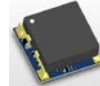


# Power Modules

A detailed look at how Power Modules are built and the implications to different applications

Anjana Govil

[www.ti.com/powermodules](http://www.ti.com/powermodules)



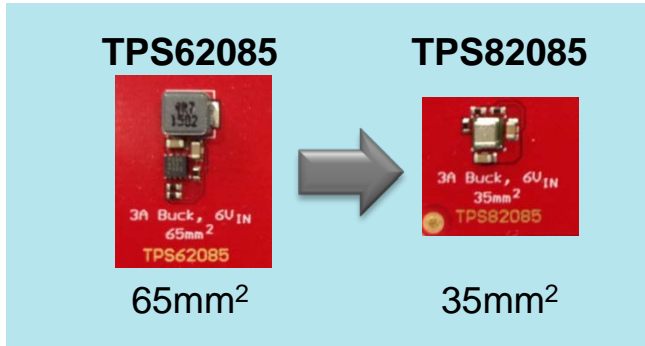
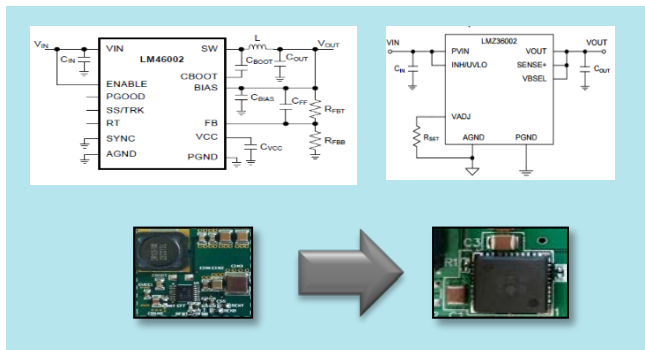
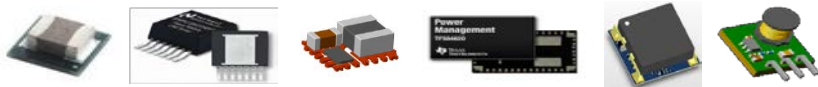
# AGENDA

- **Introduction**
- **What are Power Modules?**
- **How are Power Modules made?**
  - Pros/cons of different package types
- **Product portfolio overview**
  - Select product highlights
- **Important collateral**
  - Webench, app notes
- **Q&A**

# What are Power Modules?

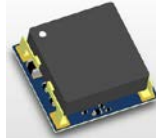
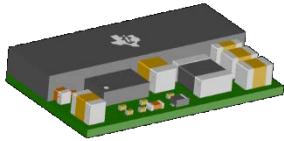
**DC/DC Converter that integrates:  
Controller, FETs and Inductor into  
single package**

- Simplifying and reducing customer's BOM



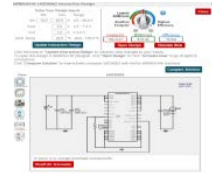
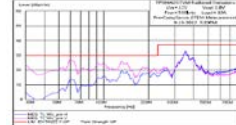
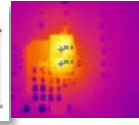
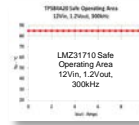
# Power Modules Simplify Design

## Small solution size



- ✓ Smaller solution size vs discrete
- ✓ Minimal external components
- ✓ Inductors over active components

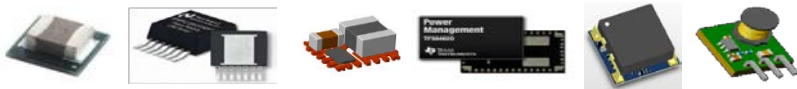
## Easy to use



- ✓ Simple design
- ✓ Best in class thermals
- ✓ Reliability data
- ✓ Meet EN55022 Class B Emissions
- ✓ Design tools

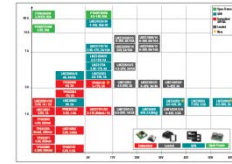
# TI's Power Modules – A Broad Portfolio

## Range of package options



- ✓ Package option matched to IC and application
- ✓ Range of surface mount, leaded and through-hole options
- ✓ Pin-Pin compatible options

## Broad portfolio



- ✓ Input voltages from 2.2V up to 60V
- ✓ Output currents up to 70A
- ✓ Stackable options for reduced noise and high lout

# Power Modules: The Next “Big Thing”

- **Module market is still relatively “new”**
  - But, it is growing quickly
- **Module technology is making strong advances**
  - Packages are getting smaller
  - Costs are coming down
  - Performance is up
  - Prices are coming down
- **Modules will be the preferred solution for many engineers in the future**
  - Easy to use. Compelling size. OK price.
  - Quality product

# Modules simplify design..... Considerably!

## DISCRETE BUCK CONVERTER DESIGN

### Converter Selection

- Control mode, voltage mode, peak current mode, constant on time, and feature set.

### External Component Selection:

- Inductor: Inductance, DCR, IDC, ISAT, operating frequency, shielded & non-shielded
- Inductor Qual- ISAT vs TA vs IBIAS, HT storage, volt withstand, Curie temp, core cracking
- Capacitors: Type (ceramic, polymer tantalum, electrolytic), amount, layout placement

### Layout and EMI

- Design length and size of current loops, be concerned with high-frequency nodes, and take precautions with ground return paths to both the IC and the input power supply, Parasitics

### Power Supply Design and Characterization

- Output voltage accuracy over line, load, and temperature.
- Compensation: Stability across  $V_{in}$ ,  $V_{out}$ ,  $F_{sw}$ , Temp and  $C_{out}$  ranges. Bode Plots
- Switching Frequency: Efficiency/Size trade-off, Inductor and  $C_{out}$  selection.
- Load Transient, Soft Start ( $V_{out}$  prebias) and Fault (OV, OC, OT) characterization.
- Thermal characterization: Safe Operating Area

### Managing Supply Chain

- Component Vendors (Approved Vendor List)
- Second Sourcing

## MODULE BASED DESIGN

### ✓ You select modules based on key design specs

- We figure out converter selection for best application needs, ease of use, and feature set

### ✓ We do component selection & qualification

- L chosen to optimize efficiency, size, stability, reliability, and cost
- C chosen to optimize  $V_o$  ripple, load transient, solution size and cost

### ✓ We provide optimized layout for EMI and thermals

- DS recommended layout meets thermal and EMI performance
- UL Tested CISPR 11 EMI

### ✓ We provide a fully characterized solution across operating range

- Characterized over  $V_{in}$ ,  $V_{out}$ ,  $I_{out}$ ,  $F_{sw}$ ,  $C_{out}$ , TA, Load Transient, Fault, Thermal and electrical over-stress

### ✓ We work with component vendors to ensure supply continuity

- Module components are 2nd sourced from engineer-selected vendors

# Power Modules – Excellent Thermals. SOA Curves

- Excellent thermals
- No airflow required
- 85 ° C ambient

TPS82130

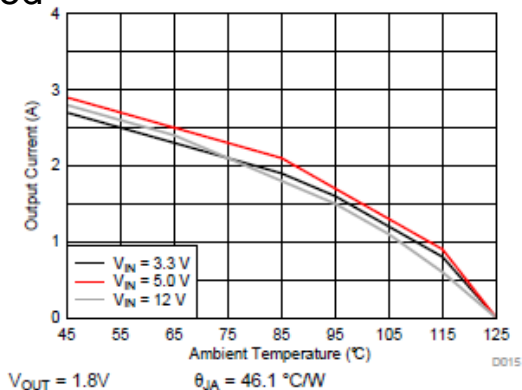
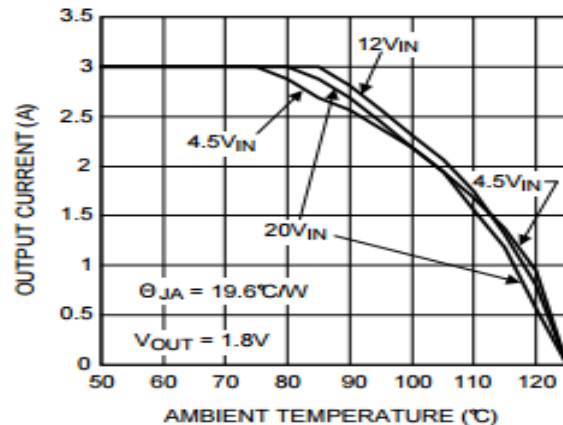
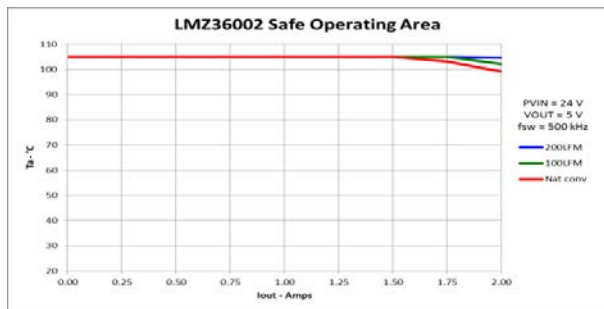


