



# MPS Power Modules for Drones

**Nicolay Garcia, Applications Engineer at MPS**

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# Our Global Presence



- MPS Global Offices
- R&D Centers
- Manufacturing Partners



Kirkland, WA USA



San Jose, CA USA



Munich, Germany



Barcelona, Spain



Ettenheim, Germany



Chengdu, China

Public Facing

# MPS Product Families



## AC/DC Power Conversion

- High-Voltage Buck Regulators
- High-Voltage LDOs
- Flyback Controllers
- Flyback Synchronous Rectifiers
- Active PFC Controllers
- LLC Resonant Converter Controllers
- LLC Synchronous Rectifiers
- PFC & LLC Combo Controllers
- X-Capacitor Bleeders

## Display Backlighting Power

- Backlight Drivers
- Electroluminescent Drivers
- Photo Flash Drivers
- LCD Power Supplies

## AI & Computing Power

- CPU & GPU Core Power
- High-Current DrMOS
  - 90A DrMOS 4mmx6mm Package
- 60A POL Module 6mmx6mm Package
- 60V Intermediate Bus Converter Modules
- Z-Axis Power Delivery (ZPD™) Multi-Phase Modules

## DC/DC Power Conversion

- Step-Up (Boost)
- Step-Down (Buck)
- Buck-Boost
- PMICs
- Power over Ethernet (PoE)
  - Power-Sourcing Equipment (PSE)
  - Powered Devices

## Power Magnetics

- Molded Inductors
- Semi-Shielded Inductors

## E-Fuse, USB & Load Switches

- Configurable Current Limit, Up to 50A per Device
- Adjustable Slew Rate
- Reverse Current Blocking
- Output Discharge (Load Switches)
- Integrated Auto-Detection
- Pin-to-Pin Compatible
- Parallelable Up to 10 Devices
- Digital Interface Command and Control
- USB Type-C and USB PD

## Motor Drivers, Position & Current Sensors

- Brushless DC (BLDC) Motor Drivers
- Stepper Motor Drivers
- Brushed DC Motor/Solenoid Drivers
- Half-Bridge/Full-Bridge/Three-Phase Power Stages
- Magnetic Angular and 3D Position Sensors
- Isolated, Integrated Current Sensors, 5A to 400A

## Automotive (AEC-Q100) & Industrial

- DC/DC
- LED Lighting
- Power Modules
- Motor Drivers
- Angular Position and 3D Position Sensors
- USB Charging
- Wireless Charging
- Display Backlighting
- Precision Analog
- ADAS Core Power
- Supervisors
- Load Switches
- Isolated, Integrated Current Sensors, 5A to 400A
- Class-D Audio
- E-Fuses, High-Side Switches

## Class-D Audio

- Digital Controllers and Processors
- Analog Input Class-D Amplifiers
- PWM Input Power Stages

## Isolated Solutions

- Isolated Gate Drivers
- Isolated Power Modules
- Digital Isolator with Integrated Power
- Digital Isolators
- Integrated Current Sensors, 5A to 400A
- Totem-Pole PFC/LLC Controllers

## Power Modules

- 6V, 600mA to 100A
- 16V, 600mA to 1000A+
- 36V, 600mA to 24A
- 55V, 1A to 3A
- 80V, 600mA

## LED Lighting & Illumination

- TRIAC-Dimmable AC/DC LED Controllers
- PWM and Analog Dimmable AC/DC LED Controllers
- DC/DC LED Controllers: Buck, Boost, Buck-Boost
- LED Protection ICs
- IR LED Drivers

## Battery Management

- Battery Monitors & Protectors
- Fuel Gauges
- Active Balancers
- Switching Chargers: Buck, Boost, Buck-Boost
- Linear Chargers

## Precision Analog

- Analog-to-Digital Converters (ADCs)
- Analog Switches
- Current-Sense Amplifiers
- Operational Amplifiers
- Voltage Reference





## What stands behind “Power”

When working with drone power the addressed challenges are:

1. Space Constraints
2. Efficiency
3. Design Simplicity
4. Thermal & EMC performance
5. FPGA Power Requirements



# Space Constraints

# MPS – Power Modules - What is a Power Module



## Features:

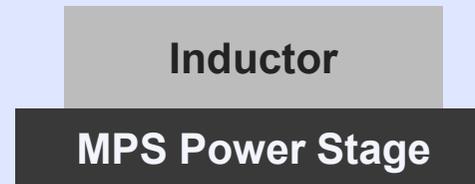
- High Efficiency
- High Power Density
- Low Output Noise
- Small BOM Count
- Wide Operating Range

## Space Saving:

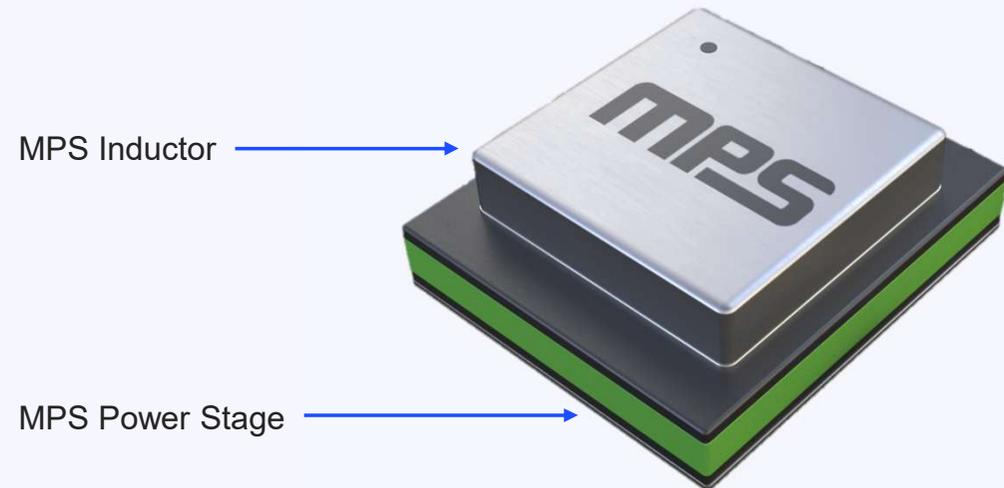
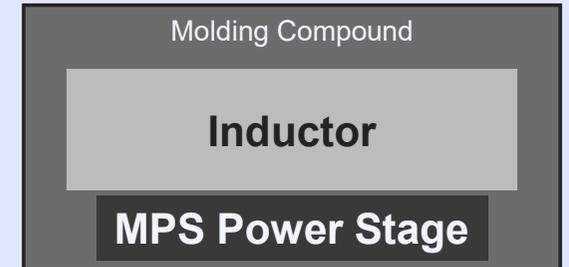
Compact Device Package

Minimal Solution Size

### Open Frame Module



### OverMolded Module



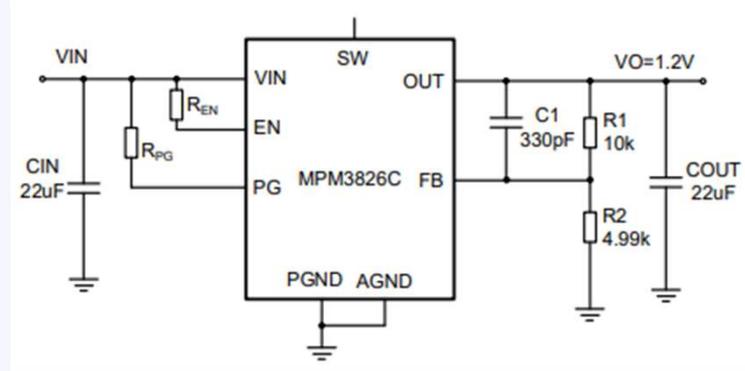
# Low Voltage Series – MPM3816C/26C/36C/46C



## Features

- 1A/2A/3A/4A Pin Compatible
- Wide 2.7V to 5.5V Operating Input Range
- Adjustable Output from 0.4V
- 100% Duty Cycle in Dropout
- FCCM Available
- 2.4MHz Frequency
- Enable (EN) and Power Good (PG) for Power Sequencing
- Output Discharge
- Constant On-Time (COT) Control

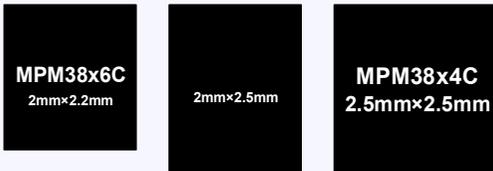
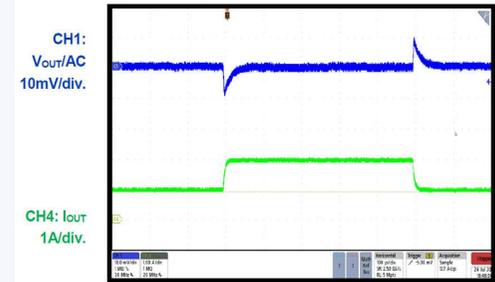
Typical Application Circuit



Excellent Transient Response with COT

### Load Transient

$V_{IN} = 3.3V$ ,  $V_{OUT} = 1.2V$ ,  $I_{OUT} = 1A$  to  $2A$ ,  
 $0.8A/\mu s$  E-load



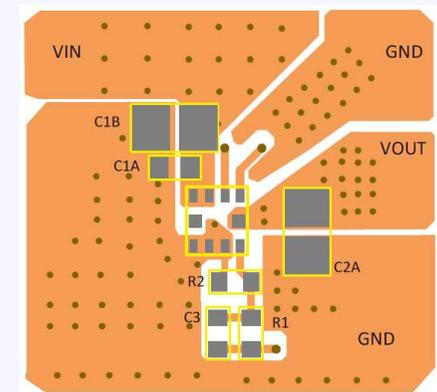
Size Comparison  
(in actual scale)

Available in an Ultra Small  
ECLGA-10 (2x2.2x1.2mm) Package

Common Footprint from 1A to 4A



Simplified Layout



# Discrete Solution vs. PMIC Module Using the MPM54304



## Discrete Solution Size:

**Width-to-Height Ratio:** 33.5mm x 20.65mm

**Total Area Used:** ~691.78 mm<sup>2</sup>

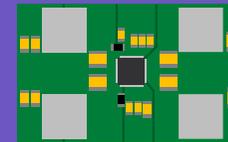
## PMIC Module Solution Size:

