ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

电源模块设计与挑战

Lorry Liang

Asia Power Systems Engineering Director

微型电源模块的需求来源

电源设计的三个挑战

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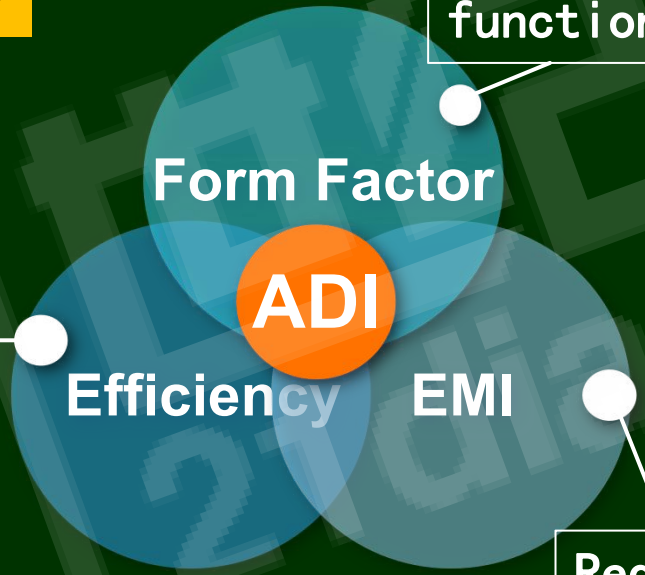
Performance
3 Key Metrics

Reduce form factor enabling customers to reduce PCB space or add incremental functionality



Manage power dissipation (heat) in the smallest of form factors

Reduce electromagnetic interference (noise)

电源设计，到底是简单还是复杂

Design requirement 5V to 3.3V @ 2A

- Input voltage range
  - V_{MAX}
  - V_{NOM}
  - V_{MIN}
- Output
  - V_{OUT}
  - I_{OUT_max}

基础参数

- Output ripple/noise
  - ΔV_{RIPPLE}
  - V_{RMS} (10Hz to 100kHz)
  - 1/f noise
- light load efficiency?
  - I_{LIGHT_LOAD}, η_{LIGHT_LOAD}
- Shutdown, Power_Good
- Size/Height limitation
- Ambient temperature
- Design time frame

进阶参数

- Transient response
  - Load step, BW (Bode plot)
  - ΔV_{OUT}
- Line regulation
  - ΔV_{OUT}
- Input reverse protection
- Output reverse protection (in case of battery related)
- Current limit, short circuit protection scheme
  - Hiccup, current foldback..
- Cold crank, jump start, load dump, AC superimpose etc.
- EMC/EMI specification
  - Industrial/International standard
- Special requirements
  - PSM, I^2C, current readback (digital/analog)
  - Sequencing, tracking
  - Margining
  - Watchdog

专业级参数

电源设计，到底是简单还是复杂

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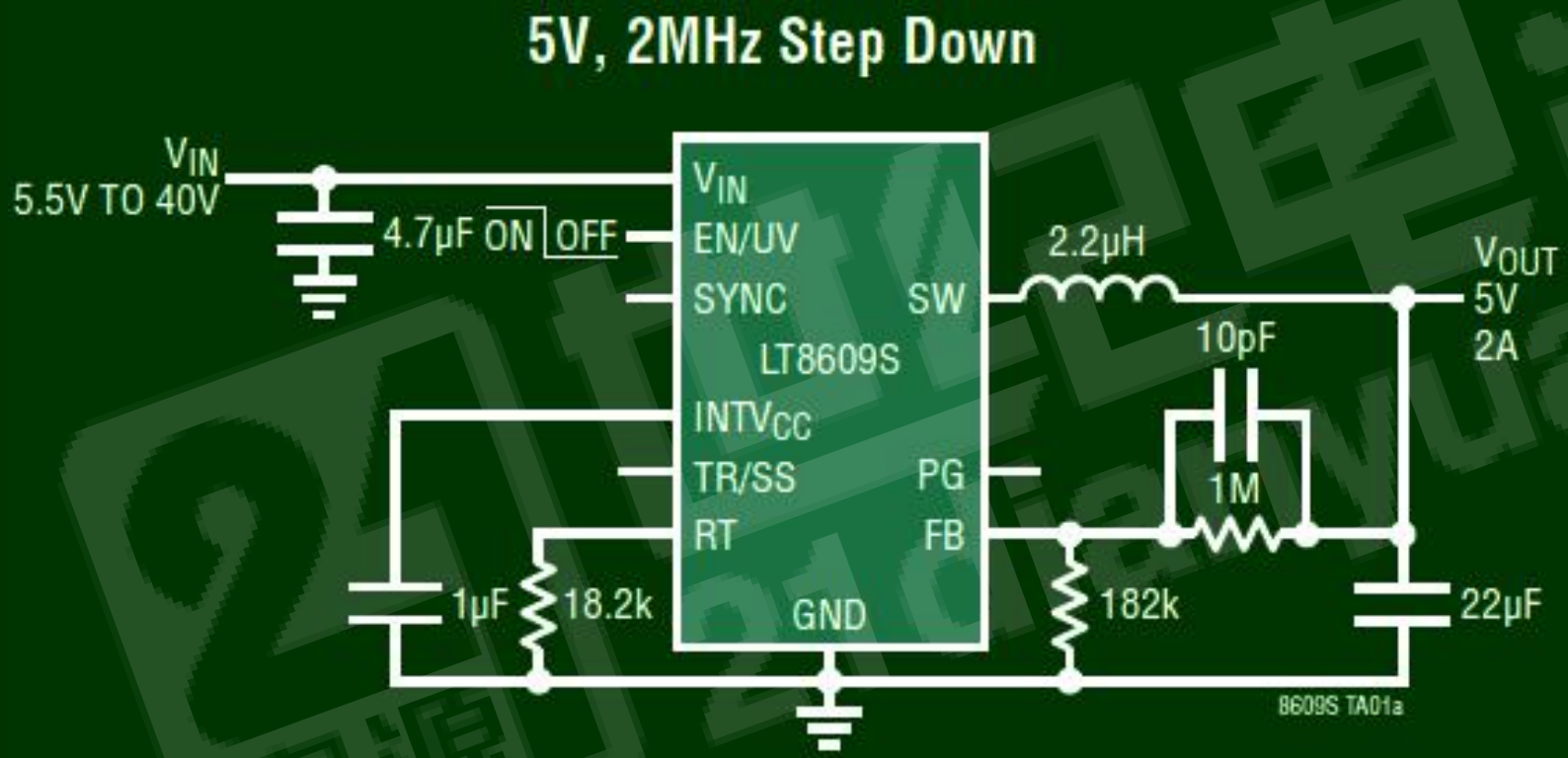

电源设计，到底是简单还是复杂

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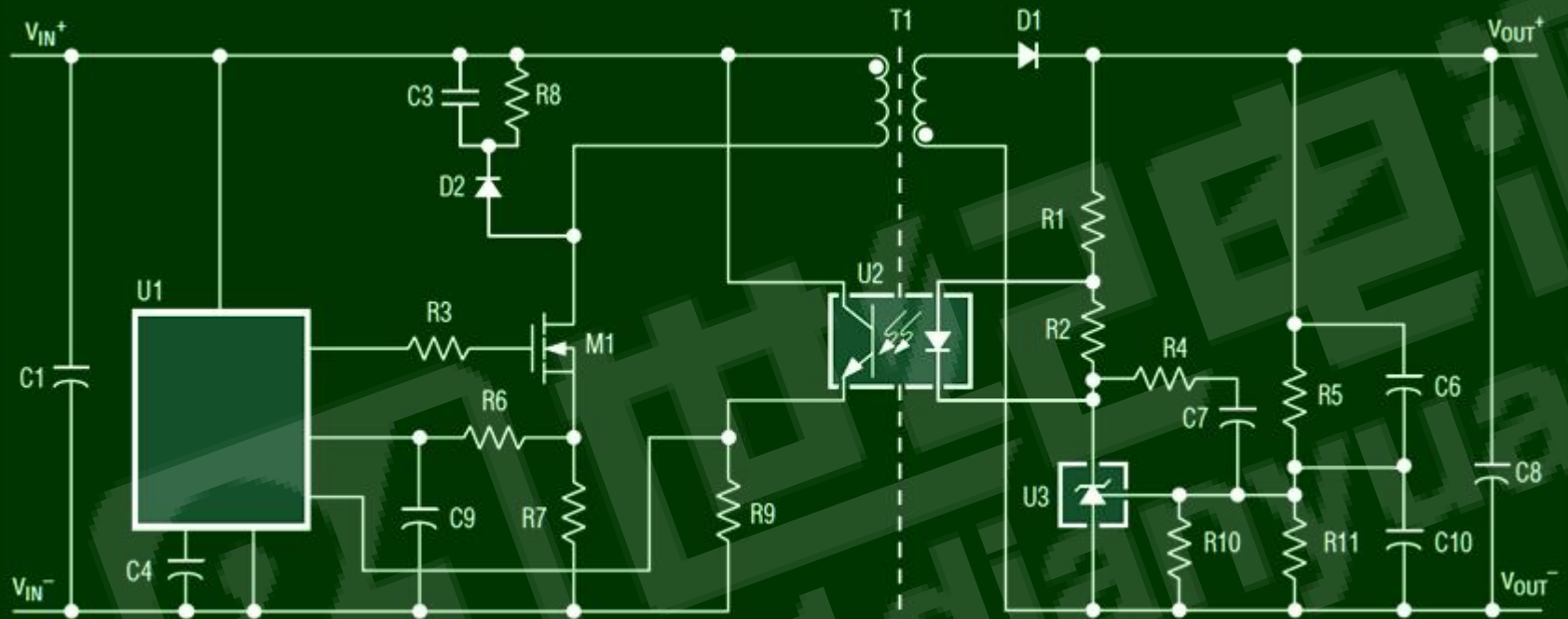

Primary Side IC

Opto

Secondary Side Reference and Loop Compensation

电源设计，到底是简单还是复杂

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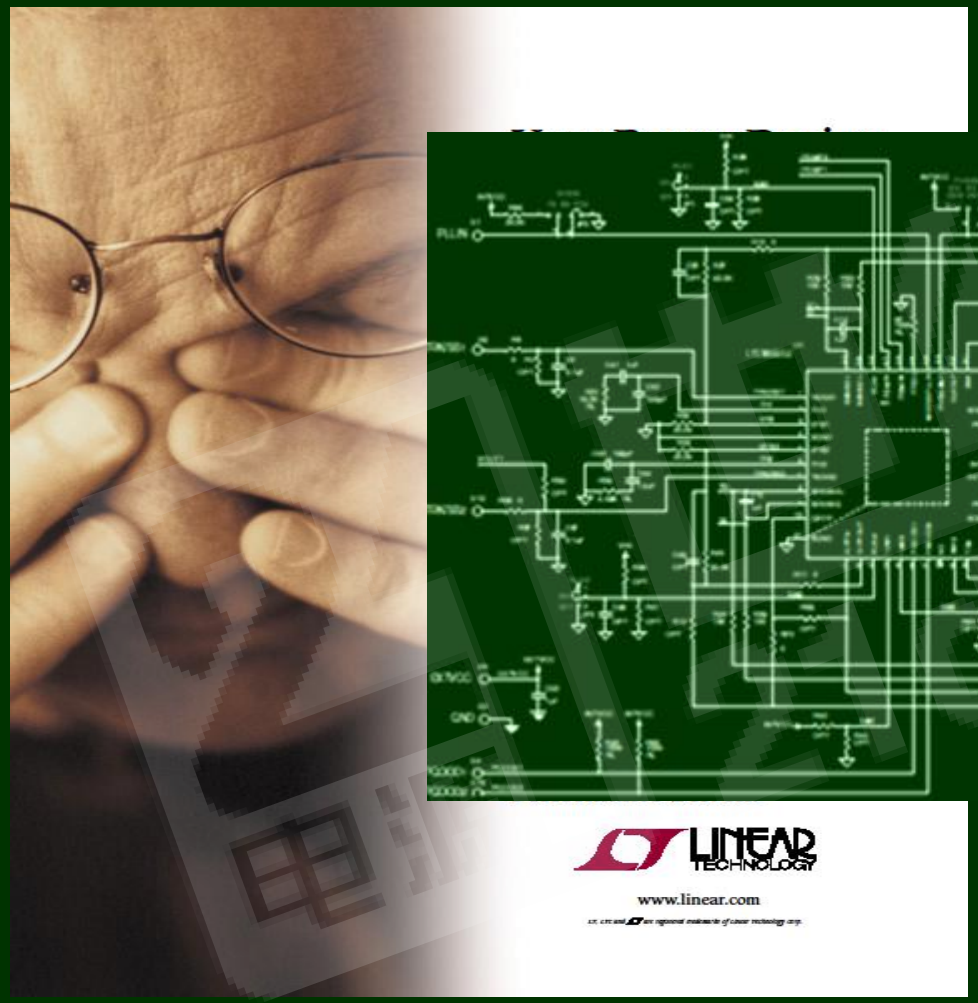

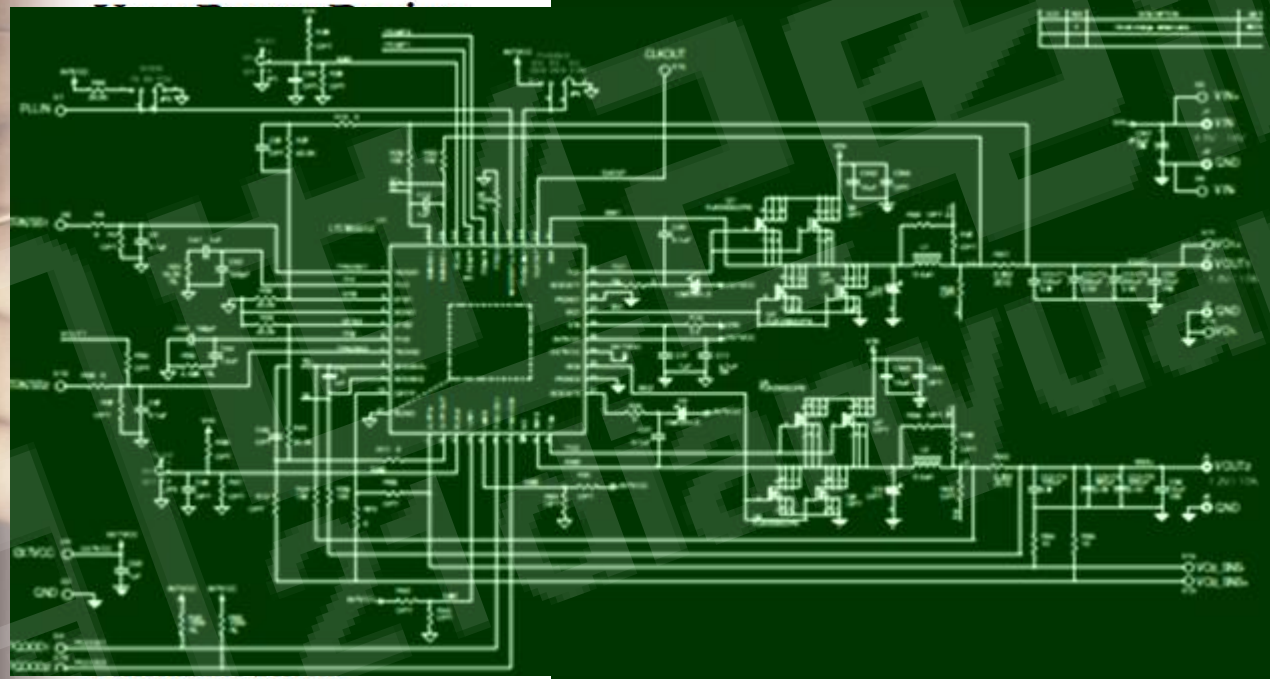

LINEAR TECHNOLOGY
www.linear.com

简化电源设计，加速产品研发

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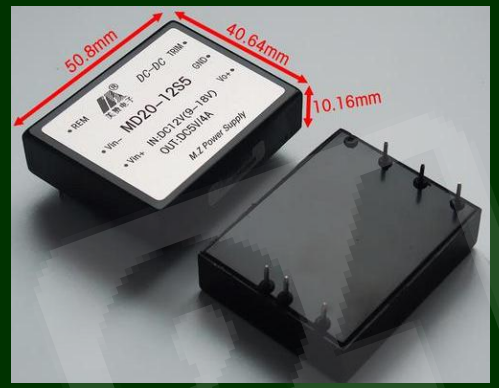

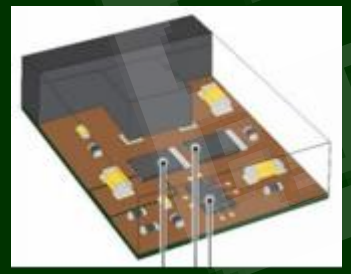

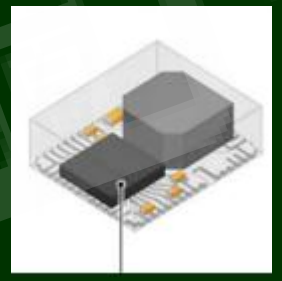

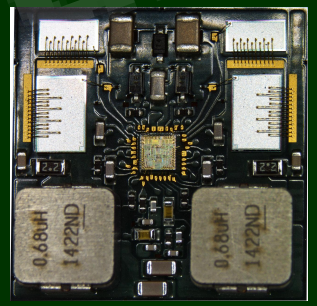

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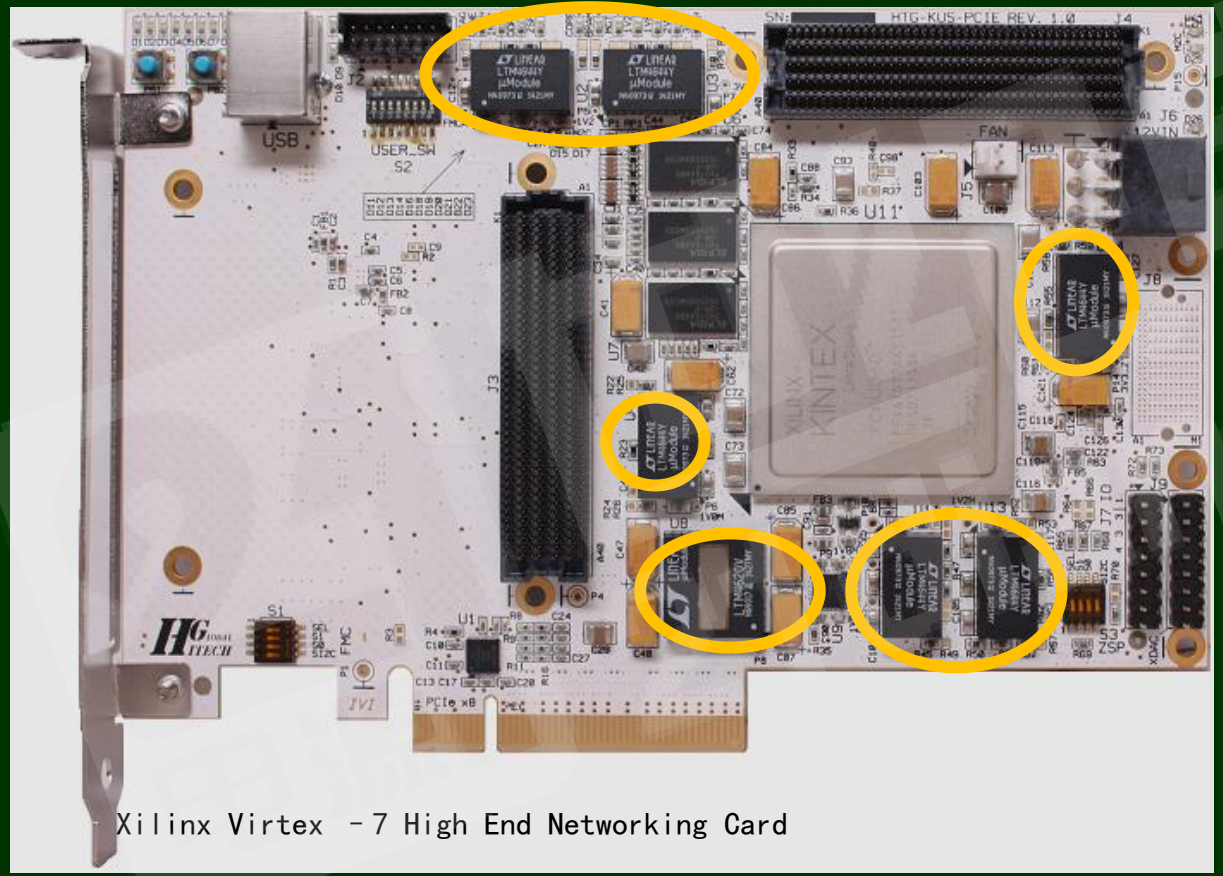
电源模块的应用及要求

