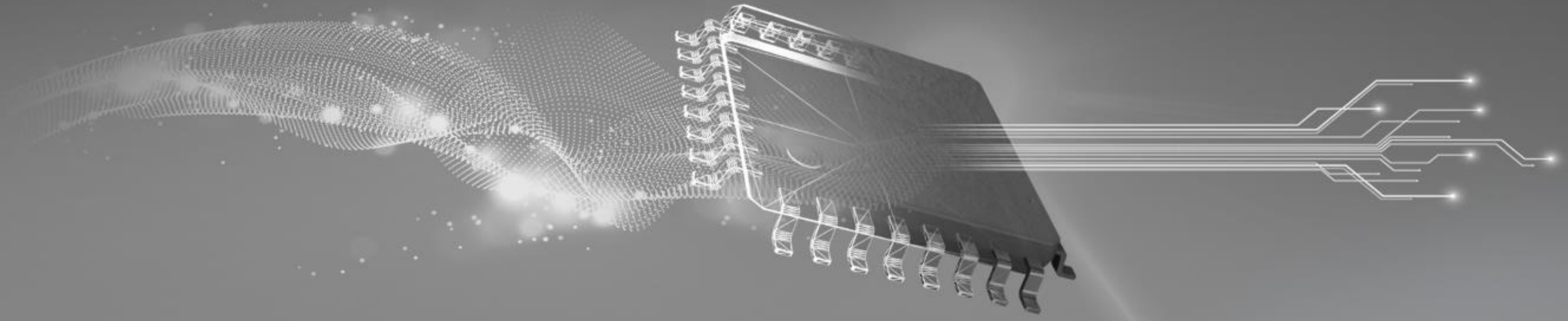
TI TECH DAYS



Buck Switching Regulator Power Modules
Get to market faster with reduced EMI and smaller power supply size

Stephen Ott – Product Marketing Engineer, Denislav Petkov – Applications Manager

Speaker organization

Texas Instruments

Presenters

Stephen Ott

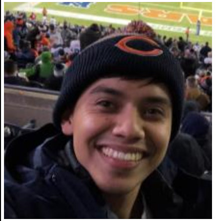
Marketing Engineer

Wide VIN Power

Short bio:

Stephen Ott is a product marketing engineer for the Wide Vin team at Texas Instruments. Stephen started his career at National Semiconductor in 2005 in power management. Throughout his career he has held various marketing roles related to power at National Semiconductor and Texas Instruments.

Stephen is based in Santa Clara, California.



Alejandro Iraheta

Applications Engineer

Wide VIN Power

Short bio:

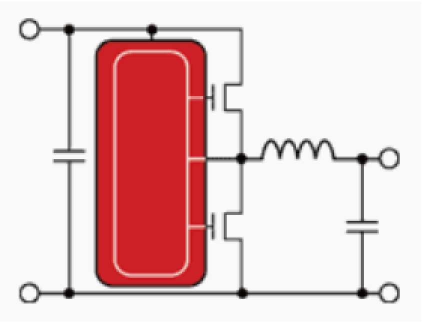
Alejandro Iraheta is an applications engineer for the Wide Vin Converter and Modules team at Texas Instruments. He started his career with TI in 2018 and has been involved with power electronics since.

Alejandro is based in Warrenville, Illinois.

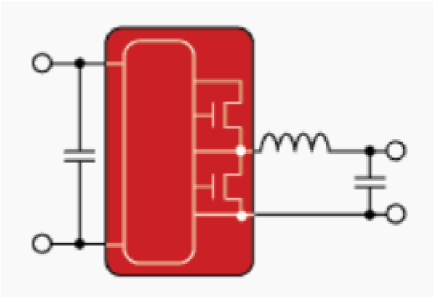
Topics

- Speed up the power supply design cycle & save board space
- EMI sources and mitigation
- Inductor selection and design tradeoffs
- New module packaging technology & product highlights
- Design tools & support

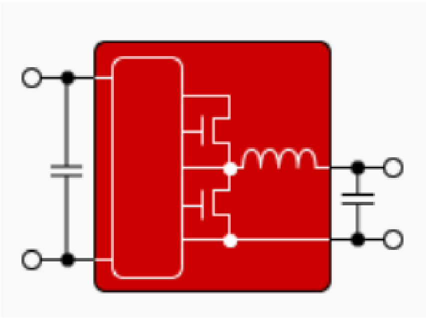
Step-down (buck) switching regulators



- External FETs
- External inductor



- Internal FETs
- External inductor



- Internal FETs
- Internal inductor
- Internal caps and resistors

Speed up the power supply design cycle & save board space

How modules shorten the design cycle

- Module designer does the heavy lifting
  - Optimal converter selected to cover design specifications
  - Selects BOM components optimal for converter
  - Characterizes solution across corner cases
  - Leverages latest technology to meet market requirements
  - Rigorous vetting of internal BOM components – not every inductor or capacitor is created equal

- Inherent module benefits reduce or eliminate
  - Control architecture influences
  - Layout challenges
  - Inductor sourcing
  - Lab prototyping

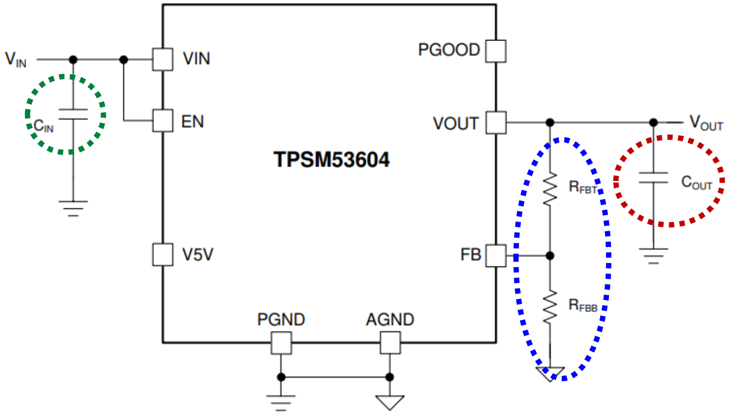
Quick design example with TPSM53604

Step 1. Select resistors to set the output voltage

Table 1. Setting the Output Voltage

V_{OUT} (V)	R_{FBB} (kΩ)[1]	$C_{OUT(MIN)}$ (µF) (EFFECTIVE)	V_{OUT} (V)	R_{FBB} (kΩ)[1]	$C_{OUT(MIN)}$ (µF) (EFFECTIVE)
1.0	open	150	3.0	4.99	57
1.1	100	143	3.3	4.32	52
1.2	49.9	132	4.0	3.32	43
1.3	33.2	123	4.5	2.87	39
1.4	24.9	115	5.0	2.49	35
1.5	20.0	107	5.5	2.21	32
1.8	12.4	91	6.0	2.00	30
2.0	10.0	82	6.5	1.82	28
2.5	6.65	67	7.0	1.65	26

Schematic

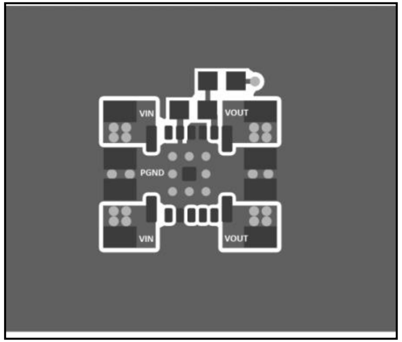


Step 2. Select input capacitor

Table 2. Recommended Input Capacitors[1]

VENDOR	SERIES	SIZE	PART NUMBER	CAPACITOR CHARACTERISTICS VOLTAGE RATING (V)	CAPACITOR CHARACTERISTICS CAPACITANCE[2] (µF)
Murata	X5R	1206	GRT31CR61H106ME01L	50	10
TDK	X5R	1206	CGA5L3X5R1H106M160AB	50	10
TDK	X7R	1206	CGA5L1X7R1H106K160AC	50	10
Murata	X7R	1210	GRM32ER71H106KA12L	50	10
TDK	X7R	1210	C3225X7R1H106M250AC	50	10

See layout example for the PCB design



Step 3. Select output capacitor

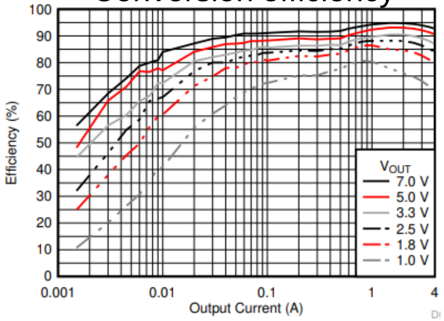
Table 3. Recommended Output Capacitors[1]

VENDOR	SERIES	PART NUMBER	CAPACITOR CHARACTERISTICS VOLTAGE RATING (V)	CAPACITOR CHARACTERISTICS CAPACITANCE[2] (µF)	CAPACITOR CHARACTERISTICS ESR[3] (mΩ)
TDK	X5R	C3225X5R0J476K	6.3	47	2
Murata	X7R	GCM32ER70J476KE19L	6.3	47	2
Murata	X5R	GRM21BR61A476ME15L	10	47	2
TDK	X5R	C3216X5R1A476M160AB	10	47	2
Murata	X7R	GRM32ER71A476KE15L	10	47	2
Murata	X5R	GRM32ER61C476K	16	47	3
TDK	X5R	C3225X5R0J107M	6.3	100	2
Murata	X5R	GRM32ER60J107M	6.3	100	2
Murata	X5R	GRM32ER61A107M	10	100	2
Kemet	X5R	C1210C107M4PAC7800	16	100	2
Panasonic	POSCAP	6TPE100MI	6.3	100	18
Panasonic	POSCAP	10TPF150ML	10	150	15
Panasonic	POSCAP	6TPF220M9L	6.3	220	9
Panasonic	POSCAP	6TPF330M9L	6.3	330	9
Panasonic	POSCAP	6TPE470MAZU	6.3	470	35

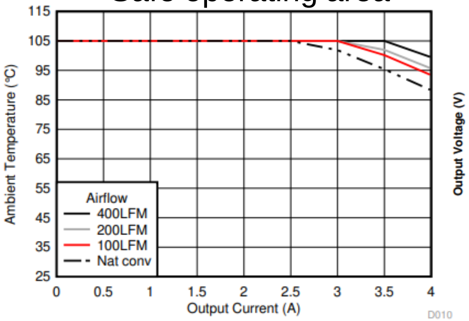
Power supply performance already characterized

- The inductor is already part of the package - the datasheet curves represent the actual solution

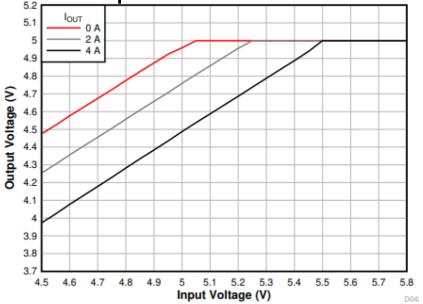
Conversion efficiency



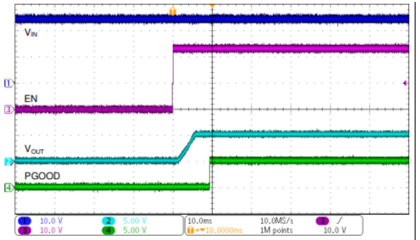
Safe operating area



Dropout characteristics

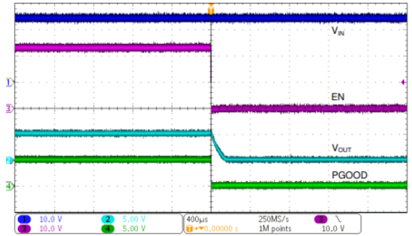


Startup behavior



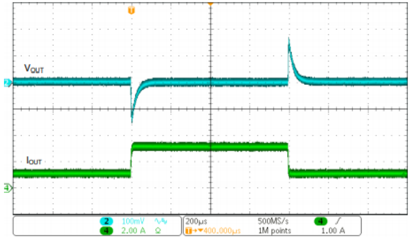
V_{IN} = 24 V V_{OUT} = 5 V C_{OUT} = 2 × 47 µF

