ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

ADI High Performance Power Products

ADI Webinar

Ken Cheng

Arrow Senior Field Application Engineer
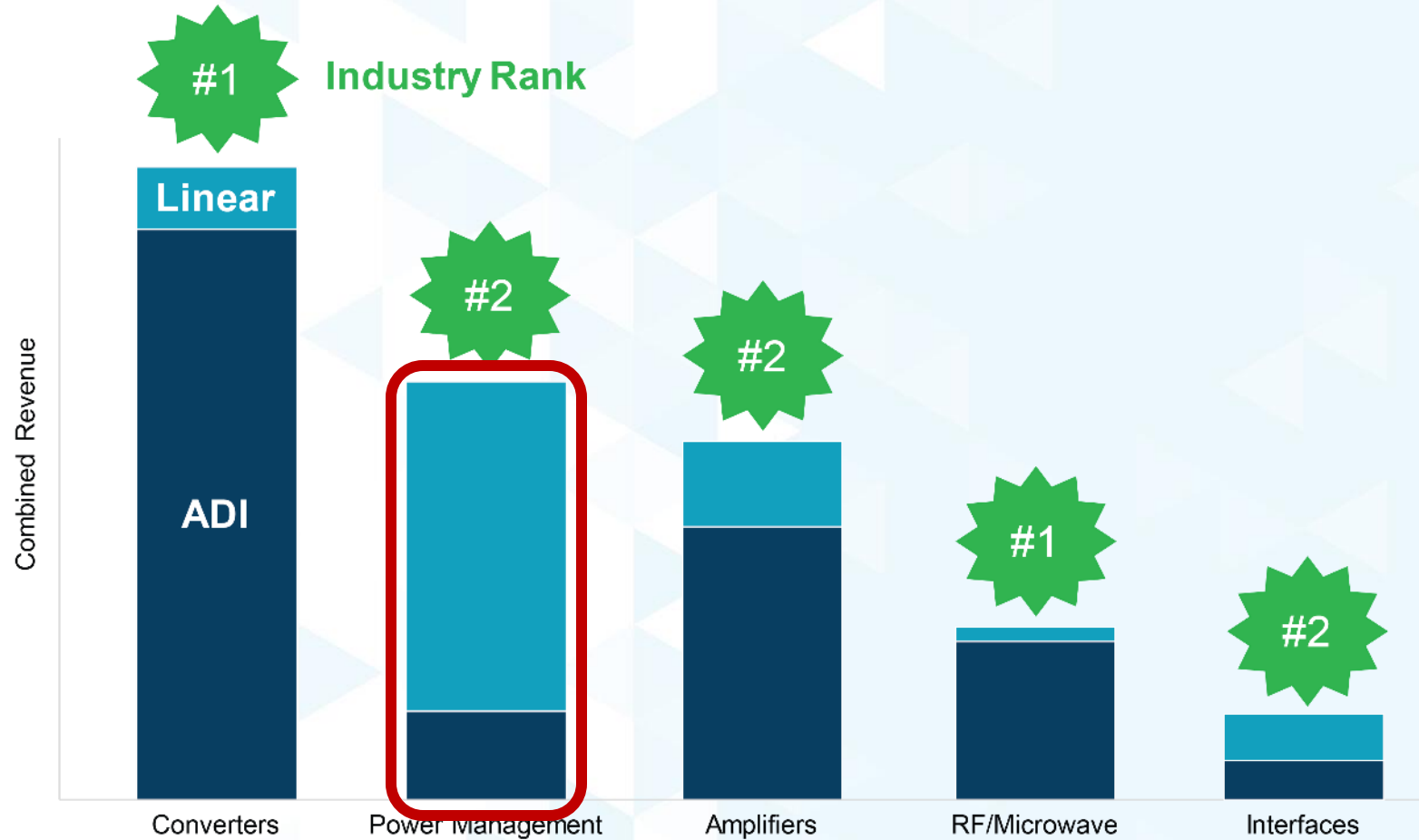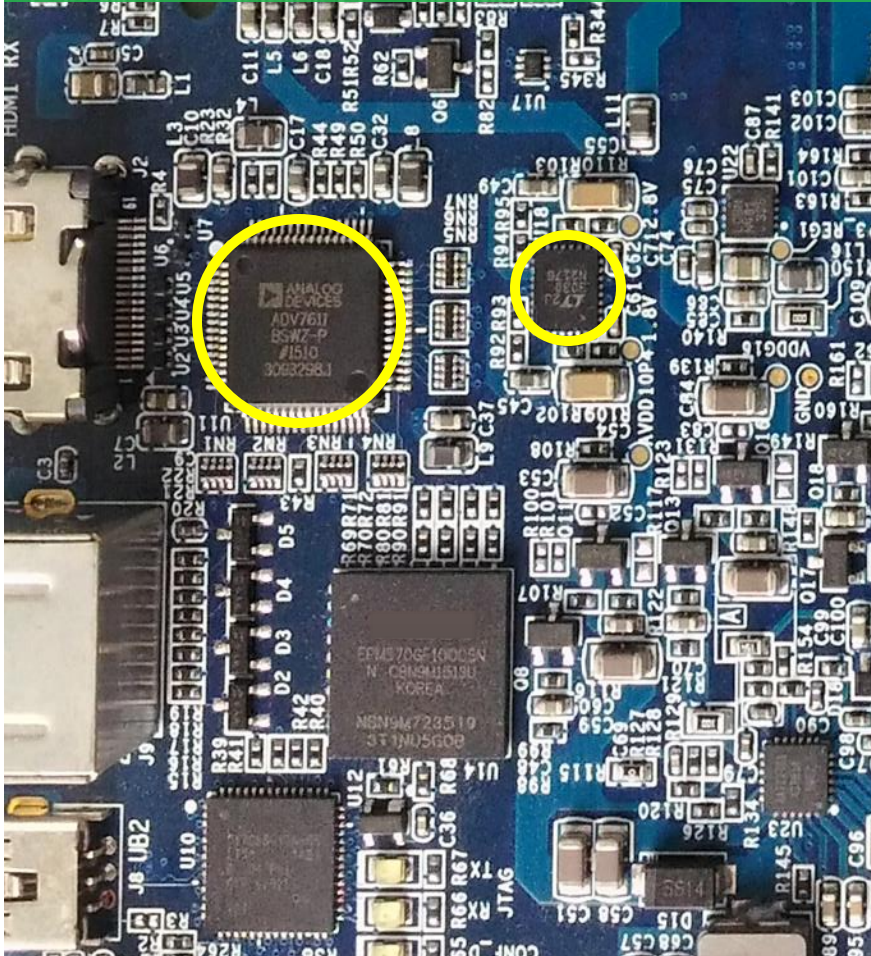
Ken.cheng@arrowasia.com

Agenda

► ADI Power Overview

► Applications - How ADI get balance with 3 key matrix

► LTpowerCAD

High Performance Analog Industry Leader …

Broad and Highly Complementary Portfolio of Leading Long Lifecycle, High Value Products

Industry Rank

#1

Combined Revenue

| Converters | Power Management | Amplifiers | RF/Microwave | Interfaces |

Data based on Gartner reports and company estimates based on FY15 data.