Figure 16. Thermal Derating,  $V_{OUT} = 1.8 V$

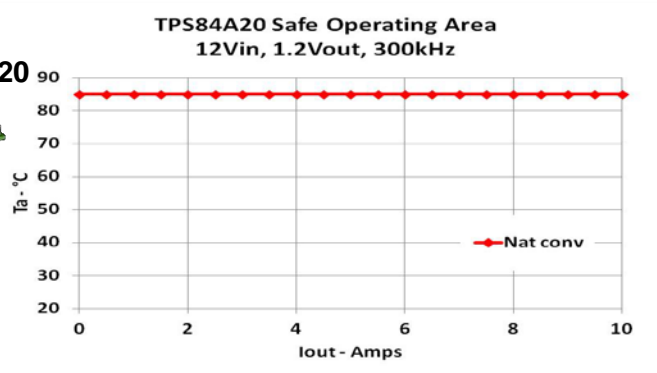
LMZ12003



LMZ36002



TPSM84A20

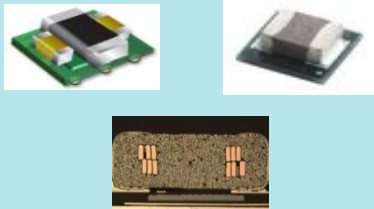




# **Power Modules: Package Technology Overview**

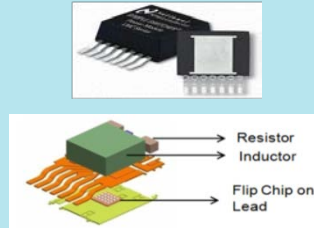
# Broad portfolio of module technologies

## Embedded solution Density



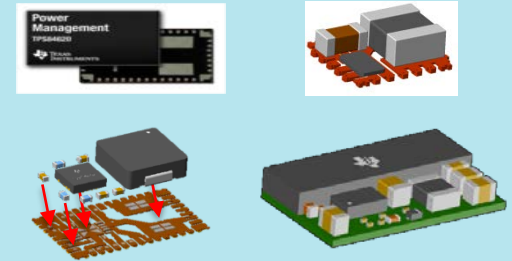
- Buck IC integrated into PCB
- Smallest solution size
  - As small as 2.3x2.9x1.1mm
- Vin up to **36V**
- Iout from 200mA to 3A

## Leaded module Ease of use



- SIMPLE SWITCHER products
- Ease of Prototyping and Manufacturing
- Standard Size/Leadpitch
- Vin up to 42V
- Iout up to 10A

## QFN module Feature rich/dense

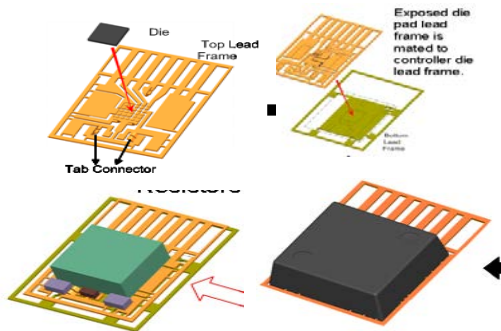


- Standard QFN Package
- 'Feature Rich and Flexible' solutions
- Vin up to 60V
- Iout up to 35A (**70A**)

# Deep Dive: Leaded

## Process Flow

FCOL → LF Bond → SMT → Mold

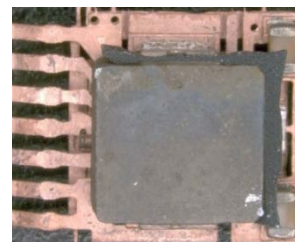
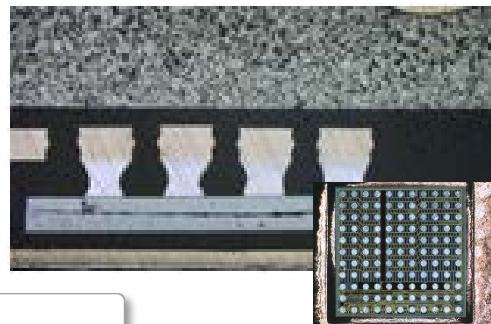
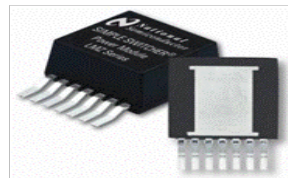


### TECH CHOICE

Overmold 200um dual LF  
High flux thermal pad  
FCOL between leadframes  
SMT components (on top LF)  
Molded inductor  
1-10A+

## LMZ14203

10 x 14 x 4.3 mm  
42V, 3A



### CUSTOMER IMPACT

3D, mid-cost assembly  
MSL3, 245°C  
T-MOD, 1.27mm pitch  
 $\theta_{JA} = 19.3^{\circ}\text{C/W}$   
46mm<sup>2</sup>/A, 200mm<sup>3</sup>/A (wide Vin)

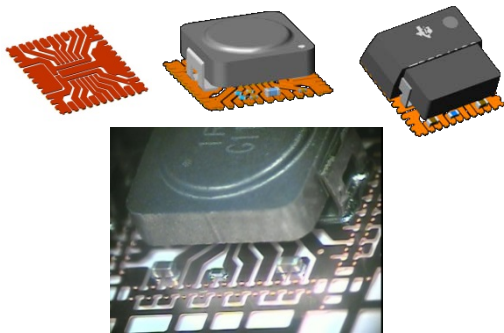
Cost	Yellow
Density	Light Green
EOU	Green
Eff	Light Green
Thermal	Yellow

Extreme High EOU, Density (3D) for low volume Industrial

# Deep Dive: QFN

## Process Flow

Leadframe → SMT → Mold

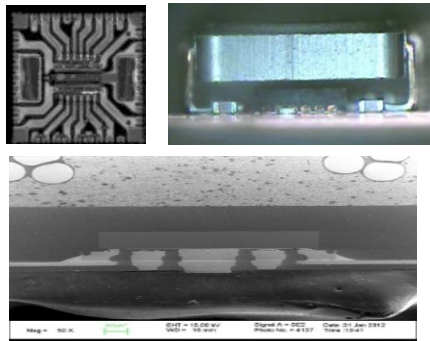


### TECH CHOICE

Overmold, 200um LF,  
High thermal flux customer pads  
Pre-packaged, tested silicon  
SMT components  
Molded inductor (2D and 3D)  
3-30A+

## LMZ31710

10 x 10 x 4.3 mm  
2.7-17V, 10A

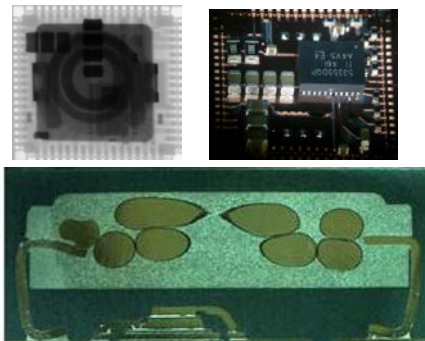


### CUSTOMER IMPACT

3D, low cost assembly  
MSL3, 245°C  
QFN, 0.8mm pitch  
 $\theta_{JA} = 13.3^{\circ}\text{C/W}$   
10mm<sup>2</sup>/A, 43mm<sup>3</sup>/A

## LMZ31530

15 x 16 5.8 mm  
4.5-15V, 30A



### CUSTOMER IMPACT

3D, low cost assembly  
MSL3, 245°C  
QFN, 0.8mm pitch  
 $\theta_{JA} = 8.6^{\circ}\text{C/W}$   
8mm<sup>2</sup>/A, 46mm<sup>3</sup>/A

