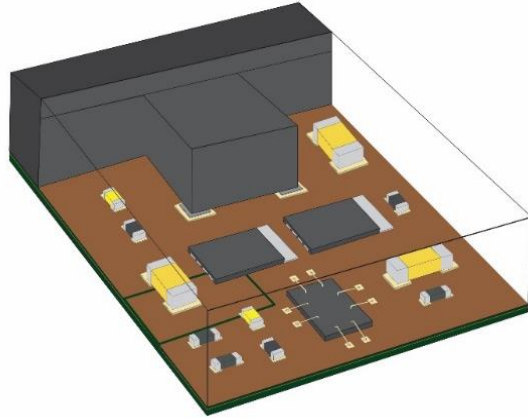


电源通道数量增多，功率密度提升

MPS电源模块的封装简介

Competitor

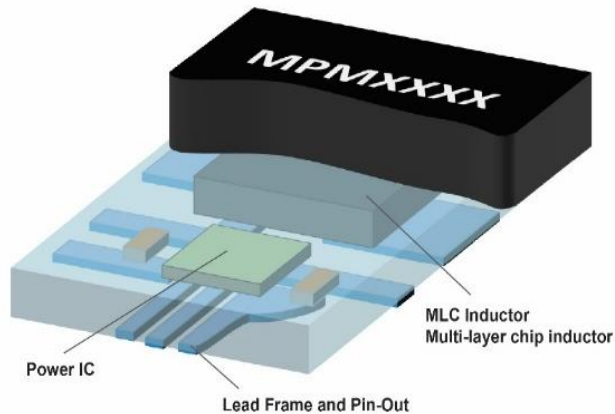
Multi-Step Assembly Process



- 金丝键合方式占用更多面积
- 控制器+功率器件分离需要更多面积

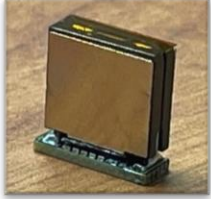
MPS

Single-Step Assembly Process



- 倒装引线框架节省面积
- Monolithic集成从源头节省面积

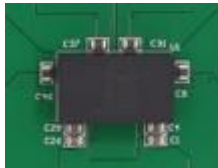
MPS电源模块的封装简介



- 架空电感封装减小模块体积



- 基板嵌入式晶圆封装减小模块体积

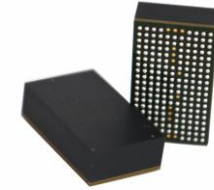
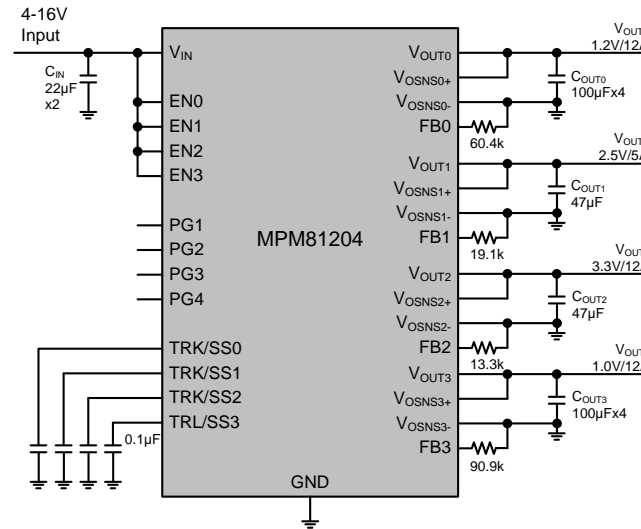


- 多路集成设计减小总占板面积

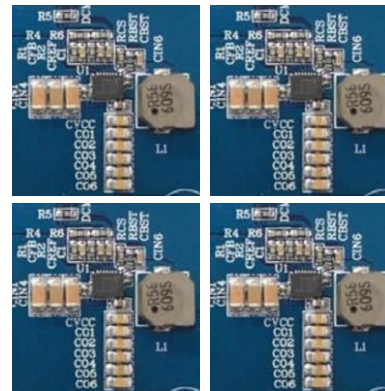
MPM81204 16V Quad Output Module in 9.5x16x5.18mm

FEATURES

- Quad Output Power Module
- Dual 12A + Dual 5A
- 3V to 16V Input Range
- 0.6V to 3.3V Output Voltage for 12A
- 0.6V to 5V Output Voltage for 5A
- $\pm 1.5\%$ Output Voltage Regulation
- 9.5x16x5.18mm BGA Package
- Four Channel Remote Sense
- Key Advantages
 - Compact Solution for Transceiver Power
 - Min Ext Components
 - No SW pins connected PCB to minimize Noise