We focus on…

Autonomous Transportation and Machines

Automotive Electrification
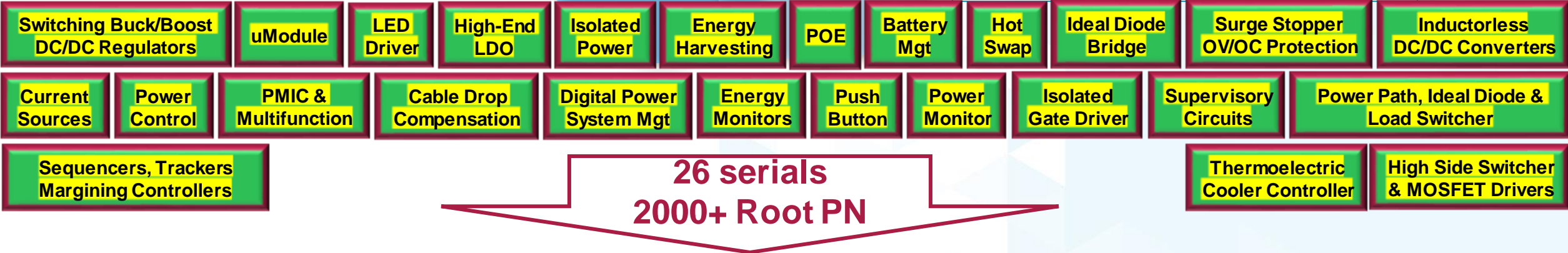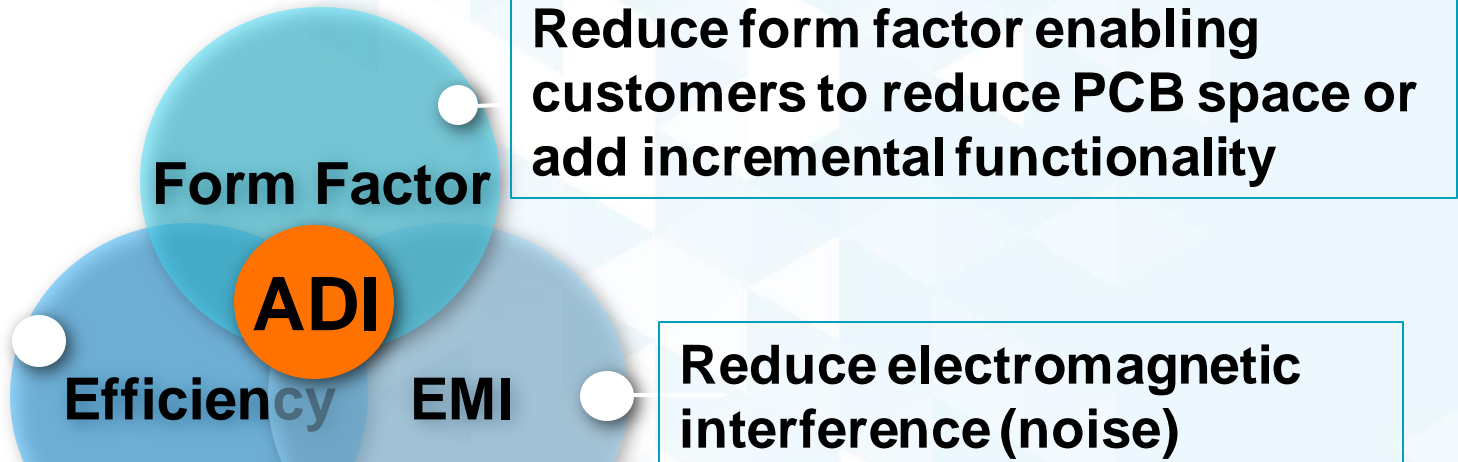
Next-Generation Connectivity

Remote Healthcare

Industry 4.0 and Smart Energy

Immersive Consumer Experiences

Power Innovation Technologies

ANALOG DEVICES · AHEAD OF WHAT'S POSSIBLE™

Performance 3 Key Metrics

Form Factor

ADI

Efficiency **EMI**

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)

Switching Buck/Boost DC/DC Regulators	uModule	LED Driver	High-End LDO	Isolated Power	Energy Harvesting	POE	Battery Mgt	Hot Swap	Ideal Diode Bridge	Surge Stopper OV/OC Protection	Inductorless DC/DC Converters

Current Sources	Power Control	PMIC & Multifunction	Cable Drop Compensation	Digital Power System Mgt	Energy Monitors	Push Button	Power Monitor	Isolated Gate Driver	Supervisory Circuits	Power Path, Ideal Diode & Load Switcher

Sequencers, Trackers Margining Controllers

26 serials 2000+ Root PN

Thermoelectric Cooler Controller

High Side Switcher & MOSFET Drivers

Autonomous Transportation and Machines

Automotive Electrification

Industry 4.0 and Smart Energy

Next-Generation Connectivity

Immersive Consumer Experiences

Small Form Factor -µModule

Year 2010

12x LTM4601

Year 2012

4x LTM4620

Year 2014

3x LTM4630

Year 2016

2x LTM4650

Form Factor

ADI
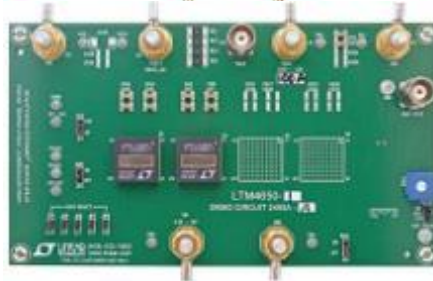
FPGA Core 0.8V @100A
Power Supplier Solution

1 x LTM4700 with *Digital Telemetry*

(July 2018)

Silent Switcher – Low EMI

► Buck regulator platform

- 20dB EMI improvement – No compromise in efficiency and size!

► Offers customers:

- High frequency
- High efficiency
- High current
- Low EMI noise
- Solder joint reliability

► Technologies

- Circuits
- Process/devices
- Package
- In-package passive

ADI

EMI

5V 4A Step-Down Converter

V_{IN} 5.8V TO 42V

4.7µF

1µF

V_{IN1} EN/UV V_{IN2}

GND1 GND2

1µF

PG LT8614 BST

10nF

SYNC/MODE SW

0.1µF 4.7µH

V_{OUT}
5V
4A

TR/SS BIAS

1µF

4.7pF

1M

INTV$_{CC}$ FB

47µF

41.2k

RT GND

243k

f_{SW} = 1MHz

8614 TA01a

20dB
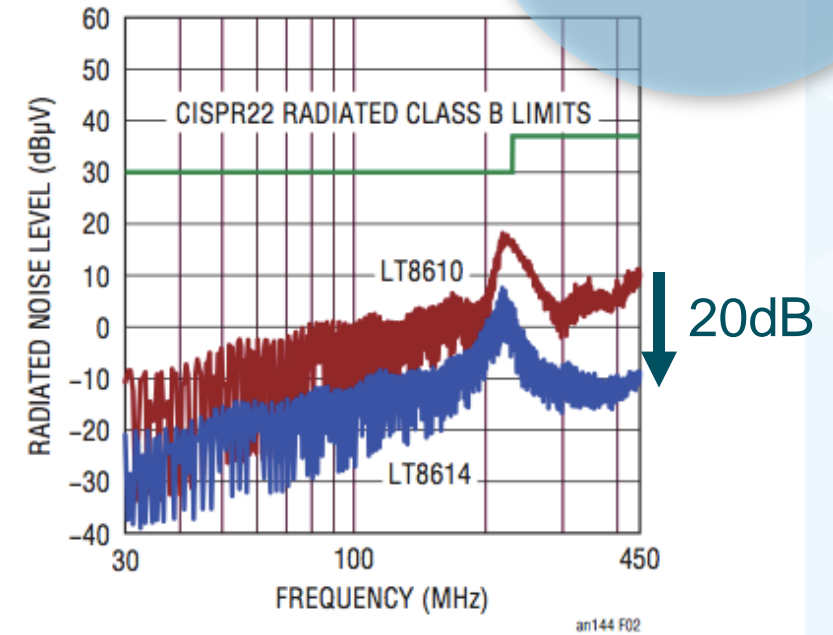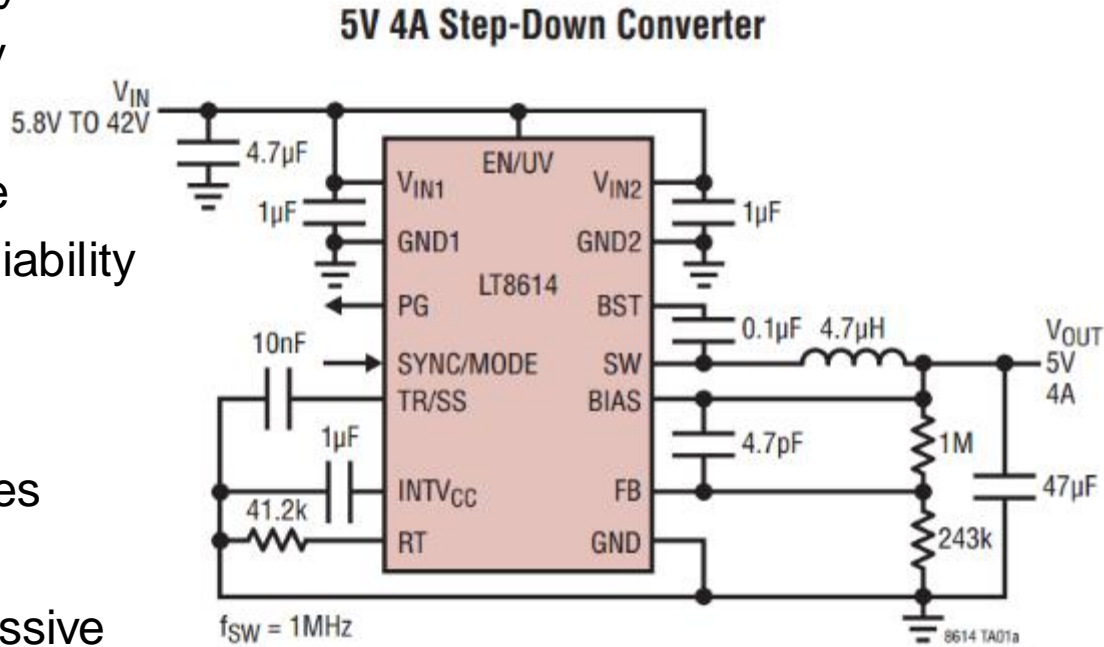
Figure 2. LT8610 and LT8614 700kHz 14V to 3.3V 2A
Radiated EMI in GTEM Corrected for OATS

New idea to achieve Higher Efficiency

ADI

Efficiency

Agenda

►ADI Power Overview

►Applications - How ADI get balance with 3 key matrix

►LTpowerCAD

48V (54V)

10-12V$_{BUS}$

VINA

48V

Hot Swap

Bus Converter 12V

R-PCB

12Vbus

Isolation

VINB 48V

100-150A

Buck POLs 1V 150A → ASICs

30-120A

Buck POLs 1V 80A →

7-40A

Buck POLs 1.2V 40A → FPGAs

3-20A

Buck POLs 2V 20A →

<5A

LDOs 1V 3A → I/Os

400W 48V-to-12V active clamp forward (96.5%)

Off-the-shelf 600W-800W 48V-to-12V Brick (97.4%)

48v direct conversion

Is ¼ current than 12v conversion!