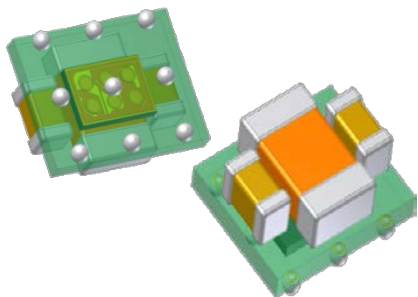
Cost	Light Green
Density	Green
EOU	Yellow
Eff	Green
Thermal	Green

High EOU, High Density for low-mid volume Industrial, Enterprise, Communications

# Deep Dive: Embedded (uSIP, Nano)

## Process Flow

Embed → SMT

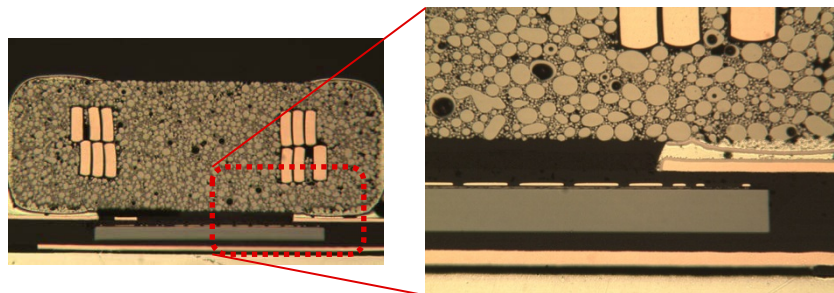


### TECH CHOICE

Open Frame, FR Laminate  
 Embedded, Die up or Die down  
 SMT components  
 Multilayer or Molded inductor  
 0.1-3A (so far...)

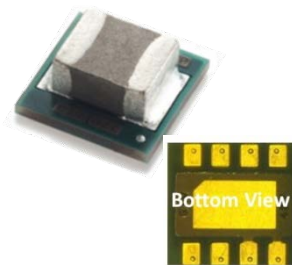
## TPS82085, TPS82130

2.8 x 3 x 1.3 / 1.5 mm  
 2.5-6V, 2.7-17V, 3A



### CUSTOMER IMPACT

3D, low to mid cost assembly  
 MSL2/3, 260°C  
 uSIP LGA, 0.65mm pitch  
 $\theta_{JA} = \sim 45^{\circ}\text{C/W}$   
 2.8mm<sup>2</sup>/A, 4.2mm<sup>3</sup>/A



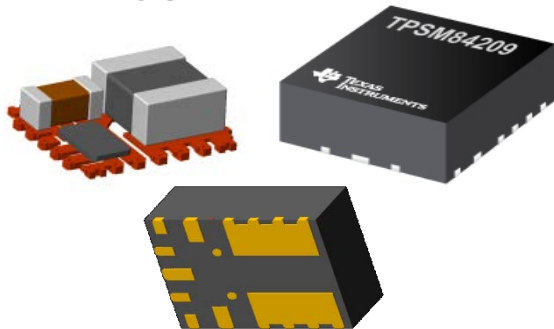
Cost	Green
Density	Green
EOU	Yellow
Eff	Green
Thermal	Yellow
EMI	Yellow
Rel	Green

**Ultra High Density for volume PE, Industrial, Enterprise, Communications**

# Deep Dive: Flip Chip On Lead (FCOL) **NEW!**

## Process Flow

FCOL → SMT → Mold



### TECH CHOICE

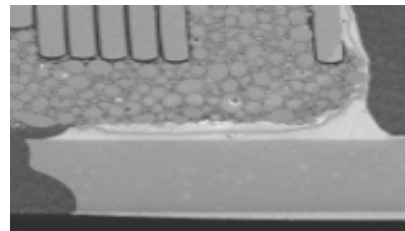
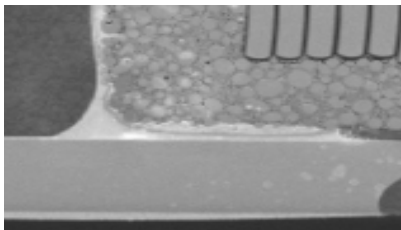
Overmold, 200um LF  
FCOL, direct die  
SMT components  
Molded inductor  
1-4A (so far...)

## TPSM84209 (RTM'd)

4 x 4.5 x 2 mm

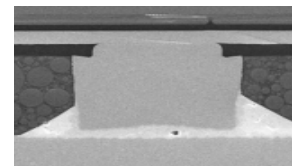
4.5 - 28V, 2.5A and

Coming soon: TPSM82135 (4.5-17V, 4A)



### CUSTOMER IMPACT

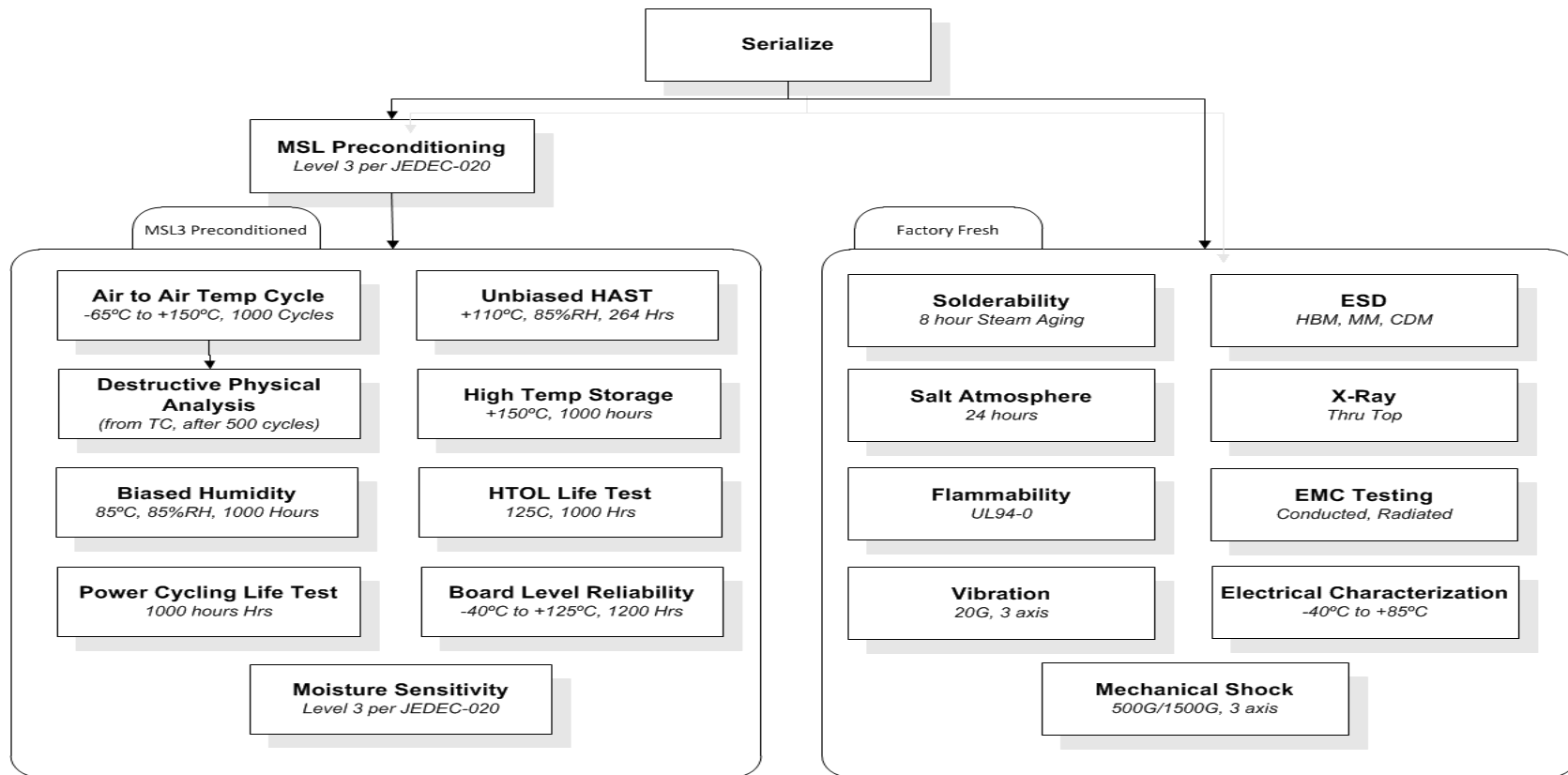
Low cost assembly  
MSL3, 260°C  
QFN, 0.65mm pitch  
 $\theta_{JA} = \sim 30^{\circ}\text{C/W}$   
~4mm<sup>2</sup>/A, 8mm<sup>3</sup>/A (82135)