Shutdown behavior



V_{IN} = 24 V V_{OUT} = 5 V C_{OUT} = 2 × 47 µF

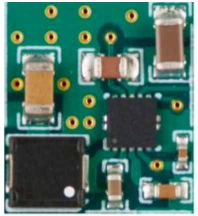
Transient behavior



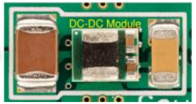
V_{IN} = 24 V V_{OUT} = 5 V C_{OUT} = 2 × 47 µF

Board area savings through integration

LM53601
36V 1A

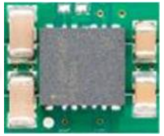


LMZM23601
36V 1A



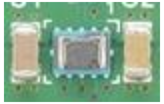
LMR33630
36V 3A

TPSM53603
36V 3A



LM5165
65V 150mA

TPSM265R1
65V 100mA



LM46002
60V 2A

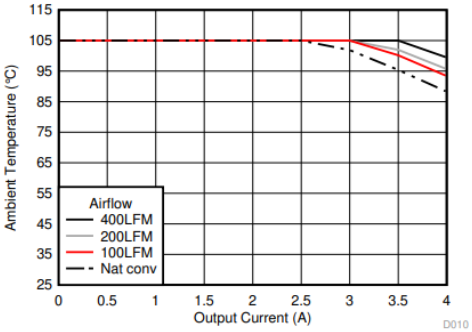
LMZ36002
60V 2A

LMR23630
36V 3A

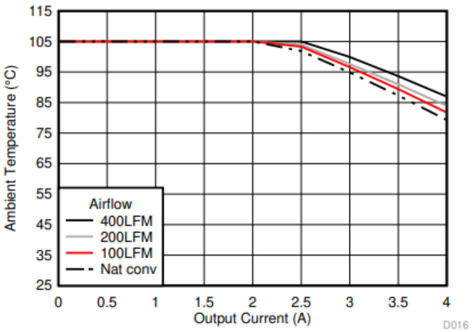
LMZM33603
36V 2A

Help with thermal design

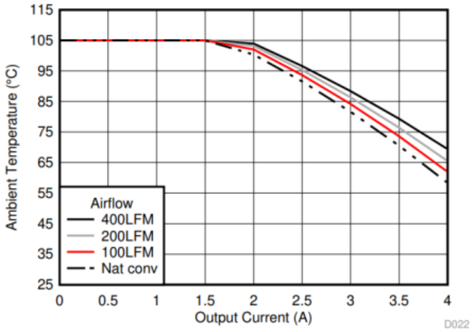
- SOA curves provided in the datasheet across the VIN, VOUT, IOUT, and Temperature range



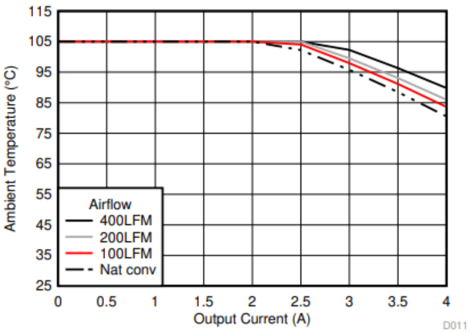
V_{IN} = 12 V V_{OUT} = 1.8 V



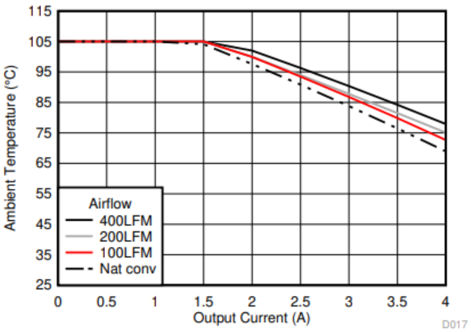
V_{IN} = 24 V V_{OUT} = 1.8 V



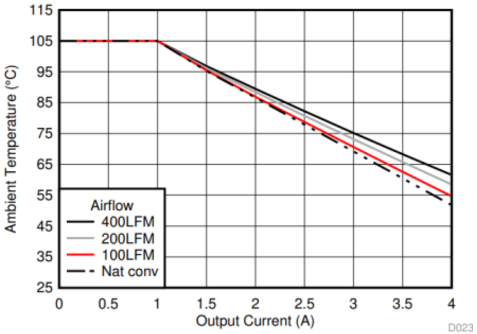
V_{IN} = 36 V V_{OUT} = 1.8 V



V_{IN} = 12 V V_{OUT} = 5 V



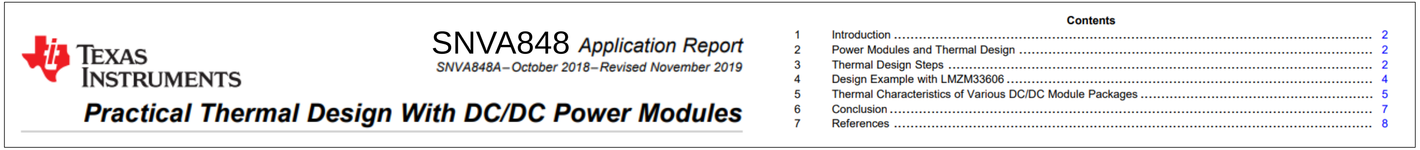
V_{IN} = 24 V V_{OUT} = 5 V



V_{IN} = 36 V V_{OUT} = 5 V

Help with thermal design

- Package thermal performance characterized across different board areas for easier thermal design



TEXAS INSTRUMENTS

SNVA848 *Application Report*

SNVA848A–October 2018–Revised November 2019

Practical Thermal Design With DC/DC Power Modules

Contents

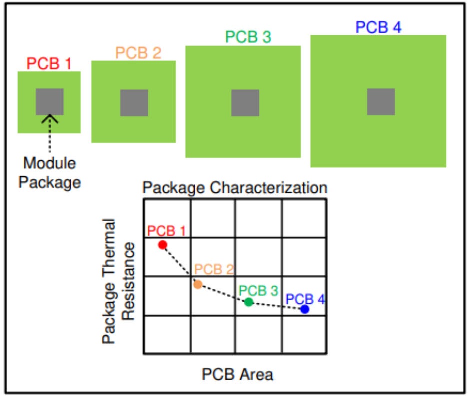


Figure 1. Package Characterization and Thermal Resistance Plot Versus Board Area

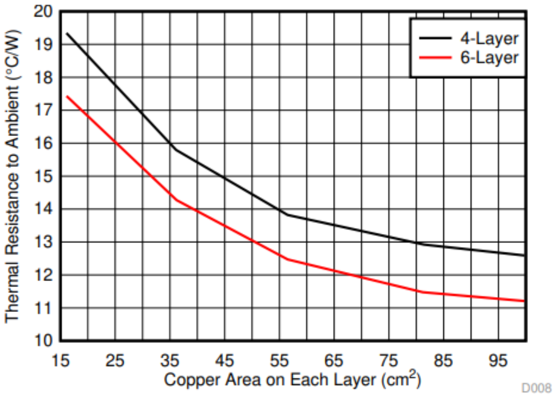
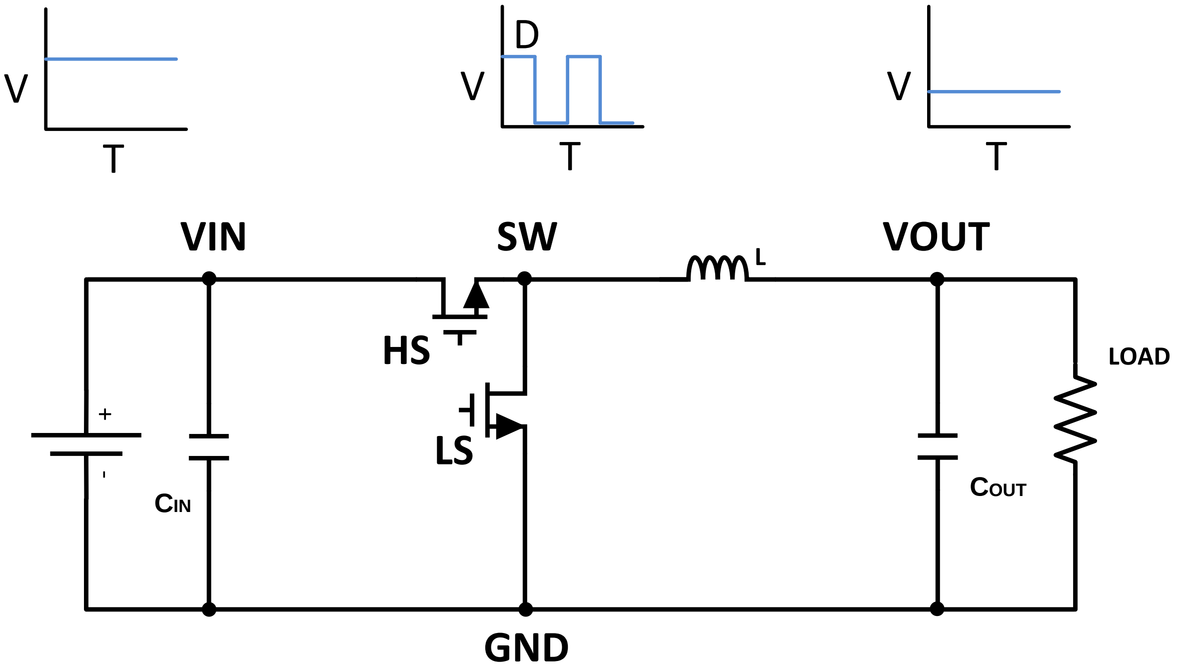


Figure 4. LMZM33606 16.00 mm × 10.00 mm QFN Package

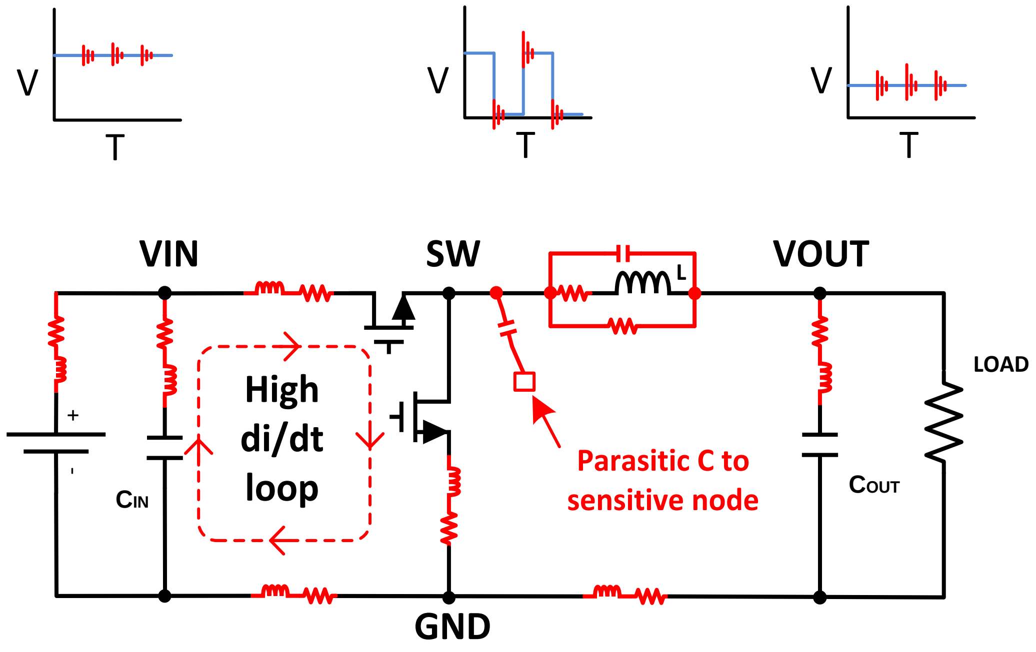
1. Look up the power dissipation.
2. Calculate required thermal resistance.
3. Estimate necessary board area from plot.