4 pcs of Discrete



1 pcs of Module

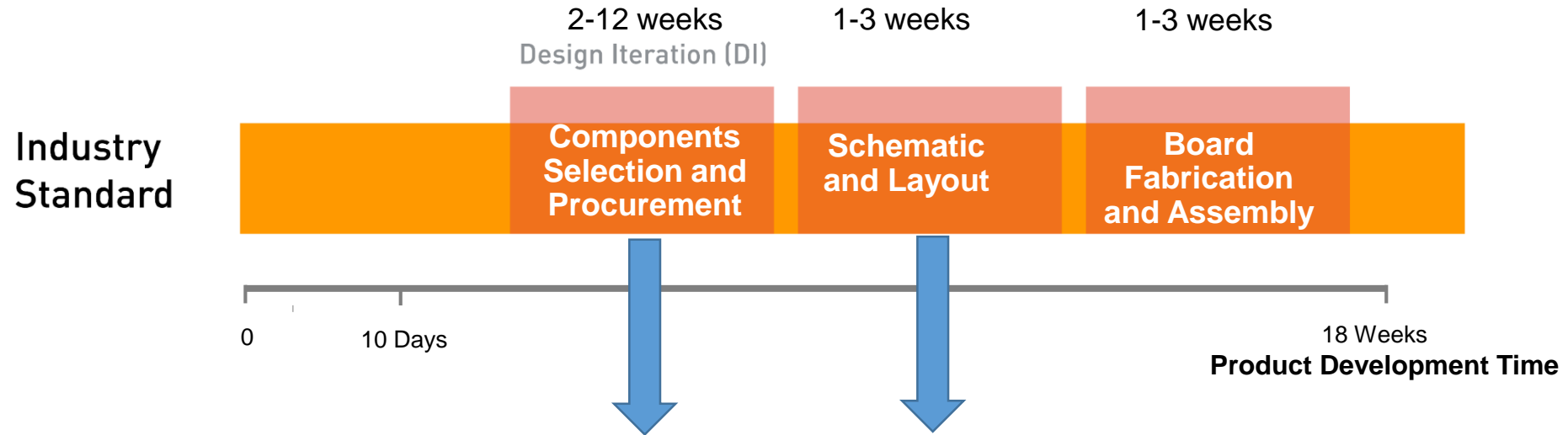


工业测试设备电源设计的关键4

更短开发周期和更高可靠性

开发验证分立电源方案往往需要18周以上的周期

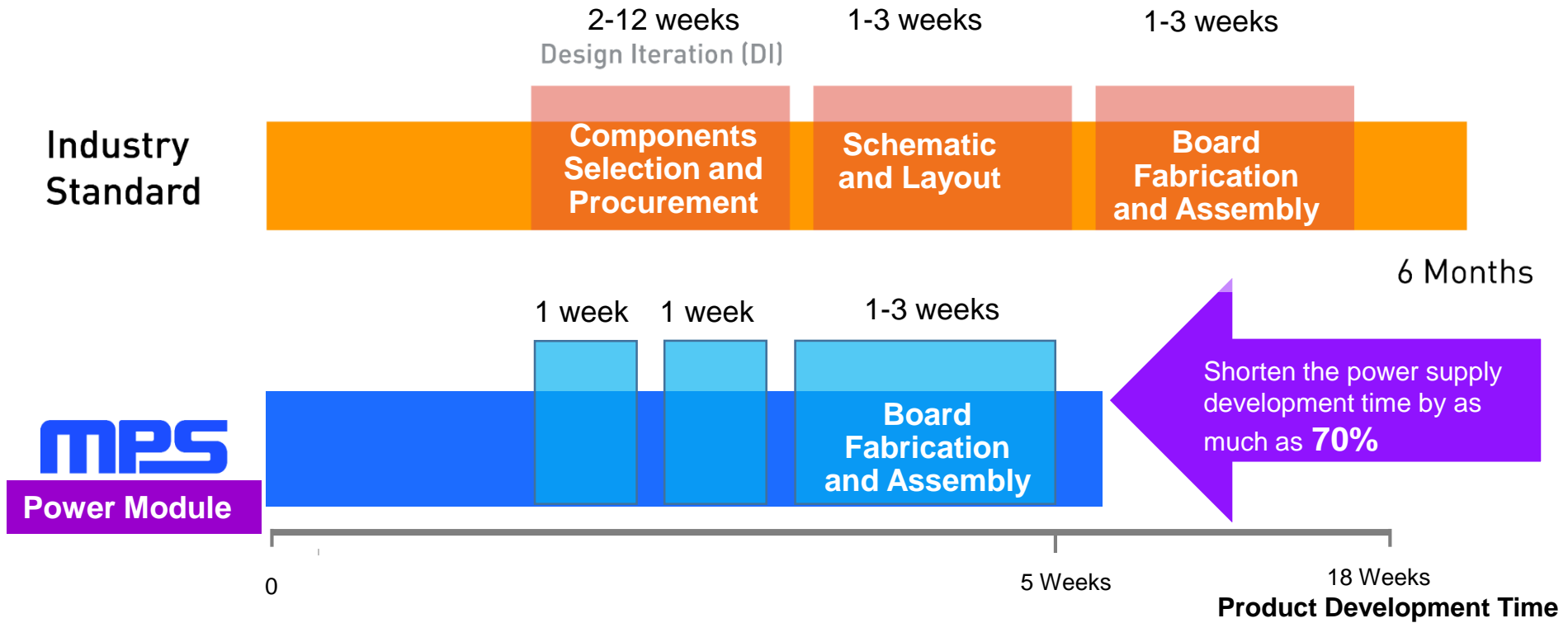
Typical Product Development Cycle with Discrete Power Solutions