电源模块的应用



Xilinx Virtex -7 High End Networking Card

电源模块的设计要求

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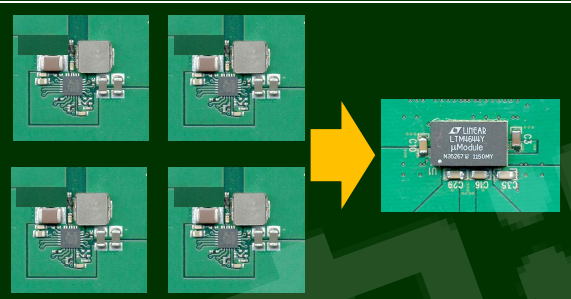
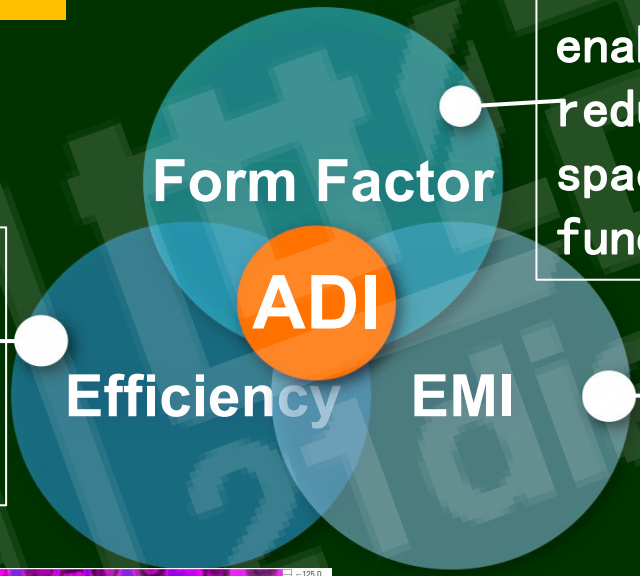
Performance
3 Key Metrics

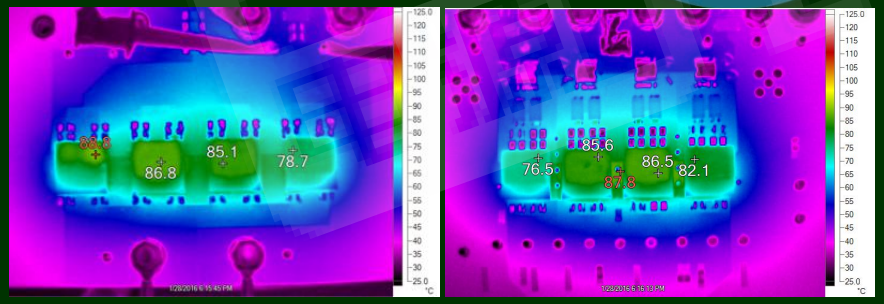


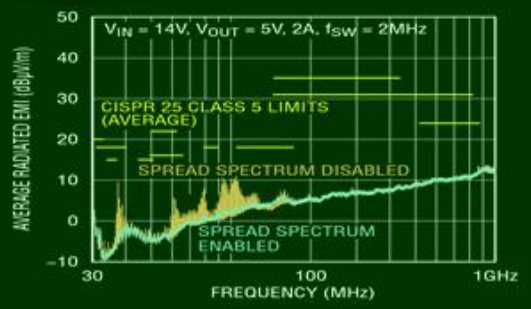


Reduce form factor enabling customers to reduce PCB space or add incremental functionality

Manage power dissipation (heat) in the smallest of form factors

Reduce electromagnetic interference (noise)





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微型电源模块的设计及挑战

成本 EMI 封装 散热

不是随便一个电源方案都适合做模块

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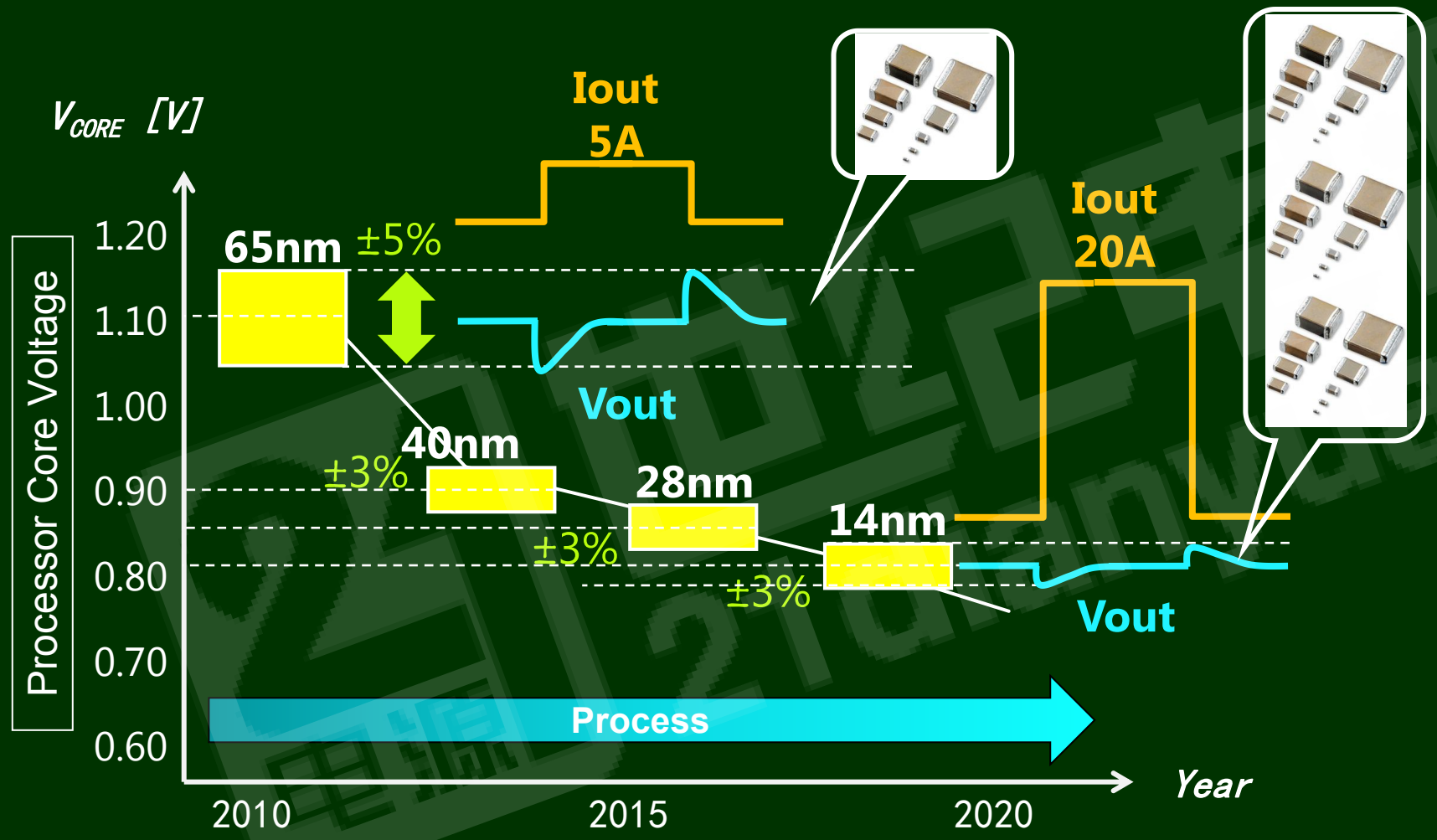


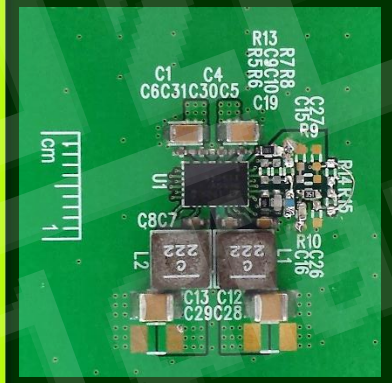
方案对成本的影响

成本分析

Example: Vin 12V (Battery) → Vout 5V/4A & 3.3V/4A

Competitor

Device	1pc
Capacitor	**32pcs**
Resistor	22pcs
Inductor	2pcs
FET	4pcs
Diode	4pcs
Total	**65pcs**



ADI / LT8650S

Device	1cs
Capacitor	**14pcs**
Resistor	7pcs
Inductor	2pcs
Total	**24pcs**

Save $

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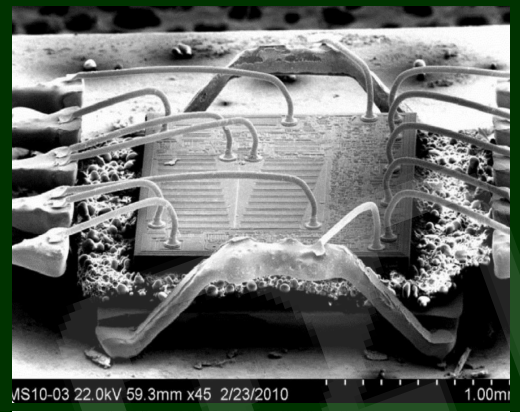
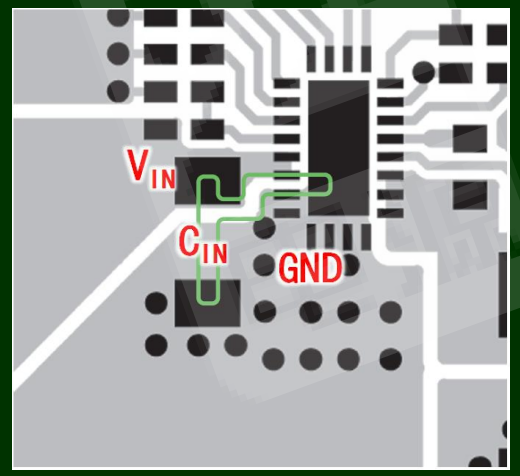
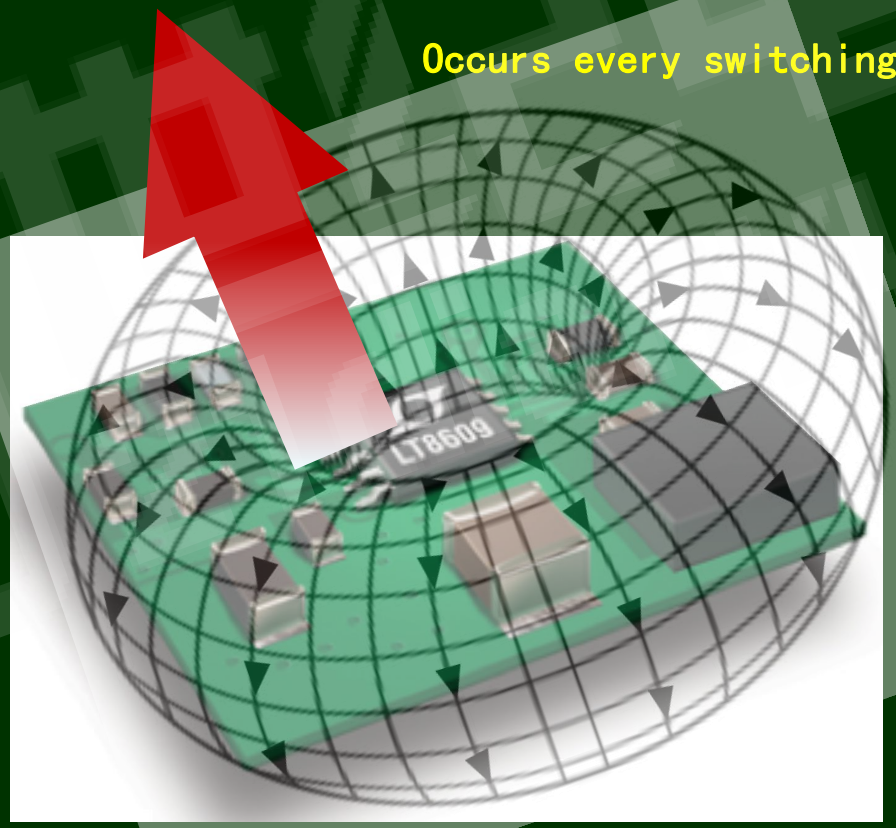
Low EMI DC/DDC Technology

EMI 来源

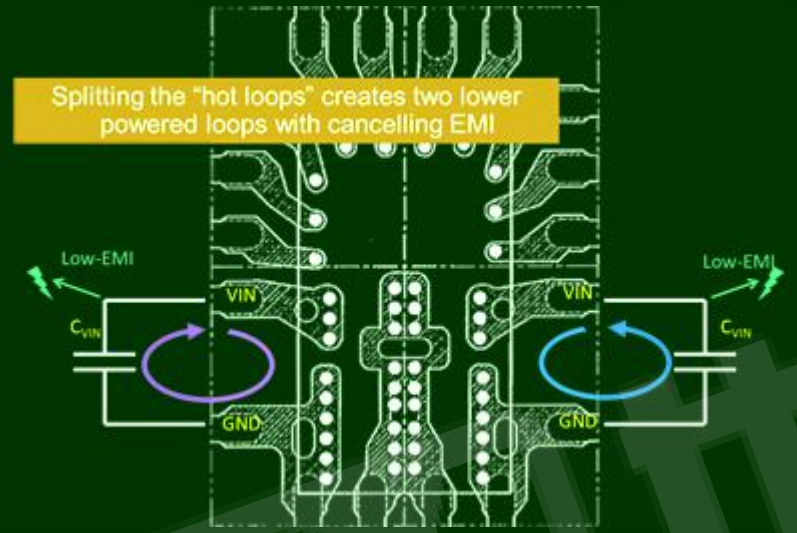
- With monolithic switcher, the best way is to place the low ESL input capacitor as close to the V_{IN} and GND as possible
- A solid GND plane with minimum distance to the hot loop is one of the most effective ways to reduce EMI

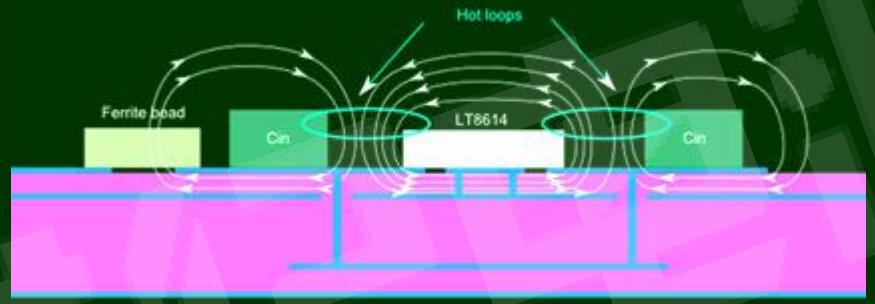


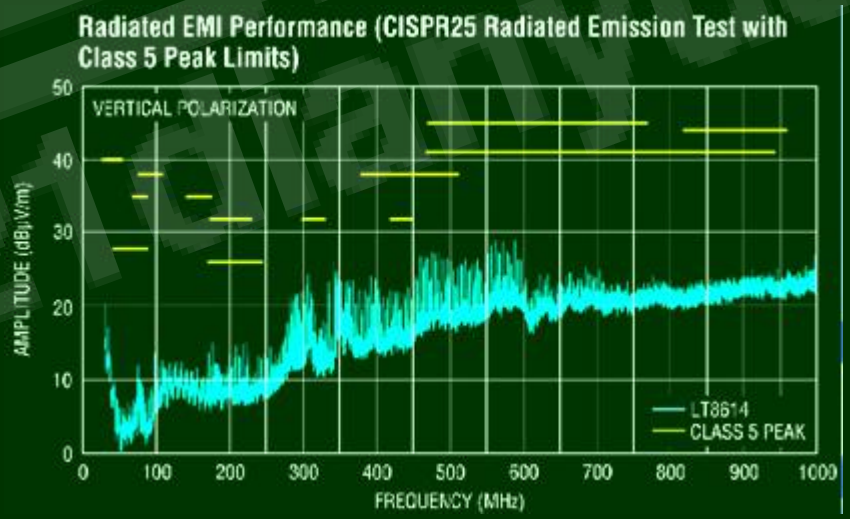




Innovation - Silent Switcher 1

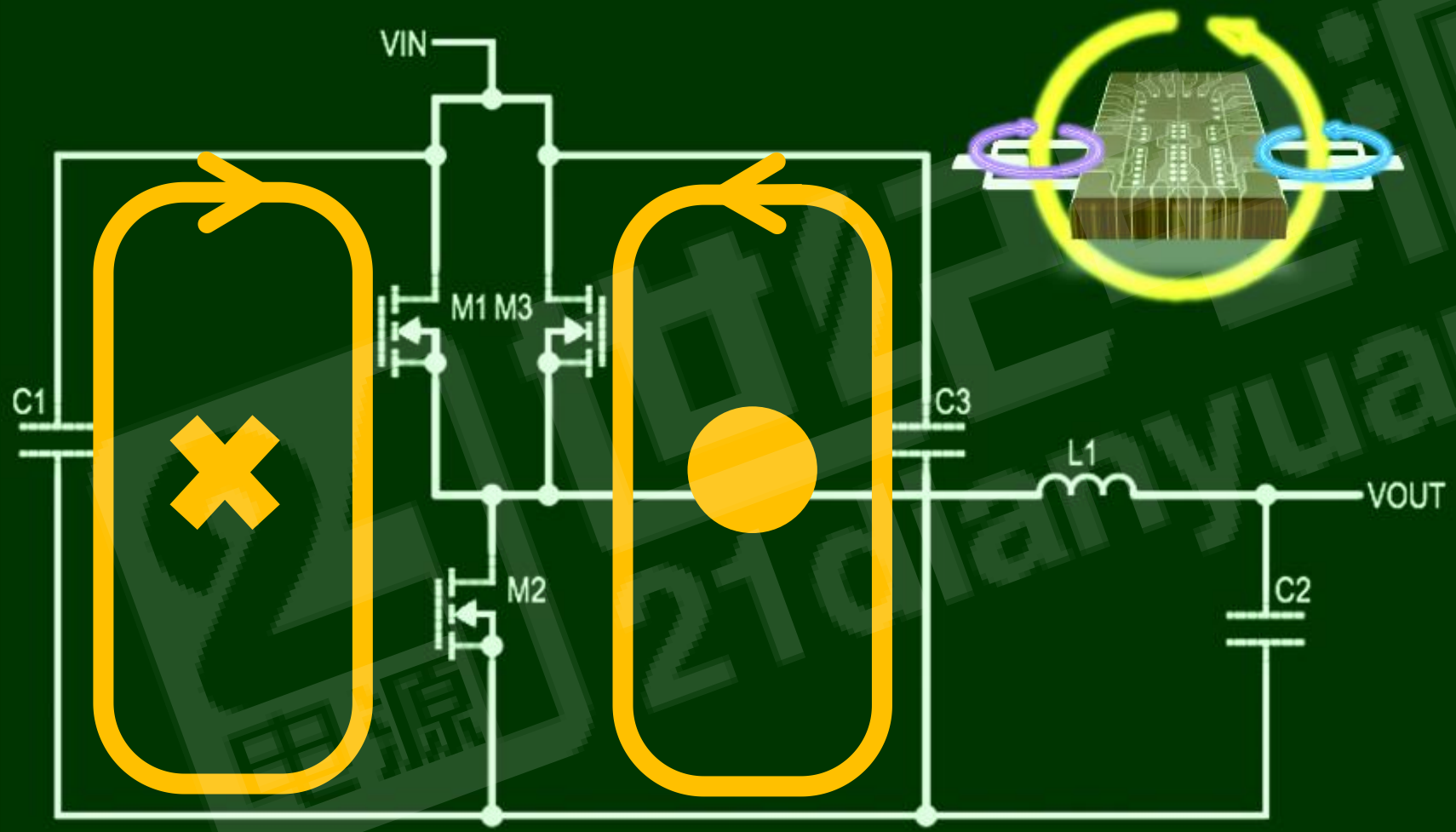




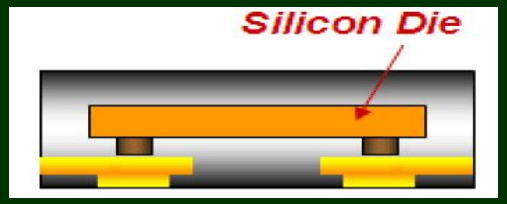


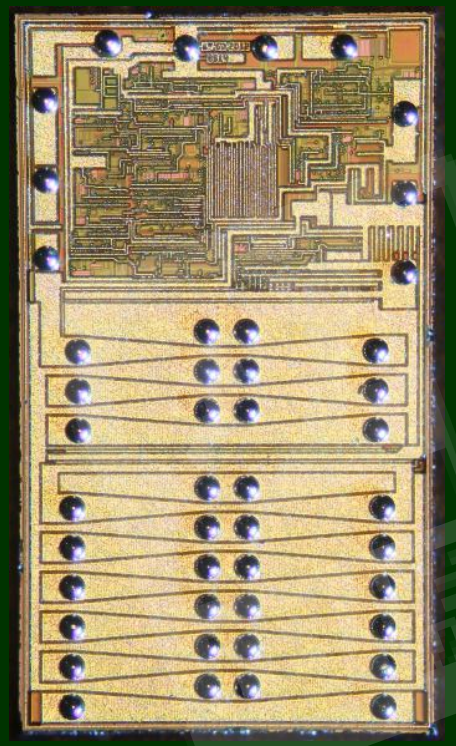
- The two high current loops cancel each others magnetic field, almost like enclosing the circuit in a metal box