Cost	
Density	
EOU	
Eff	

Low Cost, High Density for low-mid current Industrial, Enterprise, Communications

# Typical module qualification summary



\*\* - MSL 3 Preconditioning

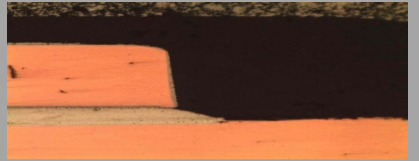
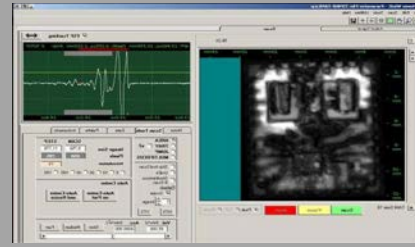
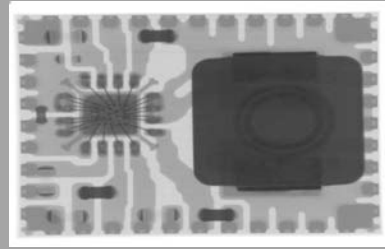
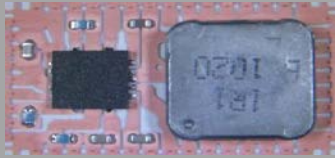
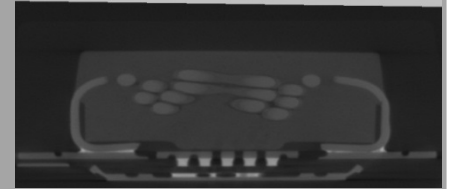
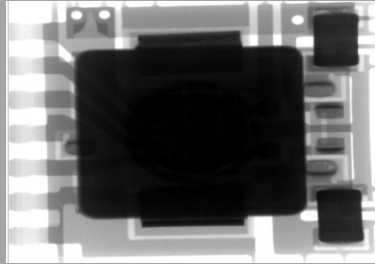
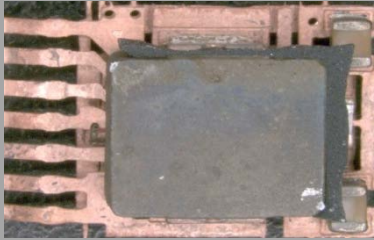
# Typical module qualification summary

Test Type	Condition/Duration	QTY Lots/Pieces	Results
Moisture Sensitivity	Level 3 as per Jedec-020	27	Pass
**Temp cycling -65C/150°C	-65C/+150°C (500, 1000* Cyc)	3/77	Pass
**Unbiased HAST	110C/85%RH/17.7 psia (96, 264* hours)	3/77	Pass
**Biased Temp. Humidity	85C/85%RH (500, 1000 hours)	1/77	Pass
BLR - Temp Cycle, -40/125°C	-40/125°C (1200 cycles)	1/42	Pass
**High Temp. Storage Bake	150°C (500 hours)	1/75	Pass
**High Temp. Storage Bake	170°C (168, 420 hours)	2/77	Pass
**Steady-State Life Test	125°C (500, 1000 hours)	2/77	Pass
**Power Cycling	15 Minute Duty Cycle 1000 hours	3/40	Pass
Vibration	MIL-STD-883D, METHOD 2007.2 - Pass 20g	1/9	Pass
Mechanical Shock	MIL-STD-883D, METHOD 2002.3 - pass 1500g	1/3	Pass
Flammability	Method A - UL94-0	3/5	Pass
Solderability	Steam age, 8 hours	3/22	Pass
Salt Atmosphere	24 hours	3/22	Pass
ESD HBM	+/-100V	1/3	Pass
ESD MM	+/-100V	1/3	Pass
ESD CDM	+/-500V	1/3	Pass
Radiated Emissions	Pass - Class B EN55022 Regulations	1/3	Pass
Conducted Emissions	Data Provided, Passed Class B EN55022	1/3	Pass

\*\* - MSL 3 Preconditioning



# Solder dynamics are reviewed as part of the qualification process



Solder evaluated after assembly

X-rayed after MSL3 / 3x reflow

CSAM/TSAM to review solder integrity

Cross-sections to review solder joints

# Component selection for modules

- **Inductors**

- Preferred Types: Molded Powdered Iron, Ferrite Staple Core (40A+)
- Pre Qualification:
  - Inductance vs. DC current vs. Temperature (saturation)
  - High Temperature Storage (6 wks @ 150°C or greater)
  - 3x Reflow, monitor change in L and DCR

- **Capacitors**

- Preferred Types: X7R, X7S
- Pre Qualification:
  - Capacitance vs. DC bias
  - Insulation resistance
  - 3x Reflow, monitor change in C and IR

- **Resistors**

- Thick Film, 1% or better, TC = 100-200 PPM
- KOA, Vishay/Dale, Yageo
- Moving to Green status when vendors are ready...

# Power Modules: MSL Ratings

- **Moisture Sensitivity Level (MSL) determines a products Floor Life**
  - The amount of time a device can be removed from Anti-Static, Dry Pack bag before being reflowed
  - If Floor life is exceeded, units must be baked prior to reflow
- **Most TI Power Modules are rated to MSL3 or higher at 30°C and 60% relative Humidity**
  - IPC/JEDEC J-STX-033C provides guidance on Floor Life at different temps and humidity levels
  - See App Note [SLVA840](#) for more info

IPC/JEDEC J-STX-033C is Industry Standard for defining MSL rating vs floor life at 30°C

MSL	Floor Life	Moisture Relative Humidity
1	Unlimited	85% RH
2	1 year	60% RH
2a	4 weeks	
3	168 hours	
4	72 hours	
5	48 hours	
5a	24 hours	
6	Bake before use and reflow within time on label	

# **Power Modules: Portfolio and Soon To Be Released**

# TI's Power Module Portfolio

Advanced Info

Output Current >4A

PTH04040W  
3.3V/5V, 60A

PTH05T210W  
5.5V, 30A

PTH08T250W  
4.5-14V, 50A

TPSM846C23/C24  
15V, 35A, PMBus **NEW!**

LMZ31520/30  
3-15V, 20A/30

TPSM84A21/2  
8-14V, 10A **NEW!**

LMZ12008/10  
6-20V, 8A/10A

LMZ13608/10  
6-36V, 8A/10A

LMZ31707/10  
2.95-17V, 7A/10A

LMZ22008/10  
20V, 8A/10A

LMZ23608/10  
6-36V, 8A/10A

TPSM82480  
2.4-5.5V, 6A **NEW!**

TPSM84824/624/424  
4.5-17V, 8A/ 6A/ 4A **NEW!**

LMZ30604/6  
6V, 4A/6A

LMZ31506/H  
4.5-15V, 6A

LMZ22003/5  
4.5-20V, 3A/5A

TPS82085  
6V, 3A

TPS82130  
3-17V, 3A

LMZ31704  
2.95-17V, 4A

LMZ23603/5  
6-36V, 3A/4A

TPS82084  
6V, 2A

TPS82140  
3-17V, 2A **NEW!**

LMZ12003  
4.5-20V, 3A

LMZM33602/3  
36V, 2/3A **NEW!**

LMZ14203/H  
6-42V, 3A

LMZ35003  
7-50V, 2.5A

LMZ20501/02  
5.5V, 1A / 2A

LMZ30602  
6V, 2A

TPS82150  
3-17V, 1A **NEW!**

TPSM84209  
4.5-28V, 2.5A **NEW!**

LMZ34202  
4.5-42V, 2A

LMZ36002  
4.5-60V, 2A

LMZ10501  
5.5V, 1A

TPS8268090/105/150  
5.5V, 1.6A

LMZ21701/00  
3-17V, 650mA / 1A

LMZ12001/2  
4.5-20V, 1A/2A

LMZ34002  
40V, 2A (Neg)