16x less loss!

Application1- Telecom application 48V to 12V

$V_{in} = 48V, V_o = 12V/20A$

❖ **Buck Converter**

❖ **Hybrid Converter**

Form Factor

ADI

Efficiency

Efficiency vs Load Current

96.7%

➢ 2

➢ 2

Q₄)

➢ F

➢ S
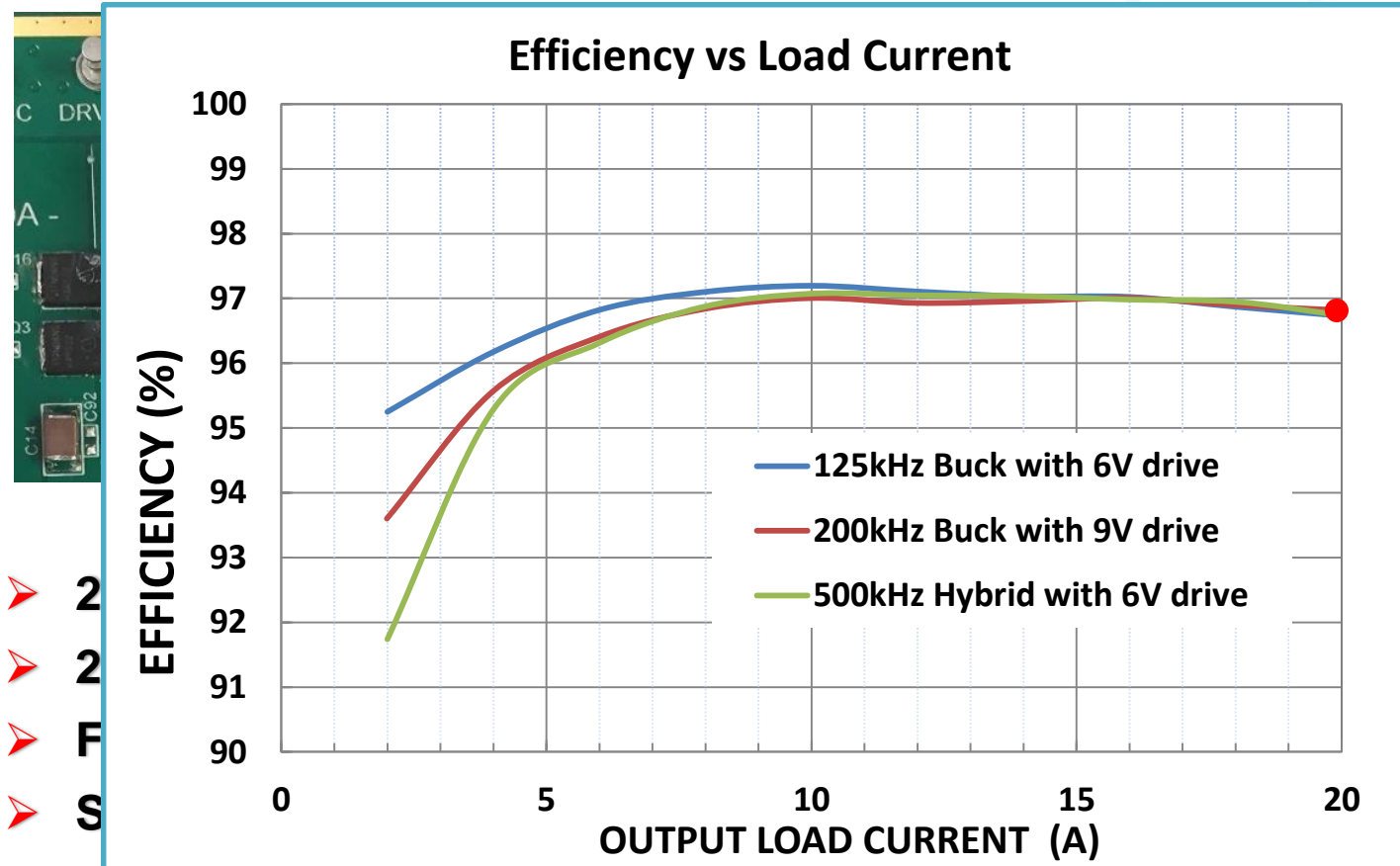
Smaller Inductor to Make Higher Power Density

125kHz Buck

200kHz Buck

500kHz Hybrid
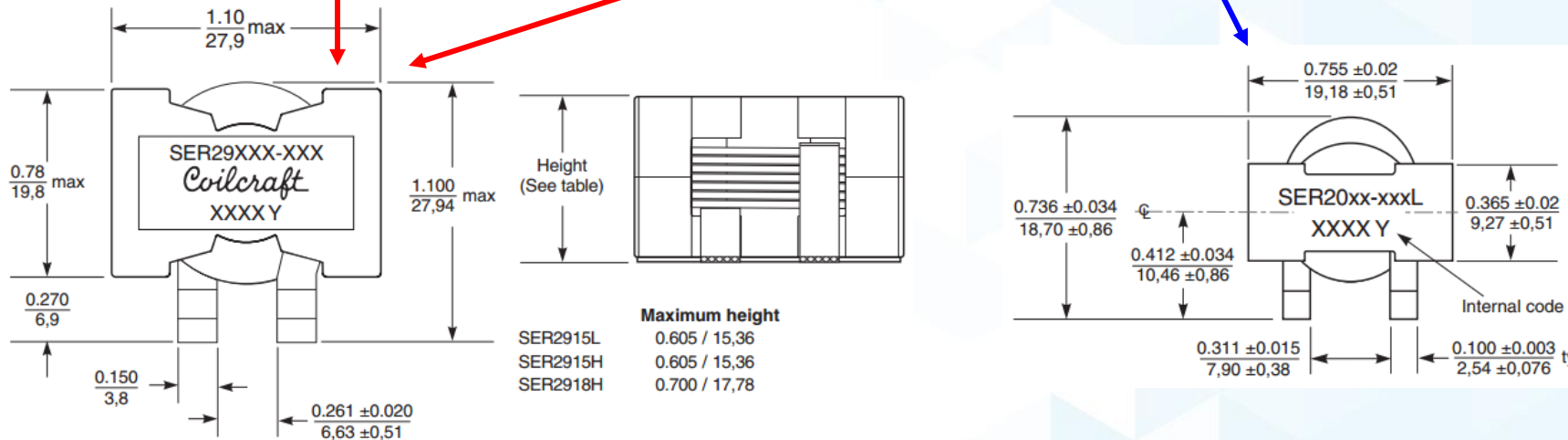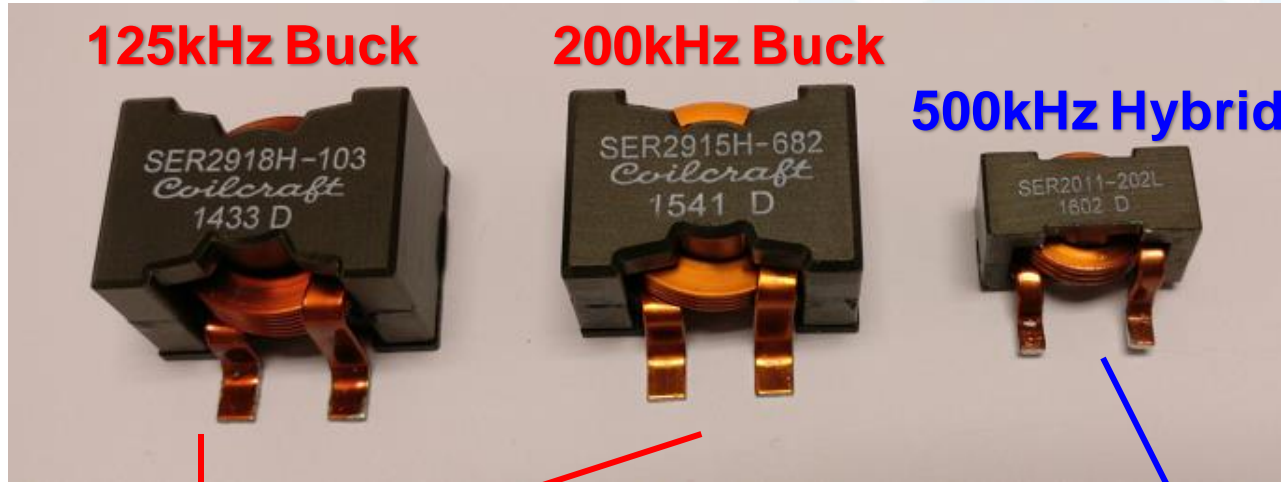
56% volume reduction