Innovation – Magnetic Field Cancellation

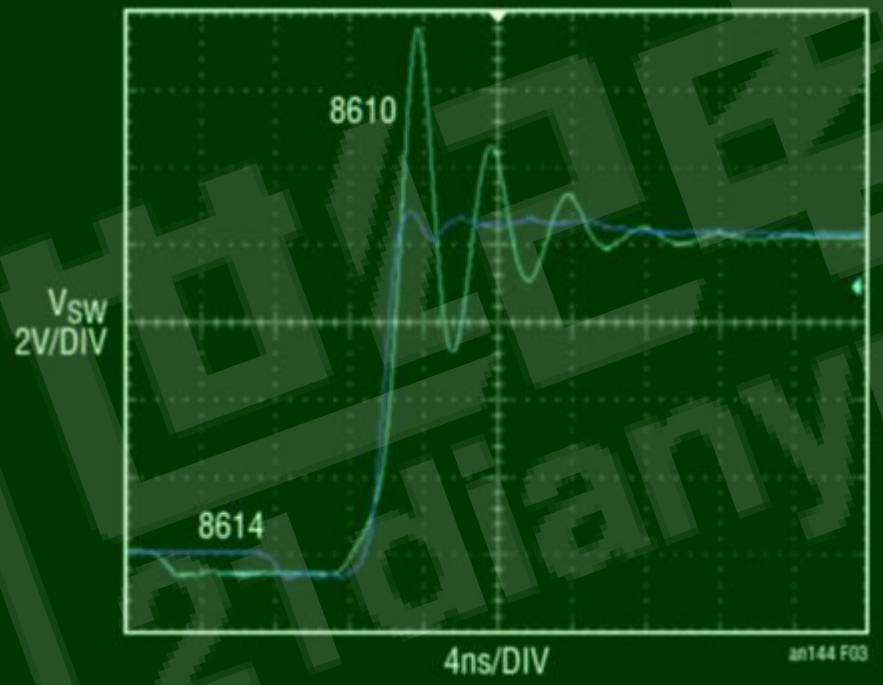


Silent Switcher 1 Eliminates Switch Ring





LT8610: Wirebonded in MS16E



LT8614: Silent Switcher 1: Magnetic cancellation + CuPillar Flip-Chip

Innovation – Silent Switcher 1

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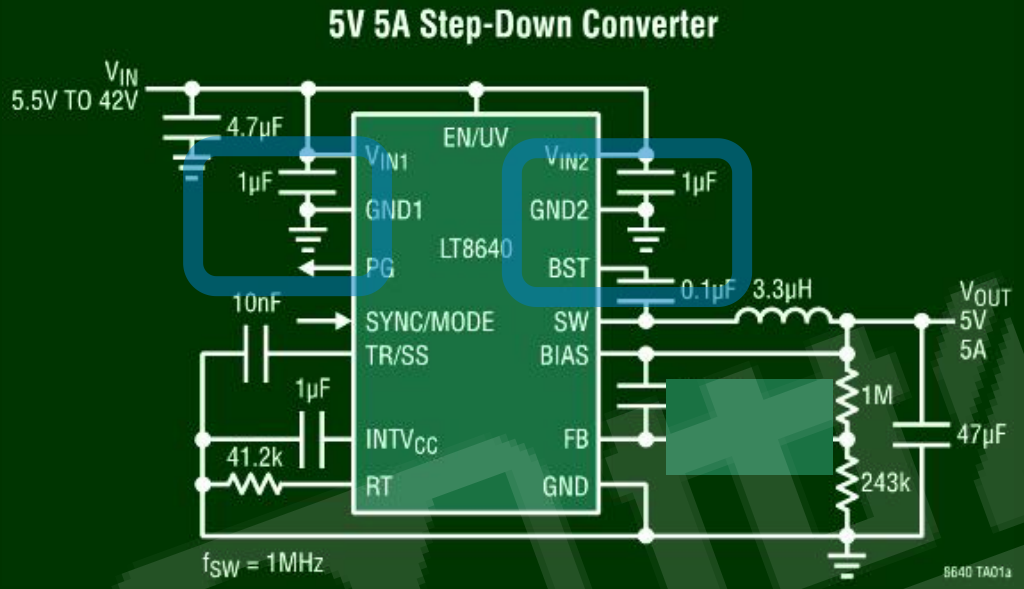

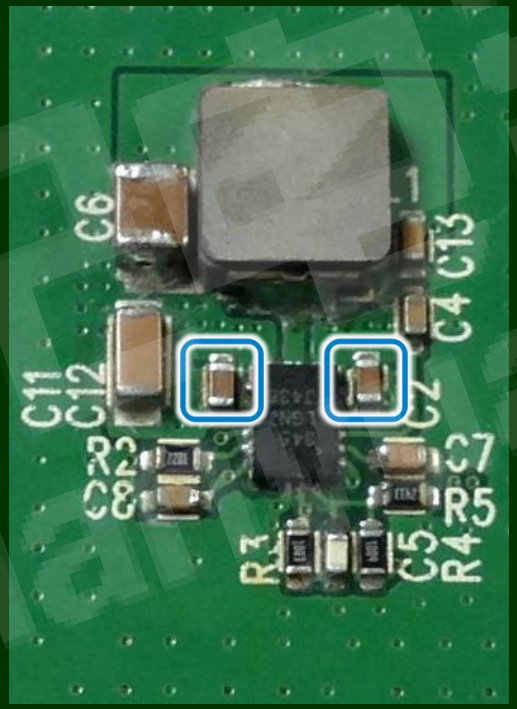

The layout is critical though!

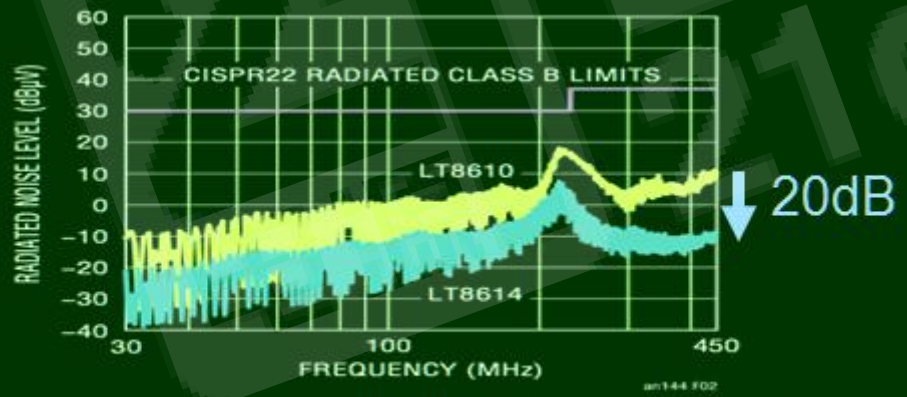

Figure 2. LT8610 and LT8614 700kHz 14V to 3.3V 2A Radiated EMI in GTEM Corrected for OATS

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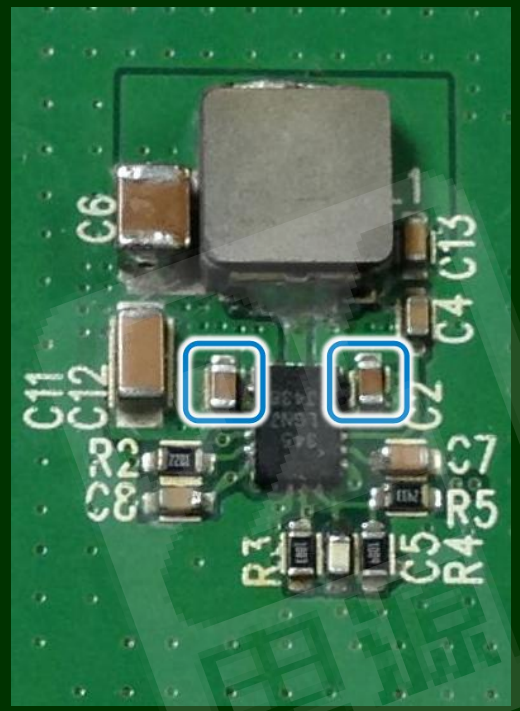
Silent Swither 2

Innovation – Silent Switcher 2

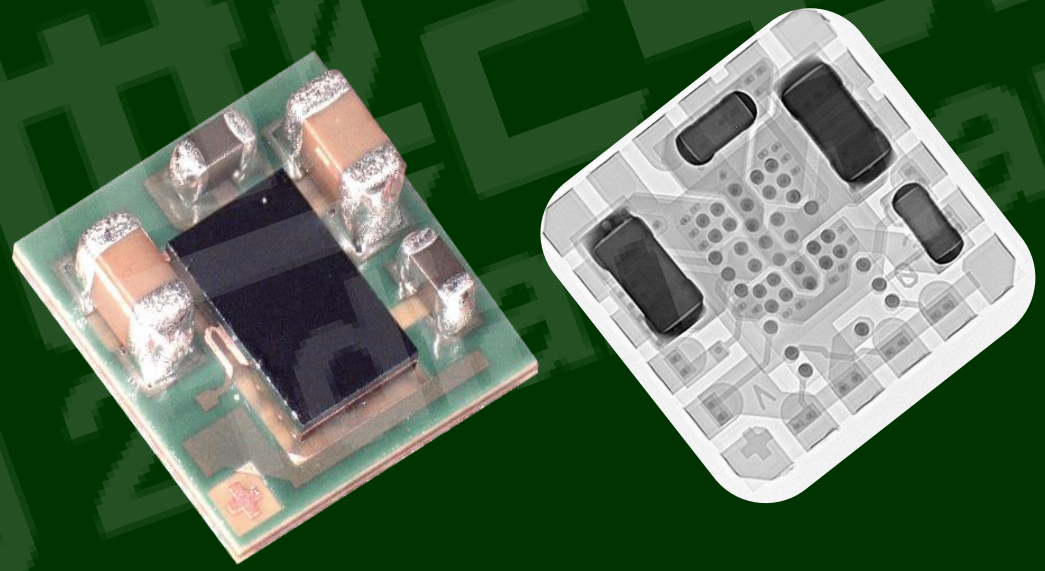
Silent Switcher 1

The layout is critical though!



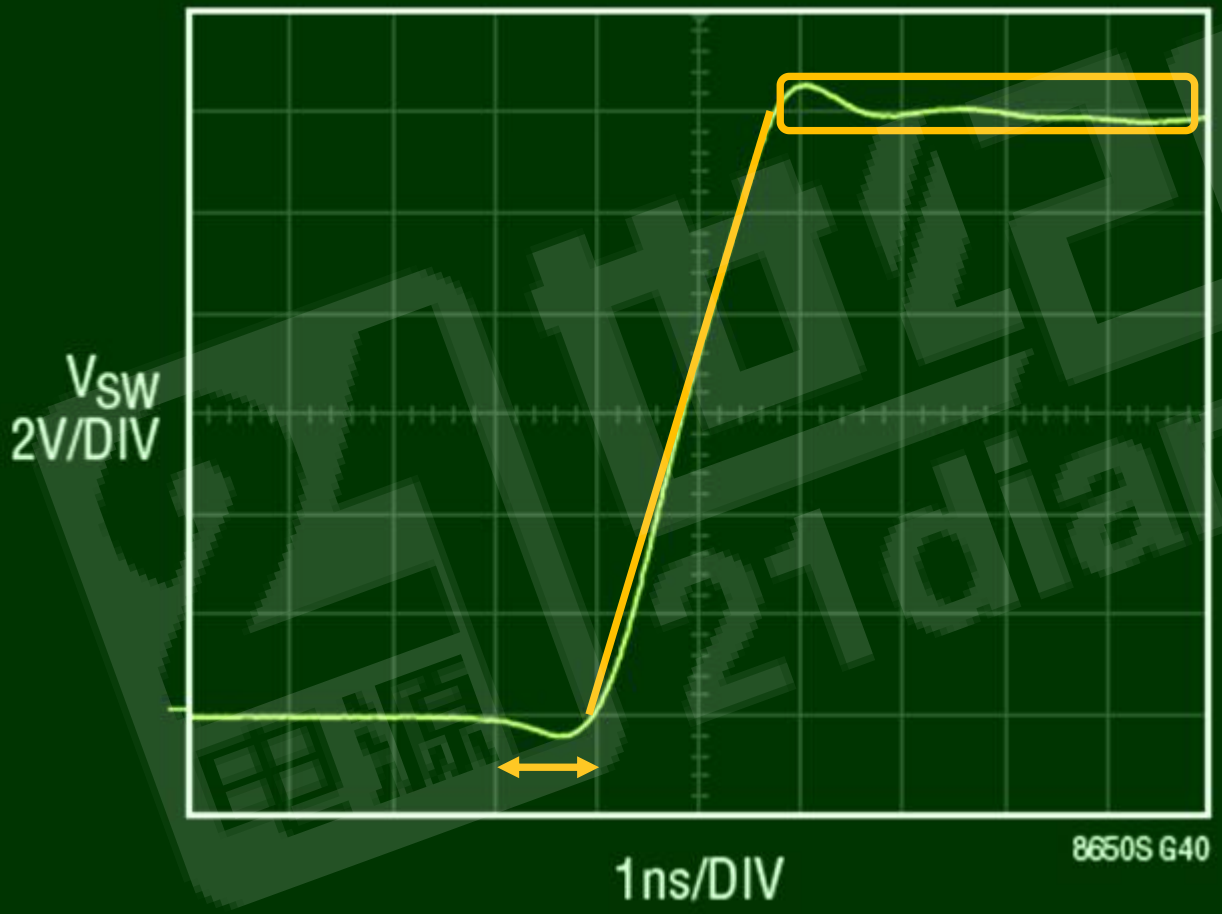
Silent Switcher 2

Flip chip on laminate (FCOL) and Cap-In-Package

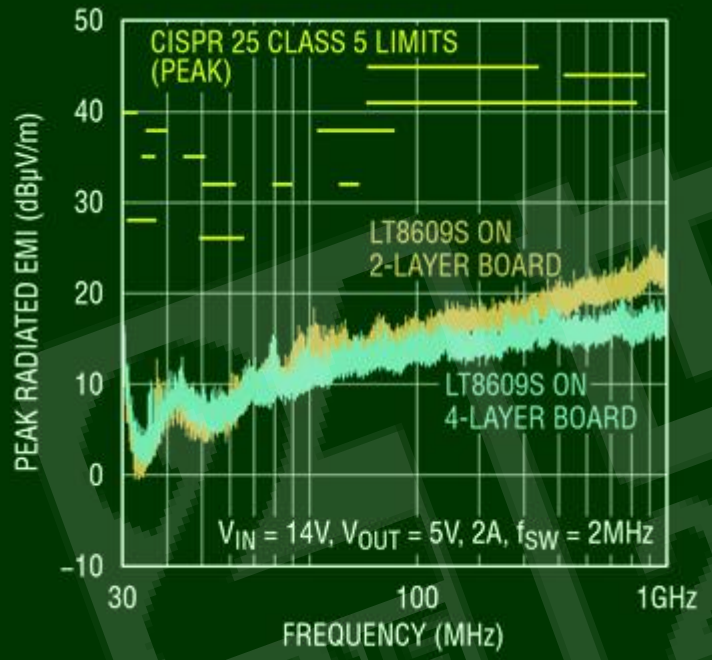


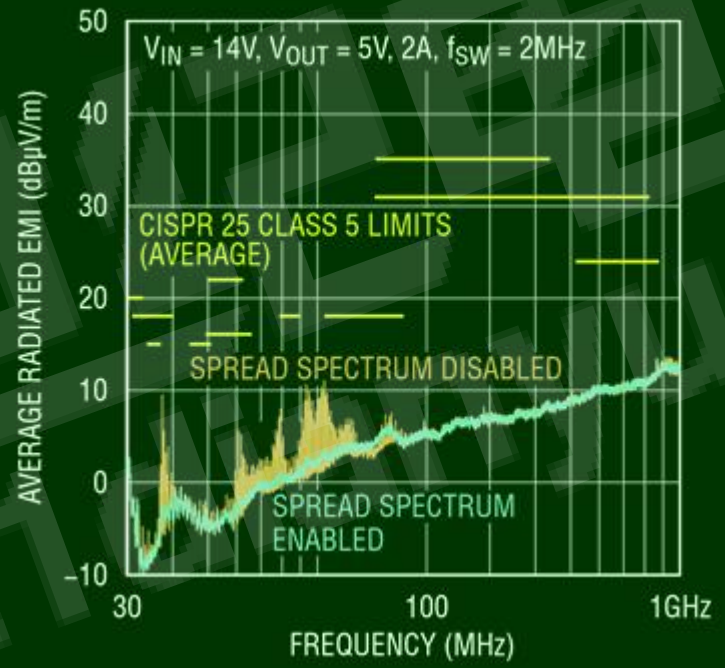
Innovation – Silent Switcher 2

No slew rate limit on switching node necessary to achieve low EMI !