LMZ14201/2/H  
6-42V, 1/2A

TPS82697/98  
4.8V, 800mA

LMZ10500  
5.5V, 0.65A

TPSM842xx  
28V, 1.5A. T0220 **NEW!**

TPS81256  
Boost, 400mA\*

TPS8267X  
4.8V, 600mA\*

LMZM23600/2  
4-36V, 0.5A/1A **NEW!**

TPS82695  
4.35V, 500mA

TPS82740  
5.5V, 0.2A

Output Current <4A



Embedded

Leaded

QFN

OpenFrame

6V










17V

36V

60V

# New Power Modules



- [TPSM82480\\*](#):  5.5V, 6A in QFN Package (7.9 \* 3.6 mm)
- [TPSM84A21/2:](#)  15V, 10A in QFN Package (9 \* 15 mm)
- [TPSM84824:](#)  17V, 8A in QFN Package (plus 6A, 4A; 7.5 \* 7.5 mm)
- [TPSM846C23/C24:](#)  17V, 35A PMBus in QFN Package ('C24 not PMBus; 15 \* 16 mm)
- [TPS82140/50:](#)  17V, 2A/1A MicroSiP Power Modules (3 \* 2.8 mm)
- [TPSM84209\\*:](#)  28V, 2.5A in QFN Package (4 \* 4.9 mm)
- [TPSM84203/5/12:](#)  28V, 1.5A TO220 LDO replacement (10 \* 15 mm)
- [LMZM23600/1\\*:](#)  36V, 0.5A/1A MicroSiP Power Module (3 \* 3.8 mm)
- [LMZM33602/3:](#)  36V, 2A/3A in QFN Package (7 \* 9 mm)

\* Advanced Information: Samples, EVM and Documentation Available on [www.ti.com](http://www.ti.com)

# LMZM23600/1

Preview on  
Web NOW

In-Development  
Release: April'18

## Industry's smallest 36V Input 0.5A/1A Step-Down DC/DC Module

### Features

- 4 to 36V Input Voltage Range, Transient to 42V
- 0.5A and 1A Output Current Options
- Fixed 3.3V, 5V & Adj (2.5V – 15V) Output Voltage Range
- Miniature 3 x 3.8 x 1.6mm Package (0.6mm Pitch)
- Mode Pin
- Forced PWM Mode w/ Freq Sync
- Auto PFM Mode option for Light Load Efficiency
- -40 °C to 125 °C Operating Junction Temperature
- Built in Compensation, Soft Start, Current Limit, Thermal Shutdown, Power Good, and Input UVLO

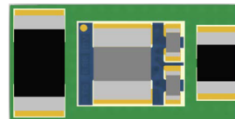
### Applications

- Factory & Building Automation, Smart Grid & Energy
- Medical
- Defense

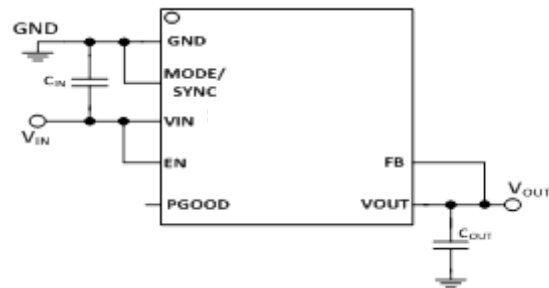
### Benefits

- Supports wide range of application requirements
- Easy to Design: only  $C_{IN}$  and  $C_{OUT}$  required (Fixed  $V_{OUT}$ )
- 32mm<sup>2</sup> solution: 45% smaller than competition; 55% smaller than discrete
- System Flexibility with choice of Fixed Frequency or Light Load Efficiency
- Synchronize to external clock

Complete 24 V to 5 V 1000 mA DC/DC Converter



8 mm x 4 mm Solution Size  
(1206  $C_{IN}$ , LMZM23601V5, 0805  $C_{OUT}$ )



# TPSM82480



## 6A Step Down Power Module with Integrated Inductors

### Features

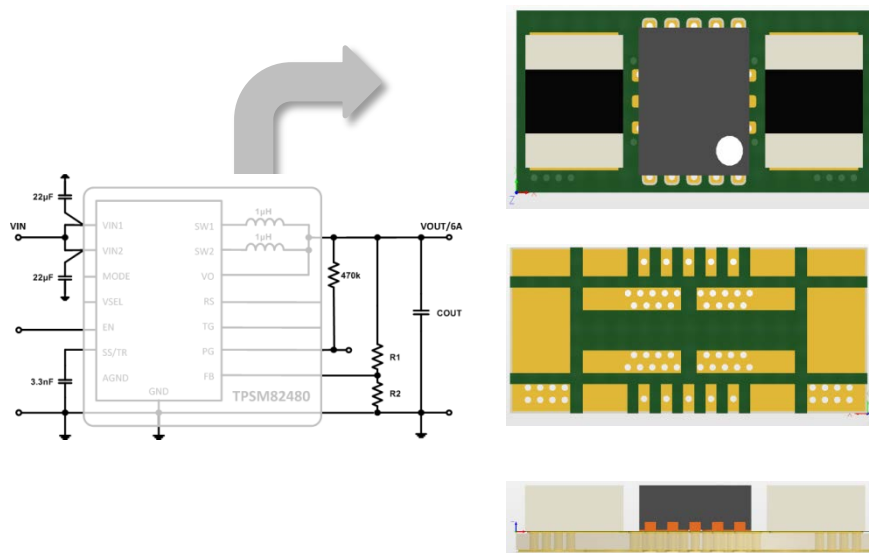
- 2.4/2.6 V to 5.5V Input Voltage Range
- 0.6 V to 5Vout
- 3.6 x 7.9 x 1.5mm Open Frame Package
- Forced PWM Option for Fixed Frequency Operation
- Design Flexibility and Performance
- 23 $\mu$ A Quiescent Current
- $\pm$ 1% Feedback Voltage Accuracy (PWM Mode)
- Power Good & Thermal Good Outputs
- Adjustable Soft Startup
- -40°C to 125°C operating temperature range

### Applications

- Low profile POL Supply
- Communications Equipment / Infrastructure
- Solid State Drive
- Portable/Embedded/Tablet PC

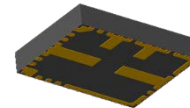
### Benefits

- Small solution size with **ultra low profile height**
- Easy to use by simplified layout
- Symmetrical structure with equal height of components





# LMZM33602/3



## 4V to 36V, 3A Step-Down Power Module in Compact 7x9x4mm QFN Package

### Features

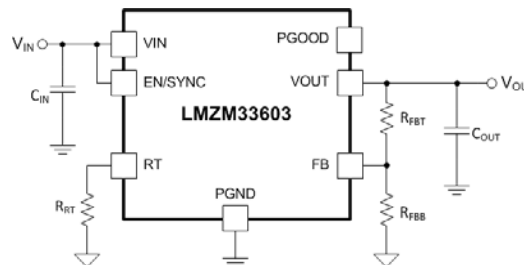
- 4 to 36V Input Voltage Range
- 2A and 3A Output Current Options:
- 1V to 18V Vout w/ 2A Iout
- 1V to 13.5V Vout w/ 3A Iout
- 7 x 9 x 4.0mm QFN Package
- All pins accessible from perimeter of package
- FPWM with Frequency Sync from 200kHz to 1.2MHz
- -40 °C - 105 °C Operating Temp Range (125 °C Junction)
- Tested to CISPR11/EN55011, Radiated EMI
- PG, Pre-Biased Start Up and Prog UVLO

### Applications

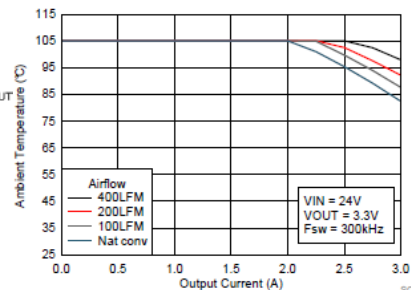
- Factory & Building Automation, Smart Grid & Energy
- Medical
- Defense