- 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

电源模块极大的缩短的开发周期

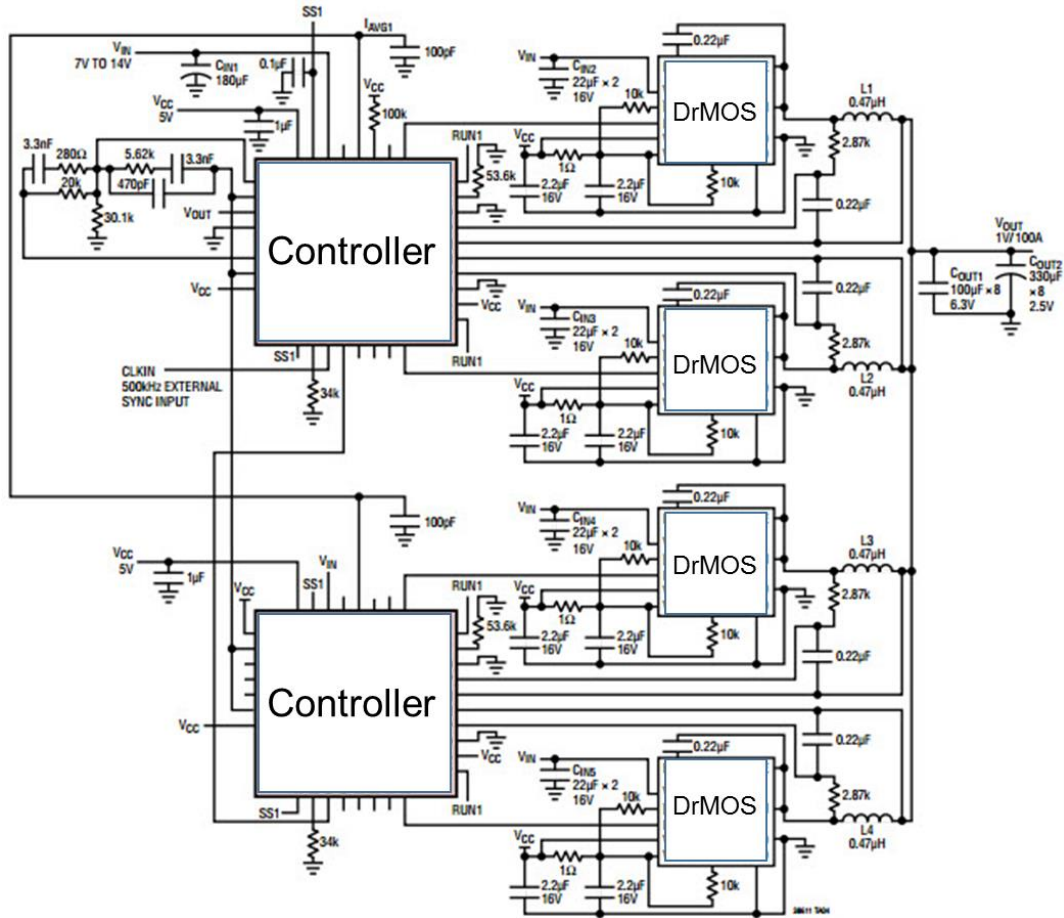
Typical Product Development Cycle



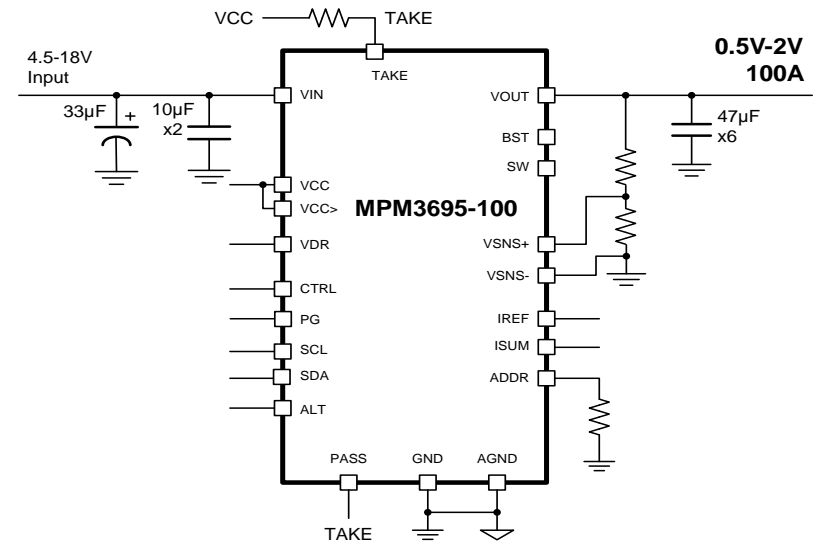
- 电源模块提供了高集成度的方案
- 优化的性能
- 大大简化的原理图和PCB布板
- 极少的外围元器件