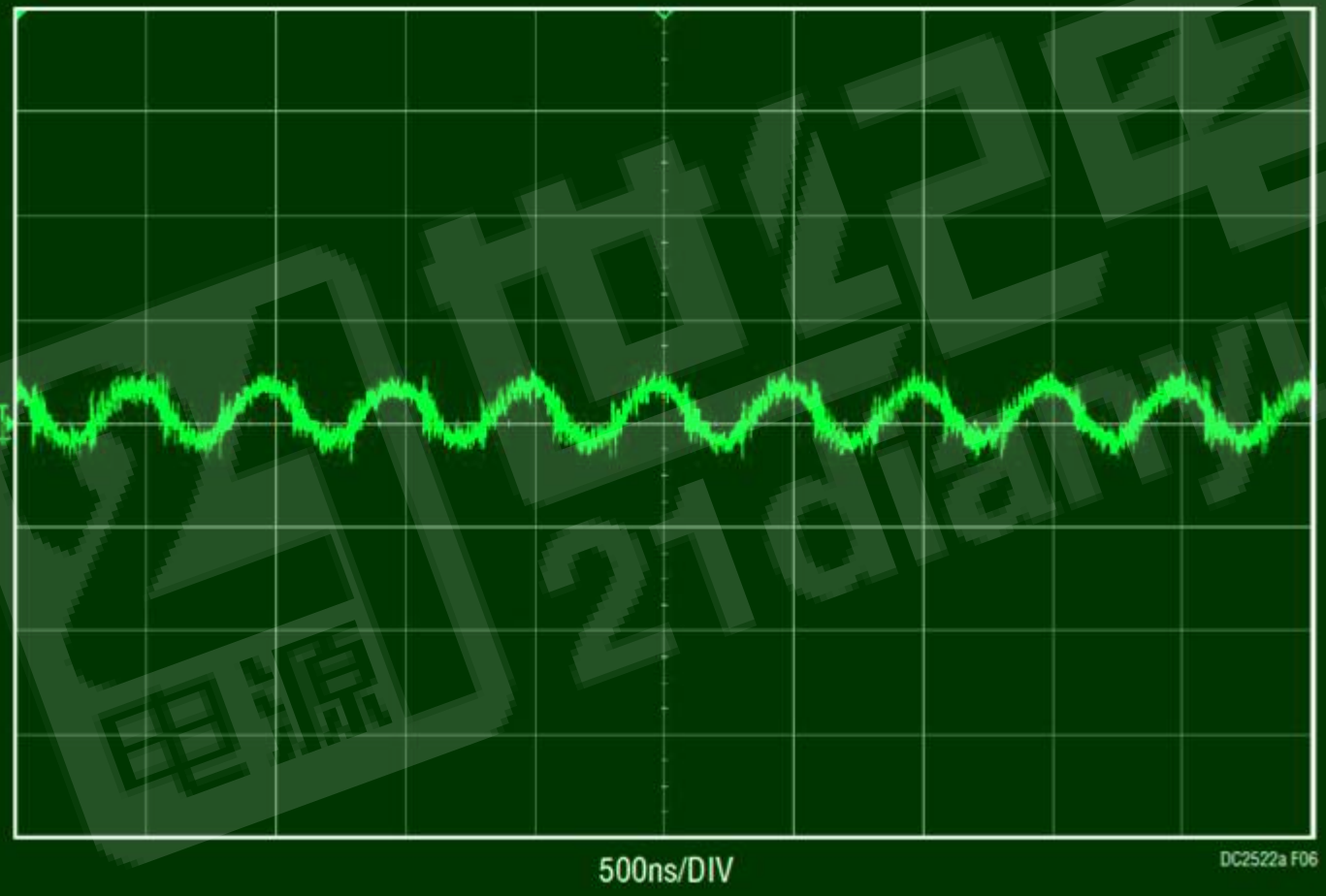
Silent Switcher 2 – Excellent EMI





Silent Switcher 2 Also Provides Low Output Ripple

LT8609S: 12V to 5V @ 2A, 2MHz switching



Silent Switcher Family

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Part Number	Silent Switcher Family	V_{IN} Range (V)	I_{OUT} (A)	$V_{OUT(MIN)}$ (V)	Frequency	I_Q (µA)	Package
65$V_{IN(MAX)}$							
LT8641	Silent Switcher	3.0 to 65	3.5	0.8	200kHz to 3MHz	2.5	3x4 QFN-18
LT8645S	Silent Switcher 2	3.4 to 65	8	0.8	200kHz to 2.2MHz	2.5	4x6 LQFN-32
42$V_{IN(MAX)}$							
LT8606	Low EMI	3.0 to 42	350mA	0.8	200kHz to 2.2MHz	3	2x2 DFN, MSOP10E
LT8607	Low EMI	3.0 to 42	750mA	0.8	200kHz to 2.2MHz	3	2x2 DFN, MSOP10E
LT8608	Low EMI	3.0 to 42	1.5	0.8	200kHz to 2.2MHz	2.5	2x2 DFN, MSOP10E
LT8609S	Silent Switcher 2	3.0 to 42	2/3 Peak	0.8	200kHz to 2.2MHz	2.5	3x3 LQFN-16
LT8609A	Low EMI	3.0 to 42	2/3 Peak	0.8	200kHz to 2.2MHz	2.5	3x3 DFN, MSOP10E
LT8614	Silent Switcher	3.4 to 42	4	0.97	200kHz to 2.2MHz	2.5	3x4 QFN-18
LT8653S	Silent Switcher 2	3.0 to 42	2x2/3 Peak	0.8	200kHz to 3MHz	6	3x4 LQFN-20
LT8640/-1	Silent Switcher	3.4 to 42	5/7 Peak	0.97	200kHz to 3MHz	2.5	3x4 QFN-18
LT8640S	Silent Switcher 2	3.4 to 42	5/7 Peak	0.97	200kHz to 3MHz	2.5	4x4 LQFN-24
LT8643S	Silent Switcher 2	3.4 to 42	5/7 Peak	0.97	200kHz to 3MHz	230	4x4 LQFN-24
LT8650S	Silent Switcher 2	3.0 to 42	2x4/6 Peak	0.8	200kHz to 3MHz	6.2	4x6 LQFN-32
LT8648S	Silent Switcher 2	3.0 to 42	15	0.6	200kHz to 3MHz	6	4x7 LQFN-36
18$V_{IN(MAX)}$							
LT8642S	Silent Switcher 2	2.8 to 18	10	0.6	200kHz to 3MHz	240	4x4 LQFN-24
LTC7151S	Silent Switcher 2	3.1 to 20	15	0.6	400kHz to 3MHz	2mA	4x5 LQFN-28
LTC7150S	Silent Switcher 2	3.1 to 20	20	0.6	400kHz to 3MHz	2mA	5x6 BGA-42
LT8652S	Silent Switcher 2	3.0 to 18	8+8	0.6	300kHz to 3MHz	6	4x7 LQFN-36
5$V_{IN(MAX)}$							
LTC3307/8/9	Silent Switcher	2.25 to 5.5	3/4/6	0.5	500kHz to 5MHz	45	2x2 LQFN-12
LTC3315	Silent Switcher	2.25 to 5.5	2+2	0.5	500kHz to 5MHz	70	2x2 LQFN-12
LTC3310S	Silent Switcher 2	2.25 to 5.5	10	0.5	500kHz to 5MHz	1.3mA	3x3 LQFN-18
LT8647S	Silent Switcher 2	2.8 to 8	7	0.6	300kHz to 4MHz	140	3x4 LQFN-20
LT8644S	Silent Switcher 2	2.8 to 8	15	0.6	300kHz to 4MHz	145	4x4 LQFN-24

DEVICE	OUT PUTS	V_{IN} RANGE	OUTPUT CURRENT	PEAK EFFICEINCY	I_Q	FEATURES	PACKAGES
LT8650S	2	3V – 42V	4A + 4A on both channels	94.60%	6.2µA	Silent Switcher 2	6mm x 4mm x 0.95mm LQFN
LT8645S	1	3.4V – 65V	8A	94%	2.5µA	Silent Switcher 2	6mm x 4mm x 0.95mm LQFN
LT8643S	1	3.4V – 42V	6A continuous 7A peak	95%	120µA	Silent Switcher 2, external compensation	4mm x 4mm x 0.94mm LQFN
LT8640S	1	3.4V – 42V	6A continuous 7A peak	95%	2.5µA	Silent Switcher 2	4mm x 4mm x 0.94mm LQFN
LT8609S	1	3V – 42V	2A continuous 3A peak	93%	2.5µA	Silent Switcher 2	3mm x 3mm x 0.94mm LQFN
LT8640	1	3.4V – 42V	5A continuous 7A peak	95%	2.5µA	Silent Switcher, LT8640 pulse skipping,	3mm x 4mm QFN-18
LT8641	1	3V – 65V	3.5A continuous 5A peak	94%	2.5µA	Silent Switcher	3mm x 4mm QFN-18
LT8614	1	3.4V – 42V	4A	94%	2.5µA	Silent Switcher. Low ripple Burst Mode operation	3mm x 4mm QFN-18

Improve efficiency

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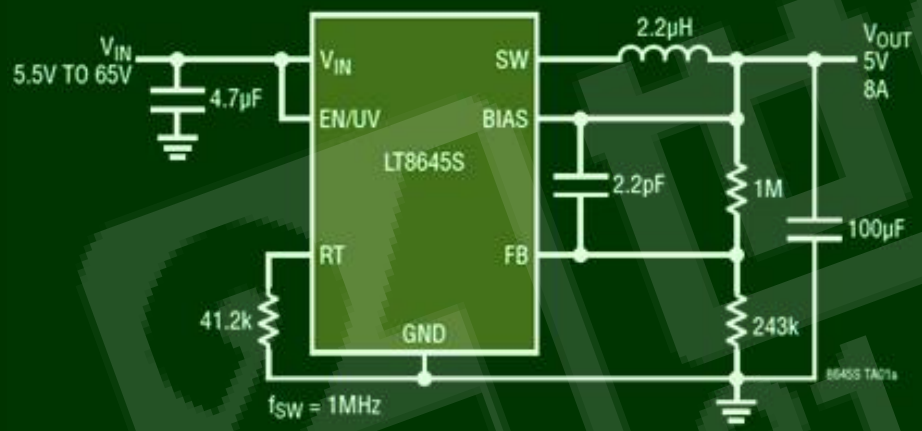
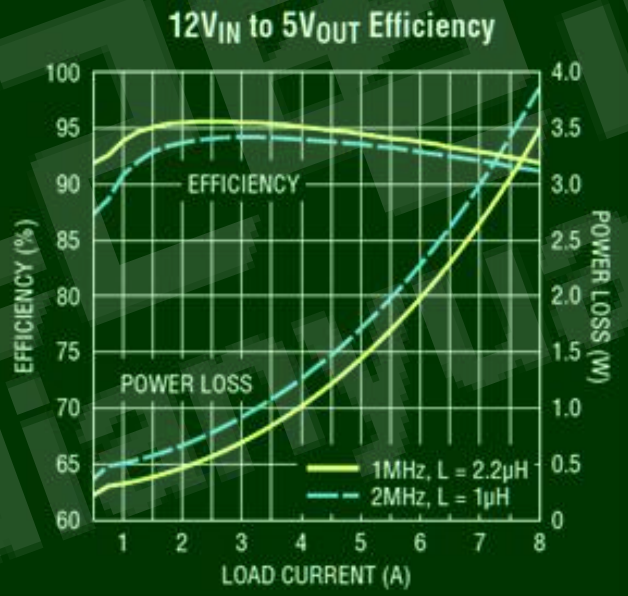
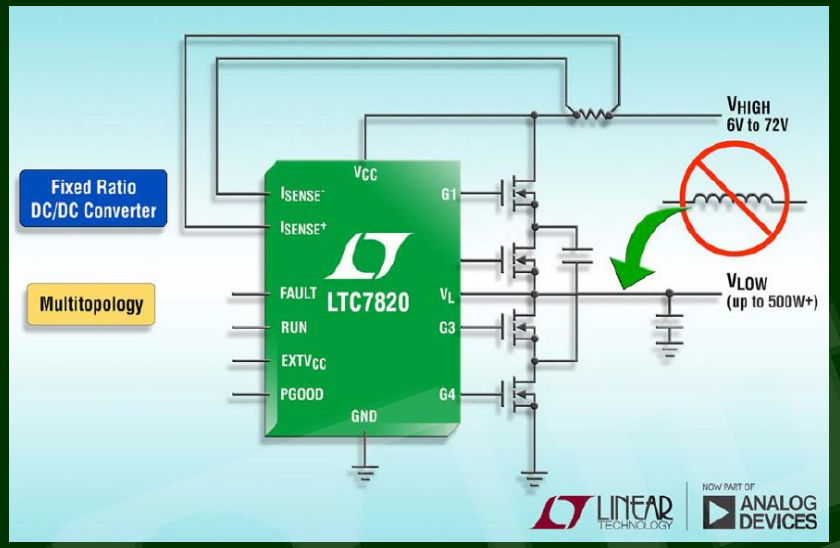
TYPICAL APPLICATION

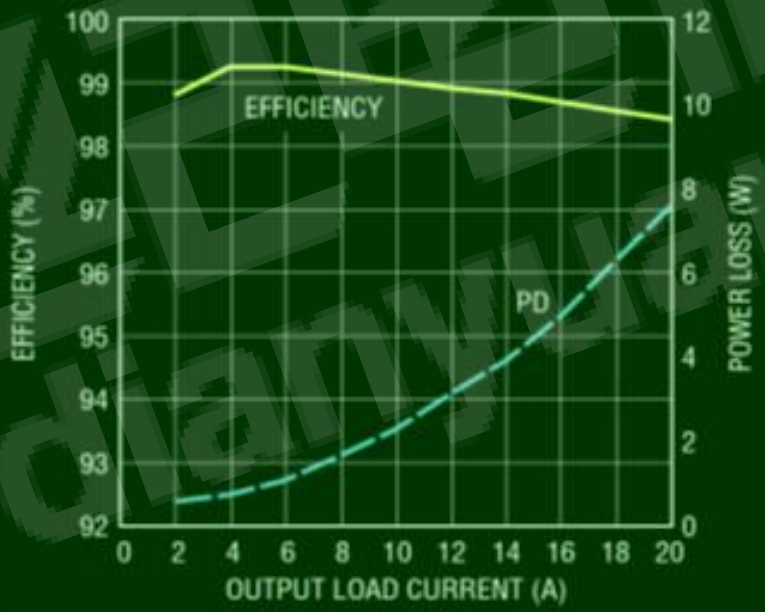
5V 8A Step-Down Converter

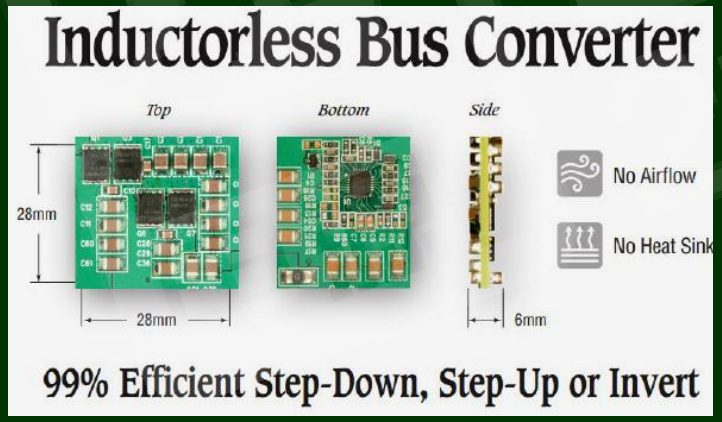




Improve efficiency







Improve efficiency

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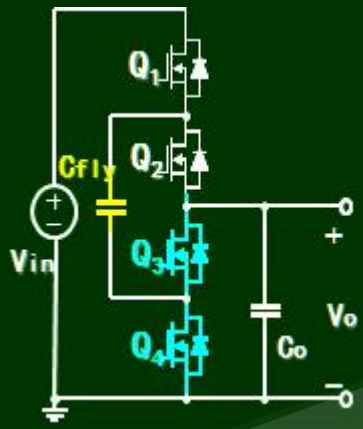
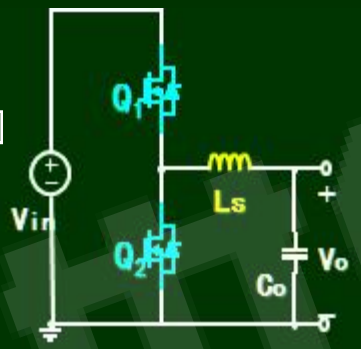
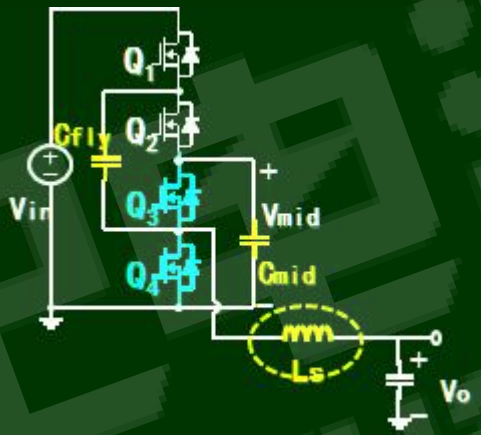
Switched Capacitor

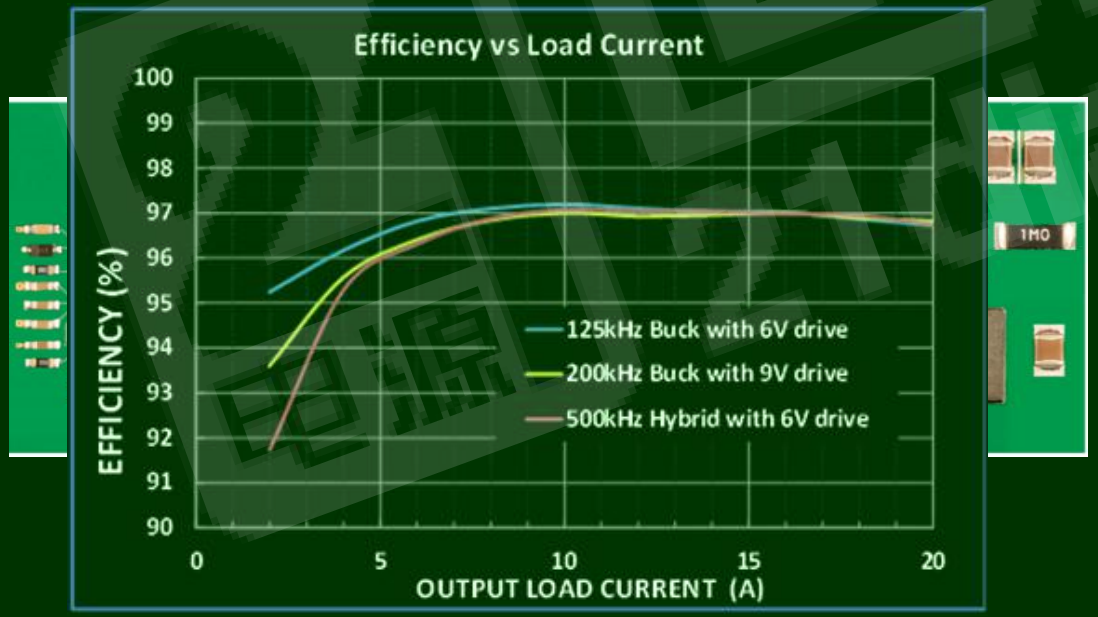


Synchronous Buck



❖ Hybrid Converter





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封装与散热

功率密度与尺寸及效率（散热）有很大关系

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FPGA Core 0.8V @100A
Power Supplier Solution

Year 2012
4x LTM46

Year 2014
3x LTM46

Year 2016
2x LTM46

Form Factor

ADI

1 x LTM4700
（July 2018）

功率密度与尺寸及效率（散热）有很大关系

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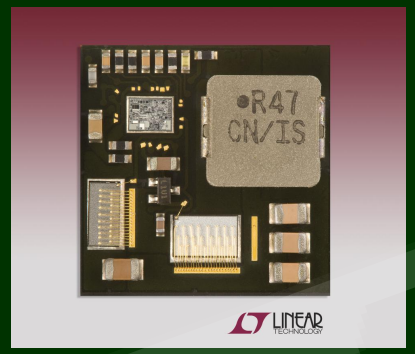
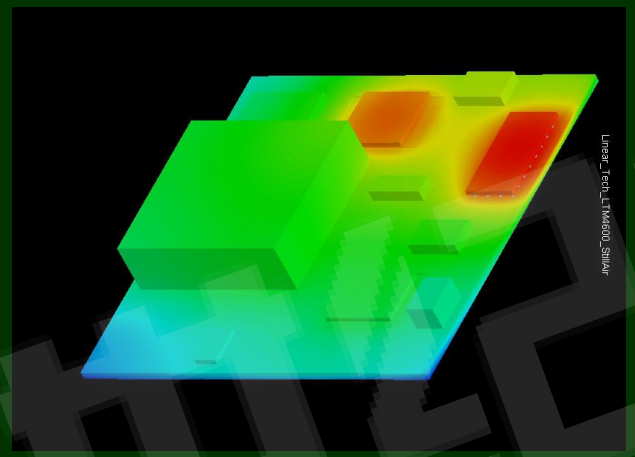
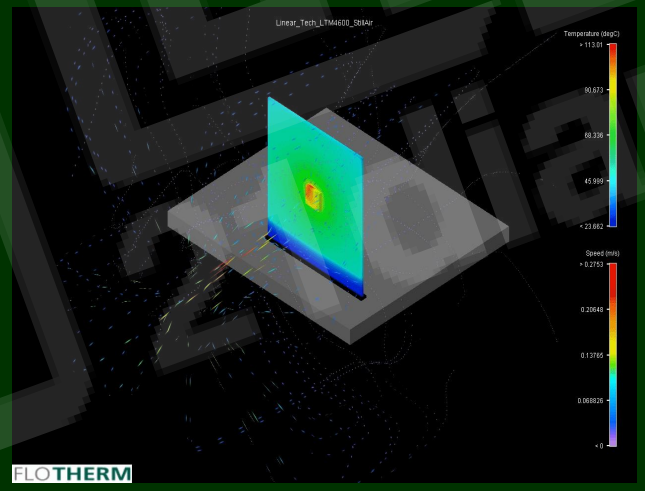
10A-12A