**Width-to-Height Ratio:** 11.25mm x 11.25mm

**Total Area Used:** ~126.5 mm<sup>2</sup>

**PMIC Module Solution Saves  
Up to 81% of Board Space**

Estimated Solution Size  
using PMIC IC



Estimated Solution Size  
using MPM54304



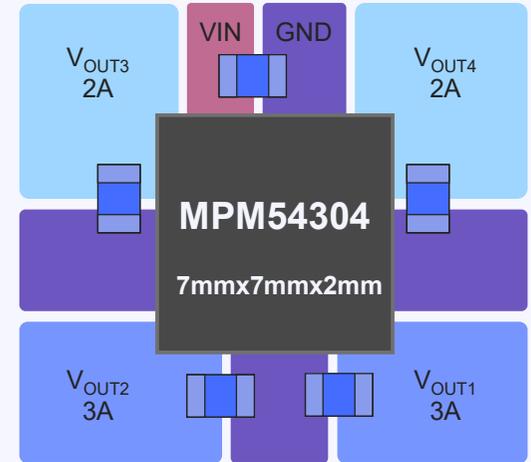
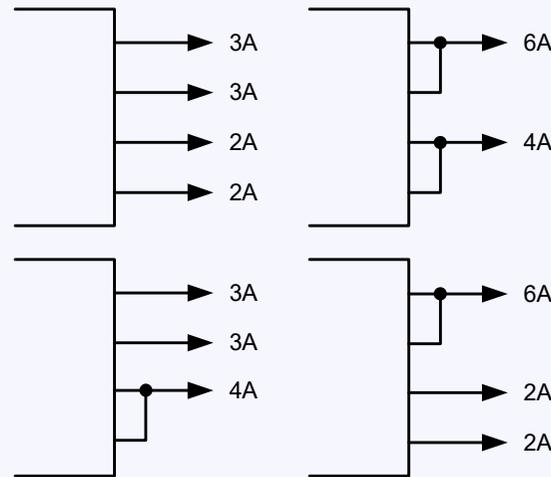
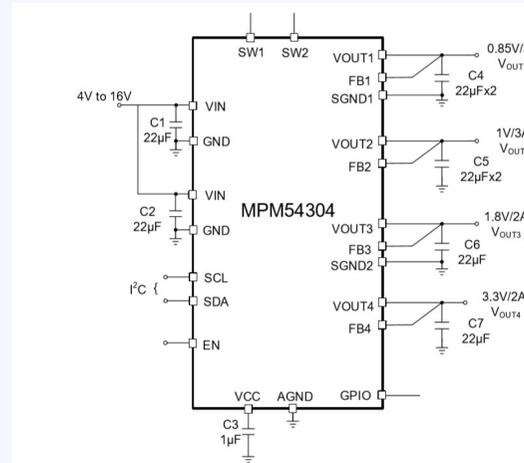
# MPM54304 – Quad 3A, 3A, 2A, 2A Power Module



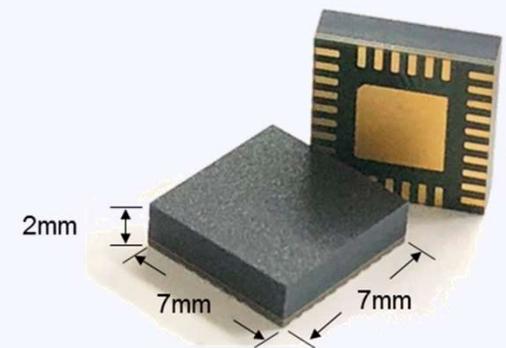
## Key Advantages:

- 4V to 16V Operating Input Voltage ( $V_{IN}$ ) Range
- Wide Output Voltage ( $V_{OUT}$ ) Range:
  - I<sup>2</sup>C-Configurable: 0.55V to 5.4V
  - External Resistor Divider: 0.6V to 7V or  $V_{IN} \times DMAX$  if  $V_{IN} < 7V$
- Continuous Current:
  - Channels 1 and 2: 3A Continuous Current
  - Channels 3 and 4: 2A Continuous Current
- Interleaved Operation, Configurable, Multi-Functional GPIO Pin
- Rails Can Be Combined
- **Adjustable Power-On/Off Sequence**
- **Power Good (PG) and Enable (EN)**
- Total Loss Allowed: 2.75W
- 2-Time Multiple-Time Programmable (MTP) Memory and I<sup>2</sup>C Function
- I<sup>2</sup>C-Configurable Parameters:
  - Paralleling Channel 1 and 2, Paralleling Channel 3 and 4
  - Switching Frequency ( $f_{sw}$ )
  - $V_{OUT}$
  - Over-Current Protection (OCP) and Over-Voltage Protection (OVP) Threshold
  - Power-On and Power-Off Sequencing
  - Forced Pulse-Width Modulation (PWM) or Auto-PWM/Pulse-Frequency Modulation (PFM)
- **Available in an Ultra-Thin LGA-33 (7mmx7mmx2mm) Package**

## Typical Application



Ultra-Thin LGA-33 (7mmx7mmx2mm) Package

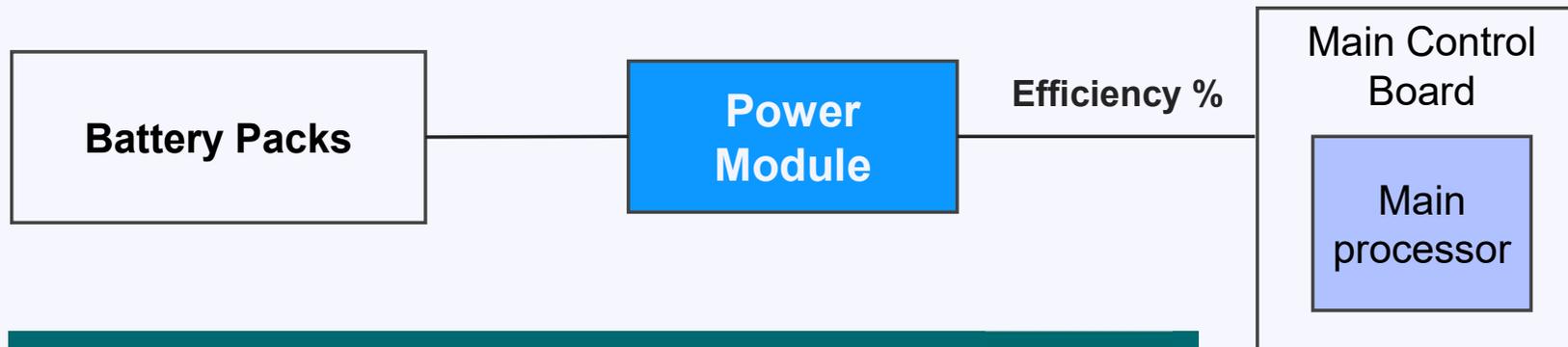


# Efficiency

## Designers need:

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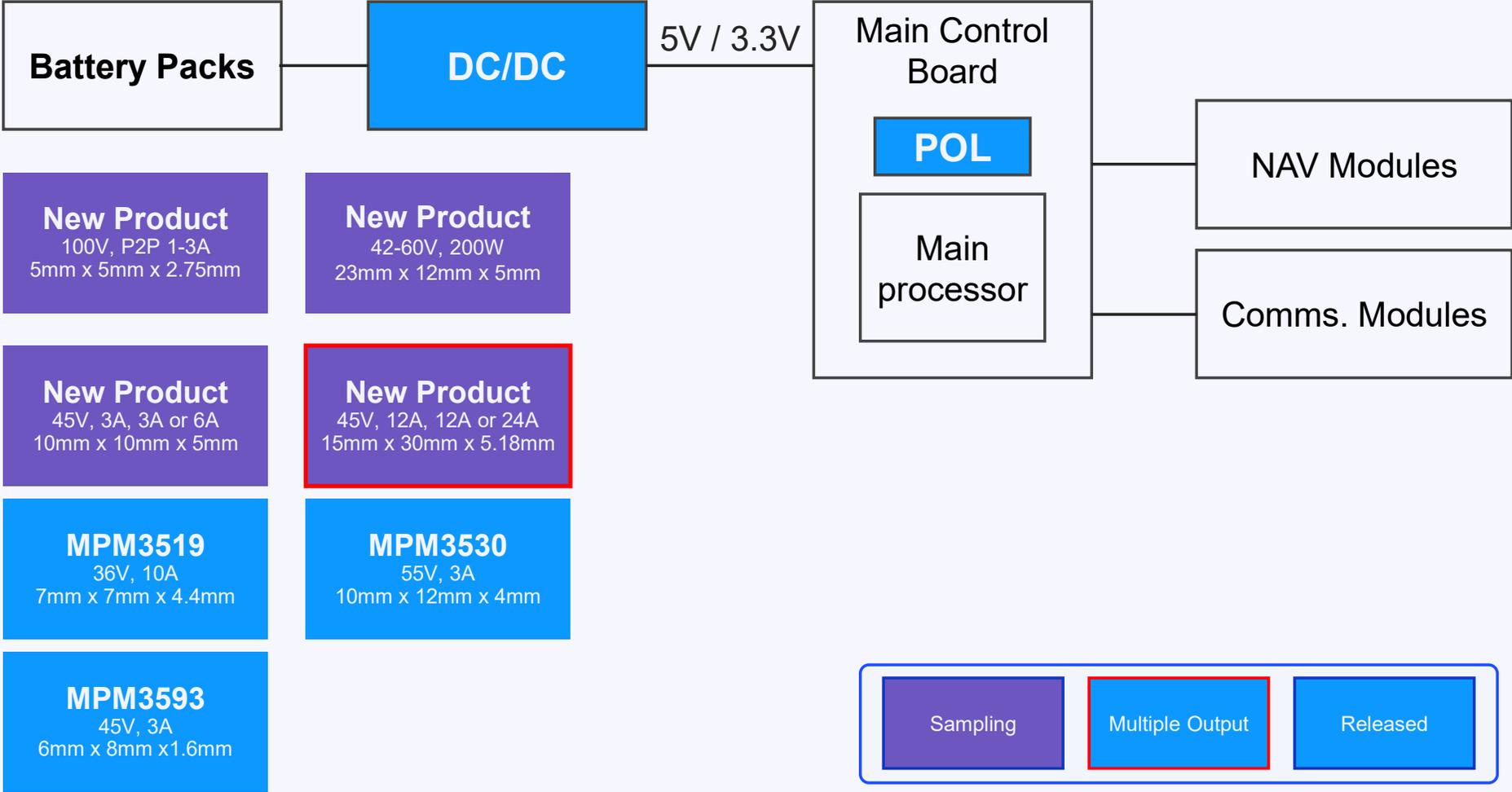
Drone productivity increases with larger battery life => directly affected by DC/DC conversion and power delivery **efficiency**.