EMI sources and mitigation

The buck regulator



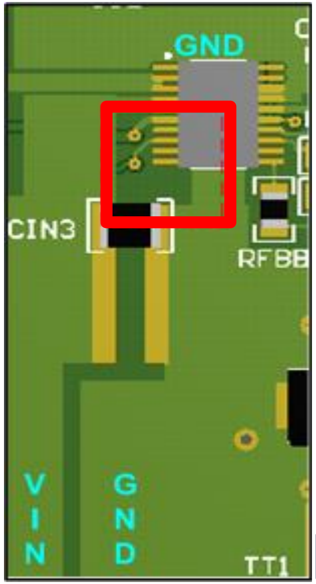
Less ideal buck regulator

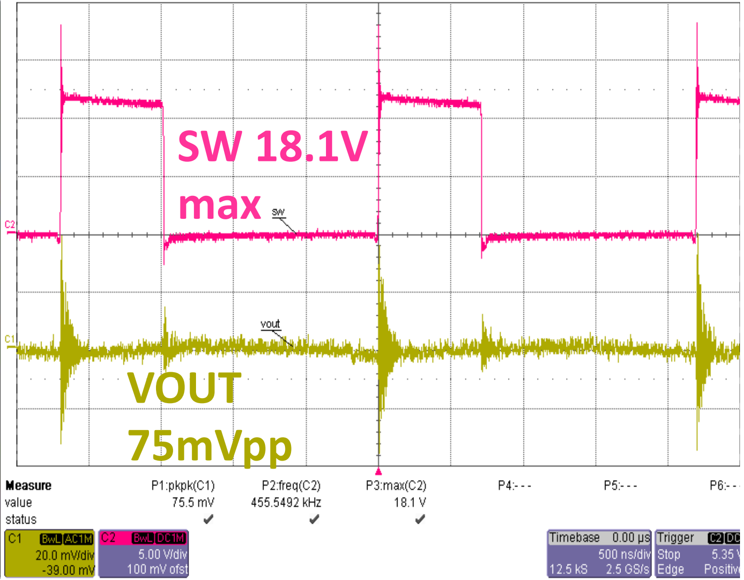


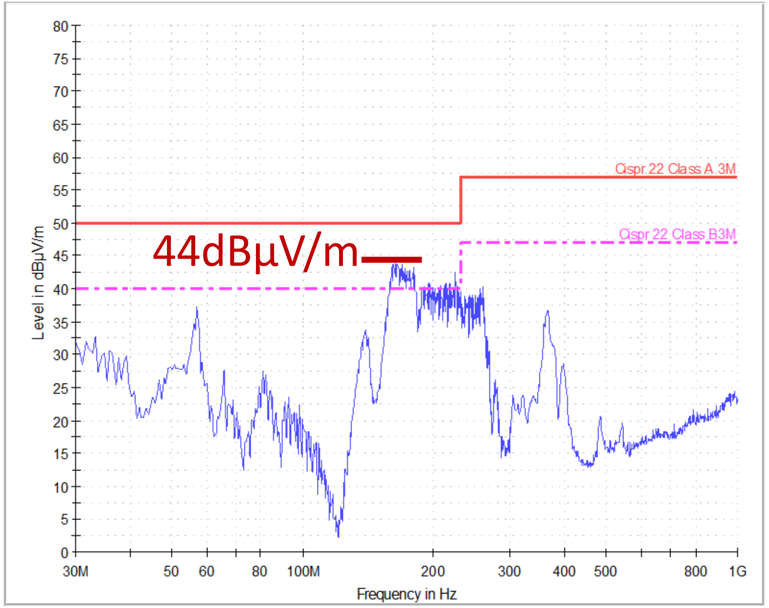
"Free" components in red

High di/dt capacitor placement - example

- Buck Regulator comparison with Cin location
- 12V input, 3.3V output, 2A Buck

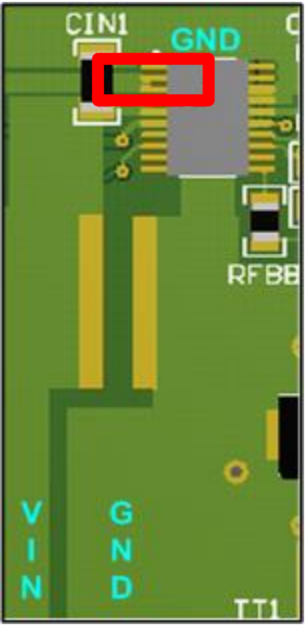


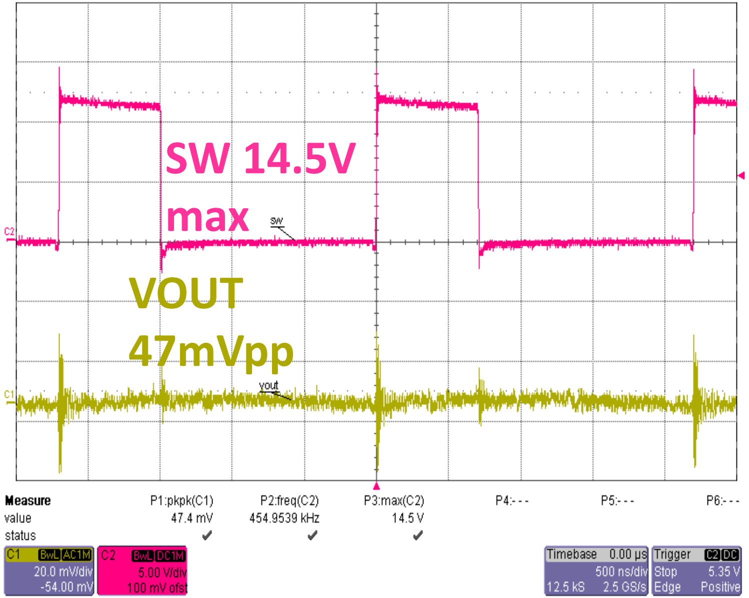


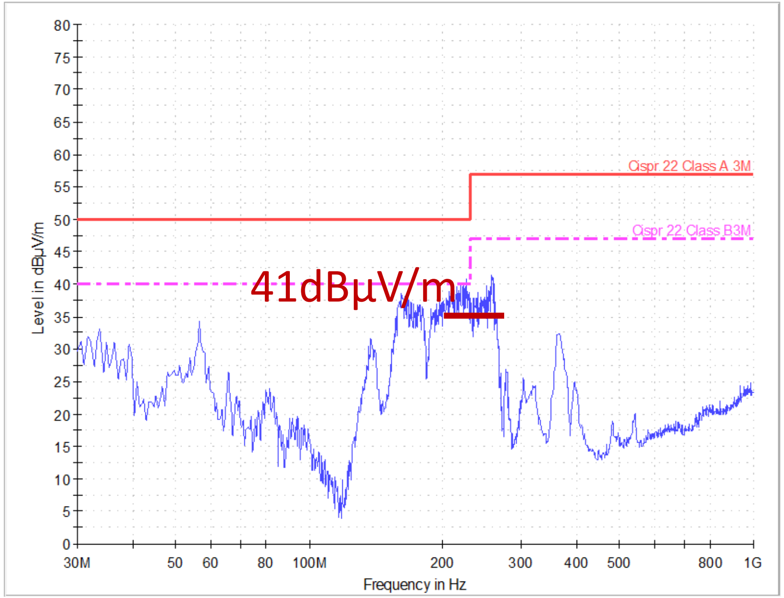


High di/dt capacitor placement - example

- Buck Regulator comparison with Cin location (2 times smaller loop area)
- 12V input, 3.3V output, 2A Buck







Noise reduction and component placement

- For a Buck converter…
  - The **INPUT cap** position affects the **OUTPUT noise**!
  - The **INPUT cap** position affects the **OUTPUT noise**!
  - The **INPUT cap** position affects the **OUTPUT noise**!
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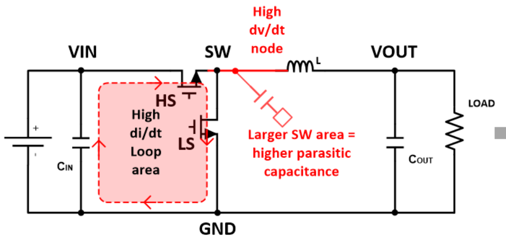
  - The **INPUT cap** position affects the **OUTPUT noise**!
  - The **INPUT cap** position affects the **OUTPUT noise**!

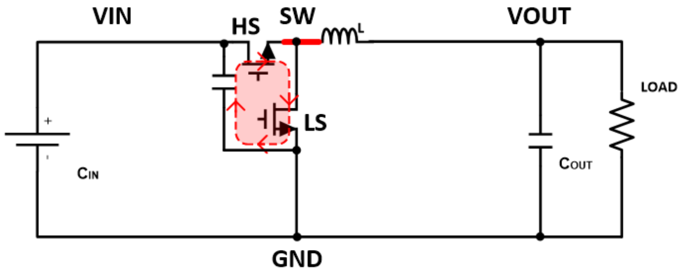
EMI advantages by optimizing layout

- Reducing the high di/dt loop area – integrated input capacitance.
- Reducing the high dv/dt node area – integrated L and smaller switch node.

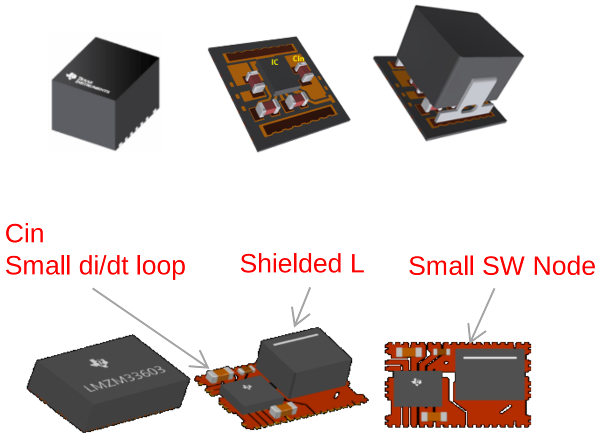
Discrete solution without optimized layout