功率密度与尺寸及效率（散热）有很大关系

ANALOG DEVICES
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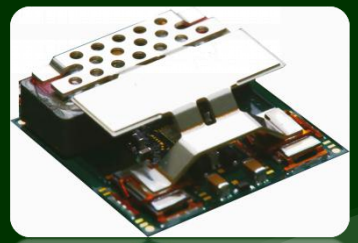
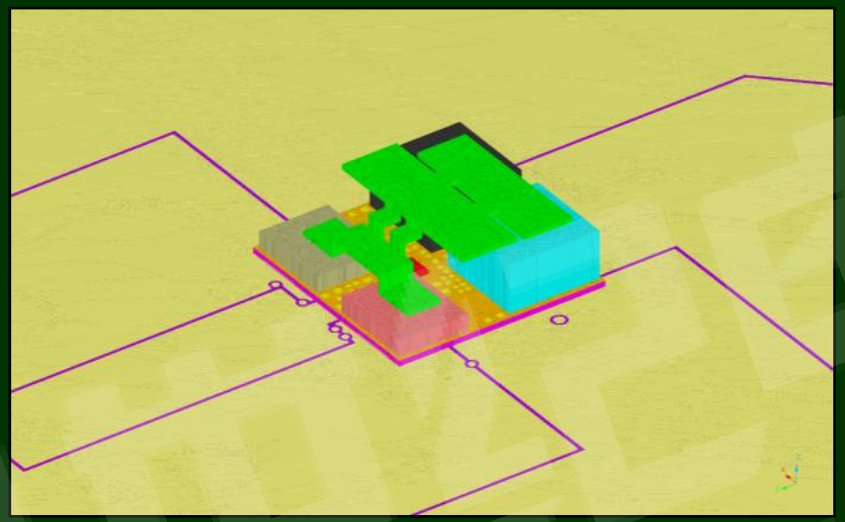
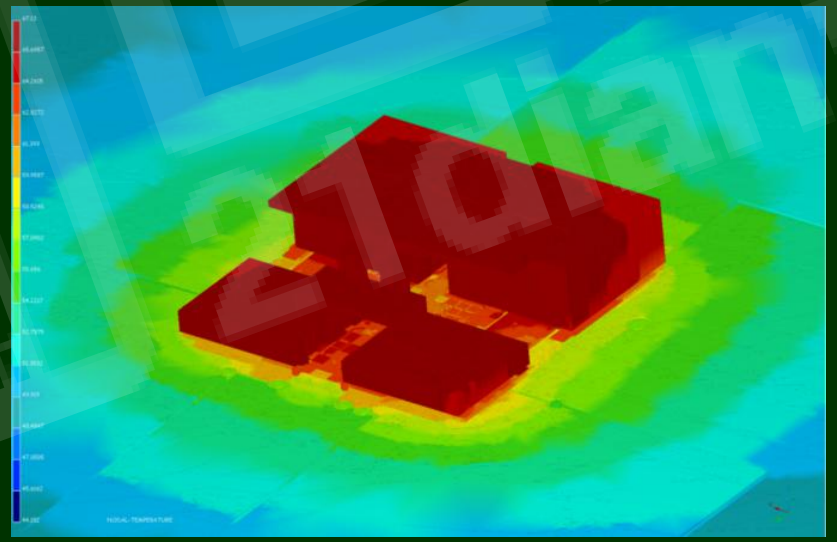
26A-50A







功率密度与尺寸及效率（散热）有很大关系

ANALOG DEVICES
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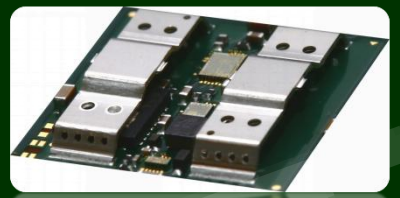
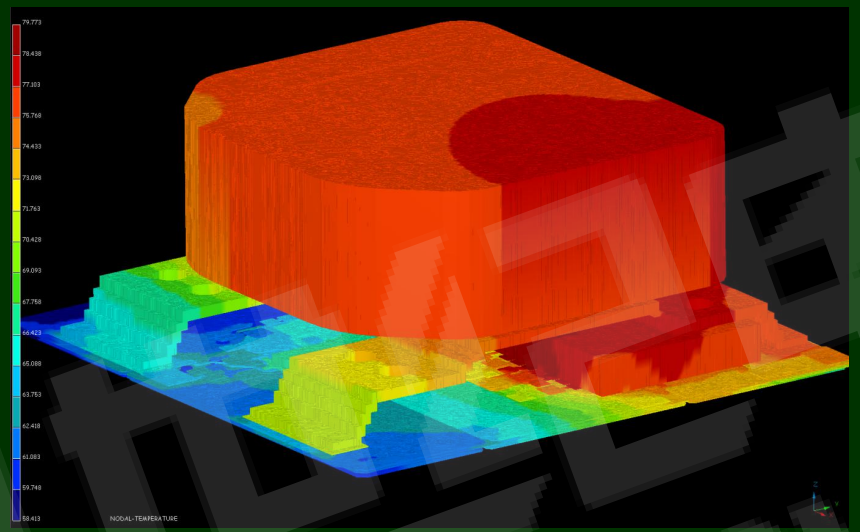
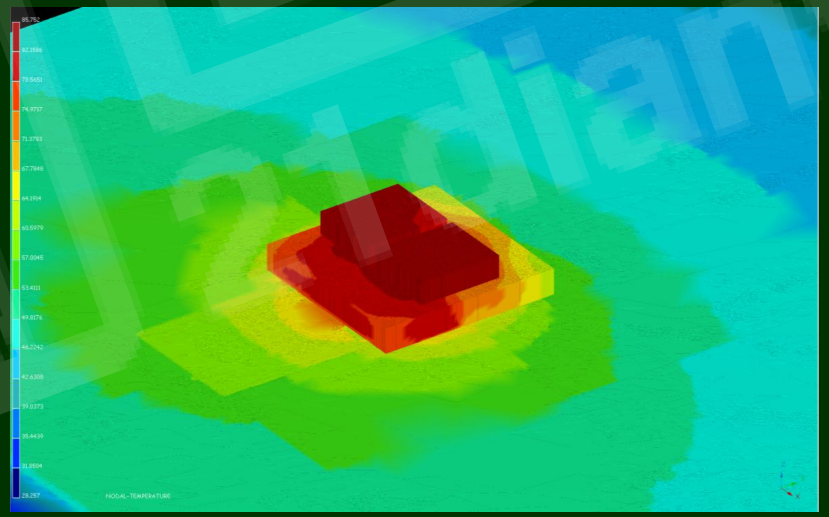
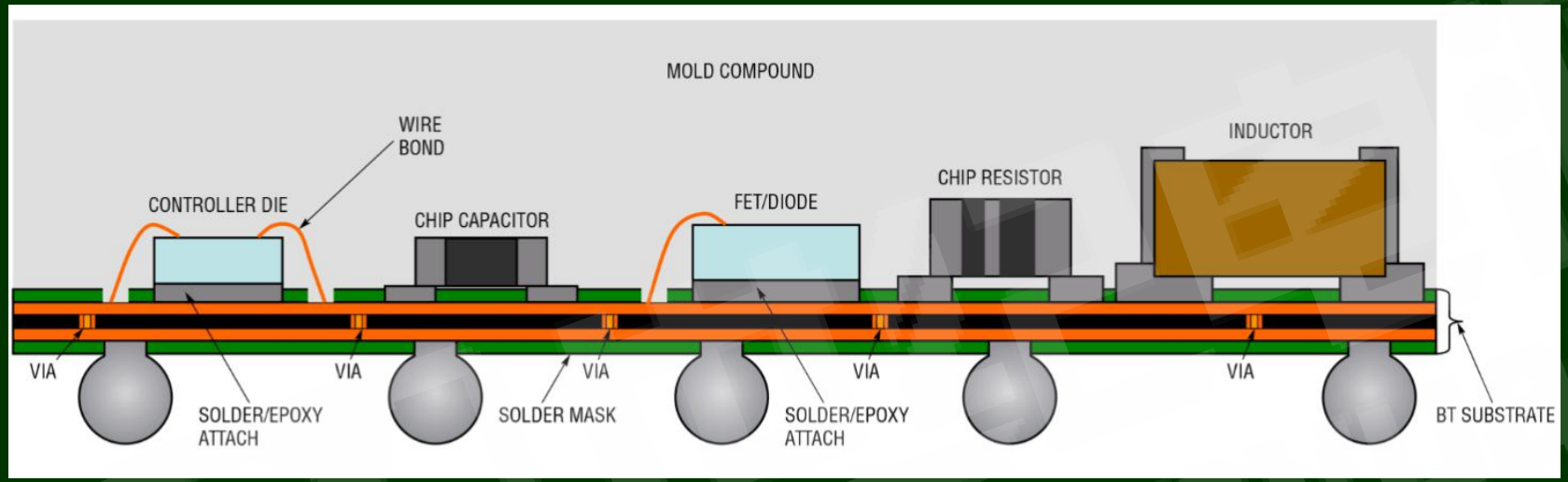
40A+

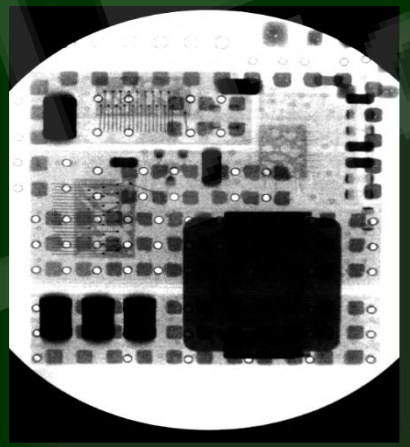




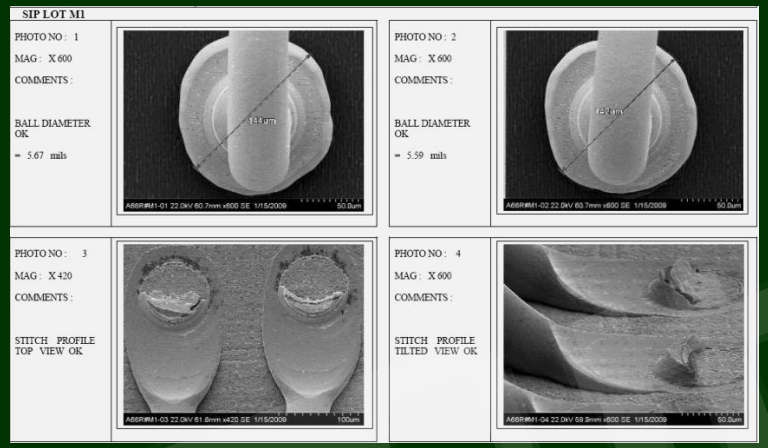


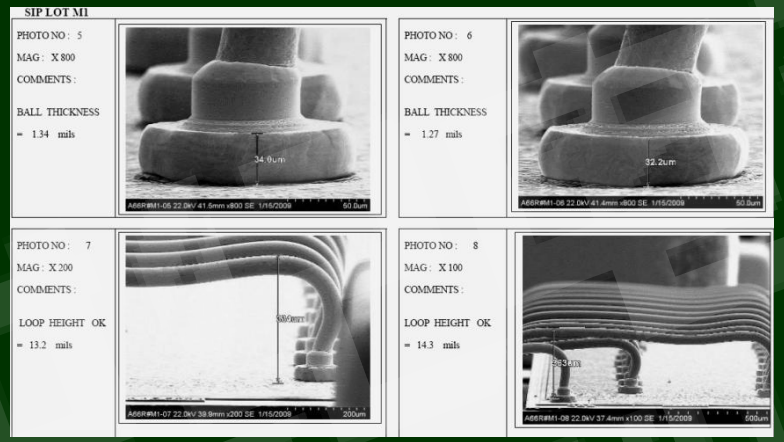
功率密度与尺寸及效率（散热）有很大关系

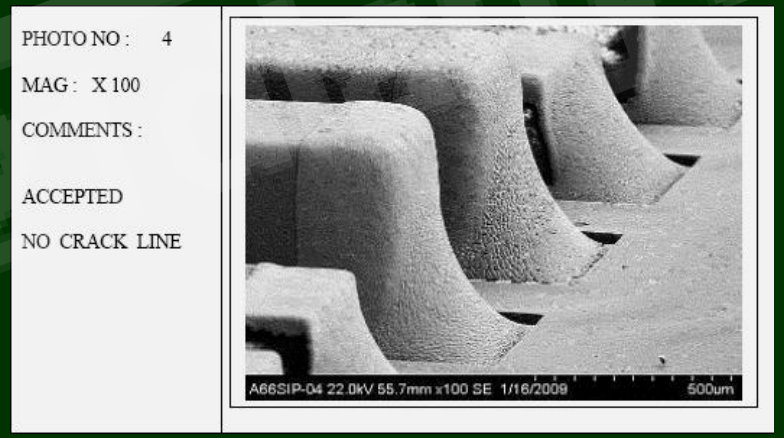




封装可靠性问题







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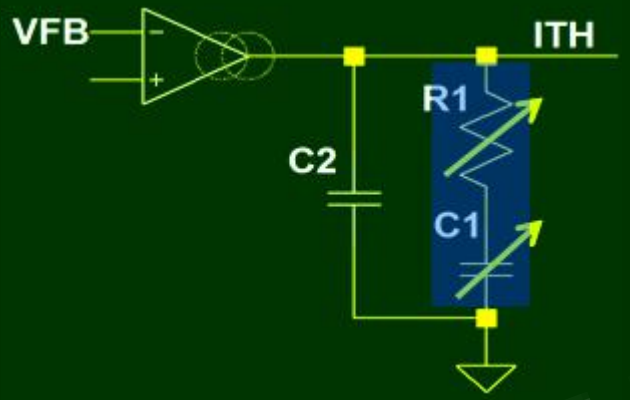
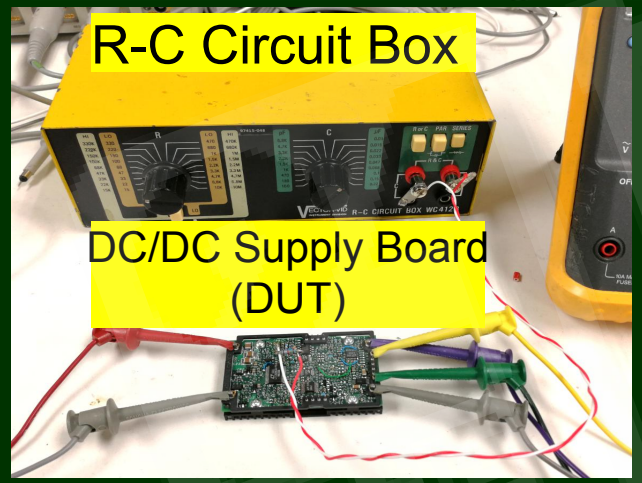
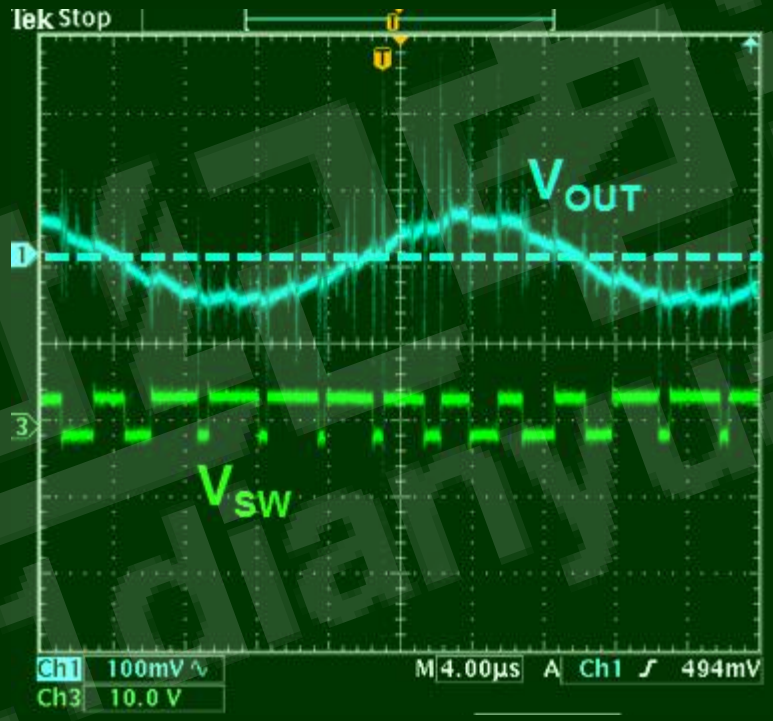
Power Supply Design Using LTpowerCAD Design Tool

电源环路优化设计







- Manually adjust R and C values.
- Check loop or load transient.
- **Accurate, but time-consuming.**

Complete Power Design Flow with Tools …

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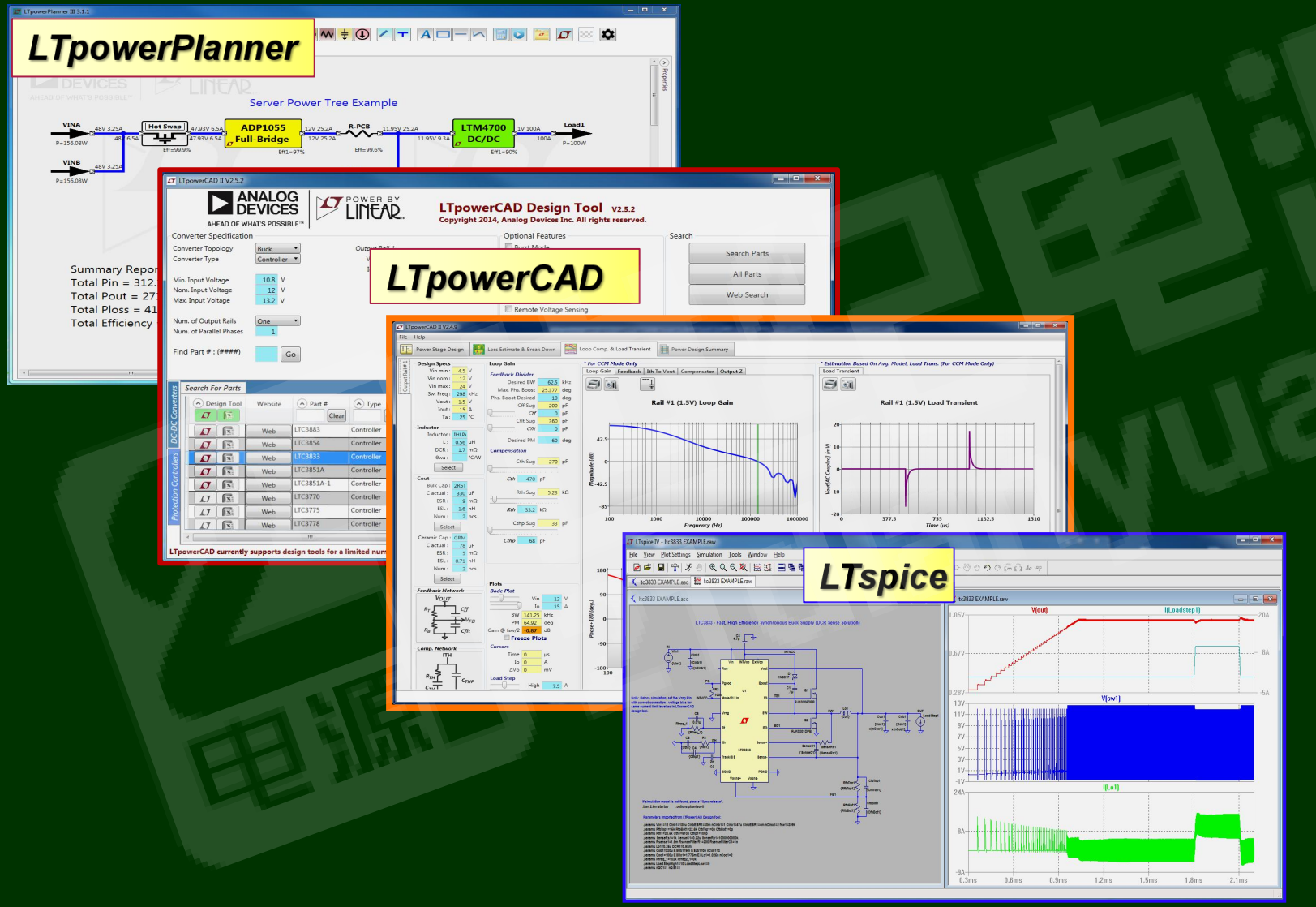

LTpowerCAD – Design Power in 5 Simple Steps!