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

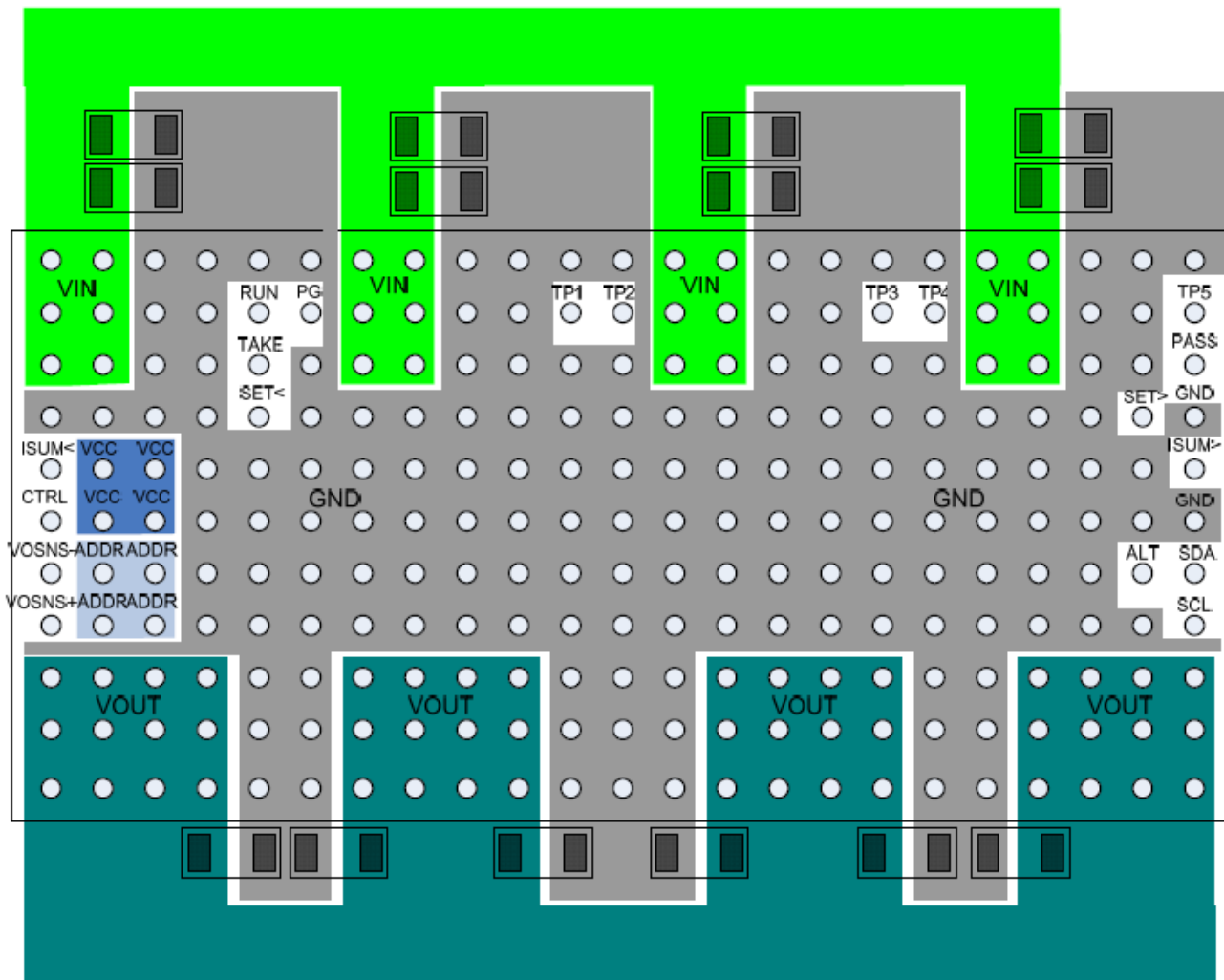


MPS 100A模块典型应用图



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

MPS电源模块的质量管控和高可靠性

- Mature/High-Quality MPS parts inside.
- Overall FIT rate<0.2 fits.
- High-Quality Fabrication Control.

4k lots/2M pcs passed MPS STRM(3*Reflow+TCC96+AC48)

	ABBR	SPEC	Device Hours or Cycles
Temperature, Bias, and Operating Life (125°C for standard and 150°C for automotive)	HTOL	JESD22-A108	32,045,000
Accelerated Moisture Resistance- Unbiased Autoclave(121°C/100%RH)	AC	JESD22-A102	12,758,304
High Temperature Storage Life(150°C)	HTSL	JESD22-A103	784,687,000
Temperature Cycling(-65°C~150°C)	TC	JESD22-A104	42,828,000
Board Level Temperature Cycling(-45°C~125°C)	BLTC	IPC9701	5,220,700
Highly Accelerated Temperature and Humidity Stress Test (130°C/85%RH)	HAST	JESD22-A110	3,187,388
Steady State Temperature Humidity Bias Life Test(85°C/85%RH)	THB	JESD22-A101	5,104,000

强力的可靠性实验室

- 标准可靠性测试项目
- 客制化可靠性测试项目





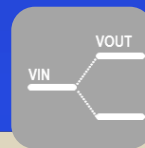
MPS电源模块介绍



Single Buck



Multi-out Buck



Boost & Buck-Boost



POE



USB Charger

MPS Power Module Road Map for Test Equipment

V_{IN} \ I_{OUT}	≤0.6A	1-1.2A	2A	3A	4-5A	6-8A	10A	20A	30A	50A	100A
(≤75V)	MPM3572 6x6x2mm			MPM3530 10x12x4mm							
(≤45V)	MPM3506A 3x5x1.6mm	MPM3510A MPM3515 3x5x1.6mm		MPM3593 6x8x1.6mm		MPM3596 10x10x4mm	MPM3599 12A+12A parallel able 15x30x5.2mm				
12V				NEW MPM3632S 3x3x1.4mm	NEW MPM3650 4x6x1.6mm	MPM3683-7 7x4x4mm	NEW MPM3683-10 7x4x4mm	MPM3695-10 8x8x2mm PMBus	MPM3695-25 10x12x4mm PMBus	NEW MPM3690-30B 16x16x5mm	
				MPM3632C 3x5x1.6mm				NEW MPM3690-20B 16x16x5mm		NEW MPM3690-50B 16x16x5mm	MPM3695-100 15x30x5.2mm PMBus
										NEW MPM3690-50D 16x16x5mm	
						NEW MPM54504 9x15x5.2mm 5A,5A,5A,5A	NEW MPM81204 9x15x5.2mm 12A,12A,5A,5A		NEW MPM82504 15x30x5.2mm 25A,25A,25A,25A PMBus		
			NEW MPM54304 7x7x2mm 3A,3A,2A,2A I2C		NEW MPM54313 8x9x2.58mm 3A,3A,3A I2C		NEW MPM54524 8x8x2.9mm 5A,5A,5A,5A I2C				

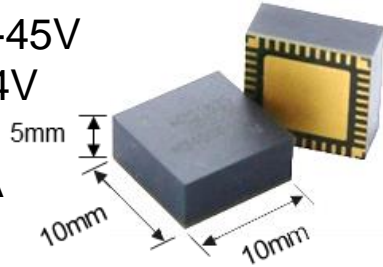
Mass Production
Developing
Sampling



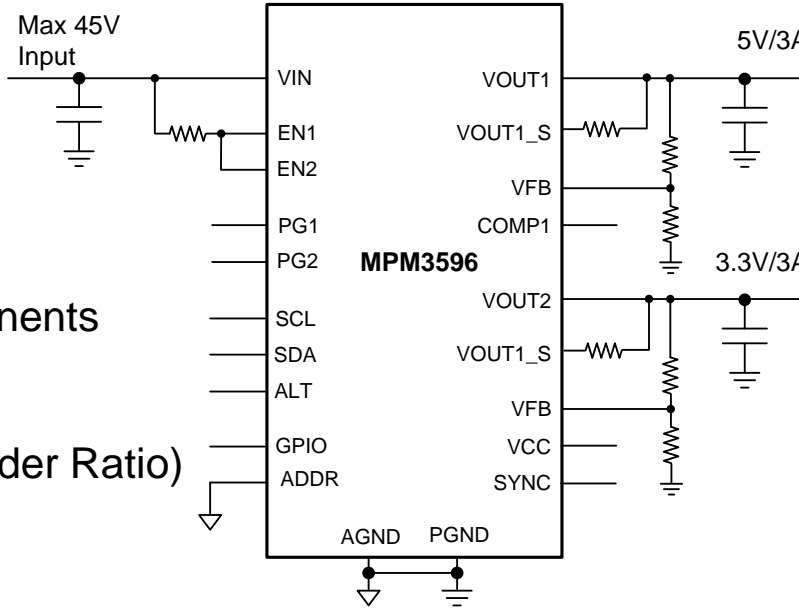
MPM3596 Introduction

FEATURES

- Wide V_{IN} Range: 4V-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: $1.5mV \cdot \text{Divider Ratio}$)
- 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