Fixed Ratio Inductor Less(Charge Pump) Converter

Vin = 48V, Vo=24V/20A, Fsw = 200kHz
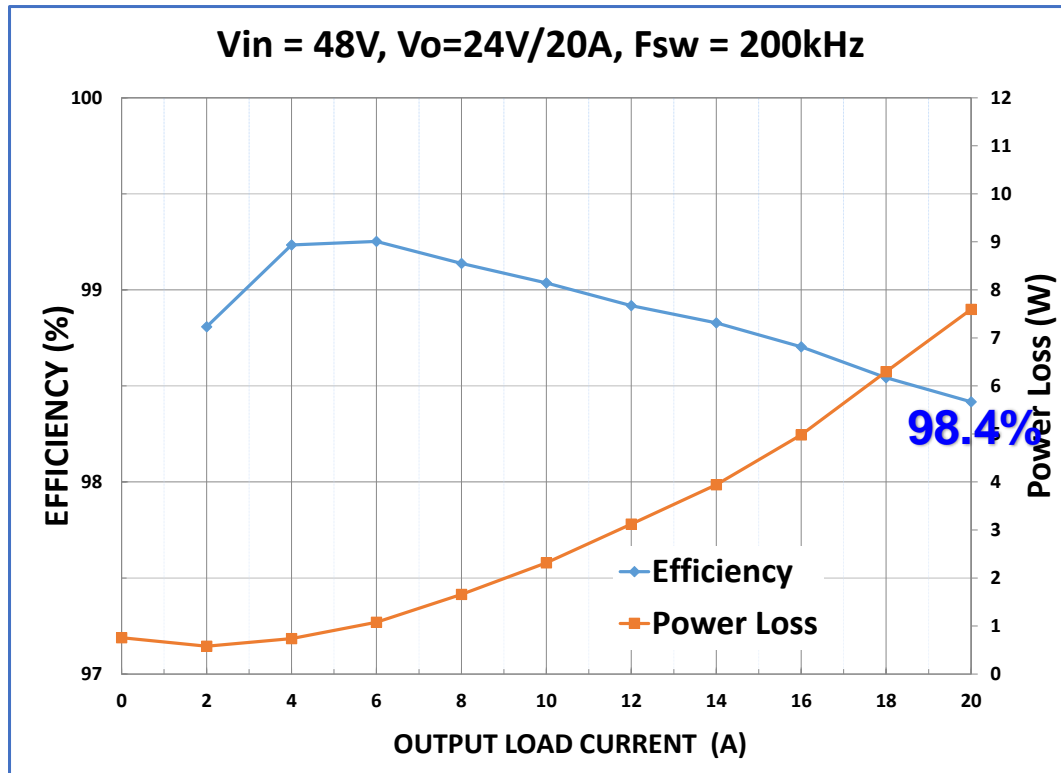
Inductorless Bus Converter
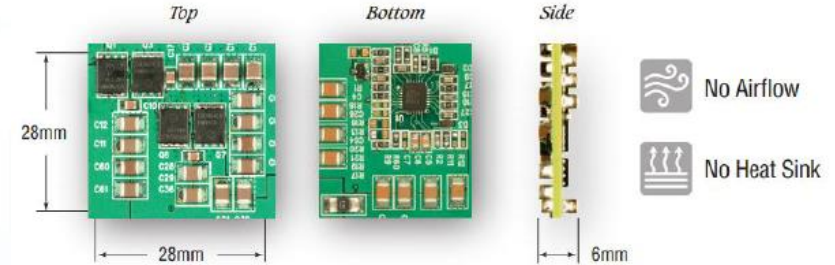
99% Efficient Step-Down, Step-Up or Invert

Application 2 – Isolated power in industrial application

- Safety: to protect the operator from dangerous voltages
- Voltage level shifting
- To provide galvanic isolation in which the two isolated circuits communicate without a direct conduction path
- Prevent ground loops
- The isolation protects the equipment from the line-level events such as surges, lightning strikes, etc.

Designing a Flyback Converter for Isolation

- ► **The Flyback Converter**
  - − Buck boost topology
  - − Transformer is really a coupled inductor
  - − Power Level 1 W to 50 W
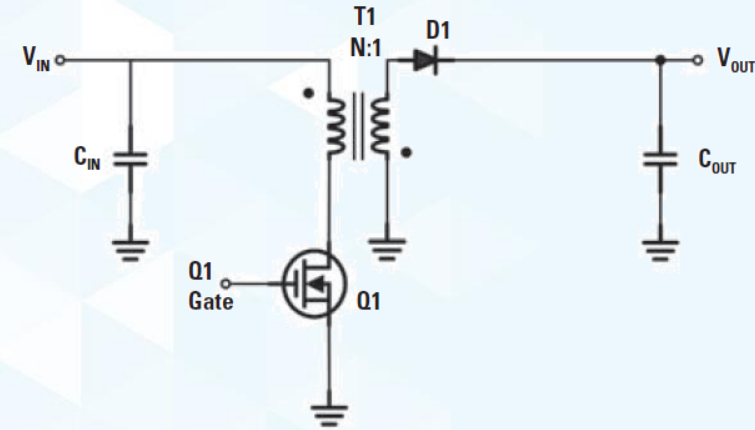
- ► Pros
  - − Simple
  - − Low cost
  - − Can easily generate multiple rails
    - • Good load sharing
  - − Flexible Output voltage
    - • can be higher or lower than input (with the same transformer)

- ► Cons
  - − Larger magnetics
    - • Energy stored in core
    - • Air gap usually required
    - • Low primary leakage inductance design
  - − High output ripple
  - − Lower Efficiency

Traditional Isolated Power Module Design
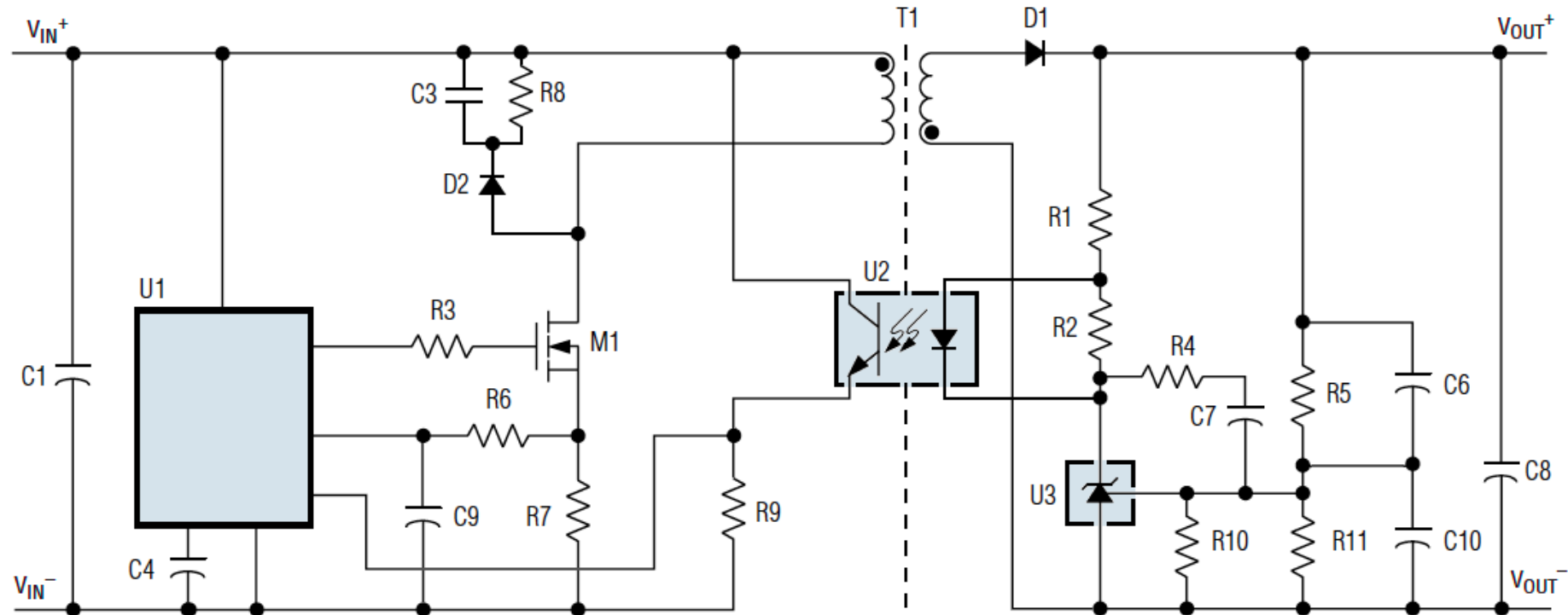
ADI Isolated Flyback – Simple & Great