DC-DC Power Module

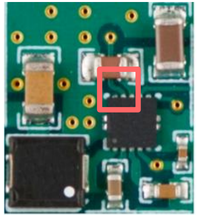


TPSM53603

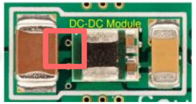


Input loop area estimate for converter and module

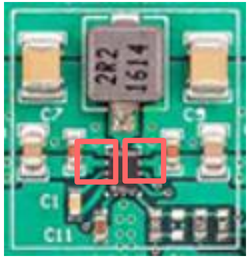
LM53601
36V 1A



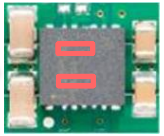
LMZM23601
36V 1A



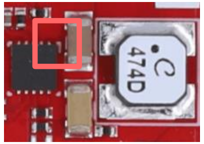
LMR33630
36V 3A



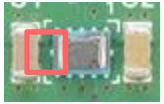
TPSM53603
36V 3A



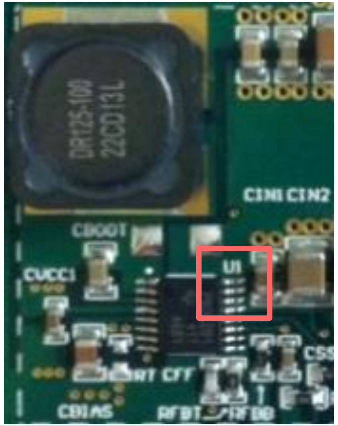
LM5165
65V 150mA



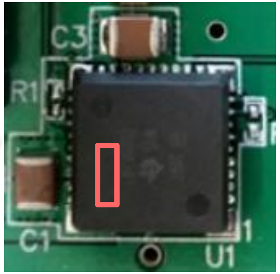
TPSM265R1
65V 100mA



LM46002
60V 2A

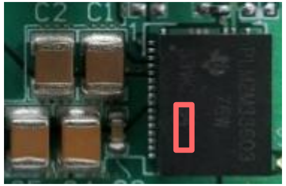


LMZ36002
60V 2A

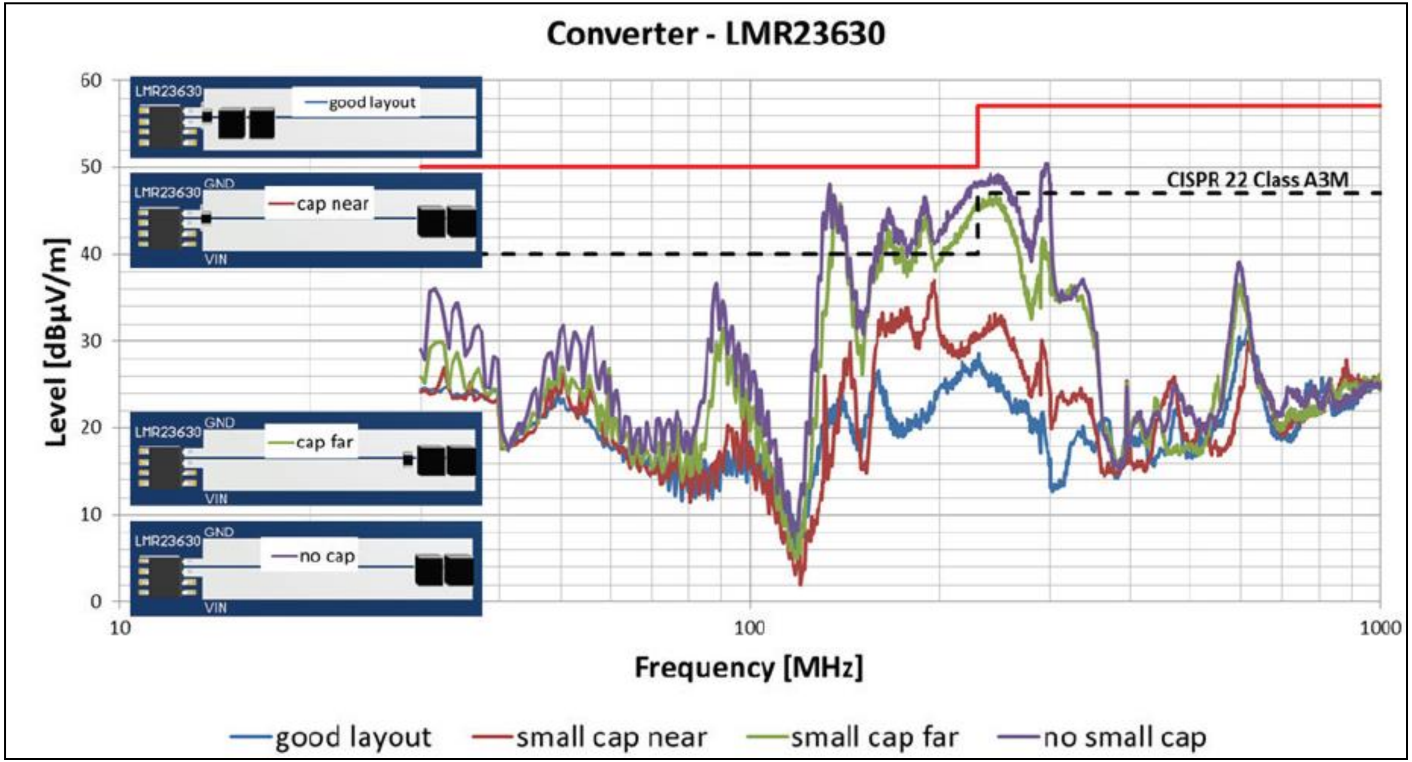


LMR23630
36V 3A

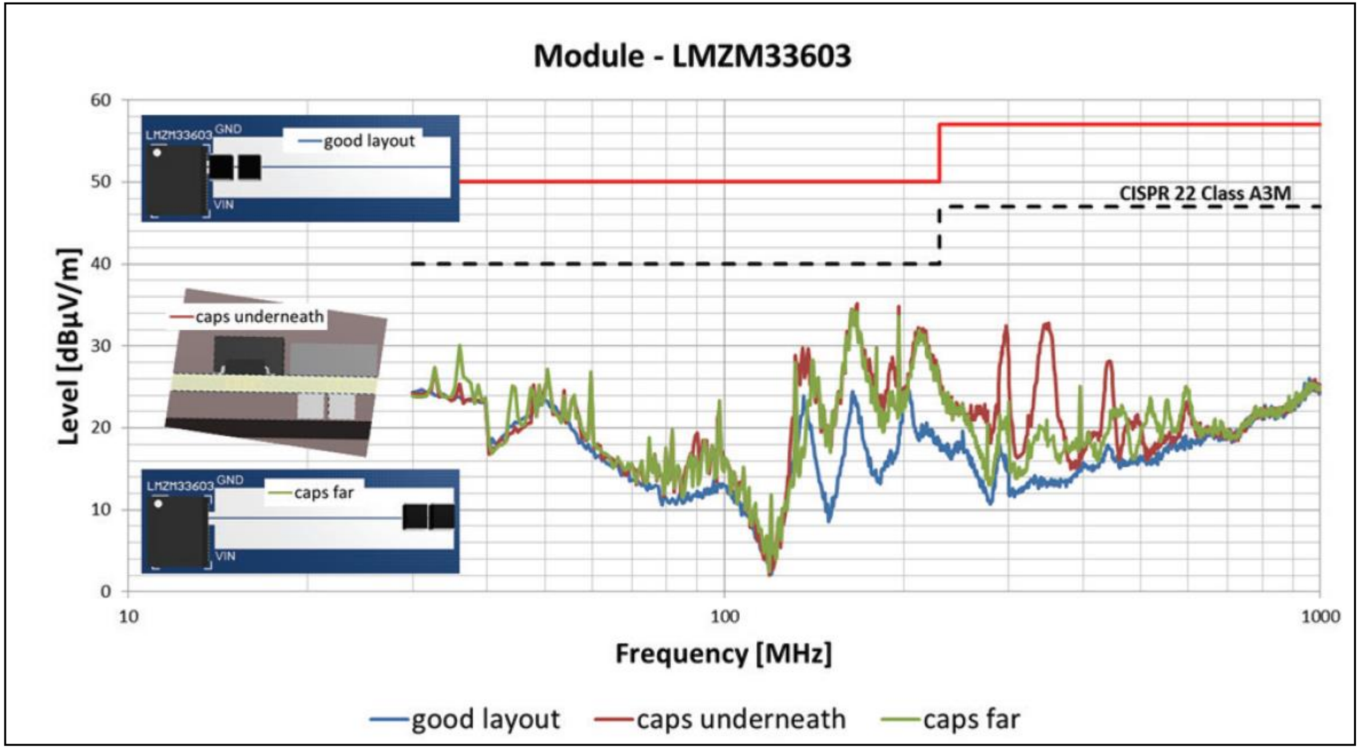
LMZM33603
36V 2A



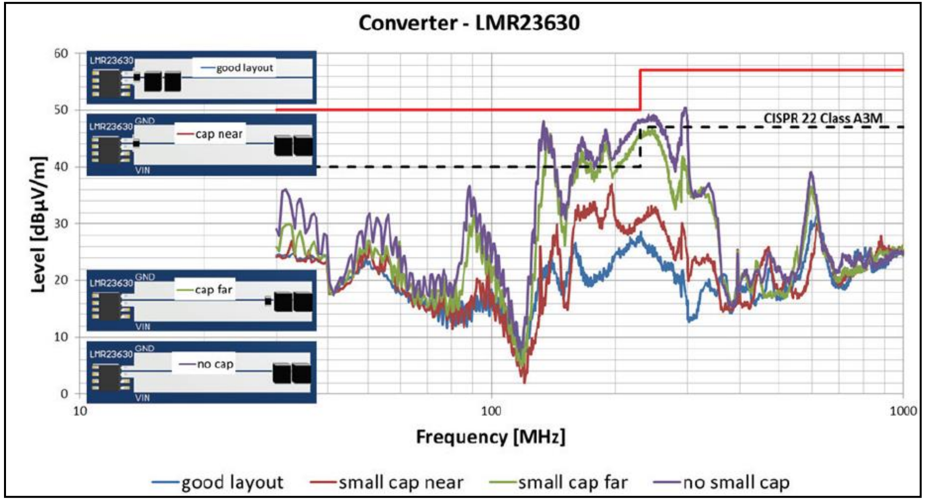
LMR23630 EMI comparison with different cap positions



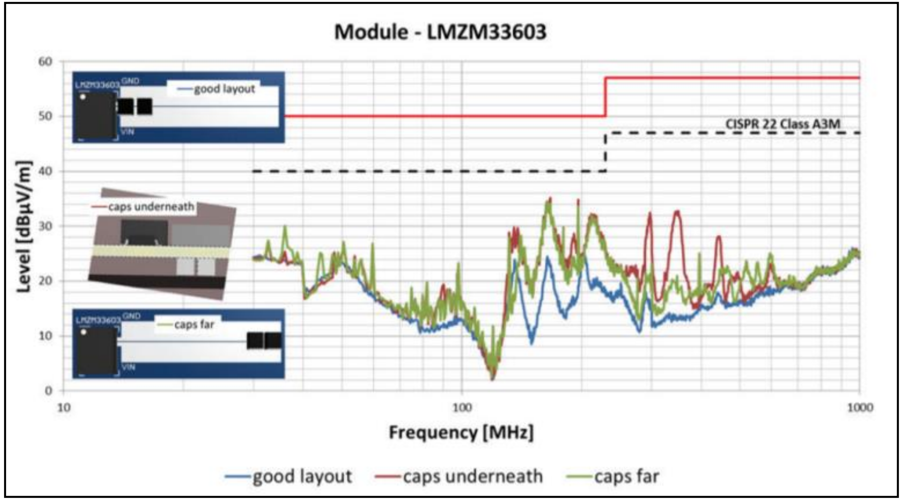
LMZM33603 EMI comparison with different cap positions

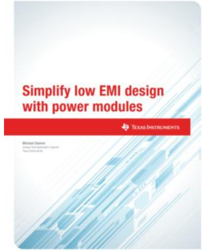


LMR23630 vs LMZM33603 EMI summary



	Peak dBuV/m	
Part	*Optimal Layout*	*Poor Layout*
LMR23630	29	46
LMZM33603	25	35



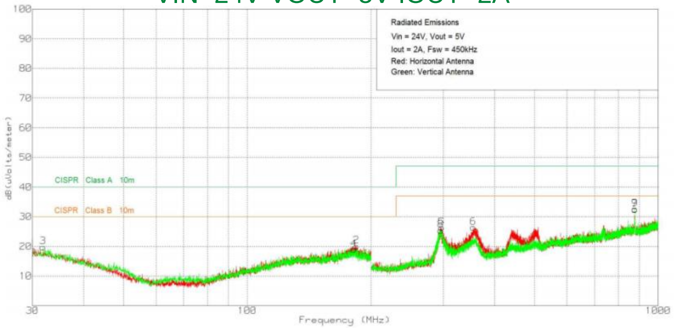


White paper: https://www.ti.com/lit/wp/slyy123/slyy123.pdf

EMI performance of modules – CISPR11 Class B

LMZM33602

VIN=24V VOUT=5V IOUT=2A



TPSM53602

VIN=12V VOUT=5V IOUT=2A

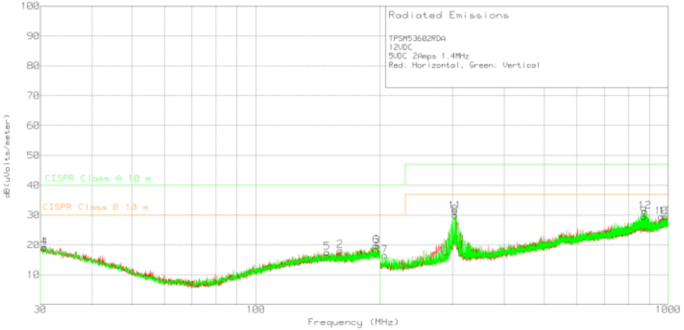
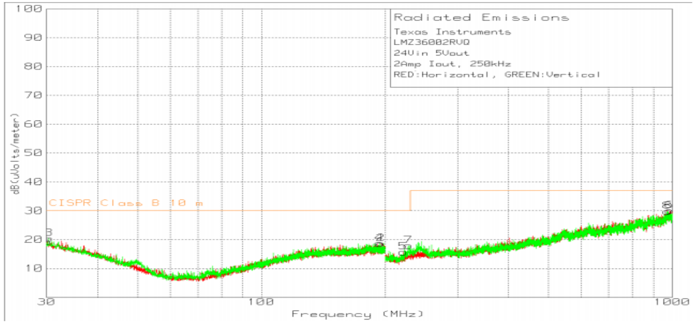