**Drones are mostly powered by batteries**



# DC/DC Converters for Drones (Generic)



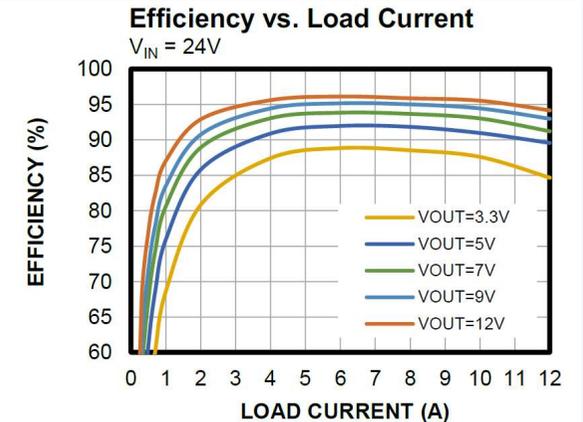
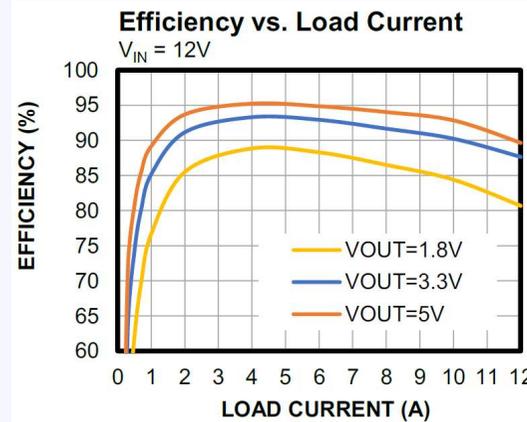
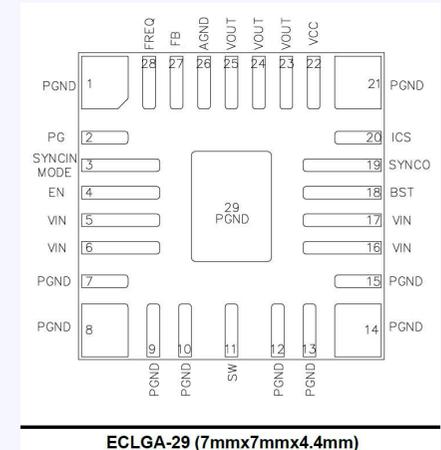
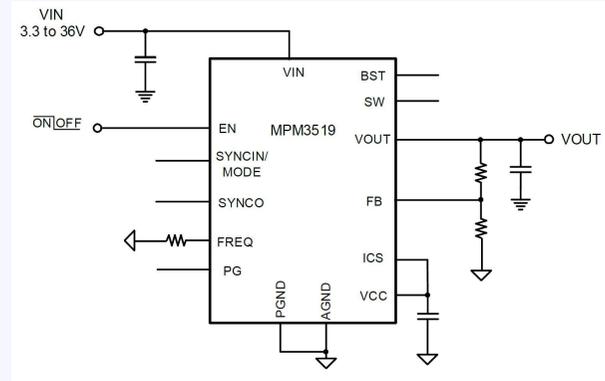
# MPM3519



## Features

- Vin range 3.3V to 36V
- Vout range 0.6V to 12V
- 10A continuous Output Current and 12A Peak Output Current
- Multi-Phase Capable up to 8-Phase and current sharing
- 200kHz to 2.5MHz Programmable Frequency
- Frequency Spread Spectrum Modulation
- Synchronization to an External Clock
- Symmetric VIN Pinout Placement for low EMI
- ECLGA 7mm x 7mm x 4.4mm package

Reference Schematic



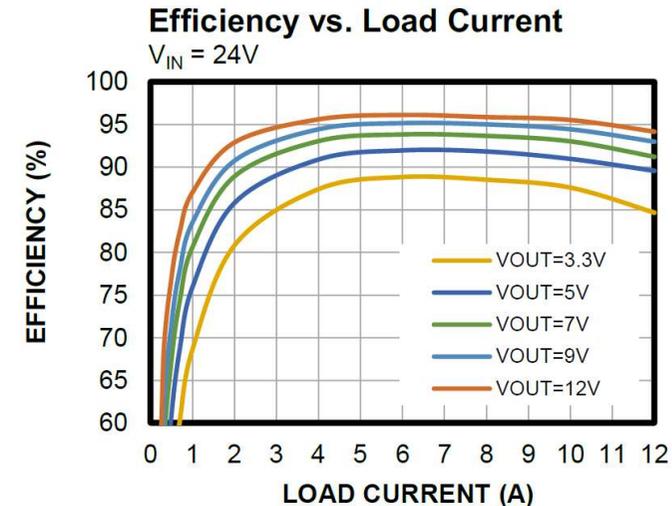
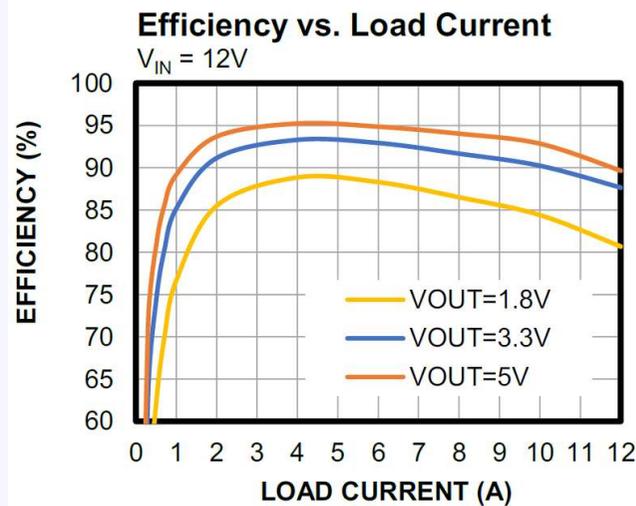
# Power Modules Efficiency Testing:

## Testing Approach:

- Automated testing Scripts
- Apples 2 Apples Testing:
  - Identical Test Conditions (Temperature, Airflow, Environment)
  - Identical Test Equipment (Power Supply, DC Load, DMM)
  - Identical, Custom (twisted pair) Cables with Kelvin Connections and Remote Sense
- Standardized Data format



**Efficiency Results:** up to 85-95% efficiency for various operating conditions

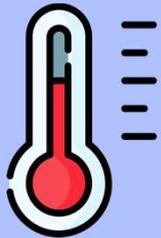


# Power Modules Efficiency Testing:

## Testing Approach:

- **Apples 2 Apples Testing:**

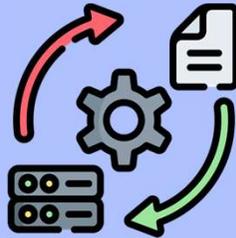
- Identical Test Conditions (Temperature, Airflow, Environment)
- Identical Test Equipment (Power Supply, DC Load, DMM)
- Identical, Custom (twisted pair) Cables with Kelvin Connections and Remote Sense