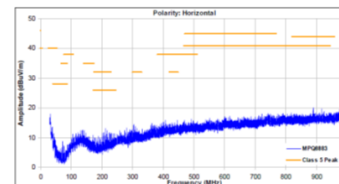
Application Circuit: Dual Output



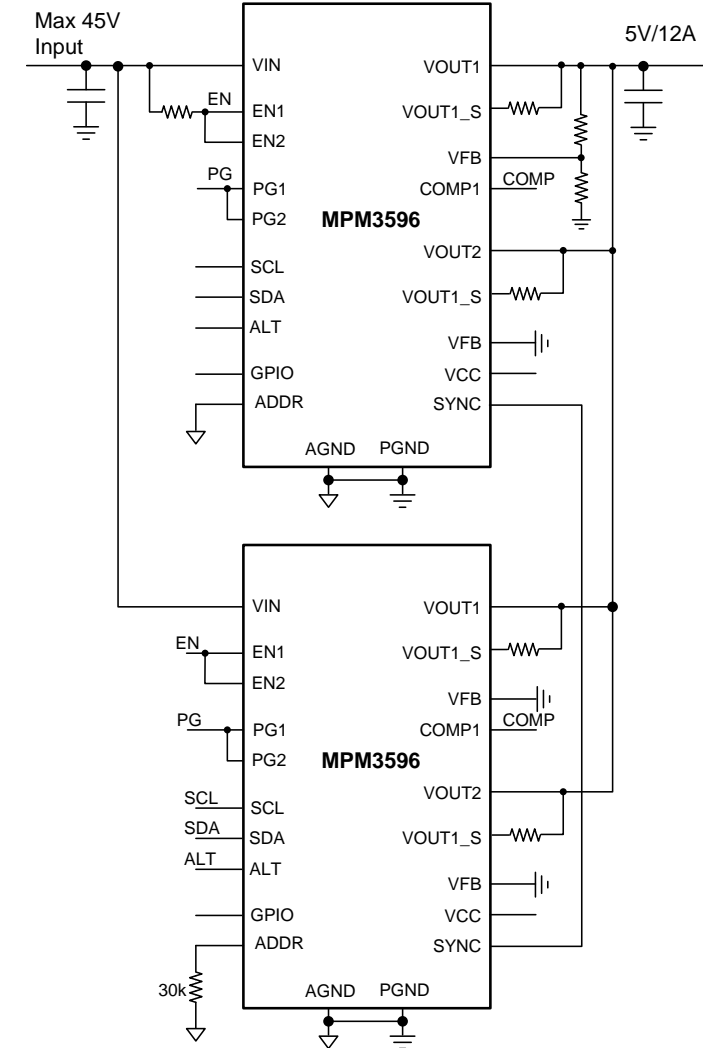
Great EMI Performances

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

CISPR25 Class 5 RE



Application Circuit: Paralleling

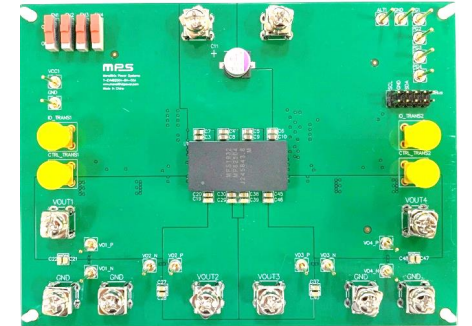
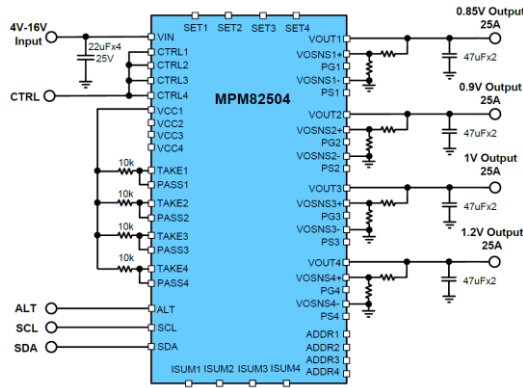


MPS

MPM82504 – 4 x 25A Power Module

Key Advantages:

- Quad 25A Output Power Module with I2C and Parallelable
- 3V to 16V Input Range
- 0.5V to 1.8V Output for 25A
- 1.8V to 3.3V Output for 15A