Figure 47. Radiated Emissions 12-V Input, 5-V Output, 2-A Load

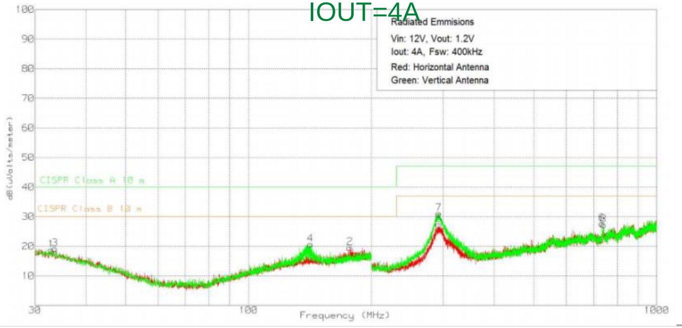
LMZ36002

VIN=24V VOUT=5V IOUT=2A



LMZM33604

VIN=12V VOUT=1.2V IOUT=4A



Inductor selection and design tradeoffs

Inductor selection

- **Inductor selection is one of the most important aspects of the DC-DC converter design**
  - Inductor characteristics
    - Inductance value
      - Affects size, ripple, transient response, peak current, efficiency
    - Winding resistance
      - Affects size, ripple, dropout, efficiency
    - Core material
      - Affects size, core power losses
    - Saturation current
      - Affects size, peak current, overload protection
    - Shielding
      - Affects EMI performance

Component selection for modules

- **Passive components undergo additional screening for modules**
  - Strict requirements for internal BOM selection
    - Industrial grade & approved TI vendor
  - Additional screening beyond passive manufacturer testing
    - Lifetime testing
    - High temperature storage
    - Capacitance vs. DC bias
    - Insulation resistance
    - 3x Reflow, monitor change in C and IR
    - Inductance vs. DC current vs. Temperature (saturation)

Design tradeoffs for modules

- Single inductance value puts constraints on several parameters of the power module
  - Minimum and maximum switching frequency
  - Output voltage range
  - Efficiency

Examples:

TPSM53604 Module output range: 1V to 7V

LMR33630 IC output range: 1V to 24V

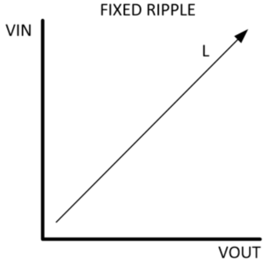
LMZ36002 Module output range: 2.5V to 7.5V

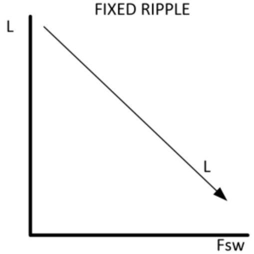
LM46002 IC output range: 1V to 24V

Modules are usually optimized to cover the most common output rails with good performance.

Inductance requirements

4A output
2.2uH inductor





500kHz

Fsw= 500 kHz

VIN (V)	Inductance (uH)								
36	1.62	2.85	3.88	5.00	7.18	11.25	13.33	14.58	15.00
35	1.62	2.85	3.87	4.98	7.14	11.14	13.14	14.29	14.57
34	1.62	2.84	3.86	4.97	7.11	11.03	12.94	13.97	14.12
33	1.62	2.84	3.85	4.95	7.07	10.91	12.73	13.64	13.64
32	1.61	2.83	3.84	4.93	7.03	10.78	12.50	13.28	13.13
31	1.61	2.83	3.83	4.91	6.99	10.65	12.26	12.90	12.58
30	1.61	2.82	3.82	4.90	6.94	10.50	12.00	12.50	12.00
29	1.61	2.81	3.81	4.87	6.90	10.34	11.72	12.07	11.38
28	1.61	2.81	3.79	4.85	6.85	10.18	11.43	11.61	10.71
27	1.60	2.80	3.78	4.83	6.79	10.00	11.11	11.11	10.00
26	1.60	2.79	3.77	4.80	6.73	9.81	10.77	10.58	9.23
25	1.60	2.78	3.75	4.77	6.67	9.60	10.40	10.00	8.40
24	1.60	2.78	3.73	4.74	6.60	9.38	10.00	9.38	7.50
23	1.59	2.77	3.71	4.71	6.52	9.13	9.57	8.70	6.52
22	1.59	2.75	3.69	4.68	6.44	8.86	9.09	7.95	5.45
21	1.59	2.74	3.67	4.64	6.35	8.57	8.57	7.14	4.29
20	1.58	2.73	3.65	4.59	6.25	8.25	8.00	6.25	3.00
19	1.58	2.72	3.62	4.54	6.14	7.89	7.37	5.26	1.58
18	1.57	2.70	3.59	4.49	6.02	7.50	6.67	4.17	
17	1.57	2.68	3.55	4.43	5.88	7.06	5.88	2.94	
16	1.56	2.66	3.52	4.37	5.73	6.56	5.00	1.56	
15	1.56	2.64	3.47	4.29	5.56	6.00	4.00		
14	1.55	2.61	3.42	4.20	5.36	5.36	2.86		
13	1.54	2.58	3.37	4.10	5.13	4.62	1.54		
12	1.53	2.55	3.30	3.99	4.86	3.75			
11	1.52	2.51	3.22	3.85	4.55	2.73			
10	1.50	2.46	3.13	3.69	4.17	1.50			
9	1.48	2.40	3.01	3.48	3.70				
8	1.46	2.33	2.86	3.23	3.13				
	1	1.8	2.5	3.3	5	9	12	15	18

VOUT (V)

1000kHz

Fsw= 1000 kHz

VIN (V)	Inductance (uH)								
36	0.81	1.43	1.94	2.50	3.59	5.63	6.67	7.29	7.50
35	0.81	1.42	1.93	2.49	3.57	5.57	6.57	7.14	7.29
34	0.81	1.42	1.93	2.48	3.55	5.51	6.47	6.99	7.06
33	0.81	1.42	1.93	2.48	3.54	5.45	6.36	6.82	6.82
32	0.81	1.42	1.92	2.47	3.52	5.39	6.25	6.64	6.56
31	0.81	1.41	1.92	2.46	3.49	5.32	6.13	6.45	6.29
30	0.81	1.41	1.91	2.45	3.47	5.25	6.00	6.25	6.00
29	0.80	1.41	1.90	2.44	3.45	5.17	5.86	6.03	5.69
28	0.80	1.40	1.90	2.43	3.42	5.09	5.71	5.80	5.36
27	0.80	1.40	1.89	2.41	3.40	5.00	5.56	5.56	5.00
26	0.80	1.40	1.88	2.40	3.37	4.90	5.38	5.29	4.62
25	0.80	1.39	1.88	2.39	3.33	4.80	5.20	5.00	4.20
24	0.80	1.39	1.87	2.37	3.30	4.69	5.00	4.69	3.75
23	0.80	1.38	1.86	2.36	3.26	4.57	4.78	4.35	3.26
22	0.80	1.38	1.85	2.34	3.22	4.43	4.55	3.98	2.73
21	0.79	1.37	1.84	2.32	3.17	4.29	4.29	3.57	2.14
20	0.79	1.37	1.82	2.30	3.13	4.13	4.00	3.13	1.50
19	0.79	1.36	1.81	2.27	3.07	3.95	3.68	2.63	0.79
18	0.79	1.35	1.79	2.25	3.01	3.75	3.33	2.08	
17	0.78	1.34	1.78	2.22	2.94	3.53	2.94	1.47	
16	0.78	1.33	1.76	2.18	2.86	3.28	2.50	0.78	
15	0.78	1.32	1.74	2.15	2.78	3.00	2.00		
14	0.77	1.31	1.71	2.10	2.68	2.68	1.43		
13	0.77	1.29	1.68	2.05	2.56	2.31	0.77		
12	0.76	1.28	1.65	1.99	2.43	1.88			
11	0.76	1.25	1.61	1.93	2.27	1.36			
10	0.75	1.23	1.56	1.84	2.08	0.75			
9	0.74	1.20	1.50	1.74	1.85				
8	0.73	1.16	1.43	1.62	1.56				
	1	1.8	2.5	3.3	5	9	12	15	18

VOUT (V)

1500kHz

Fsw= 1500 kHz

VIN (V)	Inductance (uH)								
36	0.54	0.95	1.29	1.67	2.39	3.75	4.44	4.86	5.00
35	0.54	0.95	1.29	1.66	2.38	3.71	4.38	4.76	4.86
34	0.54	0.95	1.29	1.66	2.37	3.68	4.31	4.66	4.71
33	0.54	0.95	1.28	1.65	2.36	3.64	4.24	4.55	4.55
32	0.54	0.94	1.28	1.64	2.34	3.59	4.17	4.43	4.38
31	0.54	0.94	1.28	1.64	2.33	3.55	4.09	4.30	4.19
30	0.54	0.94	1.27	1.63	2.31	3.50	4.00	4.17	4.00
29	0.54	0.94	1.27	1.62	2.30	3.45	3.91	4.02	3.79
28	0.54	0.94	1.26	1.62	2.28	3.39	3.81	3.87	3.57
27	0.53	0.93	1.26	1.61	2.26	3.33	3.70	3.70	3.33
26	0.53	0.93	1.26	1.60	2.24	3.27	3.59	3.53	3.08
25	0.53	0.93	1.25	1.59	2.22	3.20	3.47	3.33	2.80
24	0.53	0.93	1.24	1.58	2.20	3.13	3.33	3.13	2.50
23	0.53	0.92	1.24	1.57	2.17	3.04	3.19	2.90	2.17
22	0.53	0.92	1.23	1.56	2.15	2.95	3.03	2.65	1.82
21	0.53	0.91	1.22	1.55	2.12	2.86	2.86	2.38	1.43
20	0.53	0.91	1.22	1.53	2.08	2.75	2.67	2.08	1.00
19	0.53	0.91	1.21	1.51	2.05	2.63	2.46	1.75	0.53
18	0.52	0.90	1.20	1.50	2.01	2.50	2.22	1.39	
17	0.52	0.89	1.18	1.48	1.96	2.35	1.96	0.98	
16	0.52	0.89	1.17	1.46	1.91	2.19	1.67	0.52	
15	0.52	0.88	1.16	1.43	1.85	2.00	1.33		
14	0.52	0.87	1.14	1.40	1.79	1.79	0.95		
13	0.51	0.86	1.12	1.37	1.71	1.54	0.51		
12	0.51	0.85	1.10	1.33	1.62	1.25			
11	0.51	0.84	1.07	1.28	1.52	0.91			
10	0.50	0.82	1.04	1.23	1.39	0.50			
9	0.49	0.80	1.00	1.16	1.23				
8	0.49	0.78	0.95	1.08	1.04				
	1	1.8	2.5	3.3	5	9	12	15	18

VOUT (V)