>90% efficiency

+/- 0.5% regulation

ADI Isolated Flyback – Simple & Great

Part number	V_{IN} Range	Internal Power Switch	P_{OUT}
LT8301	2.7V - 42V	1.2A/65V	~2W
LT8302	2.8V - 42V	3.6A/65V	~5W
LT8300	6V - 100V	0.23A/150V	~2W
LT8303	5.5V - 100V	0.5A/150V	~4W
LT8304	3V - 100V	2.0A/150V	~12W
LT3748	5V - 100V	external	up to ~80W
LT8315	18V - 560V	0.3A/630V	~10W
LT8316	18V - 630V	external	up to ~80W

Region Isolated Power Module Design

ID	Vin	Vout	Iout	Pout	Isolated Voltage
PM32405	24V (18V-36V)	5V	600mA	3W	2500Vdc
PM62405H	24V (18V-36V)	5V	1.2A	6W	2500Vdc
PM62412	24V (9V-36V)	±12V	±250mA	6W	2500Vdc
PM62405L	24V (9V-36V)	±5V	±600mA	6W	2500Vdc
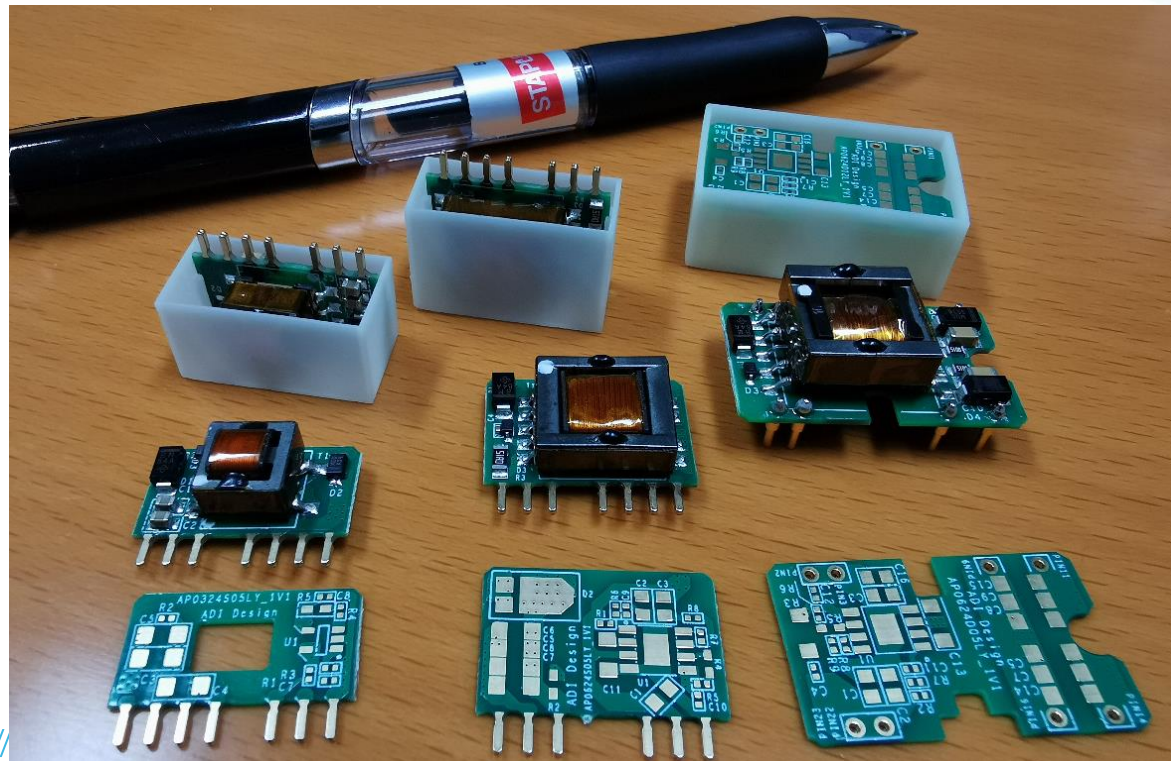
- ► Complete Isolated Power Design
- ► Transformer local Vendor Qualification
  - ► Standard Transformer PN
  - ► Can be sell to WW Market
- ► Pass Related Qualification
- ► Schematic : Free
- ► PCB Layout : Free
- ► BOM List: Free

ISO Modules EMC Test Summary

Test Items	PM32405	PM62405H	PM62412	PM62405L
Conducted Emission (EN55022 ClassB)	PASS	PASS	PASS	PASS
Radiated Emission (EN55022 ClassB)	PASS	PASS	PASS	PASS
Surge+EFT 2KV DM	PASS	PASS	PASS	PASS
ESD (4KV Contact 8KV Air)	PASS	PASS	PASS	PASS
Radiated Susceptibility (10V/m 80M-1G)	PASS	PASS	PASS	PASS
Conducted Susceptibility (3V/m 150K-80M)	PASS	PASS	PASS	PASS

Isolated Power module Development

ADI Design & Inside

Vin+   COM   Vo+

Vin-   COM   Vo-
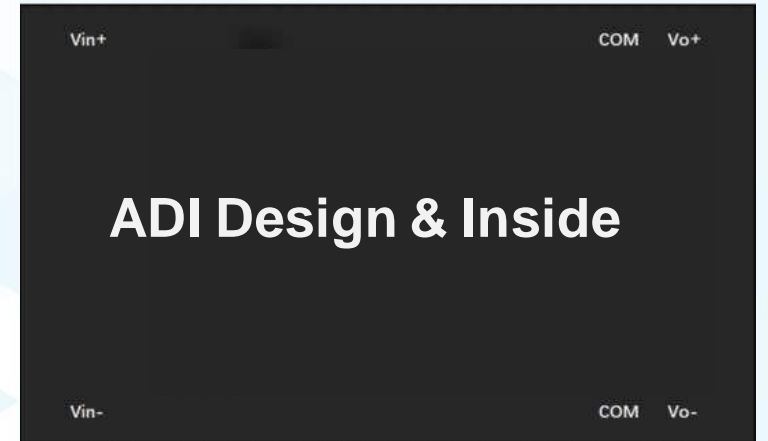
ADI power module VS Competitor

Items	PM62405H 6W module	Competitor 6W module	comments
Ripple	~30mVpk-pk	~65mVpk-pk	smaller external output cap for ADI module
Dynamic load response	150mVpk-pk	304mVpk-pk	smaller external output cap for ADI module
Isolation level	2.5KVDC	1.5KVDC	Higher isolation level for industry application
Efficiency@6W	~84%	~82%	Better Thermal
I/P quiescent current@24V	3mA	5mA	ADI module is more efficient in standby mode