### Benefits

- Ideally suited for 24V, 12V and 5V Bus Systems
- Provides wide output voltages for a broad range of digital and analog loads
- Low design effort – highly integrated, small solution
- Fixed Freq + Sync to reduce system noise
- Wide Temperature range allows wide SOA performance
- Next generation module offers improved performance vs LMZ35003 (105°C T<sub>A</sub>, Wider Vout Range, Higher current)



Ambient Temperature vs Output Current



# TPS82140/TPS82150

## 17-Vin 2-A / 1-A Step Down Converter with Integrated Inductor



### Features

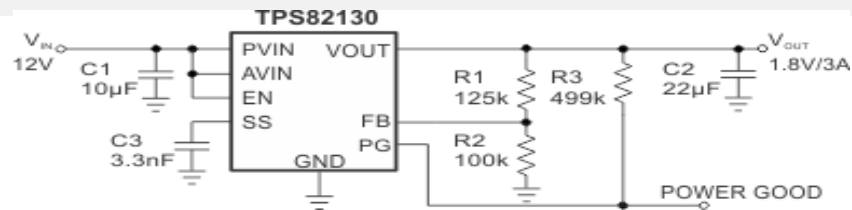
- **3V to 17V Input Voltage Range**
  - TPS82140 = 2A, TPS82150 = 1A
- **Adjustable Output Voltage**
- **Programmable Soft Startup**
- Power Save Mode for Light Load Efficiency
- Power Good Output plus Capacitor Discharge
- -40°C to 125°C operating temperature range
- **3.0 x 2.8 x 1.5mm SIL module**

### Applications

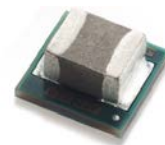
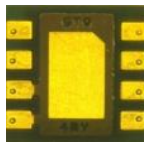
- Data Card, Network Switcher
- Optical Modules (voltage inverter)
- Test & Measurement
- SSD storage
- Portable industrial/ medical

### Benefits

- Small, low profile solution
- Save >40% PCB area, comparing with discrete solution
- Easy to use



**Solution total size: 42 mm<sup>2</sup>**



**Saves 40 mm<sup>2</sup> (>40%) versus discrete TPS62130**

# TPSM84824/624/424

## 4.5V - 17V, 8A/6A/4A Synchronous Step-Down Module



### Features

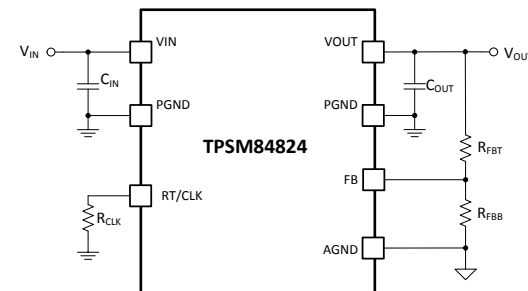
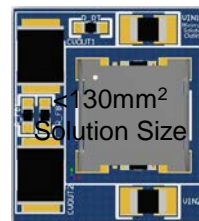
- Vout from 0.6V to 10V, w/ 1% Reference
- TurboTrans™ feature for excellent transient response over whole Vout range
- 7.5 x 7.5 mm footprint (<math><130\text{mm}^2</math> Minimum Solution Size)
- 200kHz to 1.6MHz fixed frequency operation with ability to sync to an external clock
- Low BOM Cost with few Ceramic Caps
- Pin-Pin Family: 8A, 6A and 4A Options
- Soft Start, PG and Pre-Biased Start Up. Peak Current Mode Control

### Applications

- Telecom base station and communications infrastructure equipment
- Storage, SSD, switches, hubs, routers and other networking equipment
- Power for performance DSPs, FPGAs and ASIC

### Benefits

- Suitable for wide range of Digital and Analog loads
- Excellent Transient response with minimal Output Capacitance (60mV deviation @ 50% load step; 1A/us; w/ 200uF Cout)
- Smaller than popular competitive solution
- Syncing to external clock simplifies noise reduction in many systems
- Easy to use: Only 3 external comp required for 0.6Vout



# TPSM84A21/2

## 8-14Vin, 10A, 0.55 – 2.05V Vout Compact Power Module



### Features

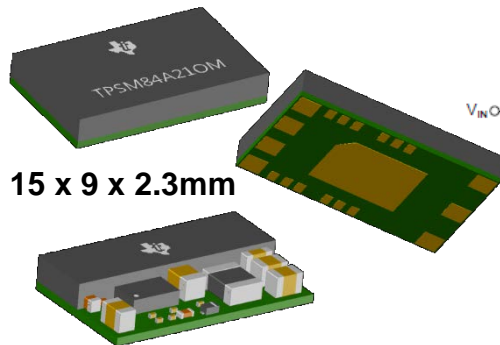
- **Integrated input and output capacitors**
- Adjustable output voltage using VADJ pin with a single resistor
- **Fast transient response with less than 3% total  $V_{OUT}$  deviation**
- Fixed frequency steady-state operation
- Low EMI & external SYNC capability
- **15 x 9 x 2.3mm power module size**

### Applications

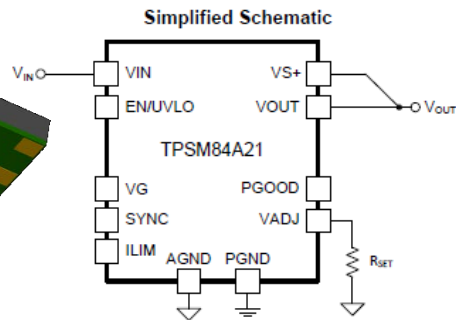
- Backside board mounting (<2.3mm height)
- Telecom base station and communications infrastructure equipment
- Storage, SSD, DDR memory, switches, hubs, routers & other networking equipment

### Benefits

- High power density
- Easy to Use: Only One External Component
- Low profile supports backside board mounting
- Meets Class B EN55022 Emissions

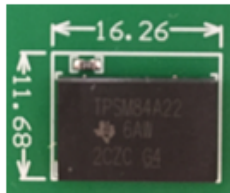
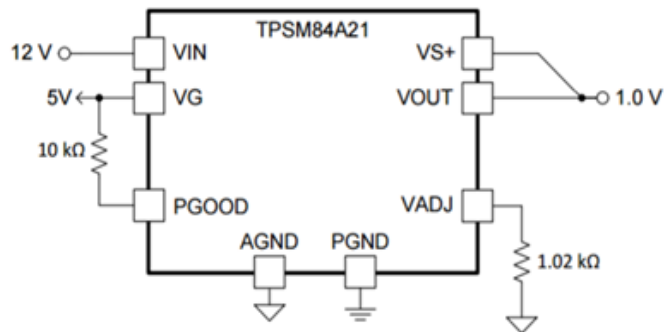


15 x 9 x 2.3mm

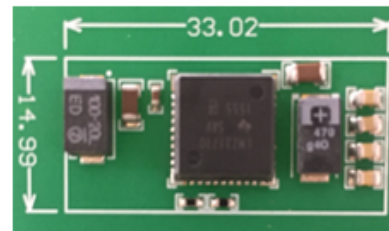
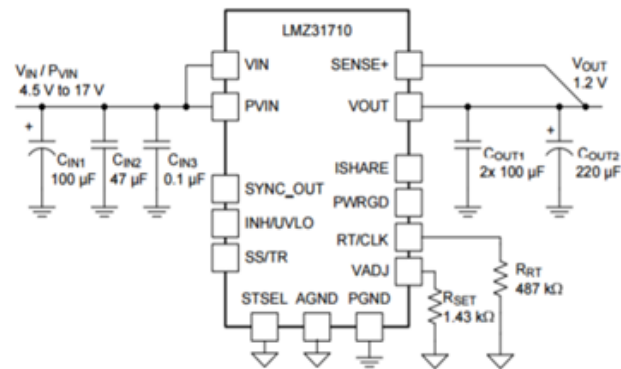


P/N	Adj. $V_{OUT}$ Range
TPSM84A21	0.55 – 1.35V
TPSM84A22	1.2 – 2.05V

# TPSM84A21/2 vs LMZ31710



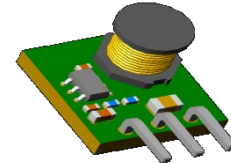
Solution size = 190mm<sup>2</sup>, 2.3mm height  
Transient response = +/-1% overshoot