2000kHz

Fsw= 2000 kHz

VIN (V)	Inductance (uH)								
36	0.41	0.71	0.97	1.25	1.79	2.81	3.33	3.65	3.75
35	0.40	0.71	0.97	1.25	1.79	2.79	3.29	3.57	3.64
34	0.40	0.71	0.97	1.24	1.78	2.76	3.24	3.49	3.53
33	0.40	0.71	0.96	1.24	1.77	2.73	3.18	3.41	3.41
32	0.40	0.71	0.96	1.23	1.76	2.70	3.13	3.32	3.28
31	0.40	0.71	0.96	1.23	1.75	2.66	3.06	3.23	3.15
30	0.40	0.71	0.95	1.22	1.74	2.63	3.00	3.13	3.00
29	0.40	0.70	0.95	1.22	1.72	2.59	2.93	3.02	2.84
28	0.40	0.70	0.95	1.21	1.71	2.54	2.86	2.90	2.68
27	0.40	0.70	0.95	1.21	1.70	2.50	2.78	2.78	2.50
26	0.40	0.70	0.94	1.20	1.68	2.45	2.69	2.64	2.31
25	0.40	0.70	0.94	1.19	1.67	2.40	2.60	2.50	2.10
24	0.40	0.69	0.93	1.19	1.65	2.34	2.50	2.34	1.88
23	0.40	0.69	0.93	1.18	1.63	2.28	2.39	2.17	1.63
22	0.40	0.69	0.92	1.17	1.61	2.22	2.27	1.99	1.36
21	0.40	0.69	0.92	1.16	1.59	2.14	2.14	1.79	1.07
20	0.40	0.68	0.91	1.15	1.56	2.06	2.00	1.56	0.75
19	0.39	0.68	0.90	1.14	1.54	1.97	1.84	1.32	0.39
18	0.39	0.68	0.90	1.12	1.50	1.88	1.67	1.04	
17	0.39	0.67	0.89	1.11	1.47	1.76	1.47	0.74	
16	0.39	0.67	0.88	1.09	1.43	1.64	1.25	0.39	
15	0.39	0.66	0.87	1.07	1.39	1.50	1.00		
14	0.39	0.65	0.86	1.05	1.34	1.34	0.71		
13	0.38	0.65	0.84	1.03	1.28	1.15	0.38		
12	0.38	0.64	0.82	1.00	1.22	0.94			
11	0.38	0.63	0.80	0.96	1.14	0.68			
10	0.38	0.62	0.78	0.92	1.04	0.38			
9	0.37	0.60	0.75	0.87	0.93				
8	0.36	0.58	0.72	0.81	0.78				
	1	1.8	2.5	3.3	5	9	12	15	18

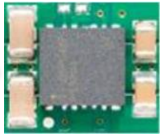
VOUT (V)

Performance comparison

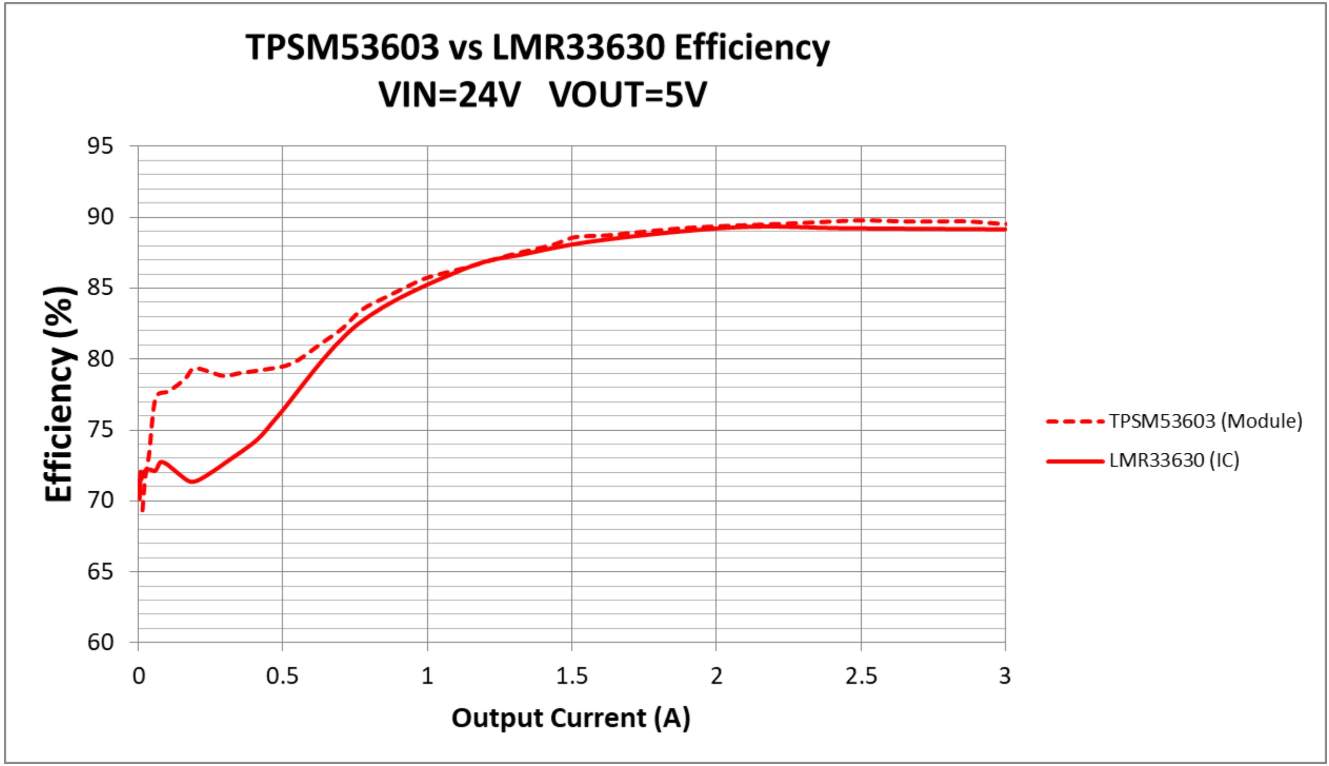
LMR33630 IC
36V 3A

2.2uH

TPSM53603
36V 3A



2.2uH

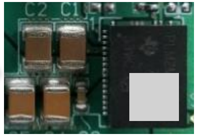


Performance comparison

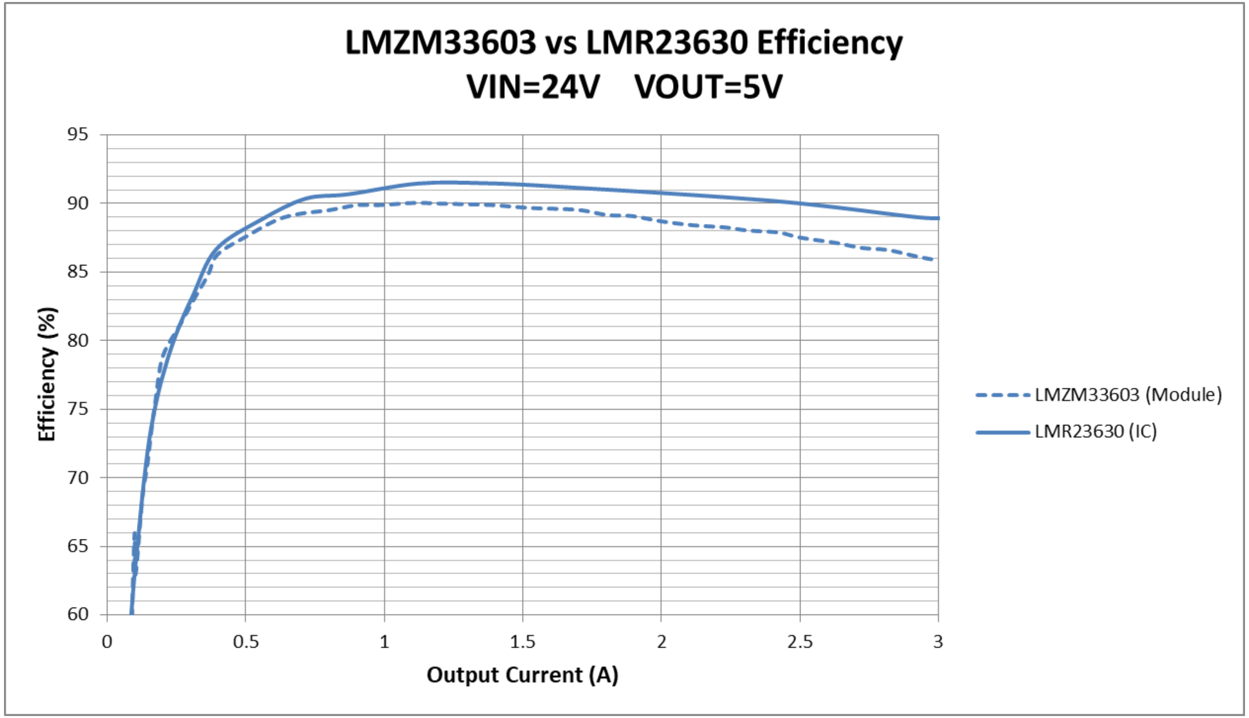
LMR23630
36V 3A

8.2uH

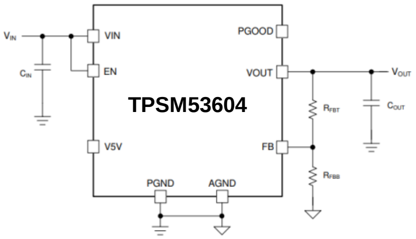
LMZM33603
36V 2A

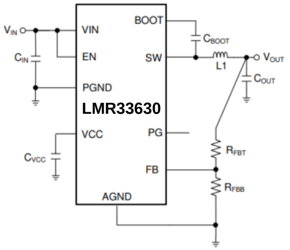


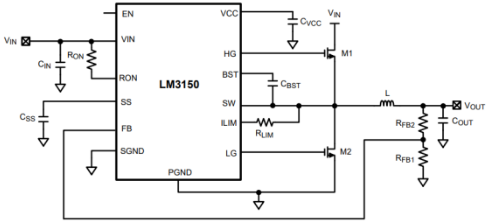
6.8uH



Like everything in life – it's a tradeoff







	Power Module	Converter	Controller
Breadth of portfolio	Emerging – fewer options to consider (pro/con)	Mature – many options can be great but also overwhelming	Mature – many options
Design difficulty (component selection & layout)	Easy	Moderate	Difficult
Solution Size	Smallest	Small-Medium but depends on IC and passive selection	Large
EMI	Low without effort	Low-Medium (depends on component selection & layout)	Depends on layout
Design Flexibility	Less – FETs and inductor fixed	Moderate – FETs fixed	High – select FETs & inductor
Total BOM Cost ($$$ to $)	$$$ to $$	$$ to $	$$ to $

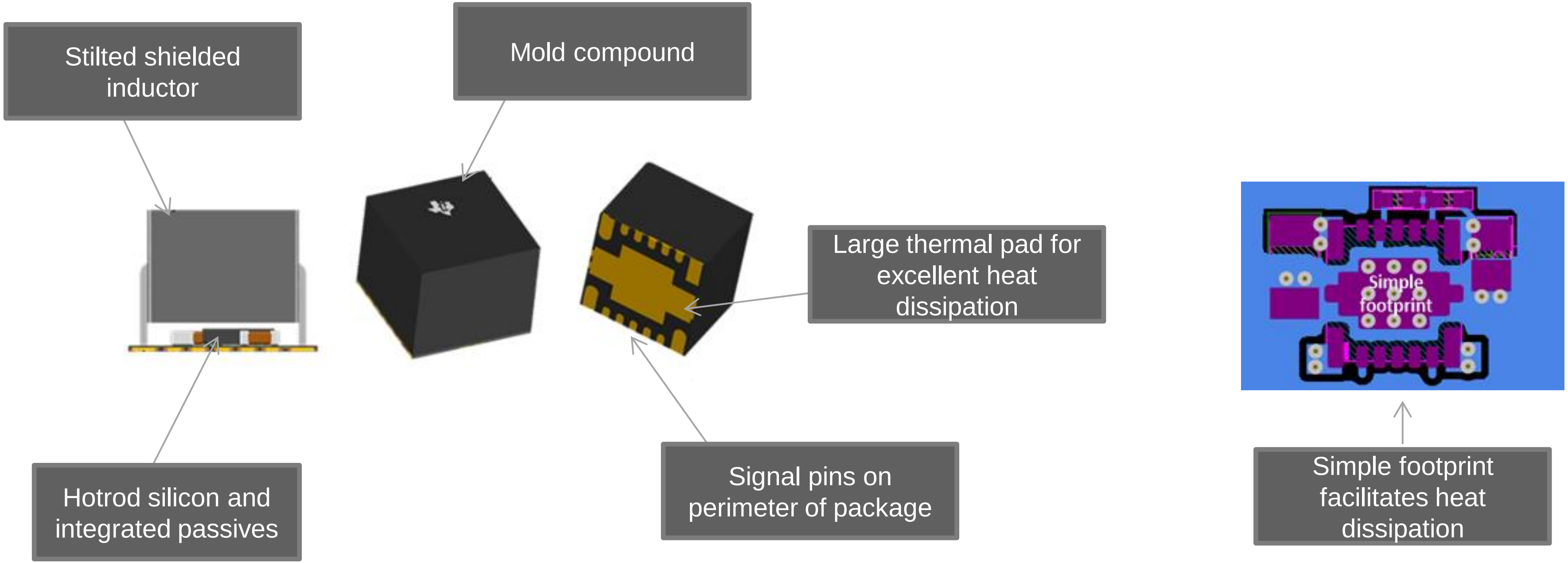
Which is the best fit for your application?