Ambient Temperature



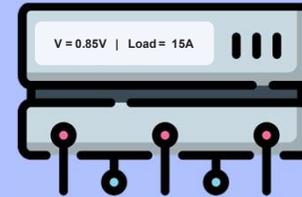
Airflow Speed



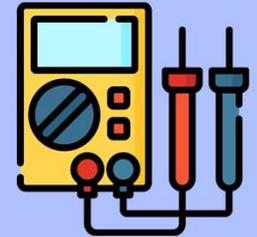
Test Environment



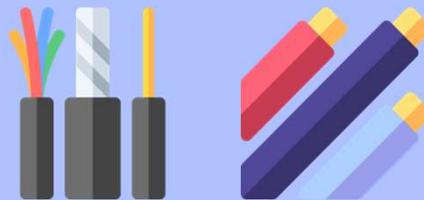
Power Supply



DC Load



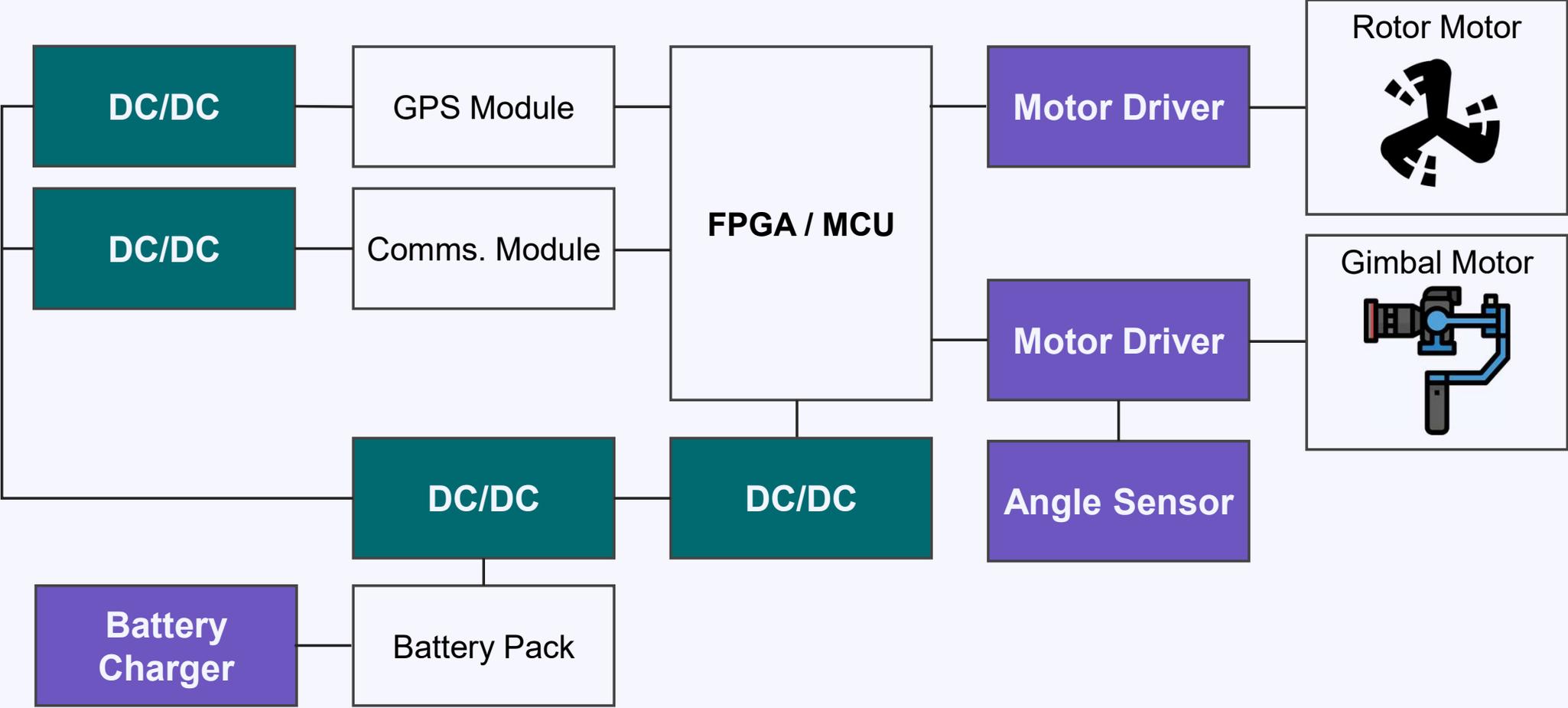
Digital Multimeter



Custom Build Cables

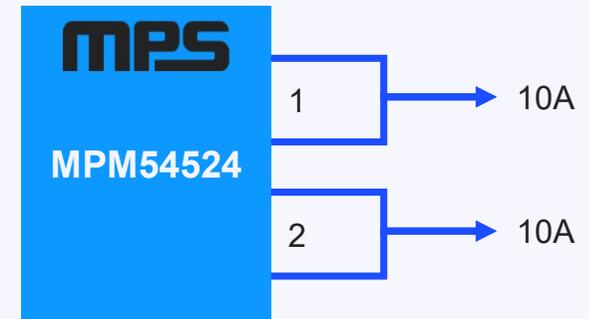
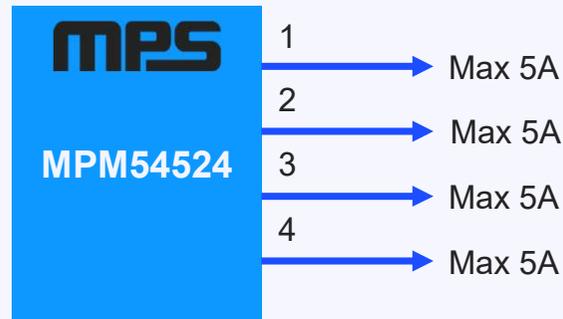
# Design Simplicity

# Drone Application Block Diagram – Board Level



## Designers Need:

- Small Solution Size & Design Simplicity



## MPS PMIC Power Modules

### MPM54304

3A, 3A, 2A, 2A,  
7mmx7mmx2mm

### MPM54322

3A, 3A, I<sup>2</sup>C,  
5mmx5.5mmx  
1.85mm

### MPM54532

6A, 6A, I<sup>2</sup>C,  
5mmx5.5mmx  
1.94mm

### MPM54522

6A, 6A, I<sup>2</sup>C,  
5mmx6.5mmx  
2.76mm

### MPM54313

Triple 3A, I<sup>2</sup>C,  
8mmx9mmx  
2.58mm

### MPM54524

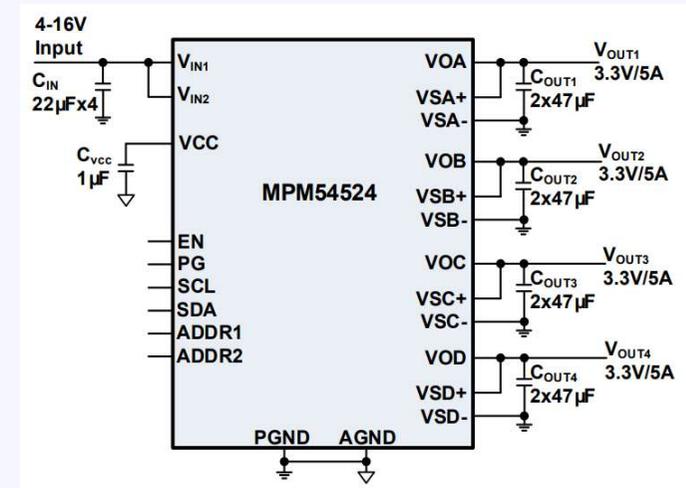
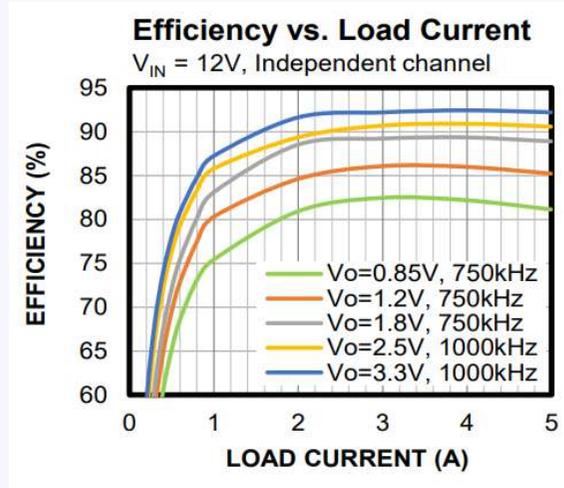
4x 5A, I<sup>2</sup>C,  
8mmx8mmx  
2.9mm

# MPM54524 – Quad 5A Power Module

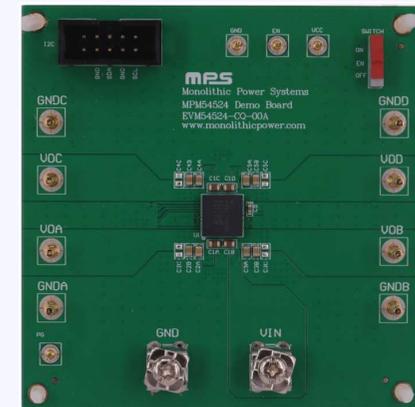
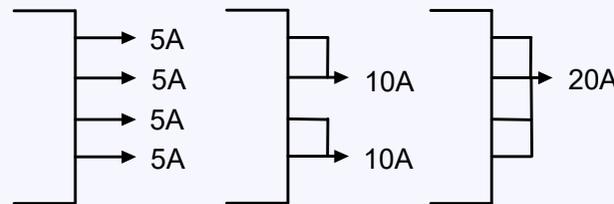


## Key Advantages:

- **Wide 4V to 16V Input Voltage ( $V_{IN}$ ) Range**
- **Adaptive COT for Ultra-Fast Transient Response**
- Channels A/B and C/D Support Up to 10A of Continuous Current in Parallel Mode
- Configurable Active Load Line (Droop Resistance) Up to 100m $\Omega$
- Differential Output Voltage ( $V_{OUT}$ ) Remote Sense
- I<sup>2</sup>C Target Address Programmable via the Multiple-Time Programmable (MTP) Memory
- I<sup>2</sup>C-Configurable Reference Voltage, Switching Frequency, Current Limit, **Power Sequencing**, Soft Start, and Pulse-Width Modulation (PWM)/Pulse-Frequency Modulation (PFM)
- **1MHz Default Switching Frequency**
- $V_{OUT}$ , Output Current ( $I_{OUT}$ ), and Junction Temp ( $T_J$ ) Monitoring via the I<sup>2</sup>C
- Open-Drain Power Good (PG) Indication
- Over-Current Protection (OCP), Under-Voltage Lockout (UVLO), Under-Voltage Protection (UVP), Over-Voltage Protection (OVP), and Thermal Shutdown



Available in an 8mm x 8mm x 2.9mm ECLGA Package



# Easy Configuration with Virtual Bench Pro 4

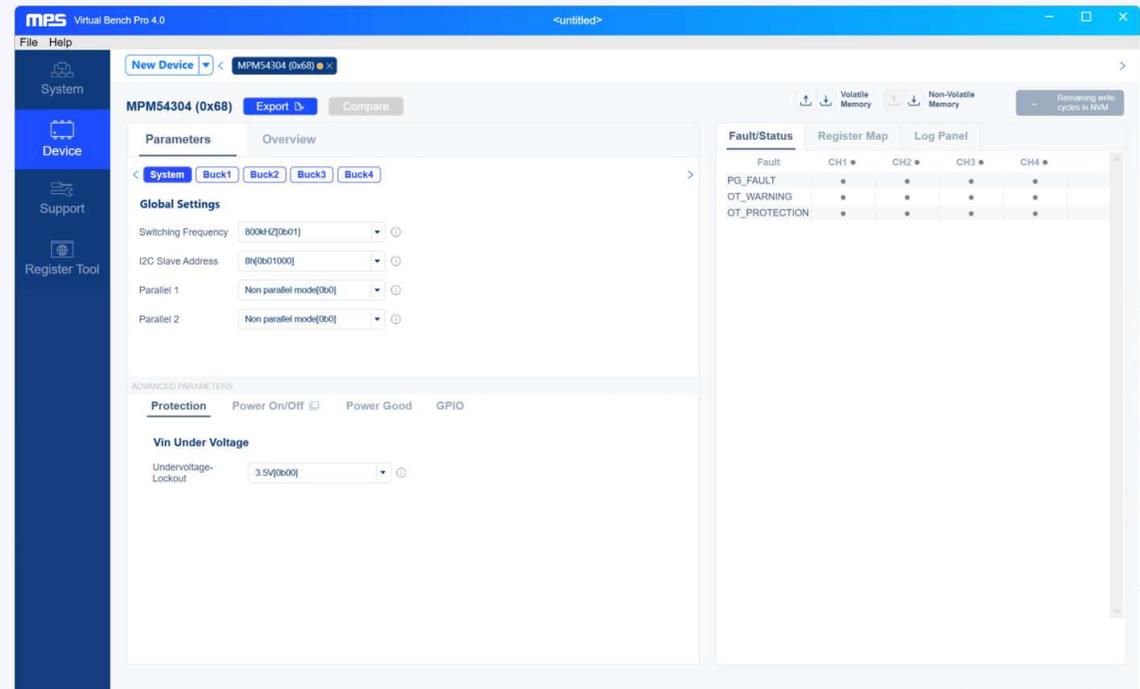


## Features:

- Supports I<sup>2</sup>C and PMBus Standard Protocol
- Tips for Parameter Configuration
- Monitor Real-Time Data ( $V_{IN}$ ,  $V_{OUT}$ ,  $I_{OUT}$ , Temp)
- Waveforms of the Main Signals
- Evaluate MPS Devices in Offline Mode