Solution size = 495mm<sup>2</sup>, 4.3mm height  
Transient response = +/-3% overshoot

# TPSM84203/5/12: TO220 Module

4.5 to 28V Input , High Efficiency, Low EMI 1.5A Module



## Features

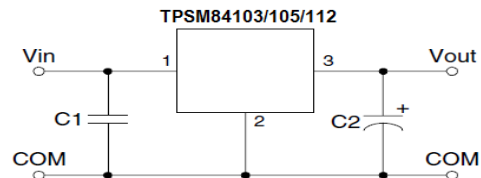
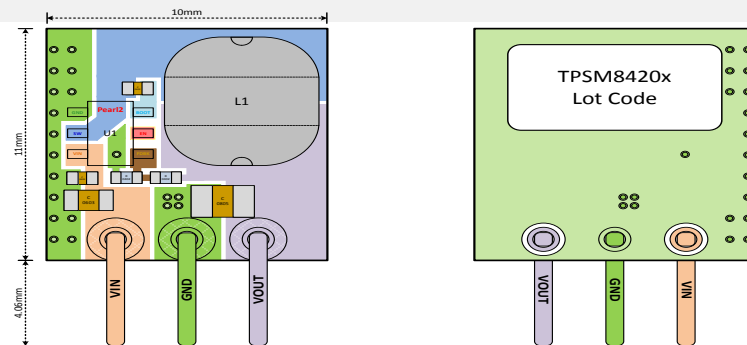
- **Maximum 28V Input Voltage**
- **Fixed 3.3V/5.0V/12V Output Voltage**
- **1.5A Maximum Continuous Output current**
- +/- 3% Vout Accuracy (25 °C, max)
- Ultra Low Quiescent Current for Higher Light Load Efficiency
- Frequency Spread Spectrum to Reduce EMI
- Fixed Soft-Start:4mS
- **780x pin-2-pin compatible.** Low External Comp Count

## Applications

- 12-V, 24-V Distributed Power-Bus Supplies
- Linear Regulator Replacement in Industrial Applications
- White Goods

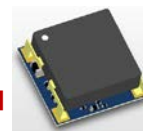
## Benefits

- High light load efficiency ( $V_{IN}=12V, V_{OUT}=5V, >88\% @ 10mA$ )
- Simple Layout
- Lowest ext. component count optimize board space, cost
- Meets Class B EN55022 Emissions with Reduced Noise



# TPSM846C23/C24

4.5V-15Vin, 35A Stackable Power Module with/without PMBus™



## Features

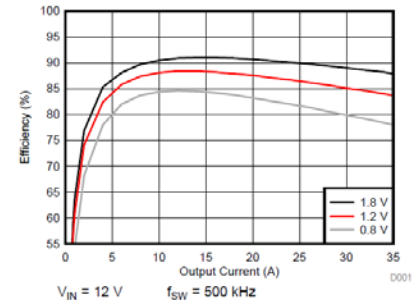
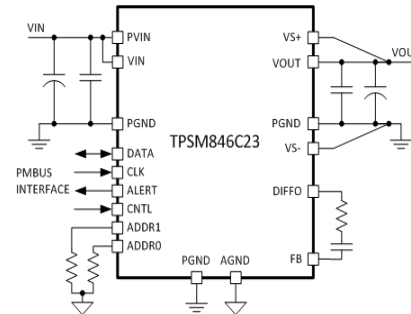
- Output Voltage Range 0.35V to 2V, **0.5% Vref (0 to 85C)**
- **Stack 2 x 35A, for Single 70A Output**
- Fully differential remote voltage sense
- FPWM with Fsync In/Out from 300KHz to 1MHz
- **PMBus v1.3 Command Set with Telemetry**
- **Tested to CISPR22 Class A Radiated EMI**
- **Compact 15 x 16 x 6.4mm package footprint**
- P2P Analog Version (TPSM846C24)

## Applications

- Telecommunication & Networking Equipment
- Industrial, Test & Measurement
- Enterprise Storage and Video Broadcasting
- ASIC, FPGA and DSP Attach

## Benefits

- High design flexibility
- **Outstanding** load regulation (100uV deviation 0 to 35A)
- Fixed frequency, 180° out-of-phase sync out when stacking
- Die temp monitoring (+/-5 C), Accurate Iout telemetry (+/-15% Iout), Set Vout with 2mV resolution
- Smaller than discrete with over-the-IC inductor



## 4.5 to 28V/2A, Adjustable Power Module with Integrated Inductor

### Features

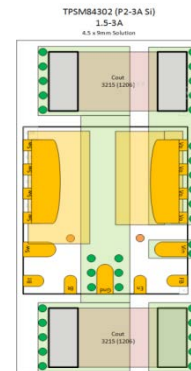
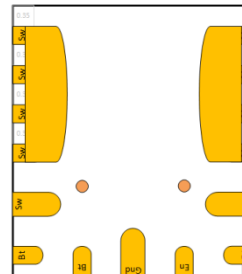
- **Maximum 28V Input Voltage**
- Adjustable Output Voltage down to 1.2V
- **2.5A Continuous Output current.**
- +/- 3% Vout Accuracy
- **Ultra Low Quiescent Current and Pulse Skip for High Light Load Efficiency**
- Fixed Soft-Start: 5mS
- **Small QFN Style Leadframe: 4 x 4.5 x 2mm**

### Applications

- 12-V, 24-V Distributed Power-Bus Supply
- Industrial Controls
- Communications Equipment
- LDO Replacement

### Benefits

- High light load efficiency(VIN=12V,VOUT=5V >88%@10mA)
- Simple Layout
- Lowest external component count to optimize board space, and less cost
- Meets Class B EN55022 Emissions with Reduced Noise





# **Power Modules: Save development cost...**

# Darnell Group Market Report

## *Ease of Design Comparison for a PSiP/MicroModule/PwrSoC Design Flow Process*

- **Module design** process takes **45.0% less** man hours to complete than a discrete dc-dc regulator “down solution.”
  - 254 vs 464 Man Hours!
- The dc-dc regulator design flow = much more complex process and with design iterations included ... takes over **2.8 times** as many steps to complete versus module design.
- *Board space requirements and density issues* = most common answer for choosing a module
- Both DCDC-regulator and PSIP users concerned about potential design issues: *noise, parasitics, load change, stability and EMI*
- 5A DCDC discrete vs module example

Source: Ease of Design Comparison for a PSiP/MicroModule/PwrSoC Design Flow Process  
A Survey by the Darnell Group – April 2012