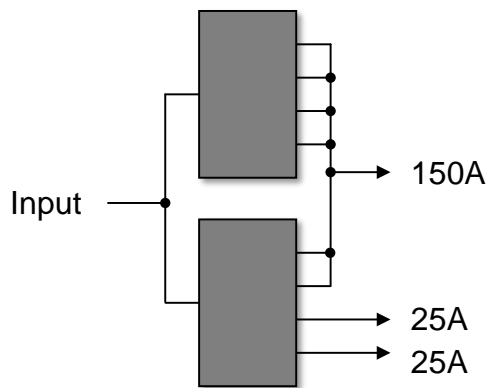
Available in a 15x30x5.18mm BGA Package

Output Configurable

- Several Output Configurations

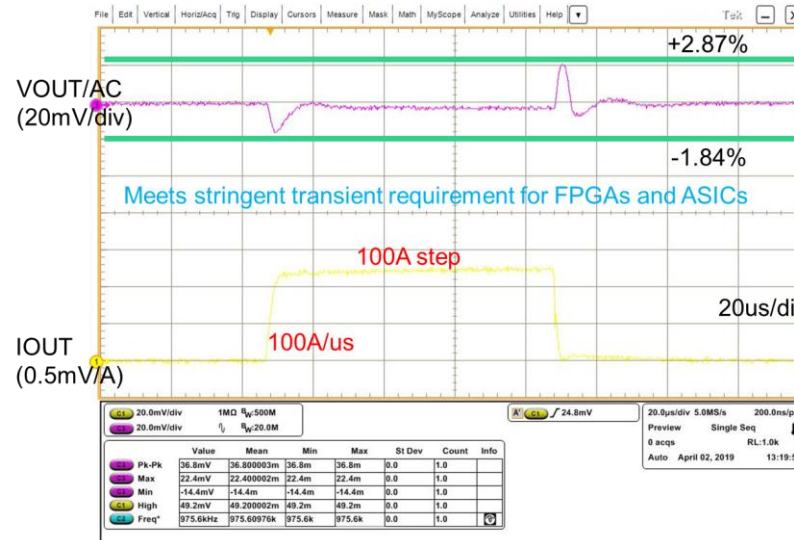


- Scalable to 800A



Fast Transient, Min C_{OUT}

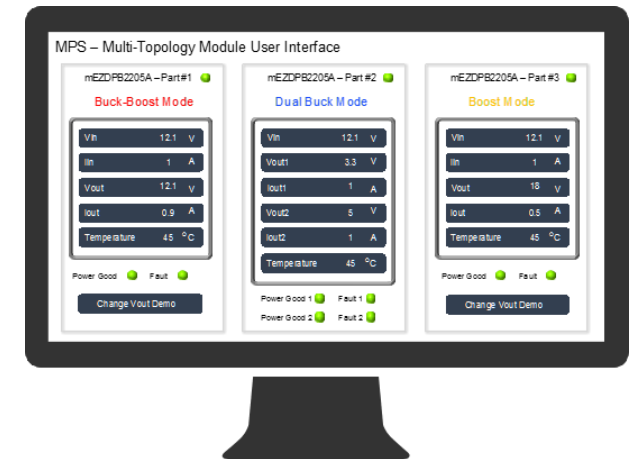
- Four-Phase Interleaved Inside
- MCOT for Fast Transient
- Save up to 50% output Capacitors Compared with competitor modules



2x Modules, 100A Step, Peak to Peak +/-3%, 2500µF C_{OUT}

Configurable + Diagnostics & Reliability

- BGA Packages enhances mechanical, thermal stress & Reliability
- I2C reports system fault
- Individual module/phases fault can be detected



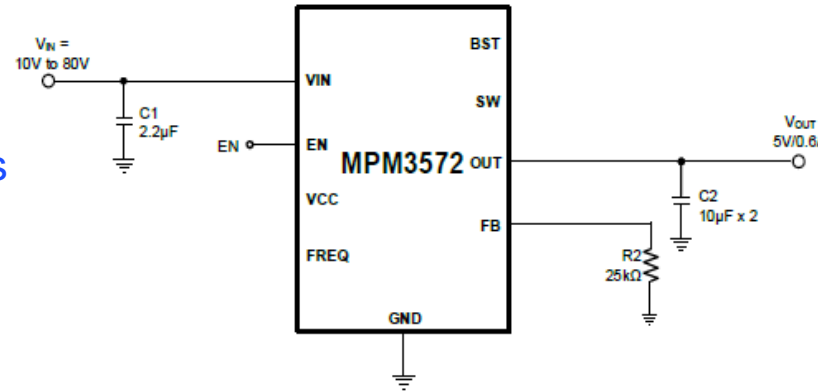
MPM3572 80V 0.6A Power Module

FEATURES

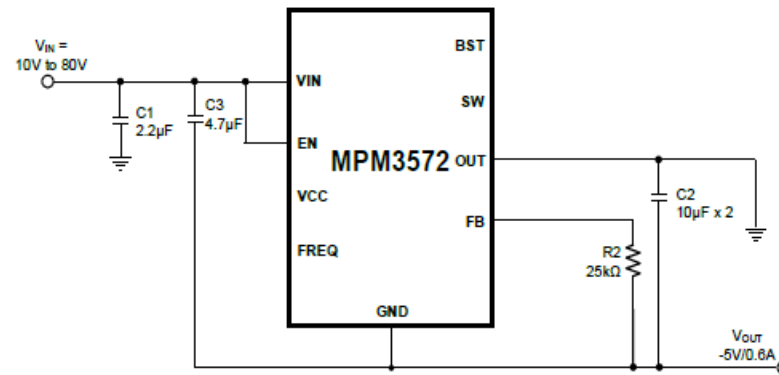
- Input range: 10V-80V;
- Output range: +/-1V to +/-12V
- Suitable for Positive to Negative Applications
- Up to 0.6A Continuous Output current
- Fast Load Transient w/ COT Control
- Programmable 400kHz to 1MHz frequency
- High Efficiency PSM in Light Load
- Package: 6x6x2mm Package

APPLICATION

- GaN gate drive
- Op-amp, ADC Power Supplies
- Industrial Power Supplies
- ATE Testers