## Once the Device Is Configured:

- Export Your Settings
- Purchase Your Custom Preconfigured Parts



Results → **Fast Evaluation and Prototyping**

# Easy Configuration with Virtual Bench Pro 4



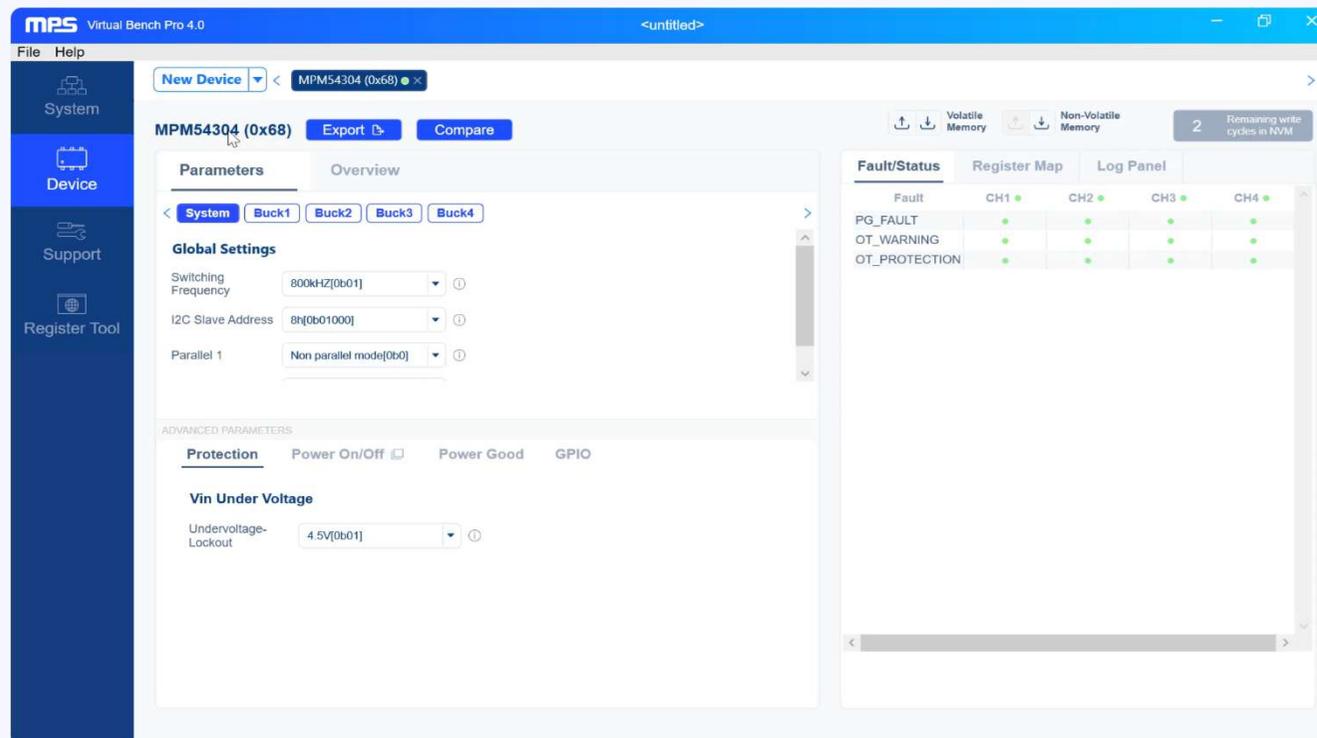
## Test Conditions:

$$V_{IN} = 12V, V_{OUT1} = 0.85V, V_{OUT2} = 0.85V$$

- $V_{OUT1}$  Soft-Start Time = 1ms
- $V_{OUT2}$  Soft-Start Time = 3ms

## Set-Up Algorithm for MPM54304:\*

- Launch **MPS Virtual Bench Pro GUI**.
- **Scan** for connected devices.
- **Select** the part number from the list.
- **Select** the required output (buck).
- **Go to** the “Power On/Off” menu.
- In the “ $V_{OUT}$  Soft Start” section **select the desired soft-start delay time** from the list.
- After selecting the desired soft-start time, **write (save) the configuration to the RAM**.
- **Read the RAM** to verify that the new configuration has been saved correctly.
- **Write the non-volatile memory (NVM)** by pressing the corresponding button.
- Perform a **power cycle to implement changes**.