- Consider a module
  - Limited time and resources
  - Limited board space
  - Save on total cost (engineering and material cost)

- Consider a converter or controller
  - BOM cost is #1 priority
  - Specific requirements outside of module operating range

New module packaging technology & product highlights

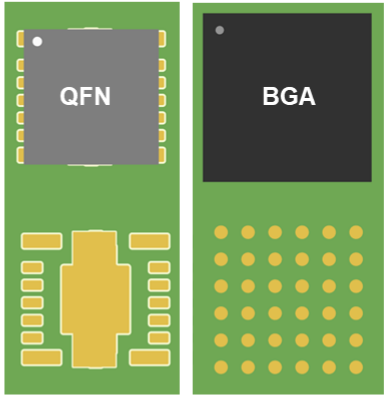
Introduction to Enhanced HotRod™ QFN package



Enhanced HotRod QFN packaging thermal performance compared to competition

TPSM53604
3.8-36 V
4 A
5x5.5 mm
QFN

Area = 27.5 mm²

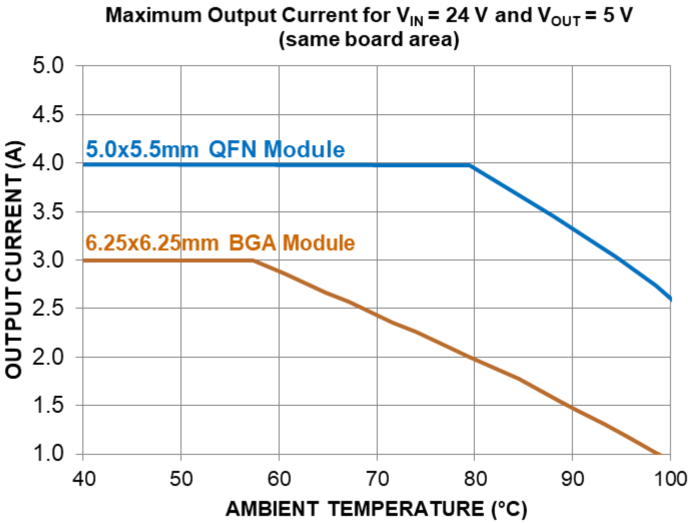


3.4-40 V
3.5 A “peak”
6.25x6.25 mm
BGA

Area = 39 mm²

Thermal contact
42% of package area

Thermal contact
18% of package area



Newly Released!!

TPSM53604/3/2

Industry's highest density 36V, 2A/3A/4A power module

Features

- **Enhanced HotRod™ QFN Packaging**
- **4 to 36V** Input Voltage Range
- **2A, 3A, and 4A** Output Current Options
- **1V to 7V** Output Voltage Range
- **5 x 5.5 x 4mm QFN Package**
- **-40 ºC - 105 ºC Operating Temp Range** (125 ºC Junction)
- Pin out engineered to **reduce EMI**
- **High efficiency across load range**
- PG, Pre-Biased Start Up and Prog UVLO
- ***LMR33630 Silicon***

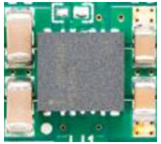
Benefits

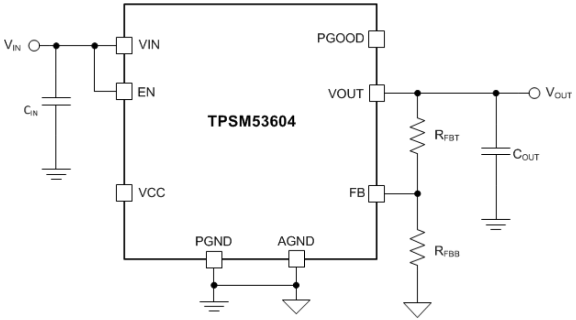
- Reduced design risk – integrated inductor and small passives in easy to handle QFN packaging
- Smallest 36V, 4A/3A solution (30% smaller than discrete implementation and competition module solution)
- Best in class efficiency (89% at 24Vin, 5Vout, 3A)
- Up to 20W output power at 85ºC with no airflow
- Low EMI – Meets CISPR11 radiated emissions

Applications

- Factory Automation
- Test & Measurement
- Grid
- Defense
- Industrial Transport

Footprint

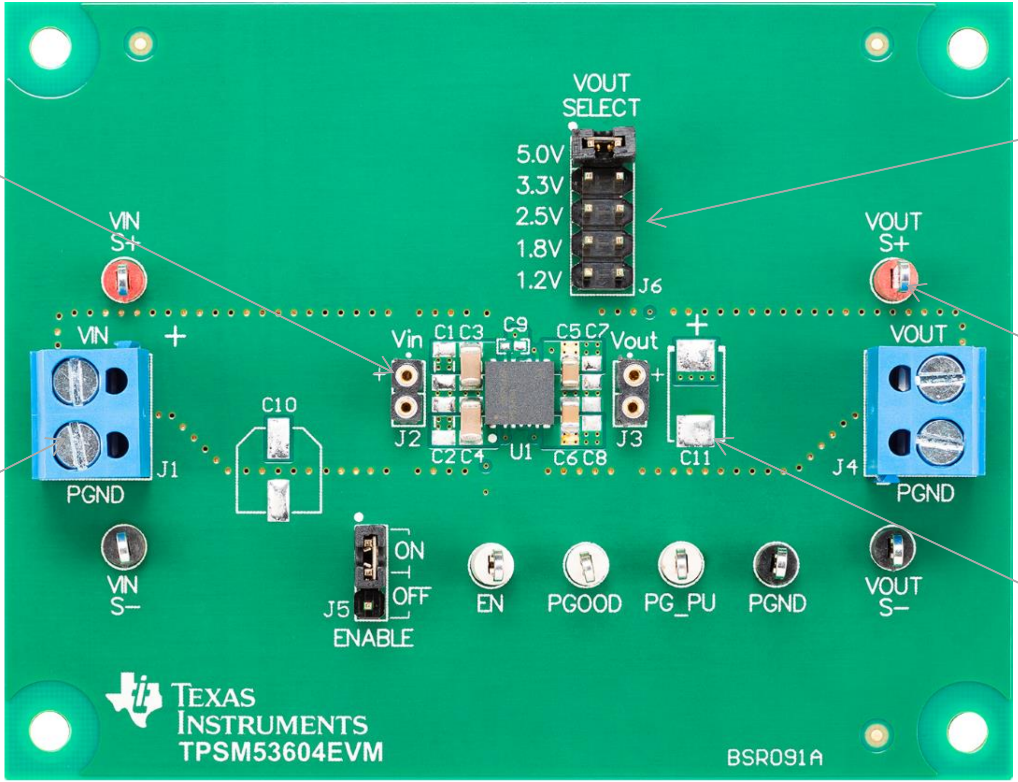




Evaluating the TPSM53604

Scope probe point for easy ripple measurements

Terminal blocks for connecting power supply



Jumpers for easy Vo selection

Output voltage monitor with DMM

Extra capacitor footprints for prototyping

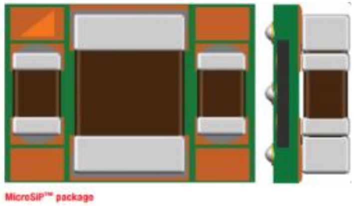
Introduction to system-in-package

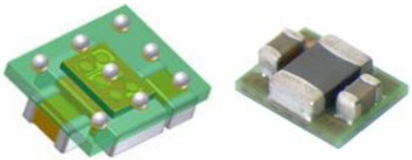
System-in-Package integrates the IC inside a laminate substrate with SMD components on top of the package

Texas Instruments is the first company that made high volume production with this packaging technology as MicroSiP™ and MicroSiL™ with an embedded die Picostar™

MicroSiP

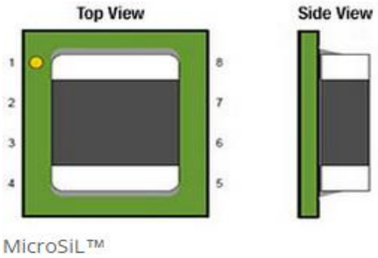
- Fully embedded IC inside substrate
- **<u>ALL</u>** Passive components (L, C_{IN}, C_{OUT}) are on top
- Module package is BGA (WCSP) format

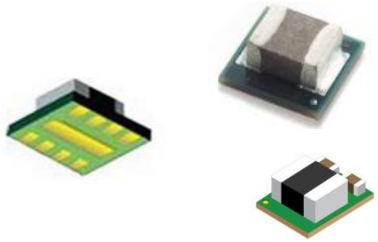




MicroSiL

- Same packaging technology as MicroSiP™
- Passive components are on top
- Module package is in QFN format





LMZM23600/1

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)**
- **Low EMI: Tested to CISPR11 Class B Radiated EMI**
- Mode Pin
    - **Forced PWM Mode** w/ Freq Sync
    - Auto PFM Mode option for Light Load Efficiency
- -40 ºC to 125 ºC Operating Junction Temperature
- Built in Compensation, Soft Start, Current Limit, Thermal Shutdown, Power Good, and Input UVLO

Benefits

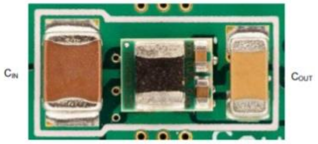
- Supports wide range of application requirements
- Easy to Design: only C_{IN} and C_{OUT} required (Fixed Vout)
- 27mm^2 solution: 45% smaller than competition; 55% smaller than discrete
- System Flexibility with choice of Fixed Frequency or Light Load Efficiency
- Synchronize to external clock

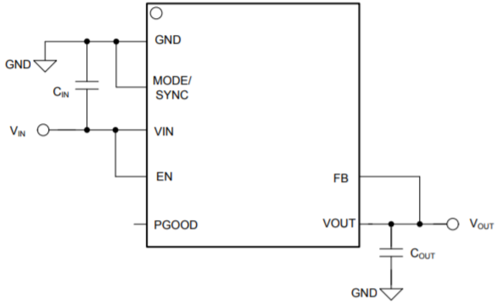
Applications

- Factory & Building Automation
- Medical Equipment
- Smart Grid & Energy
- Defense Equipment
- Inverting Output – Application Note

Single-Sided Layout Solution Size
24-V to 5-V, 0.5-A DC-DC Converter

3.8 mm x 3.0 mm package



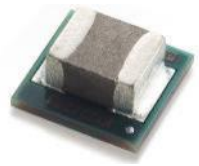


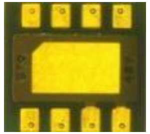
TPS82130 / TPS82140 / TPS82150

17V 1-A to 3-A step down converter module with integrated inductor

Features

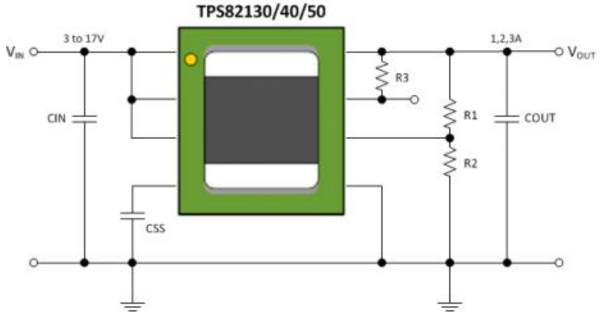
- MicroSiP™ package with integrated inductor 3.0mm x 2.8mm x 1.5mm
- 3V to 17V Input Voltage Range
- DCS-Control™ Topology
- Power Save Mode for Light Load Efficiency
- 100% Duty Cycle
- 20µA Quiescent Current
- Power Good Output plus Capacitor Discharge
- Adjustable Output Voltage
- Programmable Soft Startup
- -40°C to 125°C operating temperature range