Application 3 – Silent Switch Technology to Solve EMI issue

Parasitic inductance due to copper traces, bond wires, ESL of capacitors and FET internal metal
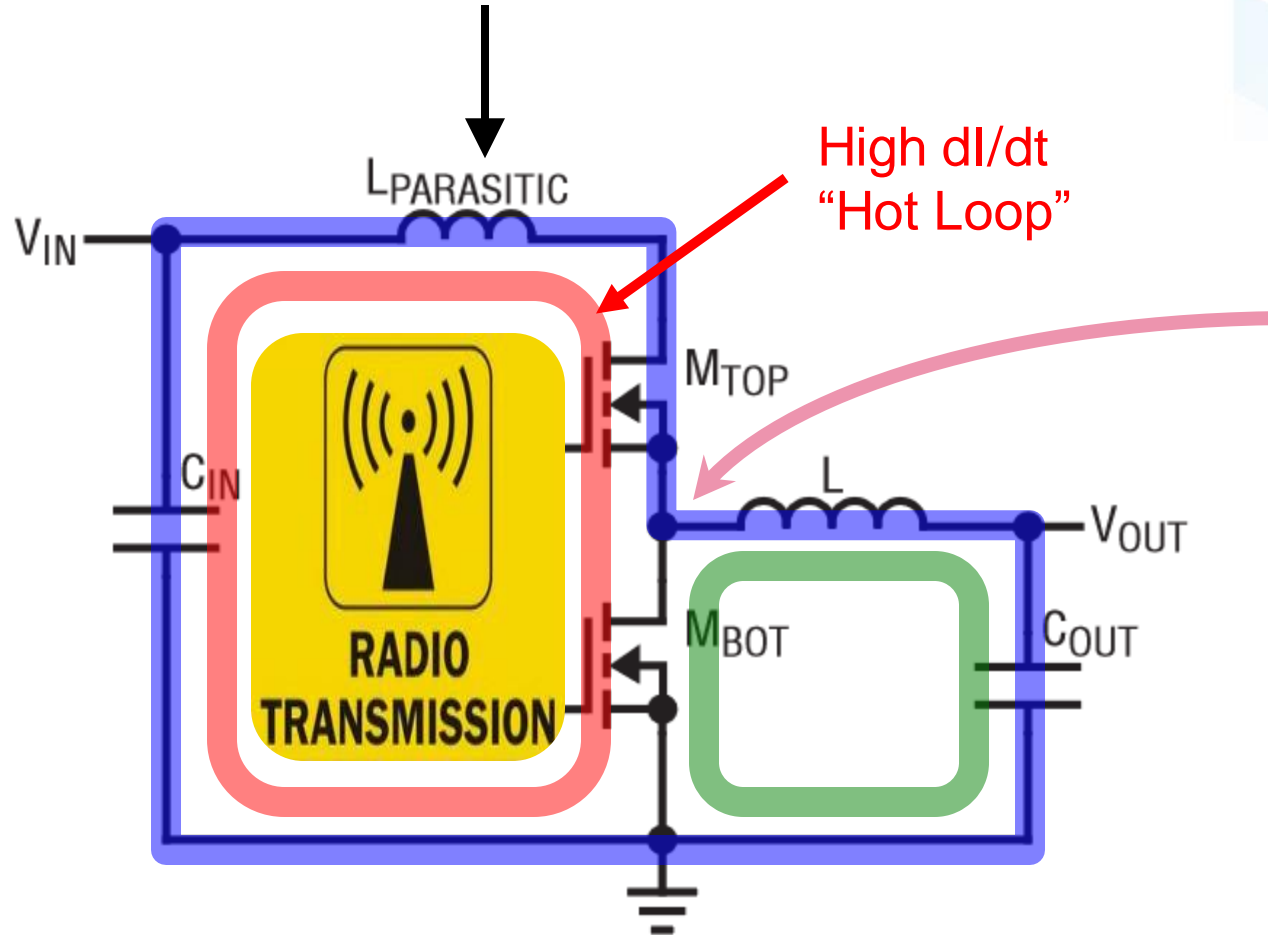
Excessive rings at the switching edges cause conduction noise and radiation

Form Factor

ADI

EMI

High dI/dt "Hot Loop"
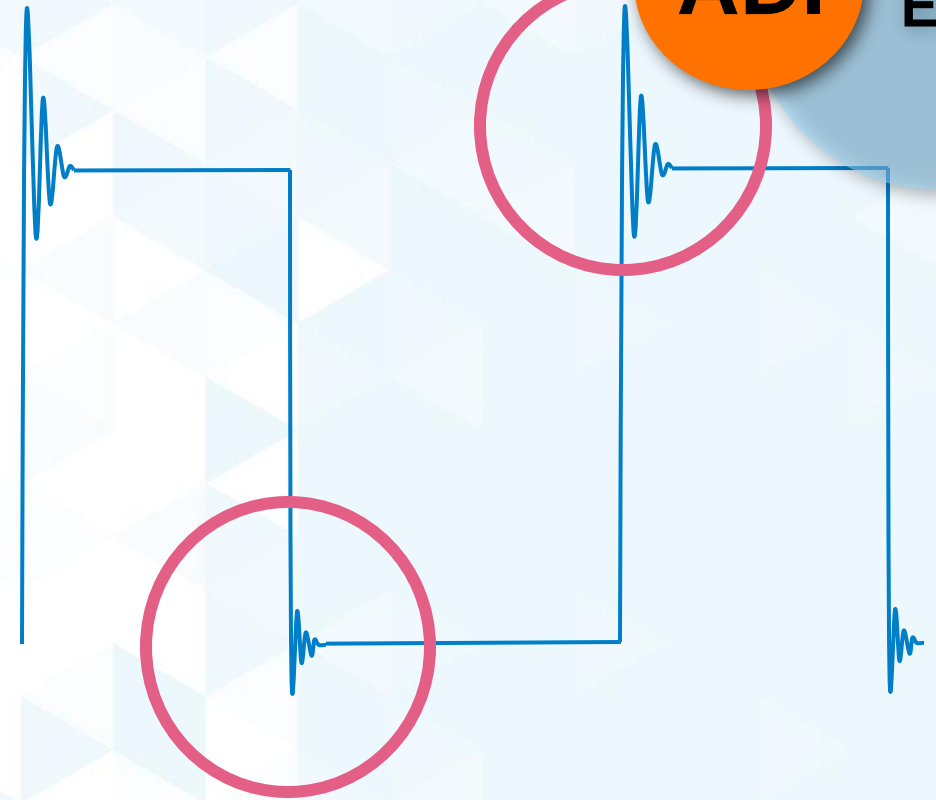
Minimizing Hot Loop

- 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

LARGE EMI BURST!

Occurs every switching cycle!

V_{IN}

C_{IN}

GND
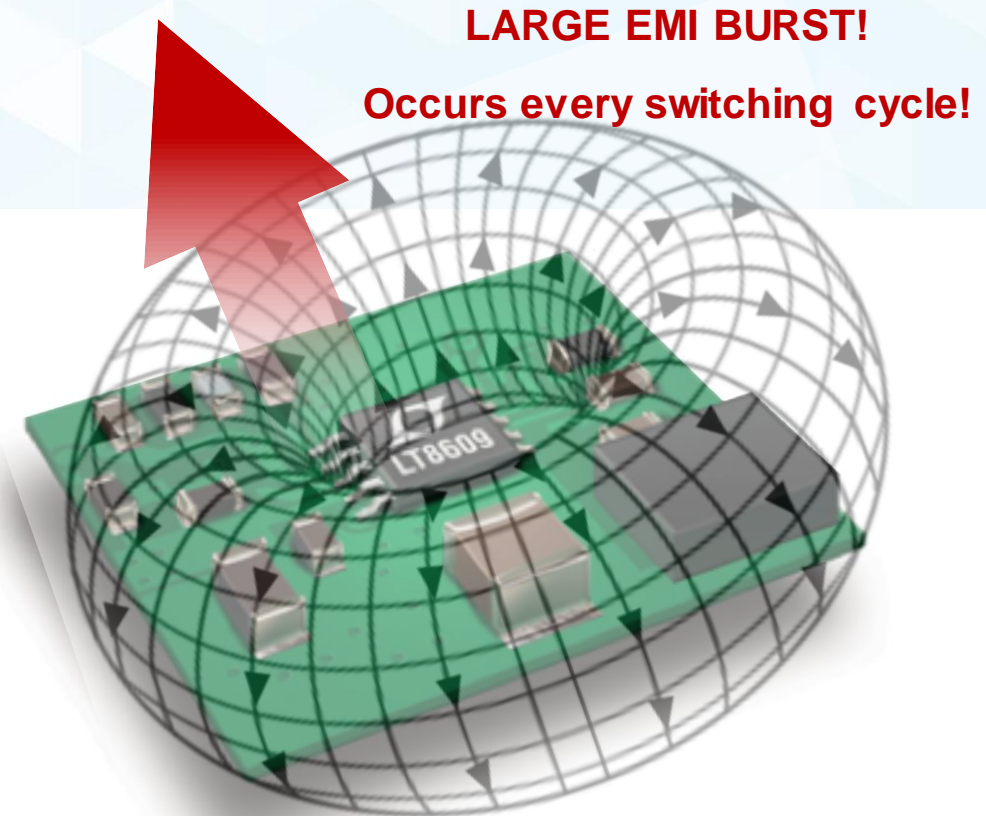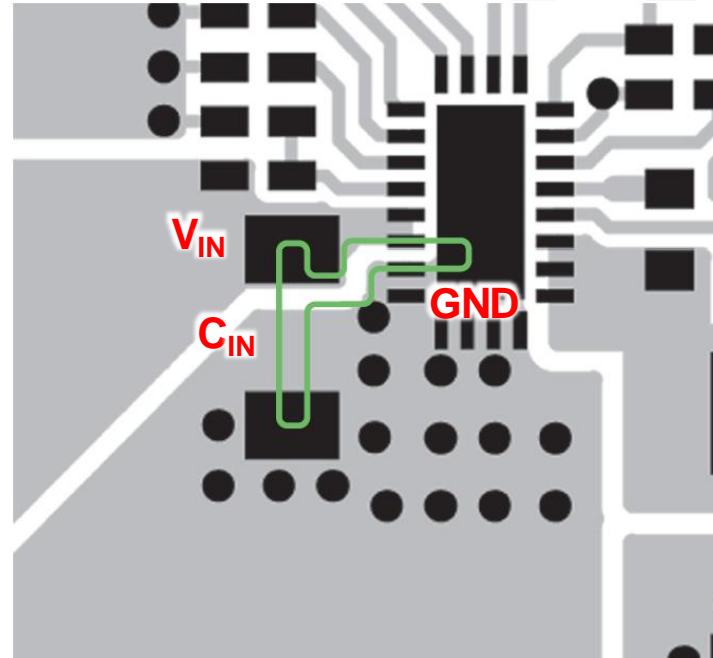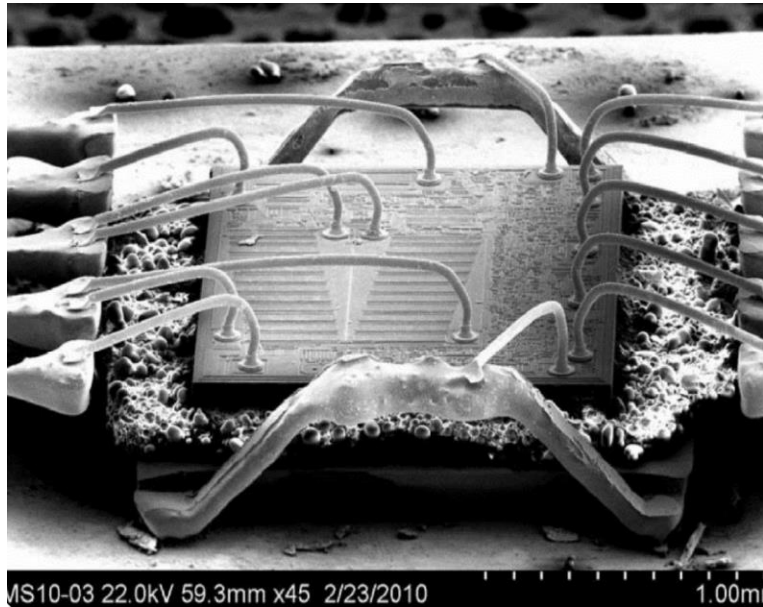
Silent Swither 1