\*Note: Depending on the IC, the menu names may be different

# Easy Configuration with Virtual Bench Pro 4



## Test Conditions:

$V_{IN} = 12V$

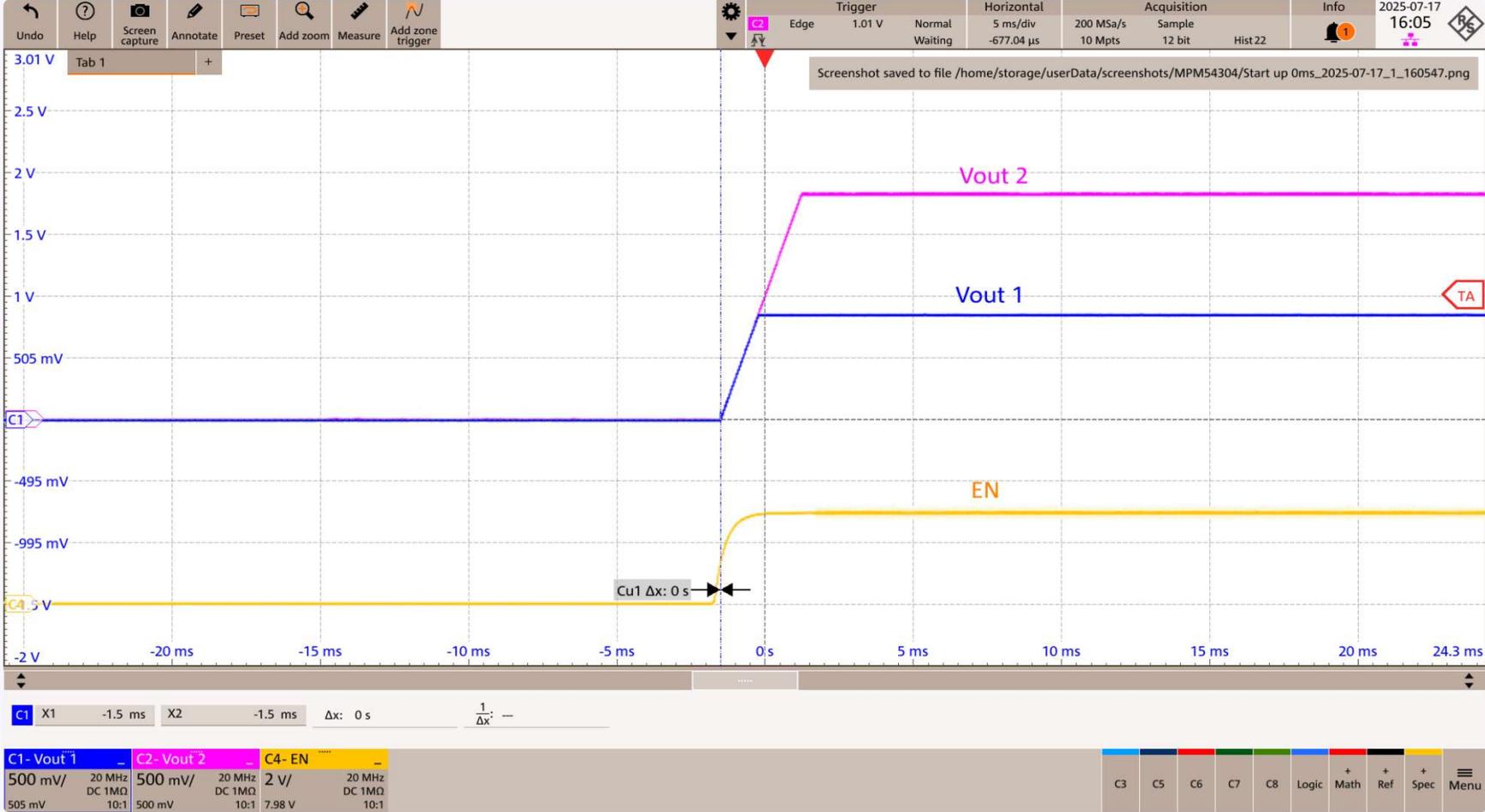
$V_{OUT1} = 0.85V$

$V_{OUT2} = 1.8V$

EN

$t_{SS1} = 0ms$

$t_{SS2} = 0ms$

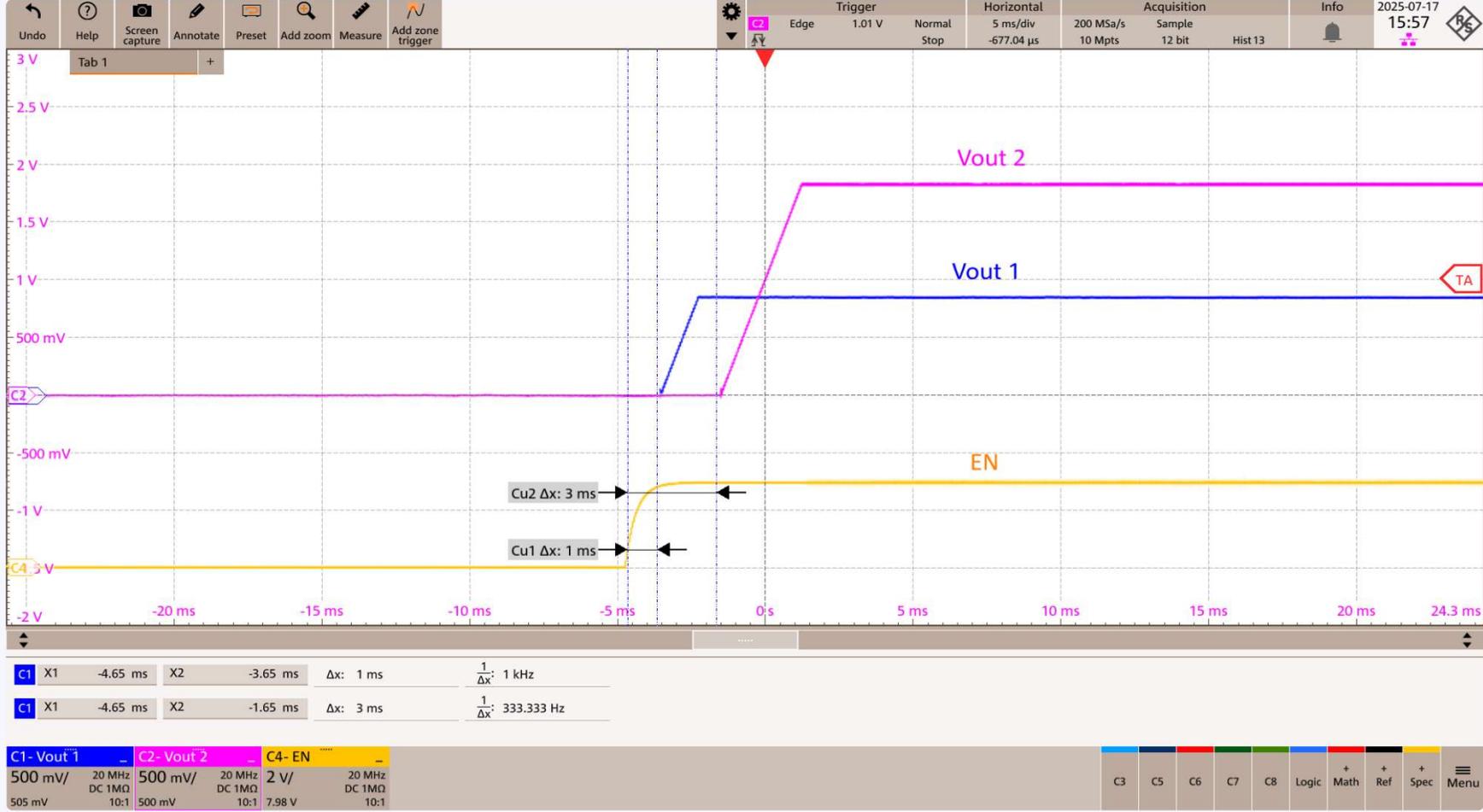


# Easy Configuration with Virtual Bench Pro 4



## Test Conditions:

- $V_{IN} = 12V$
- $V_{OUT1} = 0.85V$
- $V_{OUT2} = 1.8V$
- EN
- $t_{SS1} = 1ms$
- $t_{SS2} = 3ms$



# Thermals & EMC Testing

## Designers Need:

- **Great Testing Capabilities**

- Efficiencies'
- Thermal Testing
- EMI/EMC
- FFT Noise



### Detroit, MI



Internal

External

Customer Applications

### Ettenheim, Germany



Internal

External

Customer Applications

### Hangzhou, China



Internal

External

Customer Applications



## EMC Testing

**IEC 61000-6-3** (emission) and **IEC 61000-6-1** (immunity) – for residential/commercial environments

**IEC 61000-6-4** (emission) and **IEC 61000-6-2** (immunity) – for industrial environments

### Product EMC Standards

**CISPR 11** (emission) Industrial, scientific and medical equipment

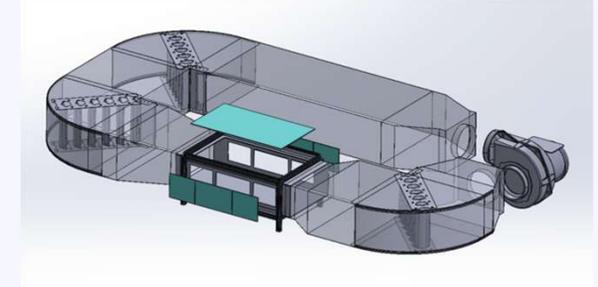
**CISPR 14-1** (emission) and **CISPR 14-2** (immunity) - for household appliances, electric tools and similar apparatus

**CISPR 25** (emission) Industrial, scientific and medical equipment

**CISPR 32** (emission) and **CISPR 35** (immunity) – for Electromagnetic Compatibility of multimedia equipment

## Quality Reports

- High Temperature Operating Life Test
- Moisture/Reflow Sensitivity Classification
- Temperature Cycling
- ESD
- Solder Joint Strength and Soldering Guidelines
- Highly Accelerated Temperature and Humidity Stress Test
- Shock and Vibration Testing



## Temperature Testing

- Industrial temp grade
  - -40C to +125C
- Custom Thermal Wind Tunnel Chamber
  - Measures module's pkg temperature at various environmental conditions: air speed and ambient temperature

# EMC – Laboratory – MPS



## CISPR25 - Chamber

Radiated emission and immunity testing acc. to automotive standards

## SAC3 - Chamber

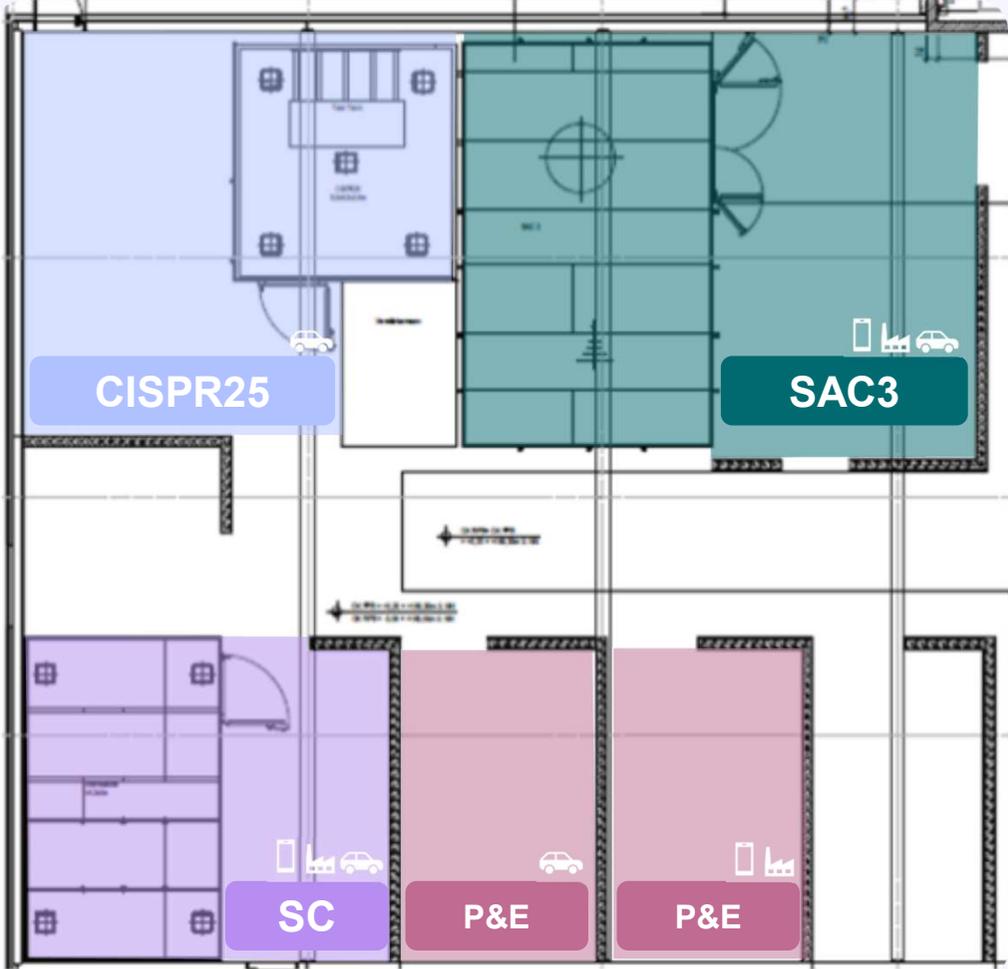
Radiated emission and immunity testing acc. to automotive, industrial and consumer standards

## Shielded Chamber

Conducted emission and immunity testing acc. to automotive, industrial and consumer standards

## Pulse and Electrical Testing

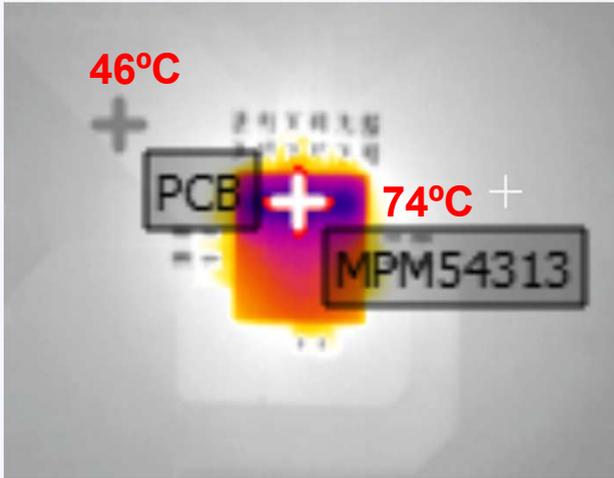
Electrical testing acc. to automotive and industrial standards