Typical application with external EN control and positive output

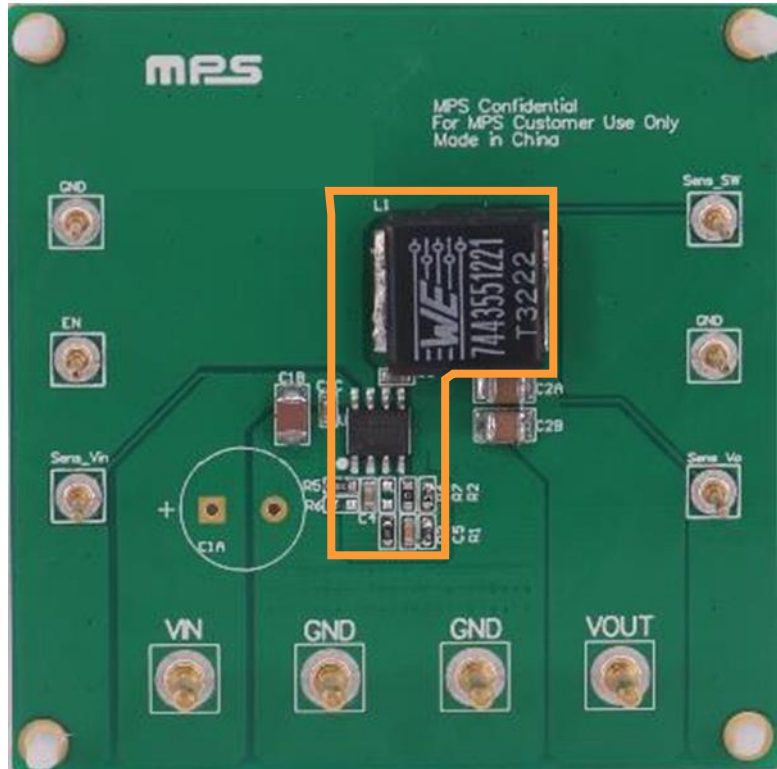


Typical application with automatic start up and negative output



MPM3572 vs. Discrete Solutions

Discrete Solution



13 components

60% Size Reduction for High Voltage Application



50% saving on external components

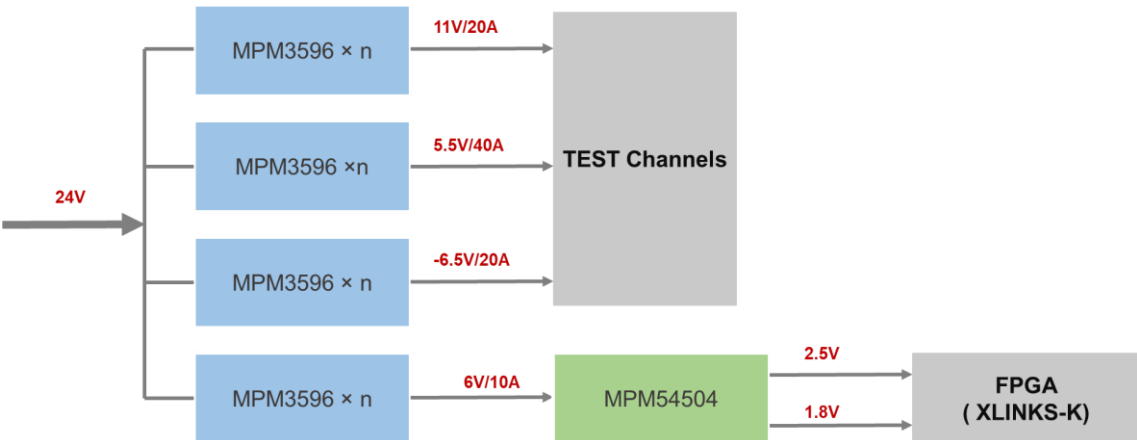
MPM3572 Solution



6 components

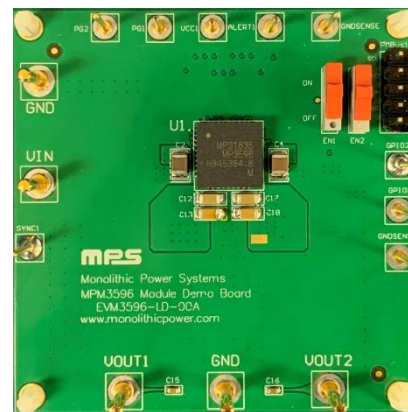
工业测试设备电源设计案例分享

某测试单元供电方案

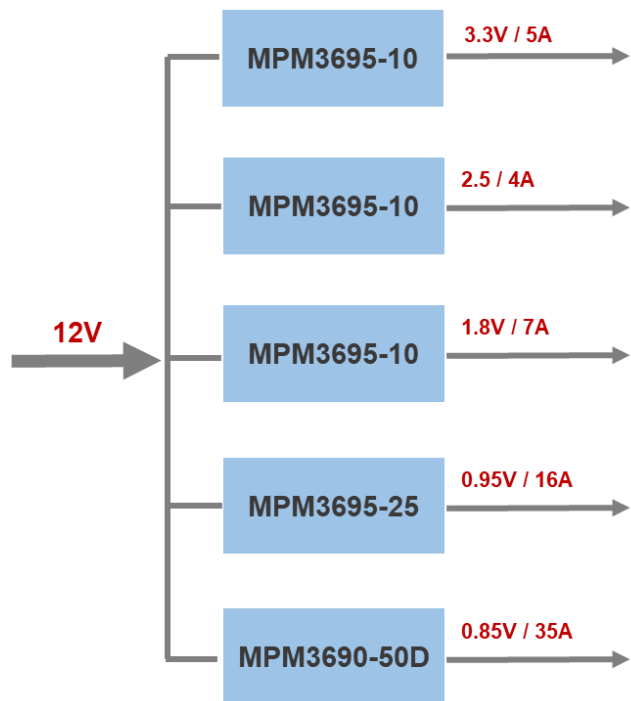


	MPM3596	MPM54504
输入电压范围	4V-45V	3V-16V
输出电压范围	0.4V-24V Or -0.4V ~ -24V	0.6V-5V
输出电流	Dual 3A, Single 6A	4x5A
尺寸	10x10x4.4mm	9x15x5.18mm
最高效率	91.8%@24V to 5V	92%@12V to 1V
I2C	Yes	No
可并联	Yes	No