Innovation - Magnetic Field Cancellation

US Patent: 8823345 B2
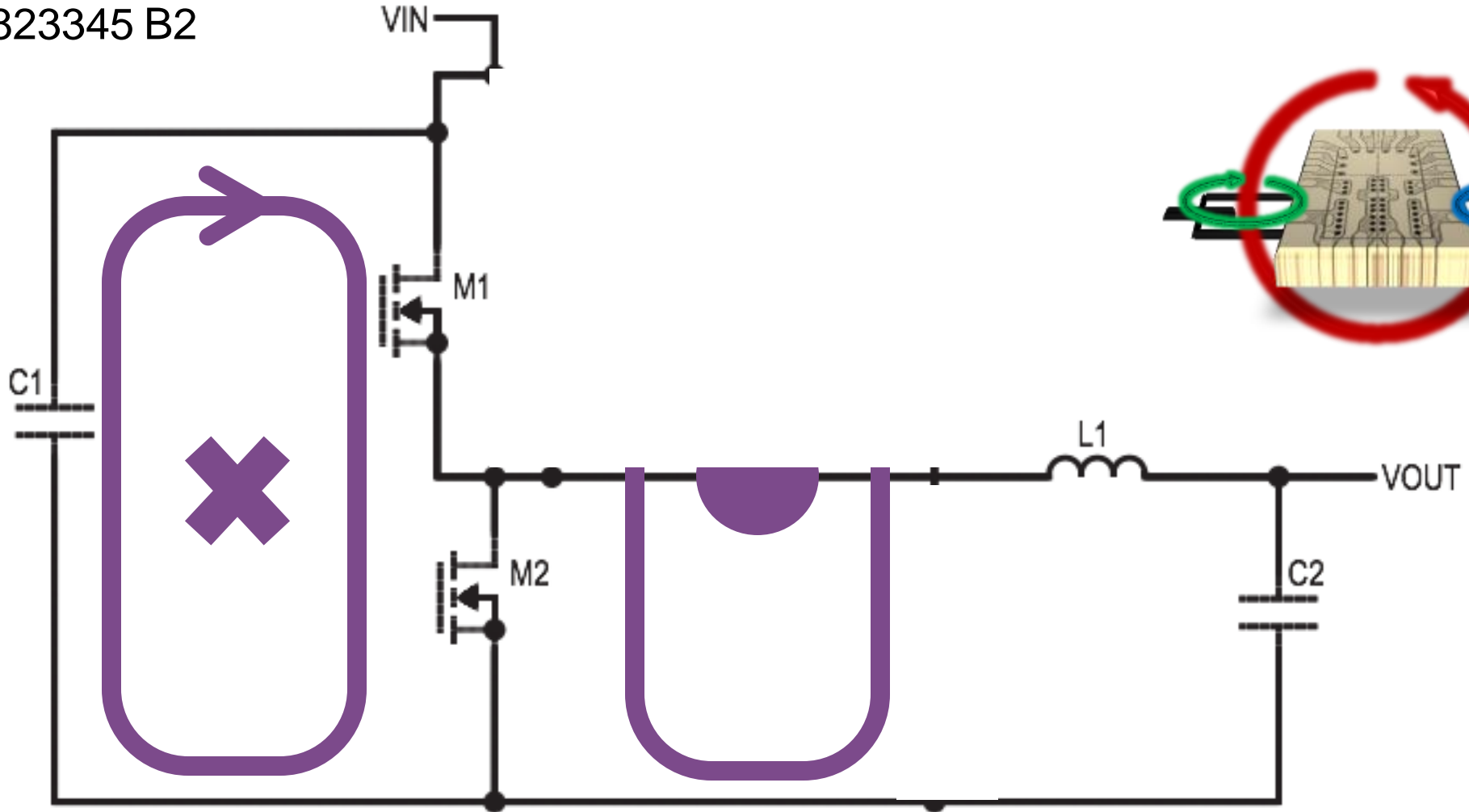
Silent Switcher 1 Eliminates Switch Ringing

Silicon Die
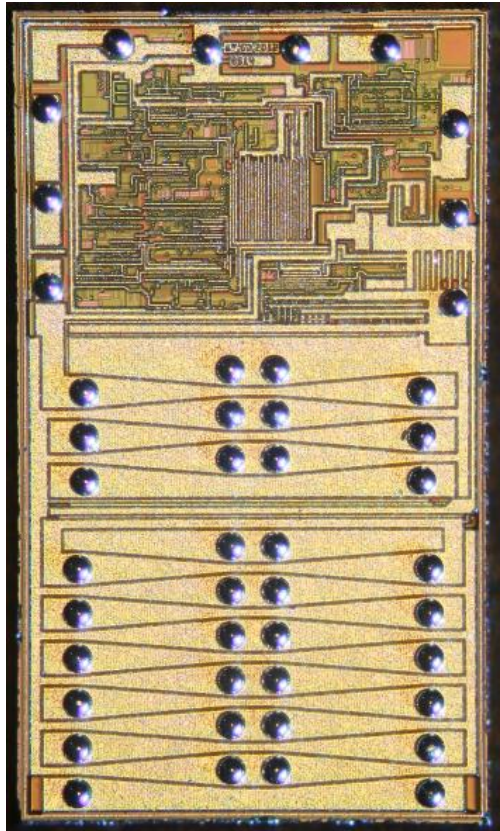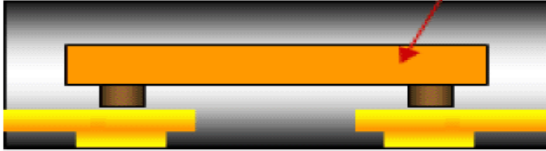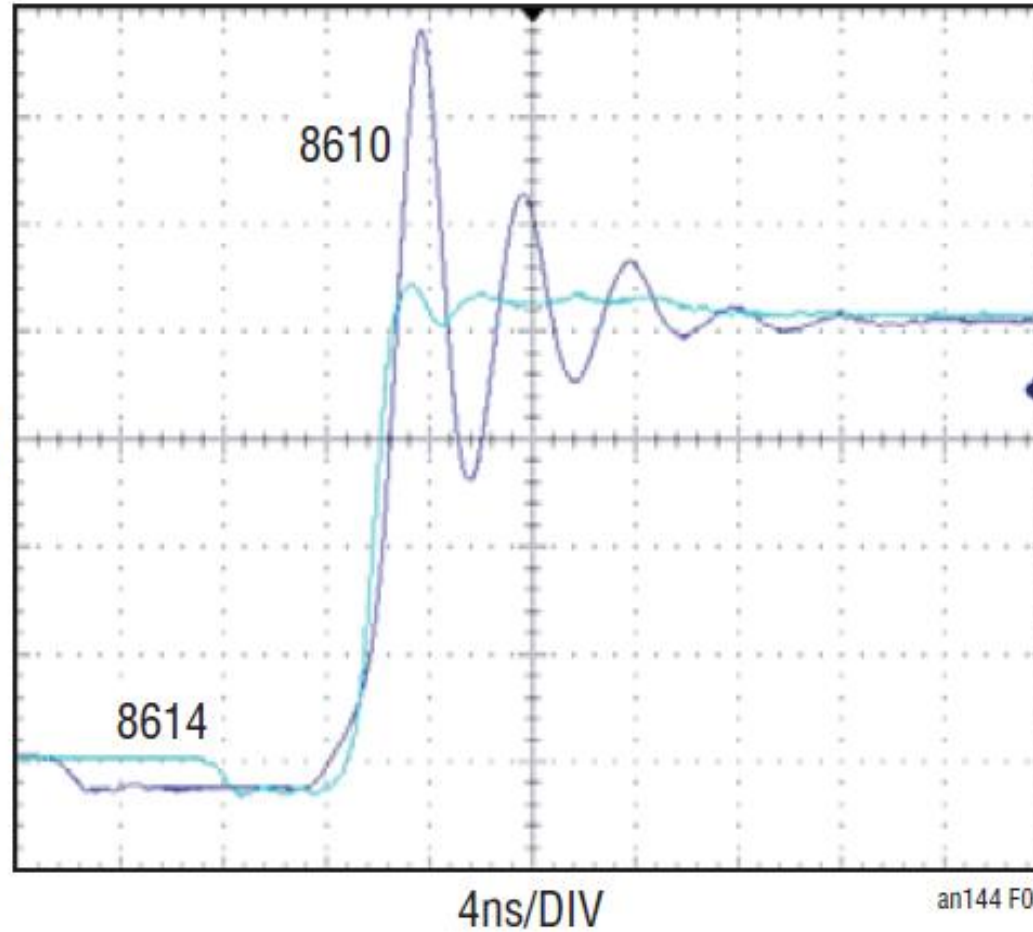
LT8610: Wirebonded in MS16E