# Power Modules – Thermals

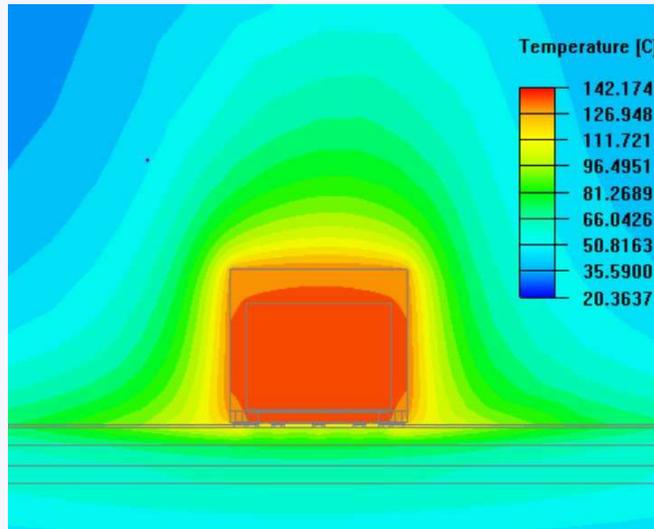
## Designed for high efficiency

3x3.3V<sub>OUT</sub>, 3x3A, P<sub>OUT</sub> = 30W



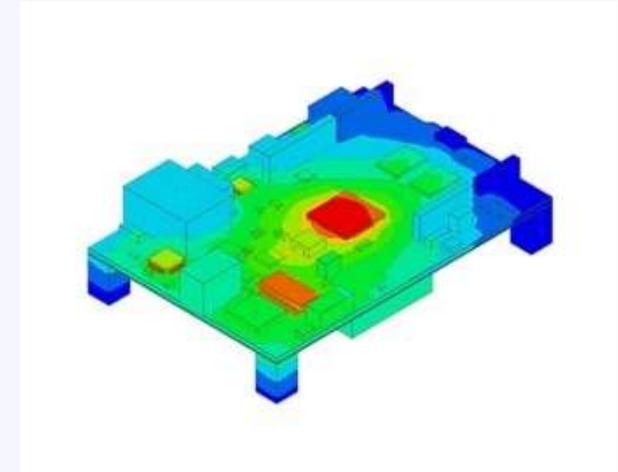
- Integrated
- High-efficiency
- Custom magnetics

## Thermal Characterization



$R_{\theta ja}$ (°C/W)	$\phi_{jt}$ (°C/W)	$\phi_{jb}$ (°C/W)
$R_{\theta jb}$ (°C/W)	$R_{\theta jc\_top}$ (°C/W)	$R_{\theta jc\_bot}$ (°C/W)

## Thermal Simulation Models



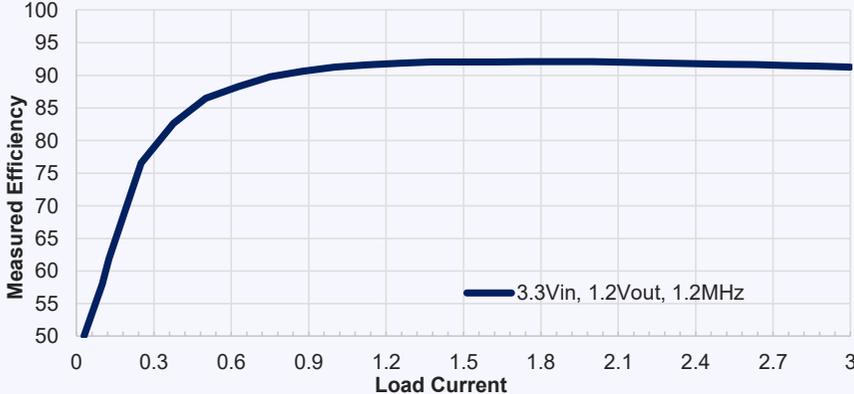
Icepak & Flotherm Models available on request

# Power Modules Testing – Summary

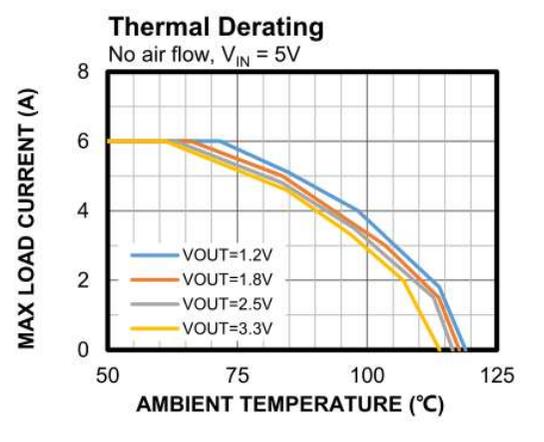


## Efficiency

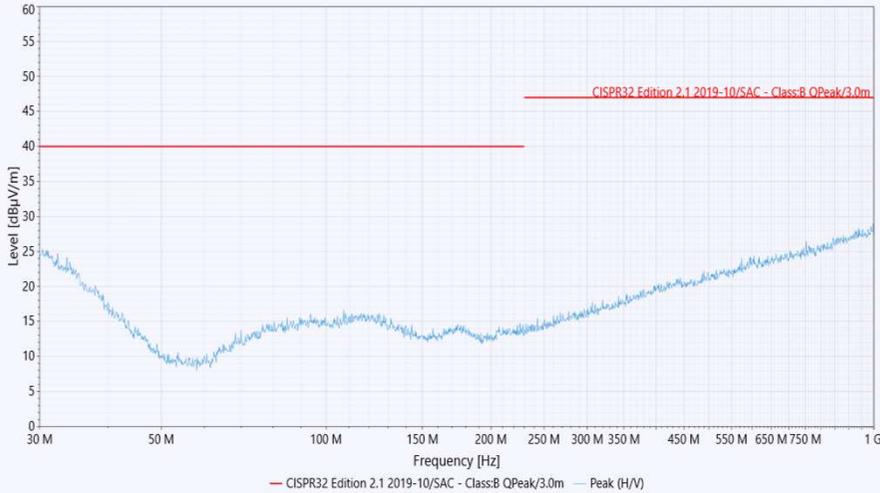
MPM Power Module  
 $V_{in} = 3.3V$ ,  $V_{out} = 1.2V$ ,  $I_{load} = 0 - 3A$ ,  $F_{sw} = 1.2MHz$



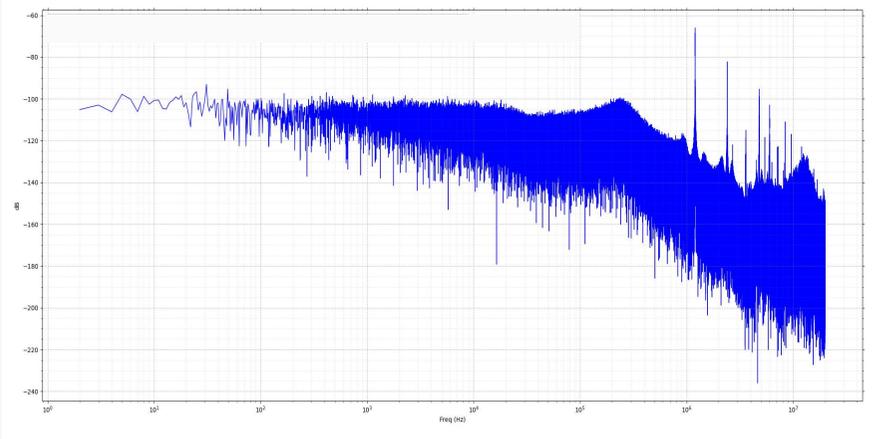
## Thermal Derating



## EMI Radiation



## FFT Noise Measurement (dB over Frequency)



# Accurate Voltage Regulation

# Drone Applications – FPGAs Power Tree (generic)



## Stage 1



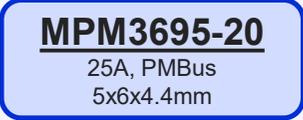
### Alternative



## Stage 2

For up to 40A per rail

**MPM3696-40**



**Xilinx Power Partner**

- High Efficiency
- Ultra-Fast Transient Response
- Small Footprint
- Full Reference Designs

[Browse our Reference designs](#)

## Designers need:

- Precise Voltage Regulation

Rail Requirement	Core	Transceiver	Auxiliary	
Accuracy	3%	3%	5%	5%
Low Ripple Specification		10 mV peak-peak 10 kHz - 80 MHz		
Transient (typical)	50% load $\leq 1 \text{ A}/\mu\text{s}$			
Sequencing order	First	Simultaneous with VCCINT	Second	Third
<b>FPGAs Rail Power Requirements:</b>				

FPGA Rails	Voltage (V)	Tolerance
V <sub>CCINT</sub>	0.72 / 0.85 / 0.9	+/- 3%
V <sub>CCBRAM</sub> , V <sub>CCINT_IO</sub>	0.85	+/- 3%
V <sub>CCAUX</sub> , V <sub>CCAUX_IO</sub> , V <sub>CCADC</sub>	1.2	+/- 3%
V <sub>CCO_1V8</sub>	1.8	+/- 5%
V <sub>CCO_3V3</sub>	3.3	+/- 5%