- 宽输入、输出电压，以及简便的负压接法
- 紧凑的多路集成模块，提供更小的占板面积

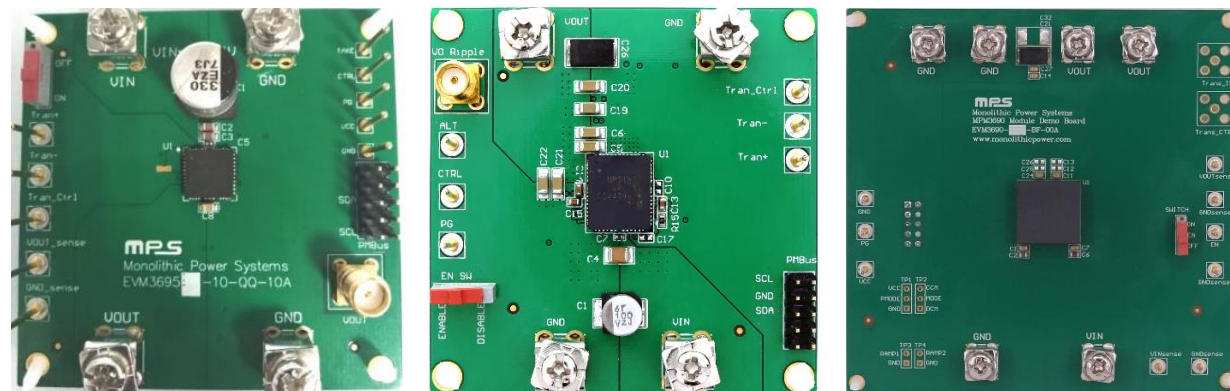


某型数字通信板供电方案

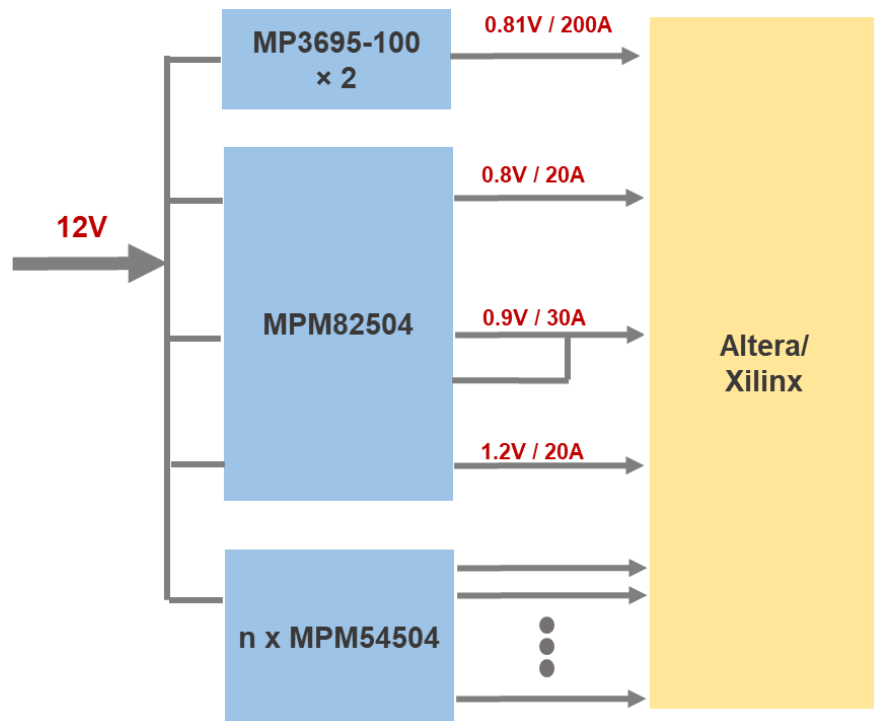


	MPM3695-10	MPM3695-25	MPM3690-50D
输入电压范围	3V-16V	3V-16V	3V-16V
输出电压范围	0.5V-3.3V	0.5V-5.5V	0.6V-3.3V
输出电流	10A	20A	50A
尺寸	8x8x2mm	10x12x4mm	16x16x5.18mm
效率 (12V-1V)	86%	90%	92%
I2C	Yes	Yes	Yes
可并联	Yes, up to 20A	Yes, 2-Phase	No

- 数字监控功能，更好的监控负荷和运行温度
- 在线调节功能，提供更丰富的系统策略



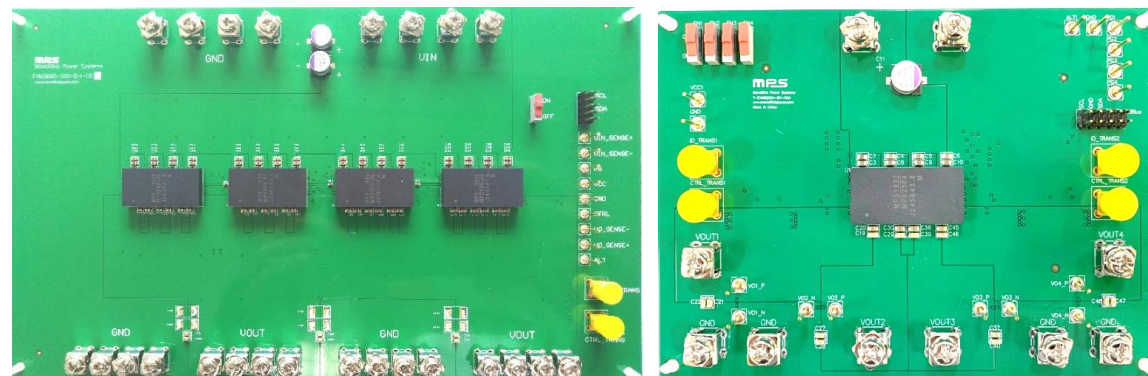
某型SSD测试板供电方案



	MPM3695-100	MPM82504
输入电压范围	3V-16V	3V-16V
输出电压范围	0.5V-3.3V	0.5V-5.5V
输出电流	100A	4x25A
尺寸	15x30x5.18mm	15x30x5.18mm
效率 (12V-1V)	92%	92%
PMBus	Yes	Yes
可并联	Yes	Yes

- 简洁可靠的大电流供电方案

- 灵活可变的负载分配选择



MPS and Partners



<https://www.monolithicpower.cn/cn/design-tools/reference-design-partners/xilinx-reference-design.html>



<https://www.monolithicpower.cn/cn/design-tools/reference-design-partners/intel-altera-reference-designs.html>



<https://www.xilinx.com/products/technology/power.html#partners>

一对一线上服务平台MPSNOW: <https://www.monolithicpower.cn/cn/support/mps-now.html>



封装模型 参考设计 应用笔记 在线购买



- 工业测试设备架构和电源需求综述
 - a. 测试设备构架
 - b. 测试设备中电源架构
- 工业测试设备电源设计的关键点
 - a. 出色的纹波噪声控制
 - b. 高效的损耗控制和热处理
 - c. 体积更加紧凑的方案设计
 - d. 更短的开发周期和更高的可靠性
- MPS电源模块产品介绍
- 工业测试设备电源设计实际案例

Thank You