ANALOG DEVICES
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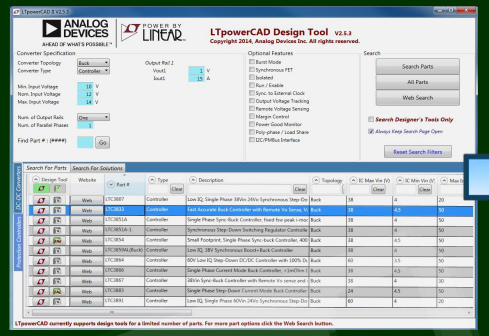
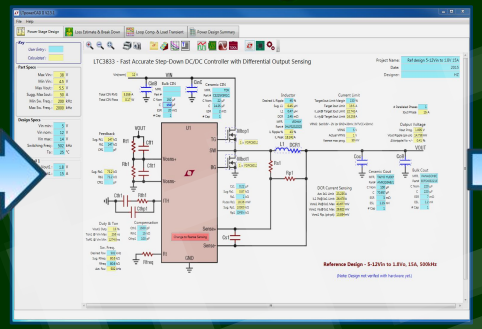
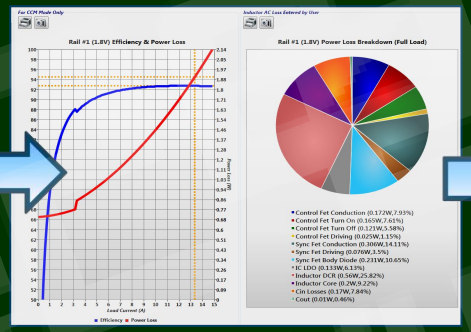
Step 1
Find Solutions



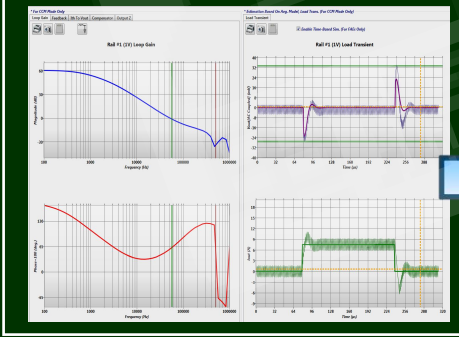
Step 2
Power Stage Design



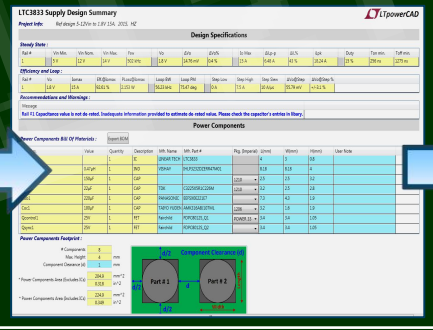
Step 3
Efficiency & Loss



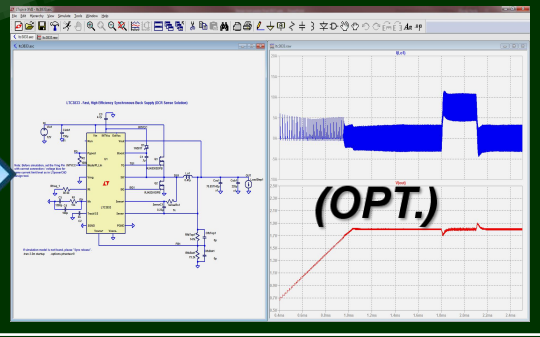
Step 4
Loop & Transient



Step 5
Summary, BOM, Size



LTspice™



LTpowerCAD Main Window

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Design Step 1- Enter Spec, Search a Part

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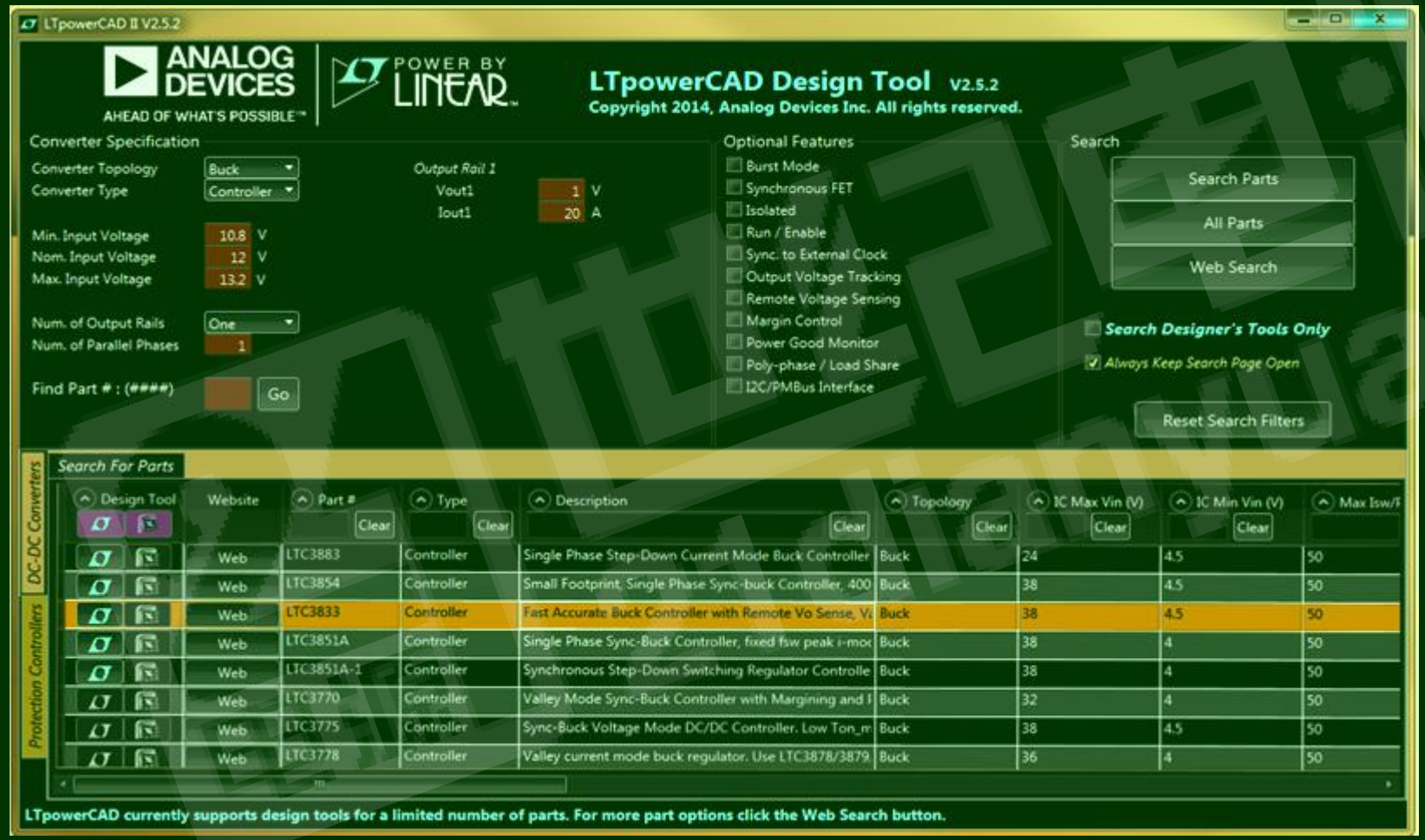

Step 2 – Power Stage Design – fSW, L, C, etc.

ANALOG DEVICES
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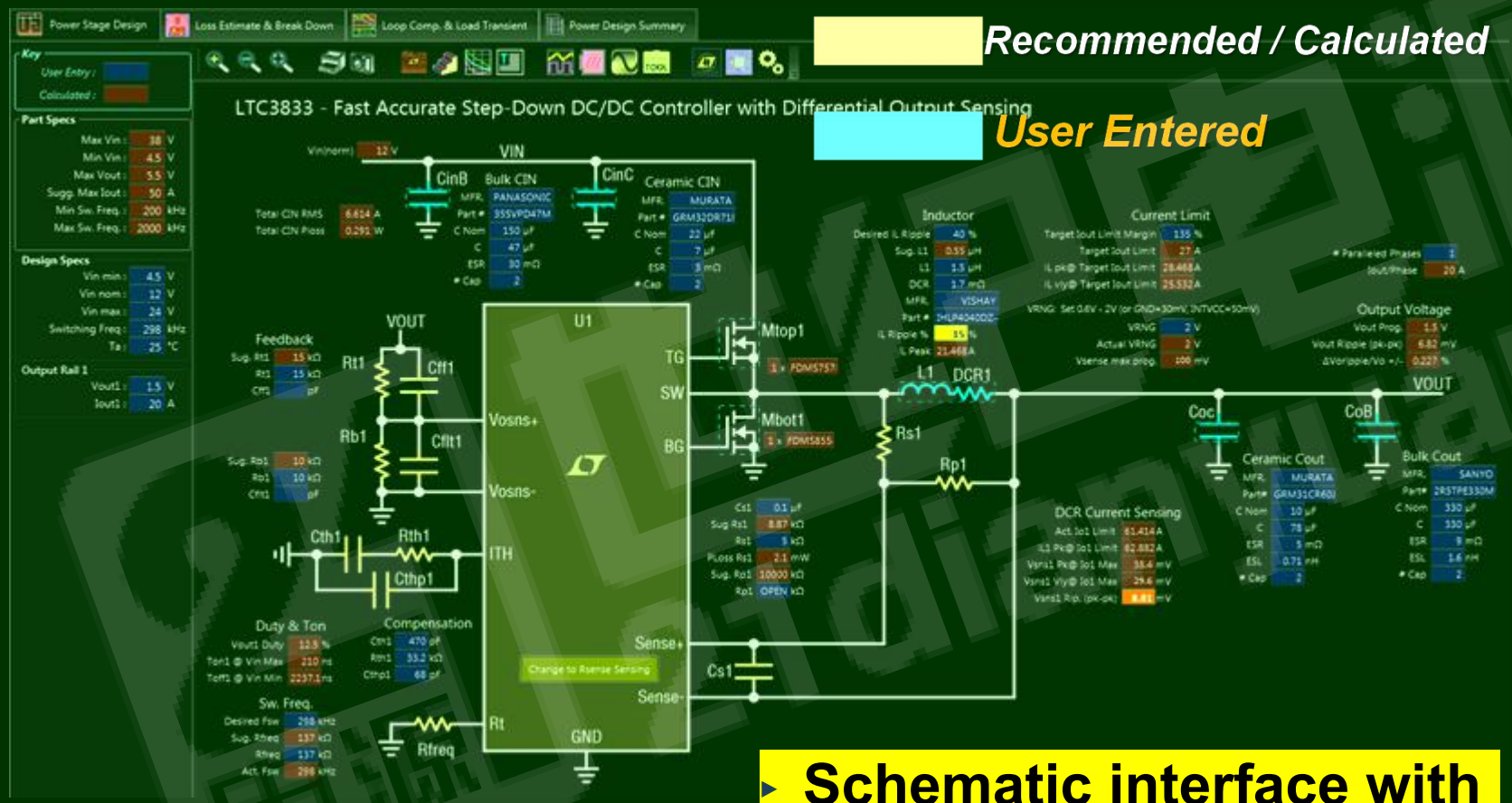


Recommended / Calculated

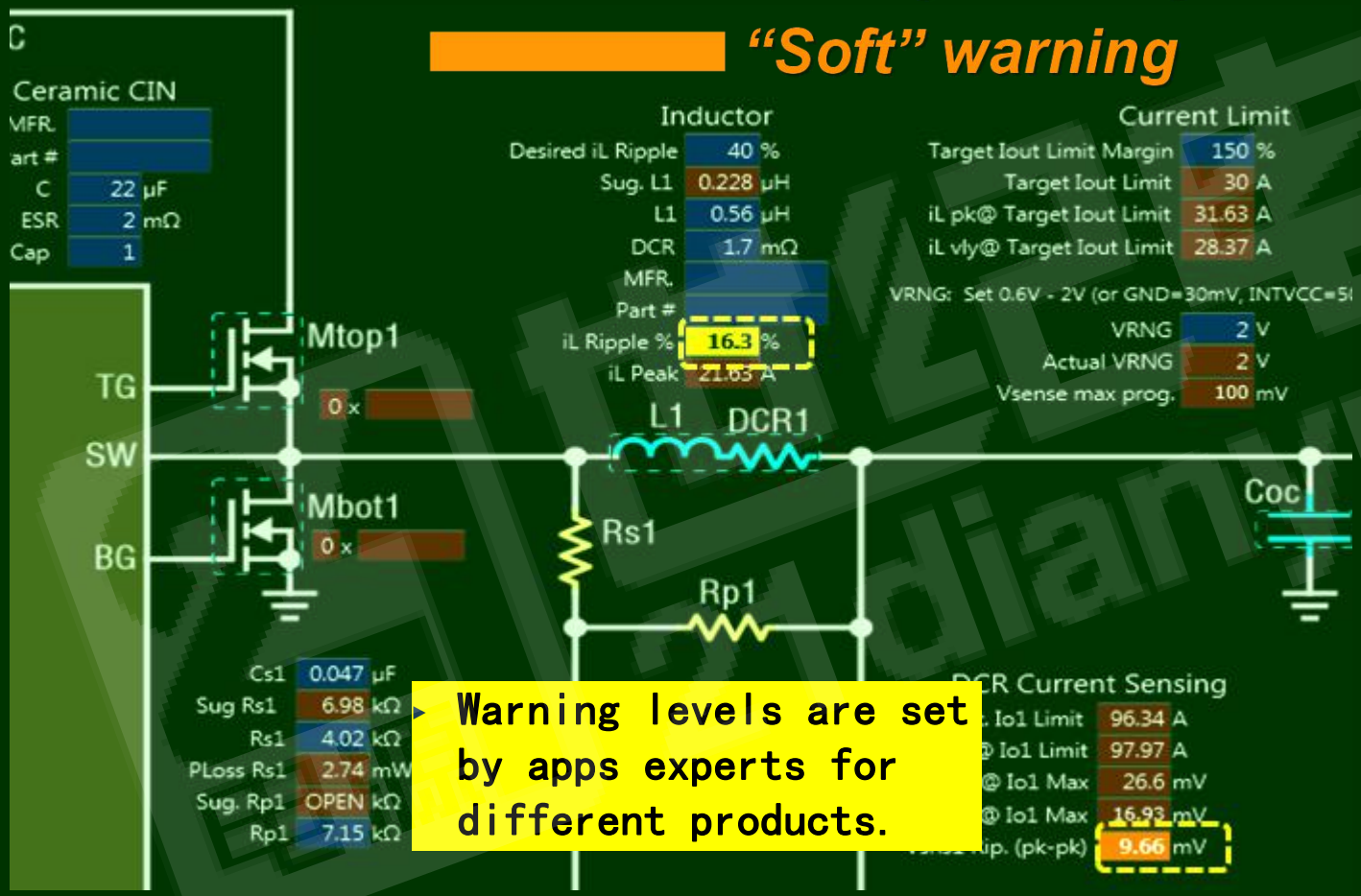
User Entered

- **Schematic interface with key component designs**

Step 2 – Power Stage – ‘Smart’ Warnings

Strong warning

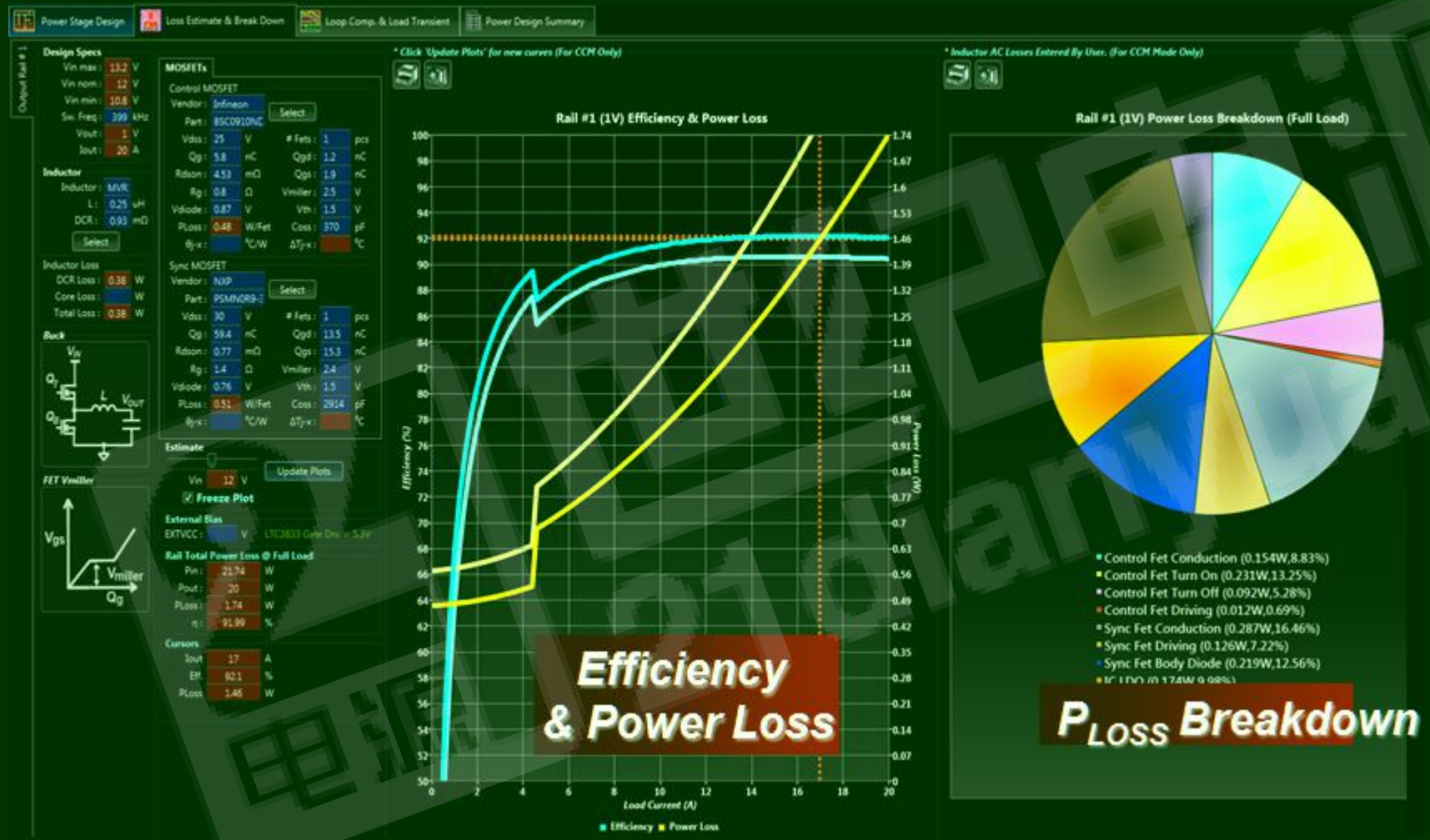
“Soft” warning



Warning levels are set by apps experts for different products.