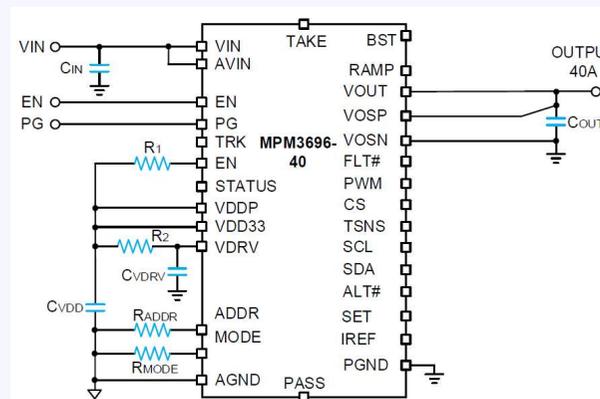
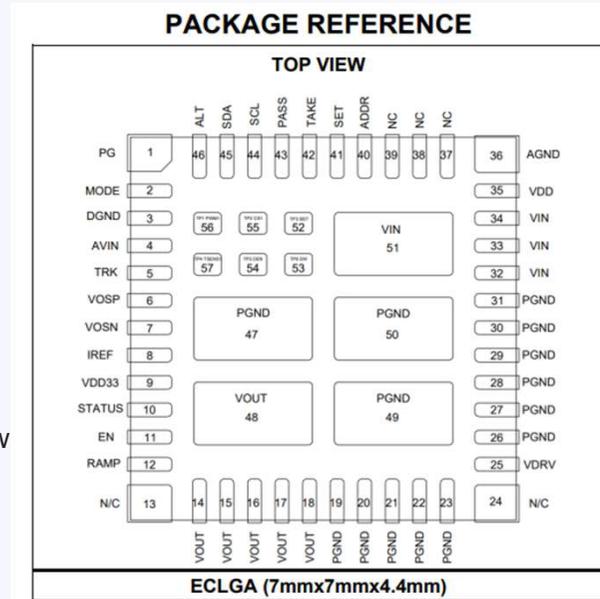
# MPM3696-40

Sampling

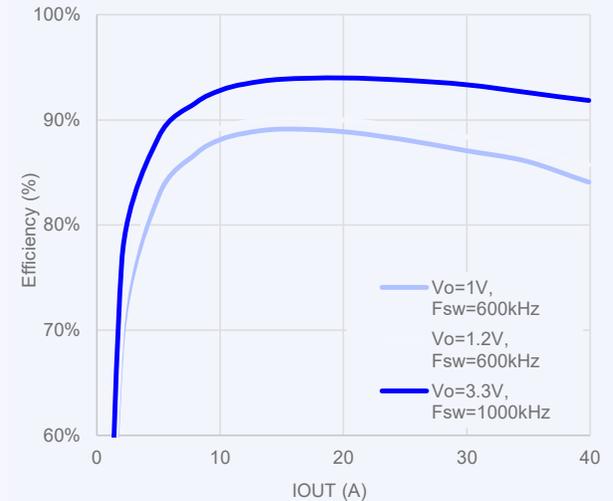


## Features

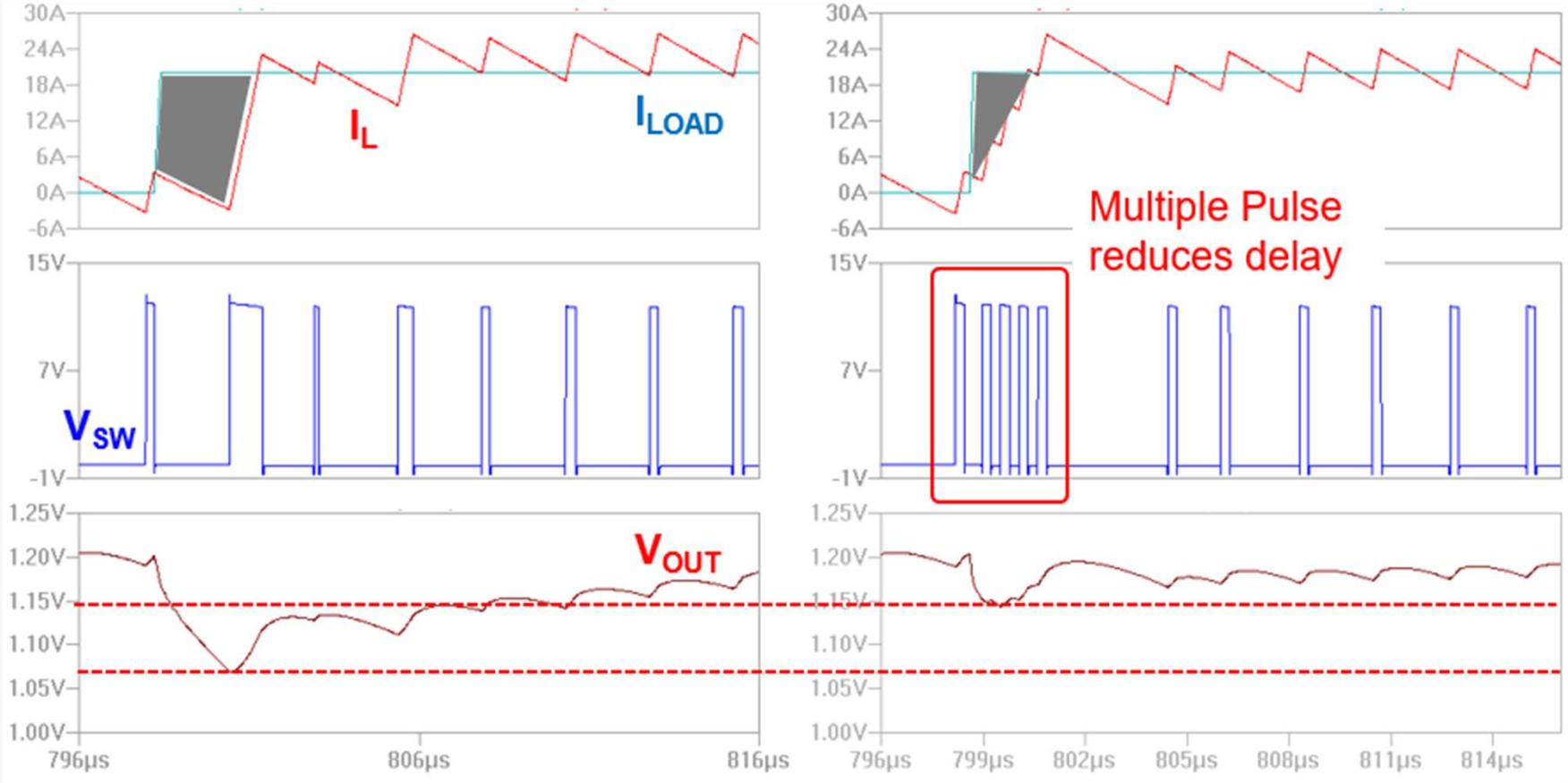
- Wide 2.8V to 16V Operating Input-Voltage Range
  - 4V-16V Without Internal 3.3V Bias
  - 2.8V-16V With External 3.3V Bias
- Adjustable Output from 0.3V to 8V
- 40A Continuous Output Current
- Stackable for Up to Six Converters
- Output Voltage Remote Sense
- Lossless and Accurate On-die Current Sensing
- 300kHz to 3MHz Switching Frequency
- Ultra-fast Transient Response with MCOT Control or Fixed Fsw with VCM control
- Tracking Function Available
- PMBus Compliance 1.3
- Programmable Via PMBus
  - Load-line Compensation
  - Output Voltage
  - Switching Frequency
  - Protection Threshold and Mode
- Accurate Telemetry
  - Input and Output Voltage
  - Output Current
  - Fault Report
  - Temperature
- Build-In MTP to Store Custom Configurations



**40A Power Module Efficiency**  
Vin=12V



# COT Control Vs Industry Standard – Faster transient



# MPM3696-40 Output Ripple Response

## Test conditions:

$$V_{IN} = 12V;$$

$$V_{OUT} = 0.85V;$$

$$I_{load} = 40A$$

$$BW = 1GHz / 20MHz$$

## Output Capacitors & VOUT

- $C_{OUT} = 12 \times 47\mu F + 2 \times 330\mu F (POSCAP)$
- $V_{OUT\_1} = 0.85V$
- $V_{PP} = \text{within } +/-3\%$

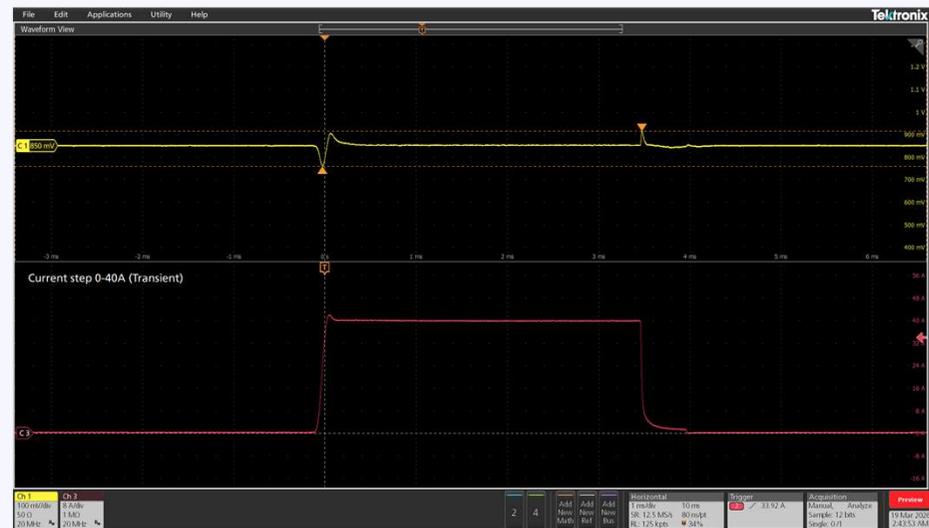
## Key Advantages:

- Reduced Output Capacitance
- Fast Transient response
- Stable Output voltage

Steady State



Load Transient



# Summary

# Power modules for Powering Drones – Summary



## Power Modules stand behind “Power”

Using MPS Power Modules helps to easily overcome the main concerns when powering Drones

1. Space Constraints
2. Efficiency
3. Design Simplicity
4. Thermal & EMC performance
5. FPGA Power Requirements





Live Engineering Support

**Contact our MPSNow team with any questions**

Fill in a form on our website or send an email to

**MPSNow:** <https://www.monolithicpower.com/mpsnow>

# Q&A

## Resource links

- MPS Webinars: <https://www.monolithicpower.com/en/support/webinars.html>
- MPS Power Modules: <https://www.monolithicpower.com/en/products/power-modules.html>