Benefits

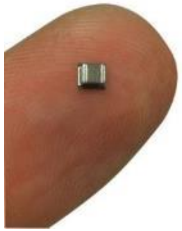
- Small, low profile solution
- Saves >50% PCB area (TPS82130), compared to discrete solution
- Easy to use



Applications

- General Purpose POL
- Data cards, Network Switcher, Line Cards
- Storage: Server, Motherboards
- Telecom Infrastructure: Optical Modules (Inverter)

Device Name	Output Current
TPS82130SIL	3-A
TPS82140SIL	2-A
TPS82150SIL	1-A



TPSM82821/2

1A/2A buck converter with integrated inductor

Preview
Samples available at TI.com

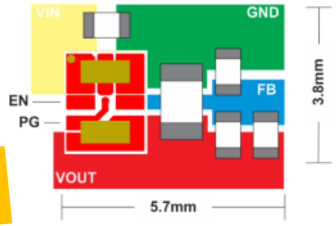
Features

- **2.0 x 2.5 x 1.1mm SIL package with integrated inductor**
- V_{IN} = 2.4V to 5.5V / V_{OUT} = 0.6V to 4.0V (adjustable)
- 4µA Quiescent Current
- Up to 95% Efficiency
- DCS-Control™ Topology
- Power Save Mode for Light Load Efficiency
- **V_{REF}= 0.6V with 1% accuracy**
- Hiccup Short Circuit Protection
- Active Output Discharge, Power Good Output
- Integrated Soft start

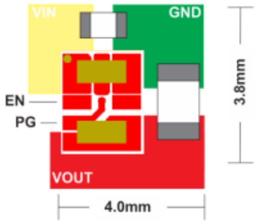
Benefits

- **Small, low profile solution for small form factor applications**
- **Easy to use, proven solution**
- DCS-Control Topology maintains an accurate output voltage at fast line and load transients plus a seamless transition between PWM and power save mode

250W/cm^3 power density



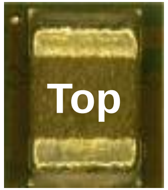
Adj. Vout: 29mm²

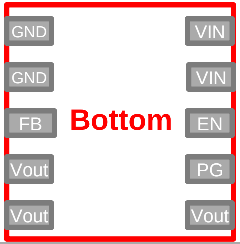


Fixed Vout

Applications

- Easy to use Point of Load
- Datacom / Networks
- Portable industrial and medical





TPSM82813/0

3A/4A buck converter with integrated inductor

Preview
Samples available at TI.com

Features

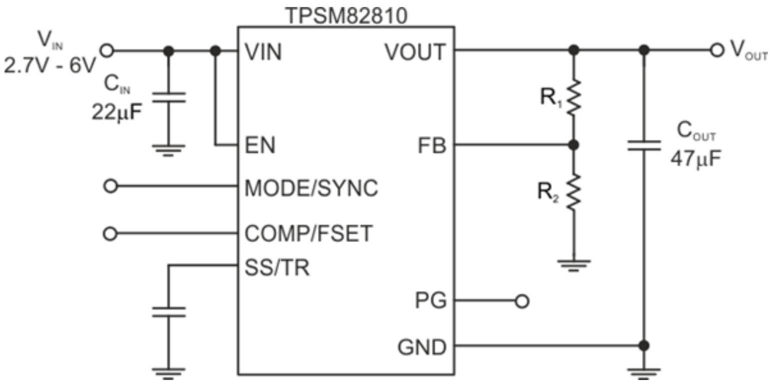
- 2.5V to 6V input voltage range
- Adjustable output voltage from 0.6V to Vin
- **-40ºC to 150ºC operating junction temperature range**
- 1% output voltage accuracy
- 10uA Quiescent current
- **Fixed frequency operation**, per default at 2.2MHz
- Adjustable switching frequency and compensation
- **Forced PWM and external synchronization (1.8 – 4MHz)**
- SS/TR provides **adjustable soft-start and tracking** capability
- Output discharge for defined ramp-down of Vout
- **Spread Spectrum Clocking** for decreased noise (optional)
- **Package 3x4x2.5mm embedded uSIL**

Applications

- Factory Automation
- Test & Measurement
- Medical
- Communications Equipment

Benefits

- **Small solution size with minimal external components**
- Fixed frequency, external sync and Spread Spectrum Clocking **facilitates design for low EMI**
- Short min on-time of 50ns allows **direct conversion of 5V to 1V at f>2MHz**
- **Allows wide range of output capacitance** to meet requirements for input of FPGAs or MCUs



TPSM265R1

Preview
Samples available at TI.com

Industry's highest density 65V, 100mA power module with ultra low Iq

Features

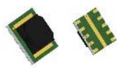
- Input voltage range from **3V to 65V**
- **10.5µA no-load I_Q, 2 µA Shutdown I_Q**
- PFM Mode For **Excellent Light Load Efficiency**
- **Miniature 2.8mm x 3.7mm x 1.9mm** package with integrated inductor
- Output Voltage options:
  - **3.3V, 5V** Fixed Vout
  - **1.3V to 15V** Adjustable Output Voltage
- Power Good flag, Internal + external soft start
- Precision input UVLO

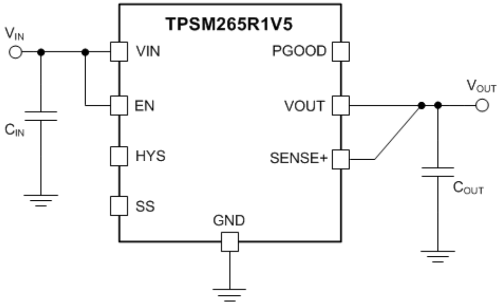
Applications

- Factory Automation
- Process and Field Sensors
- 4-20 mA current-loop powered sensors

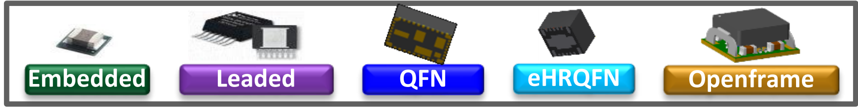
Benefits

- **Continuous 65V operation**. No need to transient suppressors.
- Smallest 65V capable 100mA solution
- Fixed output voltage versions guarantee lowest BOM count (**Just C_{IN} and C_{OUT} required**)
- Form Factor and pin out engineered to:
  - Ensure **one side to be no more than 3mm**
  - Ensure small switching current loops and low noise operation





Power module hero portfolio



Low Voltage (VIN <7V)

Vin max ranging 4.8V-6V
Current ranging 0.2A-6A
*ADJ Vout ranging 0.6-6V**

- TPSM82480 – 5.5V, 6A – 3.6x7.9x1.5mm
- TPSM82813/0 – 5.5V, 3A/4A – 3x4x2.3mm
- TPSM82821/22 – 5.5V, 1A/2A – 2x2.5x1.1mm
- TPS8268x – 5.5V, 1.6A – 2.3x2.9mm
- TPS8269/7X – 4.8V, 0.8/0.6A – 2.9x2.3mm
- TPS82740 – 5.5V, 0.2A – 2.3x2.9mm
- LMZ30602/4/6 – 6V, 2A/4A/6A – 9x11x2.8mm
- TPS82084/5 – 6V, 2A/3A – 3x2.8x1.3mm
- TPS81256 – 5.5V, Boost 5V, 0.4A – 2.9x2.6mm

Mid Voltage (7V<VIN<30V)

Vin max ranging 15V-28V
Current ranging 1.0-120A
*ADJ Vout ranging 0.25-12V**

- 2X TPSM846C23/4 – 15V, 35A – PMBus/Analog
- TPSM84A21/2 – 14V, 10A – 9x15mm
- TPSM84424/624/824 – 17V, 4A/6A/8A – 7.5x7.5x5.3mm
- TPS82150/40/30 – 17V, 1A/2A/3A – 3x2.8x1.5mm
- 2X TPSM831D31 – 15V, 120+40A, PMBus
- LMZ31520/30 – 15V, 20A/30A – 15x16x5.8mm
- LMZ31704/07/10 – 17V, 4A/7A/10A – 2X 10x10x4.3mm
- TPSM84209 – 28V, 2.5A – 4x4.5x2mm
- TPSM84203 – 28V, 1.5A – T0220 10x11mm

Wide Voltage (Vin>30V)

Vin max ranging 36V-65V
Current ranging 0.1-10A
*ADJ Vout ranging 0.8-24V**

- LMZ23608/10 – 2X 36V, 8A/10A – 15x18x6mm
- LMZM33604/6 – 36V, 4A/6A – 10x16x4mm
- TPSM53602/3/4 – 36V, 2A/3A/4A – 5x5.5x4mm
- LMZM33602/3 – 36V, 2/3A – 7x9x4mm
- LMZM23600/1 – 36V, 0.5A/1A – 3.8x3x1.6mm
- LMZ35003 – 2X 50V, 2.5A – 9x11x2.8mm
- LMZ34002 – 40V, 2A (Neg.)
- LMZ36002 – 60V, 2A – 10x10x4.3mm
- TPSM265R1 – 65V, 100mA – 2.8x3.7x1.9mm

Key

- Preview
- NEW
- -Fsync
- -Inverting Capable
- 2X -Current Sharing/ Parallel Operation

Vout range is portfolio wide not device specific

Texas Instruments

Design tools & support

TI.com resources

EMI reduction and noise mitigation:

- App Note: Simple Success With Conducted EMI From DCDC Converters
- App Note: Simplify low EMI design with power modules
- App Note: PCB layout techniques for low noise power designs
- Tech Article: Design a second-stage filter for noise sensitive applications
- App Note: Low output noise filtering for DC/DC power modules
- Training Video: Understanding, Measuring, and Reducing Output Noise in DC/DC Switching Regulators (part 1)
- Training Video: Understanding, Measuring, and Reducing Output Noise in DC/DC Switching Regulators (part 2)

TI.com resources

Inverting applications:

- App Note: Configuring the LMZM33606 36V 6A Power Module for negative output
- App Note: Configuring the TPSM53604 36V 4A Power Module for negative output
- App Note: Configuring the LMZ14203 42V 3A Power Module for negative output
- App Note: Configuring the LMZM33603 36V 3A Power Module for negative output
- Datasheet: Using the LMZ34002 40V 2A Negative Output Module
- Evaluation board: LMZ34002 with -3.3V, -5.0V, -12V, -15V selectable outputs
- App Note: Configuring the LMZM23601 36V 1A Power Module for negative output
- App Note: Configuring the TPSM265R1 65V 100mA Power Module for negative output
- App Note: Working with inverting buck-boost converters
- Training video: how to configure a buck into an inverting regulator
- Reference design: -5V at 1.75A using the LMZ36002
- Tech Article: How to create a programmable output inverting regulator

TI.com resources

Thermal design:

- App note: Practical thermal design with DC/DC Power Modules
- App note: Thermal performance of SIMPLE SWITCHER® Power Modules
- App note: Thermal design by insight, not hindsight
- Training video: Thermal design concepts
- Training video: Managing heat dissipation with DC/DC switching regulators

Soldering:

- Soldering considerations for power modules
- Power module MSL ratings and reflow ratings

Key takeaways

1. Do not need to be a power expert to design a power supply
2. Modules save board area even for the most experienced power designer
3. Modules enable you to have good board layout and low EMI
4. Modules optimized for typical output voltages
5. Converters are more flexible for performance optimization

Q&A

- Thank you for listening!

- Buck Module Portfolio

- Highlighted products:
  - TPSM5360x 36V, 2A/3A/4A
  - LMZ36002 60V, 2A
  - LMZM23601 36V, 1A
  - TPS82130 17V, 3A
  - TPSM82822 5.5V, 2A (coming soon!)
  - TPSM82810 6V, 4A (coming soon!)
  - TPSM265R1 65V, 100mA (coming soon!)

TEXAS INSTRUMENTS

Get to market faster with a DC/DC power module

Streamline the DC/DC power supply design process with an integrated-inductor step-down power module. With power modules, TI will help you get to market faster.

- Optimal converter selected for the specification
- Reduced component sourcing and qualification
- Optimized layout for EMI and thermal performance
- Full characterization across the operating range

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