# **Power Modules: important collateral**

# TI Designs

Design	Description	Application/Market	Device
<a href="#">PMP10630</a>	Xilinx Kintex XCKU040 Ultrascale Reference Design. Optimized for 6W output power.	FPGA Power	LMZ21700
<a href="#">PMP10600</a>	Xilinx Zynq 7000 Power Reference Design. Optimized for 5W output power.	FPGA Power	LMZ31503
<a href="#">PMP10601</a>	Xilinx Zynq 7000 Power Reference Design. Optimized for 8W output power.	FPGA Power	LMZ31503, LMZ31506
<a href="#">PMP10613</a>	Xilinx Zynq 7000 Series (XC7Z045) 20W Reference Design	FPGA Power	LMZ31503, LMZ31520
<a href="#">PMP7804</a>	Xilinx Kintex 7 Reference Design. Optimized for 12V input using LMZ1 series leaded modules and regulators.	FPGA Power	LMZ22010
<a href="#">PMP7975</a>	Analog Solution for Zynq	FPGA Power	LMZ12002
<a href="#">PMP7976</a>	Analog Solution for Virtex7	FPGA Power	LMZ12002
<a href="#">PMP7977</a>	Xilinx Artix 7 AC701 EVM	FPGA Power	TPS84320, TPS84621
<a href="#">PMP7978</a>	Xilinx Kintex 7 KC705 EVM	FPGA Power	LMZ12002
<a href="#">PMP8571</a>	Altera Cyclone V Power Reference Design	FPGA Power	TPS84320, TPS84621
<a href="#">PMP8610</a>	Arria V Power Reference Design	FPGA Power	LMZ31503, LMZ31710
<a href="#">PMP9335</a>	Multi-output Multi-buck 20W Power Supply for Xilinx Zynq	FPGA Power	TPS84320, TPS84A20
<a href="#">PMP9353</a>	Altera Cyclone V Power Reference Design	FPGA Power	LMZ31503/6
<a href="#">PMP9365</a>	Altera Stratix V Power Reference Design	FPGA Power	LMZ31503, LMZ31520
<a href="#">PMP9444</a>	Xilinx Kintex Ultrascale Power Reference Design. Optimized for 12V Input.	FPGA Power	LMZ31503, LMZ31506
<a href="#">PMP10595</a>	Miniature (30mm <sup>2</sup> ) 2A Power Supply with LMZ20502 Nano Module	Building Block	LMZ20502
<a href="#">PMP10618</a>	15V to 60V Wide Input Four-Output SIMPLE SWITCHER® Reference Design Using LM46002 and LMZ21701	Building Block	LMZ21701
<a href="#">PMP10638</a>	Inverting Buck Boost Power Module Reference Design (3.1V-3.3V to -5.2V 4A)	Building Block	LMZ31710
<a href="#">PMP10651</a>	2.2MHz Switching, Synchronous Split Supply Reference Design for 12V Battery with all Protections	Building Block	LMZ21700
<a href="#">PMP10743</a>	7V to 40V Wide Input, 3-Output SIMPLE SWITCHER® Reference Design Using LMR14050 and LMZ20502	Building Block	LMZ20502
<a href="#">PMP8372</a>	40V Dual 1A Module w/Low Noise LDOs Split-Rail (±5V) Output Voltages Reference Design	Building Block	TPS84250, TPS84259
<a href="#">PMP9464</a>	LMZ31530 with PMBUS control via LMZ5056 and output voltage margining	Building Block	LMZ31530
<a href="#">PMP9483</a>	7V to 36V in, 5Vout @ 2A , 1.8V@1A and 2.5V@1A. 15W Total Output Power.	Building Block	LMZ10501
<a href="#">TIDA-00582</a>	100-A Current Source Reference Design Using Two Power Modules in Parallel	Building Block	PTH08T250W
<a href="#">TIDA-00783</a>	Space Optimized Wide Vin Triple-Output Power Module	Building Block	LMZ20502, LMZ36002
<a href="#">TIDA-00808</a>	Space-optimized DC/DC Inverting Power Module	Building Block	LMZ36002
<a href="#">TIDA-01405</a>	Inverting O/P using TPS82130	Building Block	TPS82130
<a href="#">TIDA-01457</a>	Inverting O/P using TPS82130	Building Block	TPS82130
<a href="#">TIDA-00172</a>	Reference Design for an Interface to a Position Encoder with EnDat 2.2	Factory AutoMation	LMZ14201
<a href="#">TIDA-00175</a>	Interface to a 5V BiSS Position Encoder Reference Design	Factory AutoMation	LMZ14201
<a href="#">TIDA-01461</a>	EtherCAT P® One Cable for Power and EtherCAT® Reference Design	Factory AutoMation	LMZ35003
<a href="#">TIDA-01352</a>	400-W Continuous, Scalable, ±2.5- to ±150-V, Programmable Ultrasound Power Supply Reference Design	Medical/Ultrasound	LMZ34002
<a href="#">TIDA-01050</a>	Optimized Analog Front End DAQ System Reference Design for 18 bit SAR Data Converters	T&M	LMZ14201/3/5
<a href="#">TIDA-01051</a>	Reference Design Optimizing FPGA Utilization and Data Throughput for Automatic Test Equipment	T&M	TPS82084
<a href="#">TIDA-01052</a>	ADC Driver Reference Design Improving Full Scale THD Using Negative Supply	T&M	LMZ14201/3/5
<a href="#">TIDA-01054</a>	Multi-Rail Power Reference Design for Eliminating EMI Effects in High Performance DAQ Systems	T&M	LMZ14201/3/5
<a href="#">TIDA-01022</a>	Flexible 3.2 GSPS Multi-Channel AFE Reference Design for DSOs, RADAR, and 5G Wireless Test Systems	T&M, Radar, Software Defined Radio	TPS82130



# Applications collateral

- **Application Notes and Blogs**

- **EMI and Noise Reduction**

- [Simple Success With Conducted EMI From DCDC Converters](#)
    - [Simplify low EMI design with power modules](#)
    - [Understanding, measuring, and reducing output voltage ripple](#)
    - [Design a second-stage filter for noise sensitive applications](#)
    - PCB layout techniques for low noise power designs (in progress)

- **Inverting Applications**

- [Inverting application for the LMZ14203 SIMPLE SWITCHER® Power Module](#)
    - [Inverting application for the LMZM33603](#)
    - [Inverting application for the TPS82130](#)
    - Inverting supply for space constrained systems with the LMZM23601 (in progress)

- **Thermal Design**

- [PCB design and thermal performance of SIMPLE SWITCHER® Power Modules](#)
    - [Improving the Thermal Performance of MicroSiP Power Modules](#)
    - Thermal design made easy with TI Power Modules (in progress)

- **Transient Performance**

- [TurboTrans technology: transient performance and reduced solution size](#)

- **Webench**

- **A priority for all Power Modules**

[www.ti.com/powermodules](http://www.ti.com/powermodules)

## Innovative DC/DC Power Modules



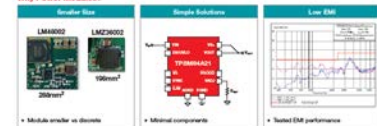
### Overview

The broad range of DC/DC power modules are designed specifically to help designers get to market faster with validated, high performance solutions. In a single package, these power modules integrate inductors, FETs, compensation, and other passive components to reduce development time for design and verification, and speed up time to market with proven reliability. To browse the entire portfolio and learn more on the latest products, visit: [www.ti.com/powermodules](http://www.ti.com/powermodules)

### Featured Products

<b>TPS82130</b> <ul style="list-style-type: none"><li>• 4.5 to 18V<sub>IN</sub></li><li>• 30A Output Power for 10A</li><li>• PFM or 1.2-GHz Fixed-Freq</li><li>• 10 × 10 × 8.5mm</li><li>• Thermal Pad for Heat Spreading</li></ul>	<b>TPS82130-01</b> <ul style="list-style-type: none"><li>• 4.5 to 18V<sub>IN</sub></li><li>• Fixed-Freq. 100 and 12V Output</li><li>• 1.5A Output Current</li><li>• Low EMI with Spread Spectrum</li><li>• PFM with 100-1000 Package</li></ul>	<b>TPS82130-02</b> <ul style="list-style-type: none"><li>• 4.5 to 18V<sub>IN</sub></li><li>• 10A Output Current</li><li>• 10 × 10 × 8.5mm Package</li><li>• Fixed-Freq. PFM and Low EMI</li></ul>	<b>TPS82130-03</b> <ul style="list-style-type: none"><li>• 4.5 to 18V<sub>IN</sub></li><li>• 1.7 and 3A Output Current Options</li><li>• 10 × 10 × 8.5mm</li><li>• Top 3.0 × 3.0 × 1.5mm Package</li><li>• 1.5GHz Fixed-Freq</li></ul>
<b>LMZ14203</b> <ul style="list-style-type: none"><li>• 4.5 to 18V<sub>IN</sub></li><li>• 1.5A Output Current</li><li>• 10 × 10 × 8.5mm Package</li><li>• Fixed-Freq. PFM and Low EMI</li></ul>	<b>LMZ14203-01</b> <ul style="list-style-type: none"><li>• 4.5 to 18V<sub>IN</sub></li><li>• 1.5A Output Current</li><li>• 10 × 10 × 8.5mm Package</li><li>• Fixed-Freq. PFM and Low EMI</li></ul>	<b>LMZ14203-02</b> <ul style="list-style-type: none"><li>• 4.5 to 18V<sub>IN</sub></li><li>• 1.5A Output Current</li><li>• 10 × 10 × 8.5mm Package</li><li>• Fixed-Freq. PFM and Low EMI</li></ul>	<b>LMZ14203-03</b> <ul style="list-style-type: none"><li>• 4.5 to 18V<sub>IN</sub></li><li>• 1.5A Output Current</li><li>• 10 × 10 × 8.5mm Package</li><li>• Fixed-Freq. PFM and Low EMI</li></ul>

### Why Power Modules?



**SLYT685C**

# Questions?

Thank you!



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