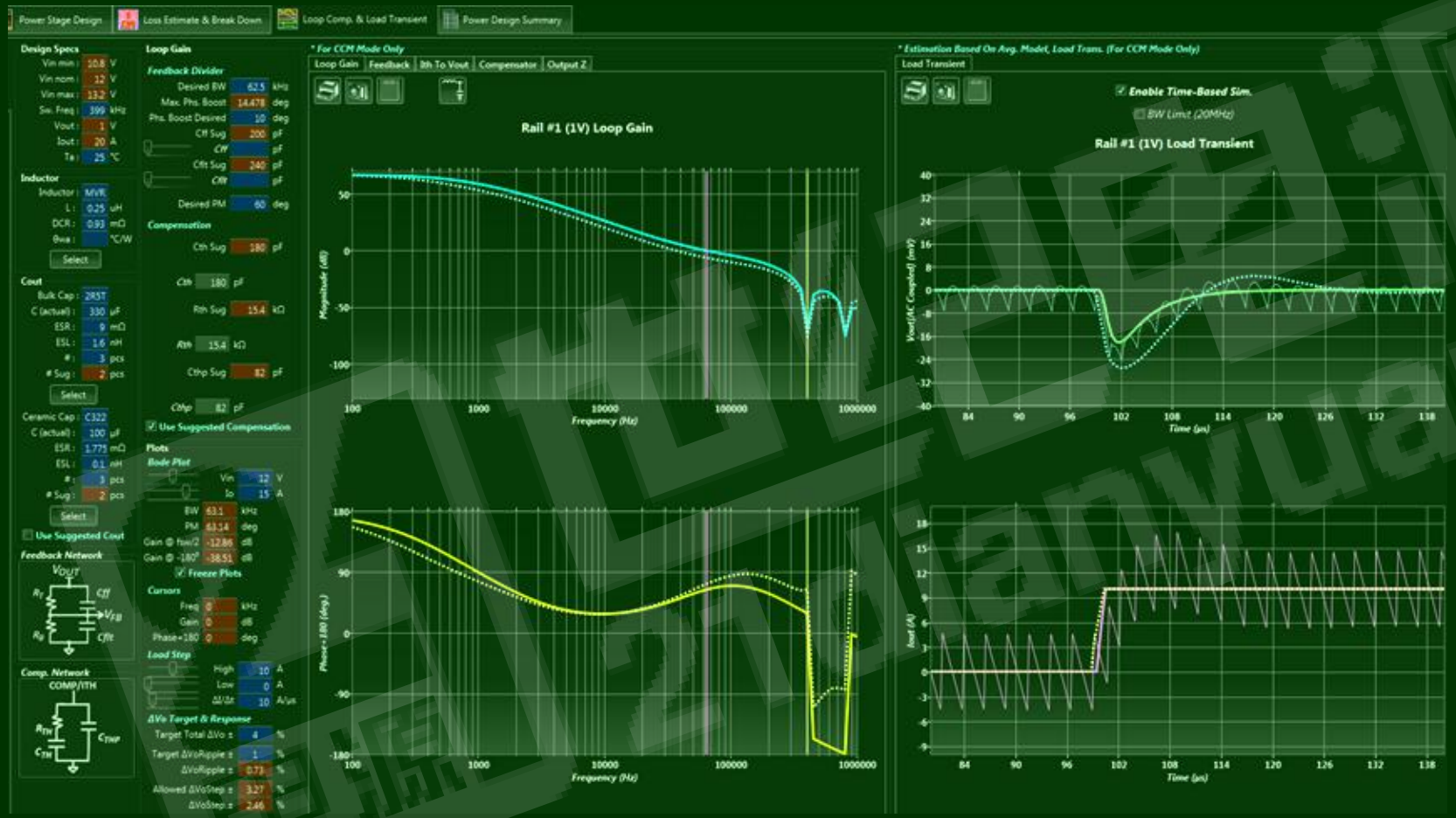
Automatic warnings guide to proper values

Step 3 – Efficiency Optimization



Real-time Estimations for Optimum η%

Step 4- Feedback Loop & Transient Designs



Real-time Loop & Transient Optimization

Step 5- Design Summary, BOM, Size

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Loss Estimate & Break Down | Loop Comp. & Load Transient | Power Design Summary

Print Summary Report

Summary Report

LTC3833 Supply Design Summary

Project Info: *Ref Design 12Vin to 1V/20A, 10/2014, H.Z.*

Design Specifications

Performance Summary

Steady State :

Rail #	Vin Min.	Vin Nom.	Vin Max.	Fsw	Vo	ΔVo rip. p-p	ΔVo rip.%	Io Max
1	10.8 V	12 V	13.2 V	399 kHz	1 V	7.82 mV	0.4 %	20 A

Efficiency and Loop :

Rail #	Vo	Iomax	Eff.@Iomax	PLoss@Iomax	Loop BW	Loop PM	Step Low	Step High	Step Slew	ΔVo@Step	ΔVo@Step %
1	1 V	20 A	91.99 %	1.741 W	79.43 kHz	79.26 deg	0 A	10 A	10 A/µs	22.1 mV	+/-2.2 %

Recommendations and Warnings :

Message

Power Components

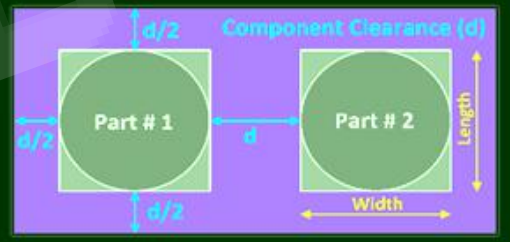
Power Components Bill Of Materials : Export BOM

BOM

Ref. Des.	Value	Quantity	Description	Mfr. Name	Mfr. Part #	Pkg. (Imperial)	L(mm)	W(mm)	H(mm)	User Note
U1		1	IC	LINEAR TECH	LTC3833		4	3	0.8	
Lo1	0.25µH	1	IND	COILCRAFT	MVR1251T-251		11.5	9.75	5.1	
Cinb1	180µF	1	CAP	PANASONIC	16SVP180MX	F8	10.3	10.3	7.9	
Cinc1 Cinc2	47µF	2	CAP	MURATA	GRM32ER61C476KE15	1210	3.2	2.5	1.7	
Cob1 Cob2 Cob3	330µF	3	CAP	SANYO	2R5TPE330M9	D2E	7.3	4.3	1.8	
Coc1 Coc2	100µF	2	CAP	TDK	C3225X5R0J107M	1210	3.2	2.5	1.7	
Qcontrol1	25V	1	FET	Infineon	BSC0910NDI_Q1		6.35	5.35	1.1	
Qsync1	30V	1	FET	NXP	PSMN0R9-30YLD		6	5	1.7	

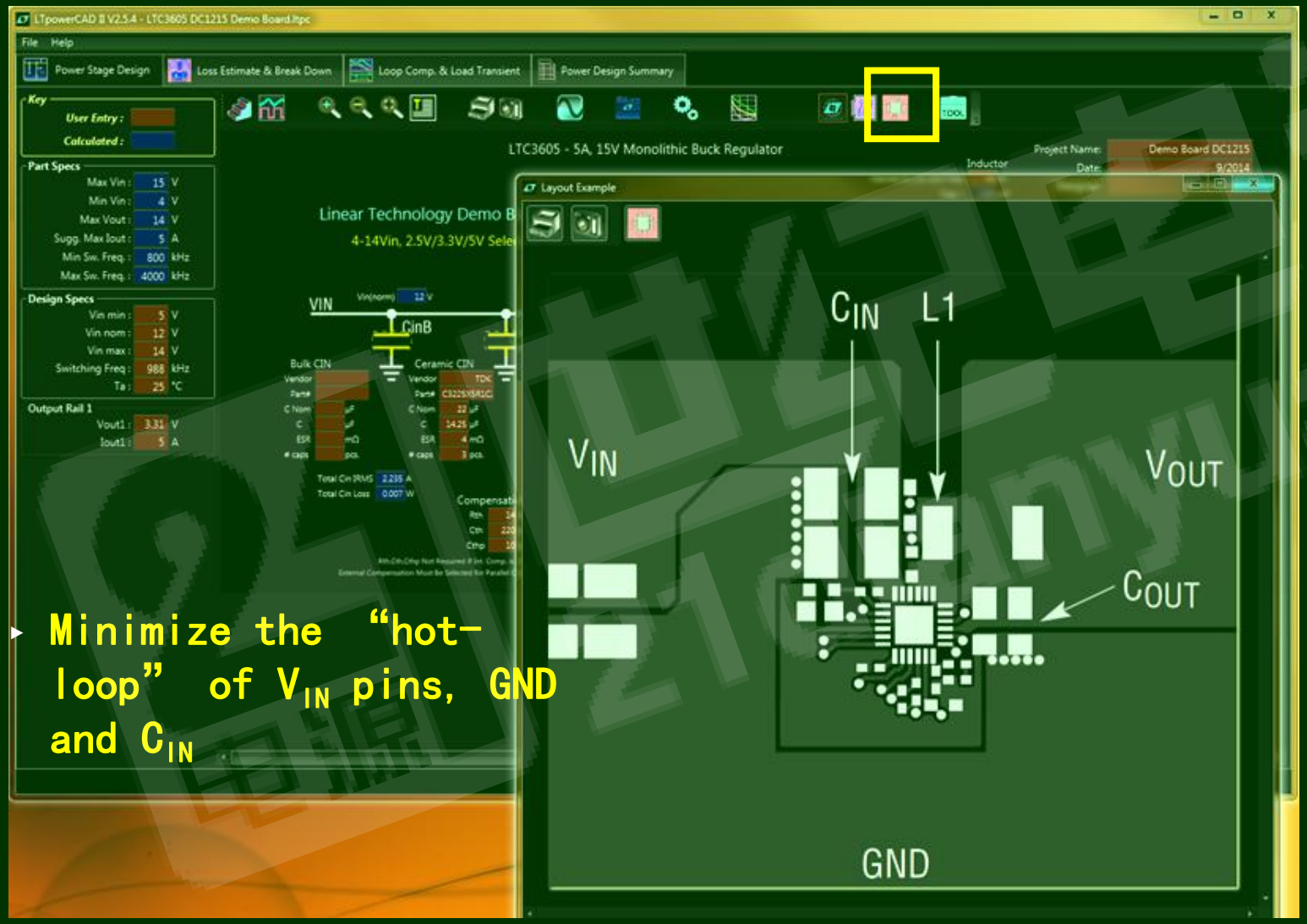
Power Components Footprint :

# Components	12	
Max. Height	7.9	mm
Component Clearance (d)	1	mm
* Power Components Area (Excludes ICs)	541.5	mm^2
	0.839	in^2
* Power Components Area (Includes ICs)	561.5	mm^2
	0.87	in^2



Solution Size

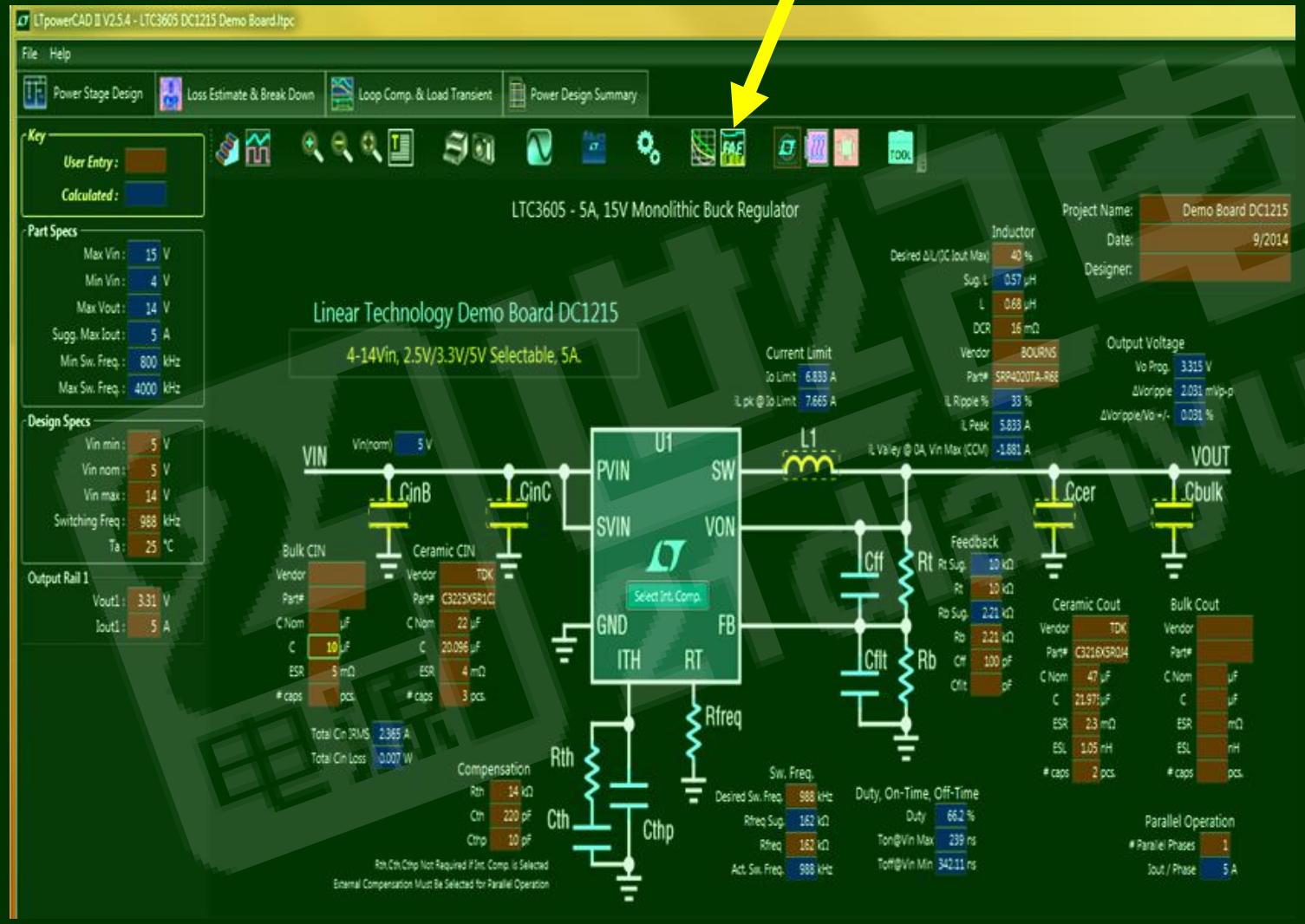
PCB Layout reference



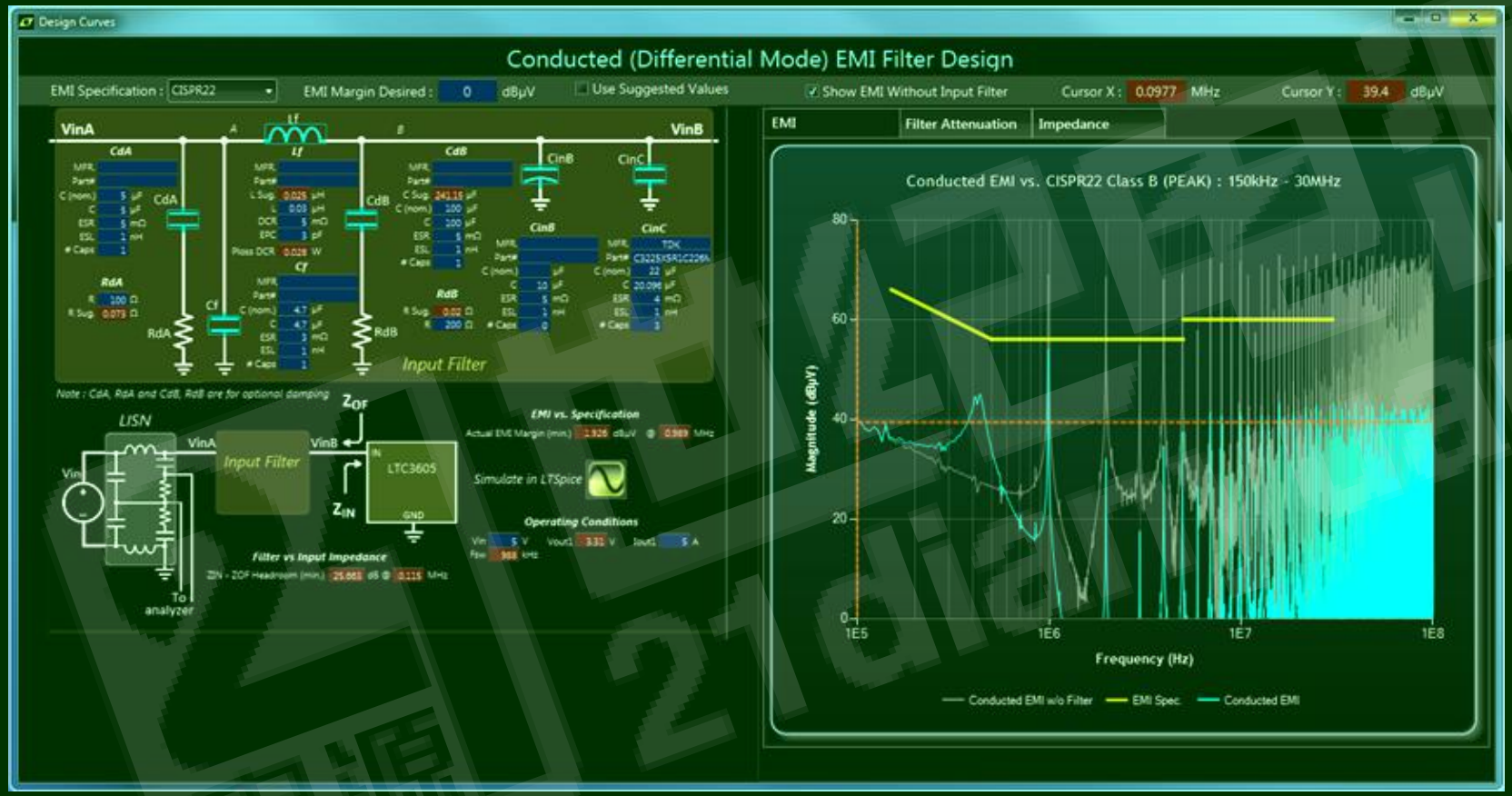
- Minimize the "hot-loop" of V_{IN} pins, GND and C_{IN}

LTpowerCAD DM Conducted EMI Filter Tool

- Open the EMI tool from the icon on schematic page.

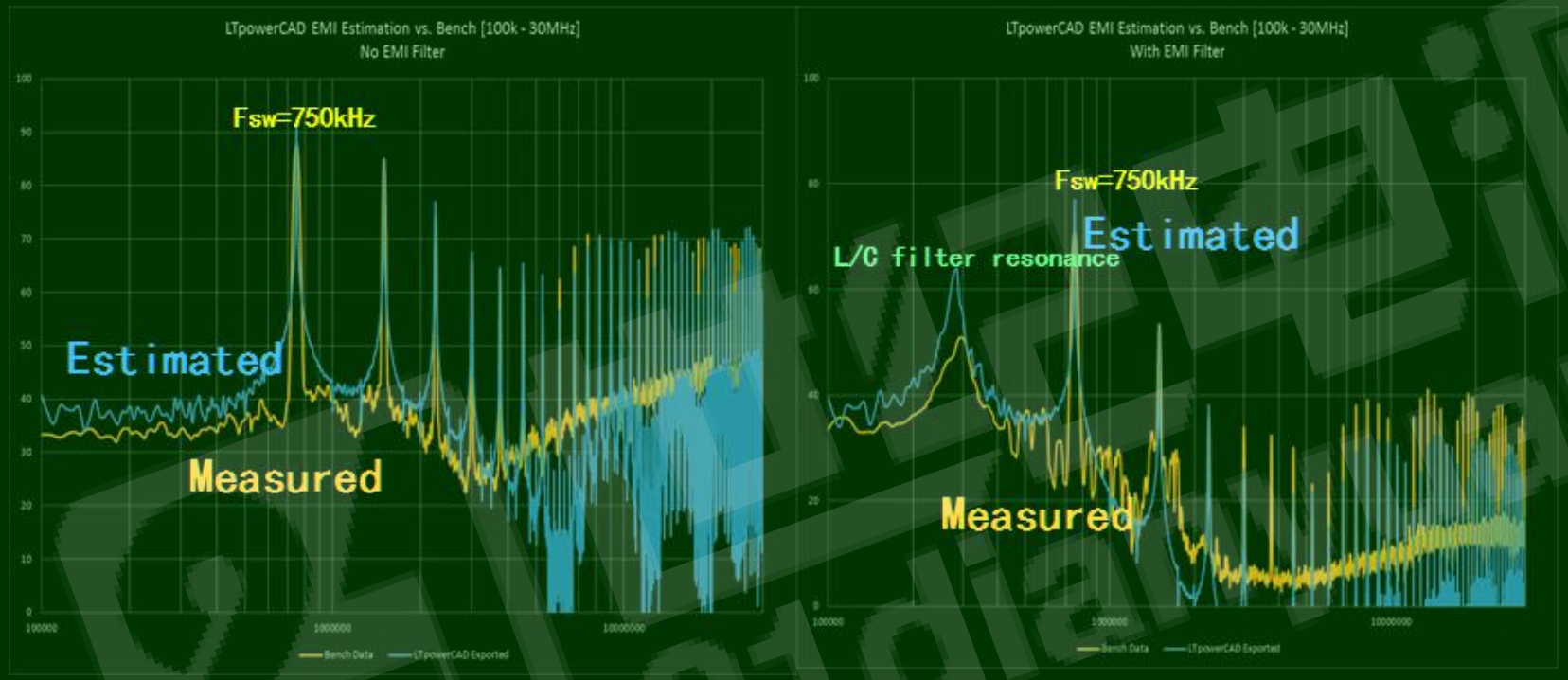


DM EMI Filter Design – Integrated in LTpowerCAD



- First few orders of harmonics determine the filter size.

DM EMI Noise – Estimated vs. Measured Data



- LTC3851A single phase buck demo board.
  (12Vin to 1.5Vo/15A, 750kHz).
  - Good matching of peak values.

LT power CAD 下载 - 免费！！！

- LTpowerCAD power supply design tool
- Free download @ www.analog.com/LTpowerCAD
- Runs on Windows PC.

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Application Example
How to get balance with 3 Key Metrics

Typical signal sampling system power design

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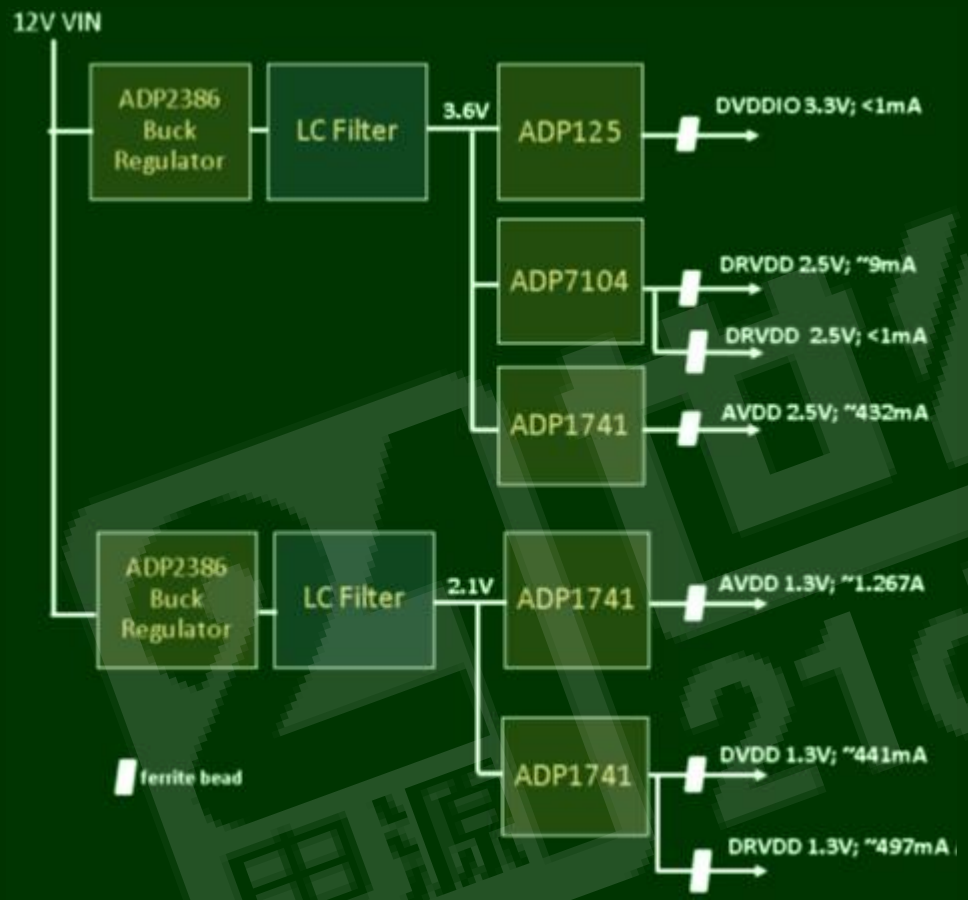

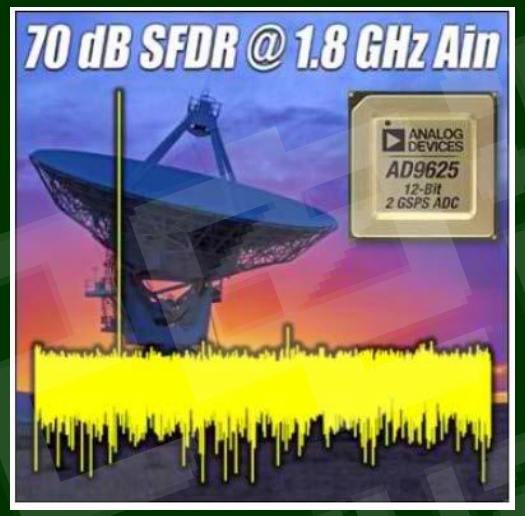

- Good Performance
- 48% efficiency
- Thermal issue
- Big power size

Package technology improves performance

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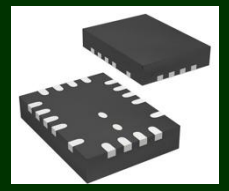
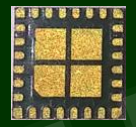
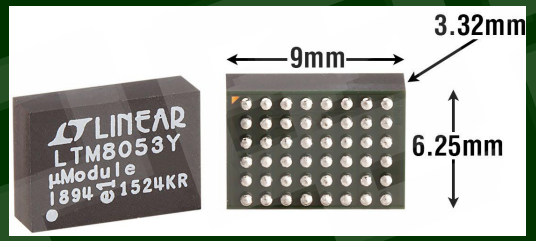
LT8640
QFN

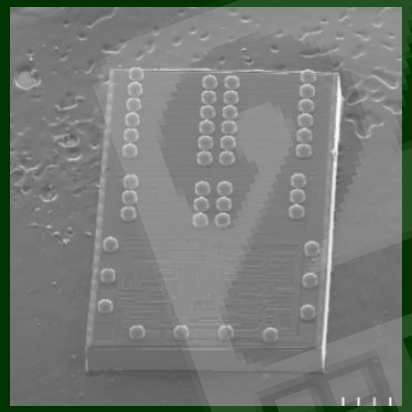


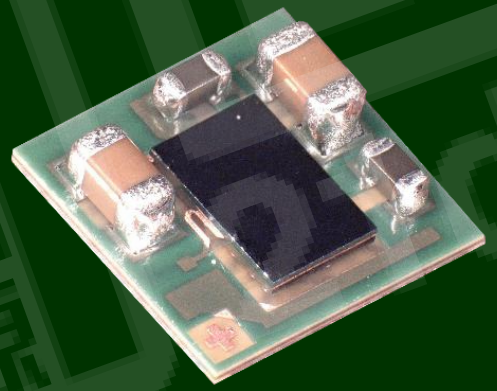
LT8640S
(BT laminate LGA)

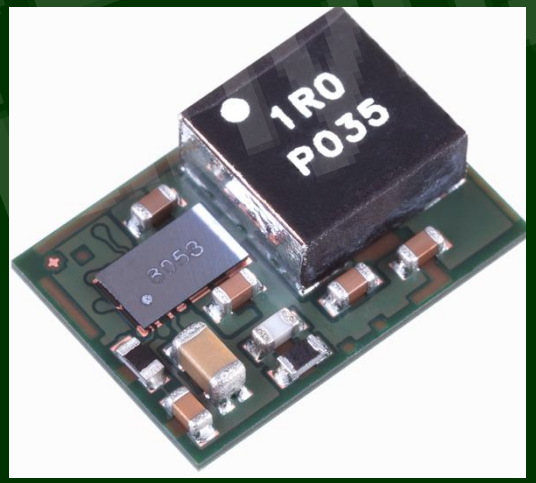


LTM8053
6x9 BGA









40Vin Silent Switcher µModule Regulators

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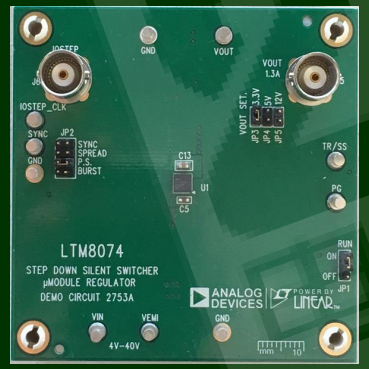
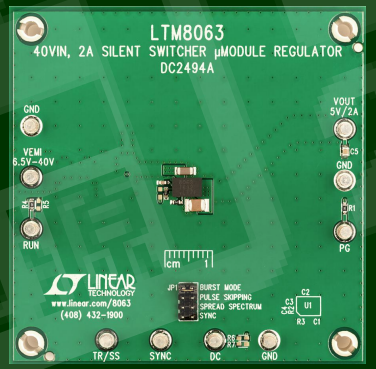
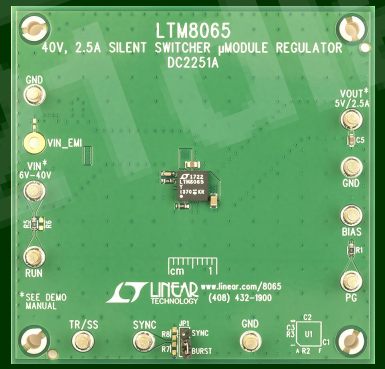
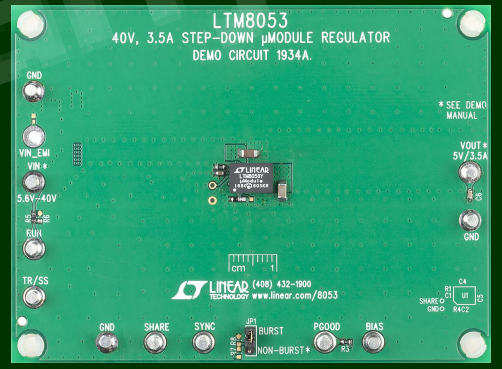
	LTM8074	LTM8063	LTM8065	LTM8053
Silent Switcher	Yes			
CISPR22 Class B	Yes			
Vin Range	3.2V to 40V	3.2V to 40V	3.4V to 40V	3.4V to 40V
Vout Range	0.8V to 12V	0.8V to 15V	0.97V to 15V	0.97V to 15V
Iout	1.2A (Continuous) 1.75A (Peak)	2A (Continuous) 2.5A (Peak)	2.5A (Continuous) 3.5A (Peak)	3.5A (Continuous) 6A (Peak)
Switching Frequency		200kHz to 2.2MHz	200kHz to 3MHz	200kHz to 3MHz
Package Size (mm)	4 x 4 x 2.22	4 x 6.25 x 2.22	6.25 x 6.25 x 2.32	6.25 x 9 x 3.32
Package Type	BGA	BGA	BGA	BGA









New Power Solution

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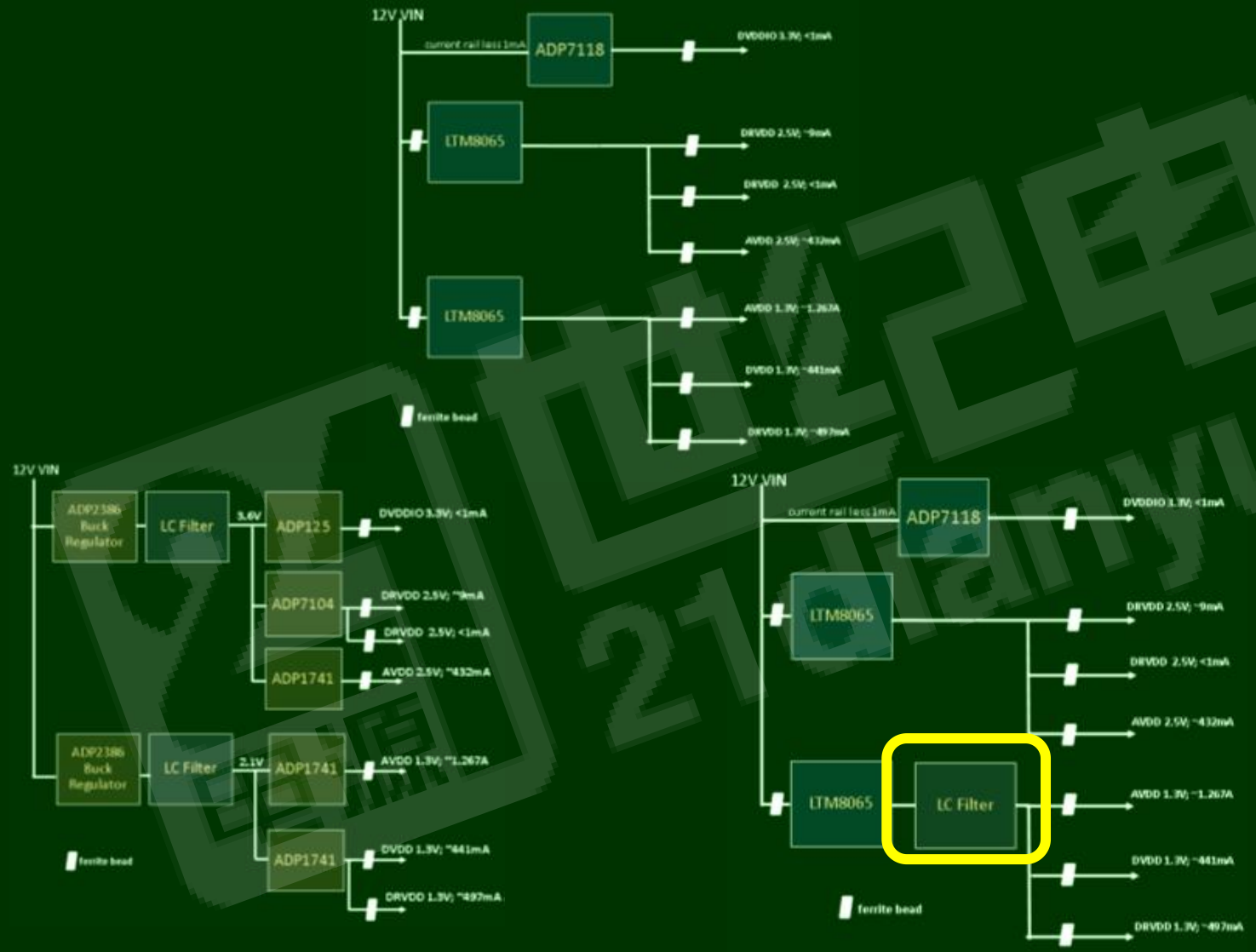

Good Power solution and performance

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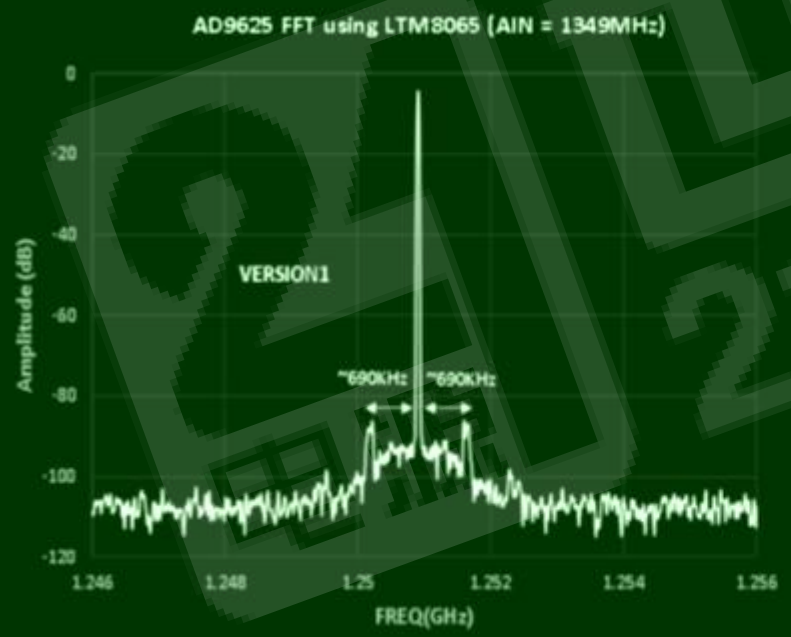
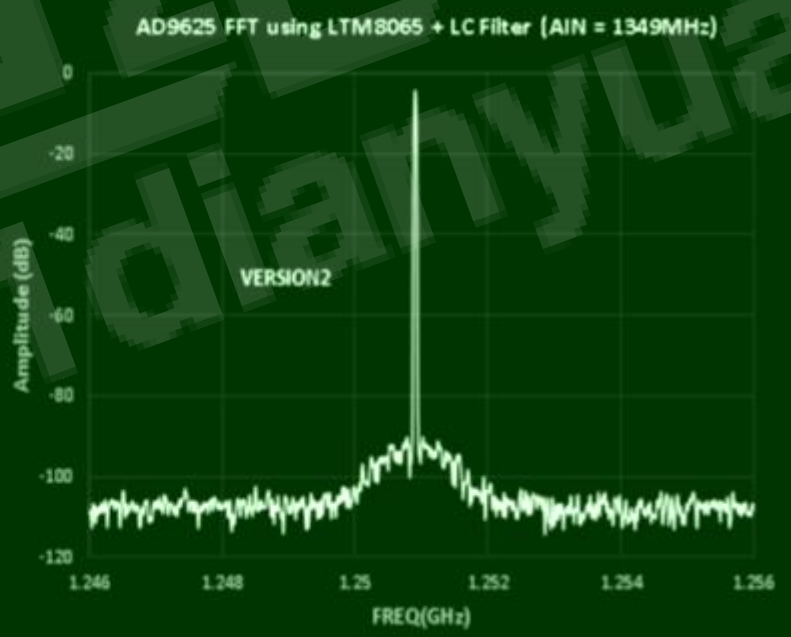
AD9625-2.6 GHz Dynamic Performance						
Input Frequency (MHz)	SNRFS (db)			SFDR (dbc)		
	Baseline Power Supply	LTM8065 Version1	LTM8065 Version 2	Baseline Power Supply	LTM8065 Version1	LTM8065 Version 2
729	57.01	57.03	57.01	79.87	79.72	80.11
1349	56.53	56.49	56.54	78.41	80.06	80.77





Good Power solution and performance

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Baseline Power Supply		Voltage (V)	Current (A)	Power (W)
PIN		11.729	0.676	7.929
POUT	AVDD_1.3V	1.268	1.222	1.549
	DRVDD_1.3V	1.301	0.521	0.678
	DVDD_1.3V	1.305	0.406	0.530
	AVDD_2.5V	2.589	0.408	1.056
	DRVDD_2.5V	2.590	0.0047	0.012
	DVDD_2.5V	2.590	0.0001	0.0003
	DVDDIO_3.3V	3.301	0.0004	0.0013
			POUT TOTAL:	3.827
			Efficiency (%):	**48.26**

LTM8065 Version 2		Voltage (V)	Current (A)	Power (W)
PIN		11.885	0.442	5.256
POUT	AVDD_1.3V	1.303	1.308	1.704324
	DRVDD_1.3V	1.302	0.531	0.691
	DVDD_1.3V	1.305	0.459	0.599
	AVDD_2.5V	2.486	0.440	1.094
	DRVDD_2.5V	2.494	0.005	0.012
	DVDD_2.5V	2.496	0.0001	0.0002
	DVDDIO_3.3V	3.301	0.0004	0.0013
			POUT TOTAL:	4.102
			Efficiency (%):	**78.05**

+30%

Silent Switcher uModule – Save PCB size

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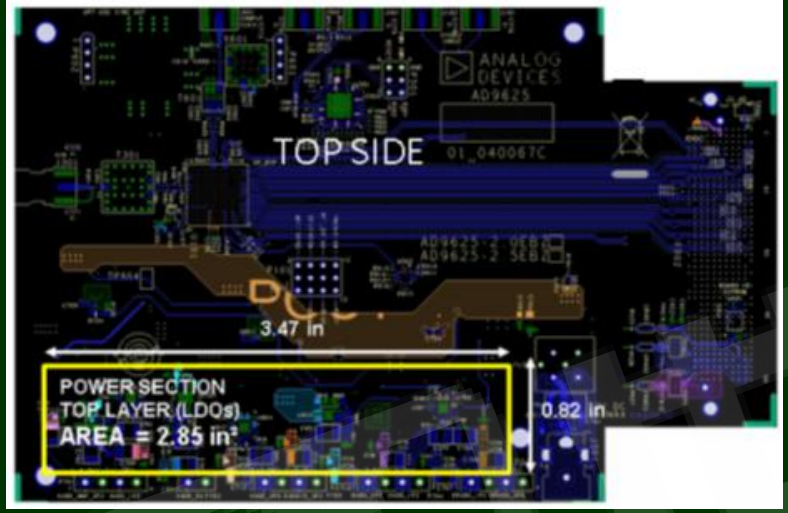
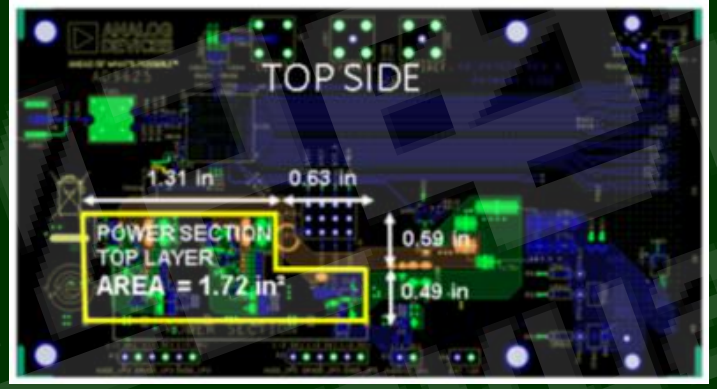
EVAL-AD9625 Evaluation Board



REVISED Evaluation Board USING LTM8065 POWER SOLUTION



PCB Size

6.32in^2 VS 1.72in^2

Save 73% space

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- The End!