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

Silent Switcher 1 –To Deal with Hot Loop

- ► Buck regulator platform
  - ▪ 20dB EMI improvement – No compromise in efficiency and size!

- ► Offers customers:
  - ▪ High frequency
  - ▪ High efficiency
  - ▪ High current
  - ▪ Low EMI noise
  - ▪ Solder joint reliability

- ► Technologies
  - ▪ Circuits
  - ▪ Process/devices
  - ▪ Package
  - ▪ In-package passive
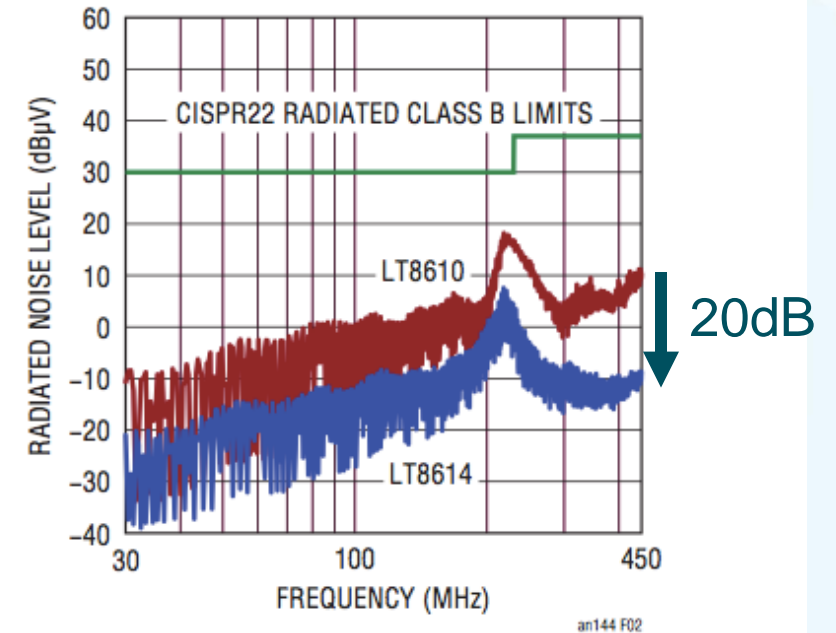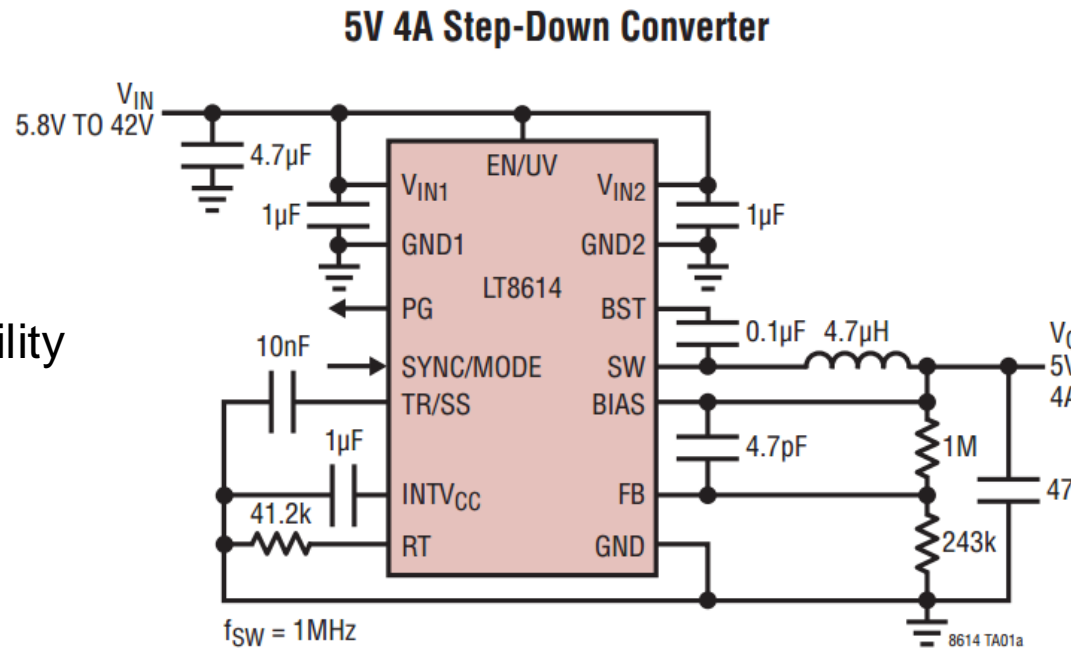
Figure 2. LT8610 and LT8614 700kHz 14V to 3.3V 2A Radiated EMI in GTEM Corrected for OATS

Innovation - Silent Switcher 1

5V 5A Step-Down Converter

The layout is critical though!

8640 TA01a
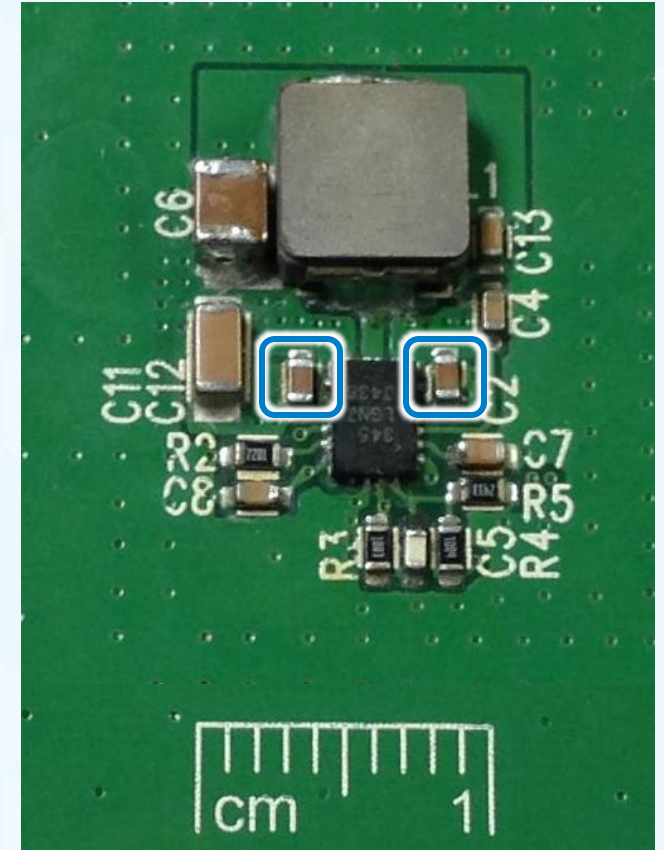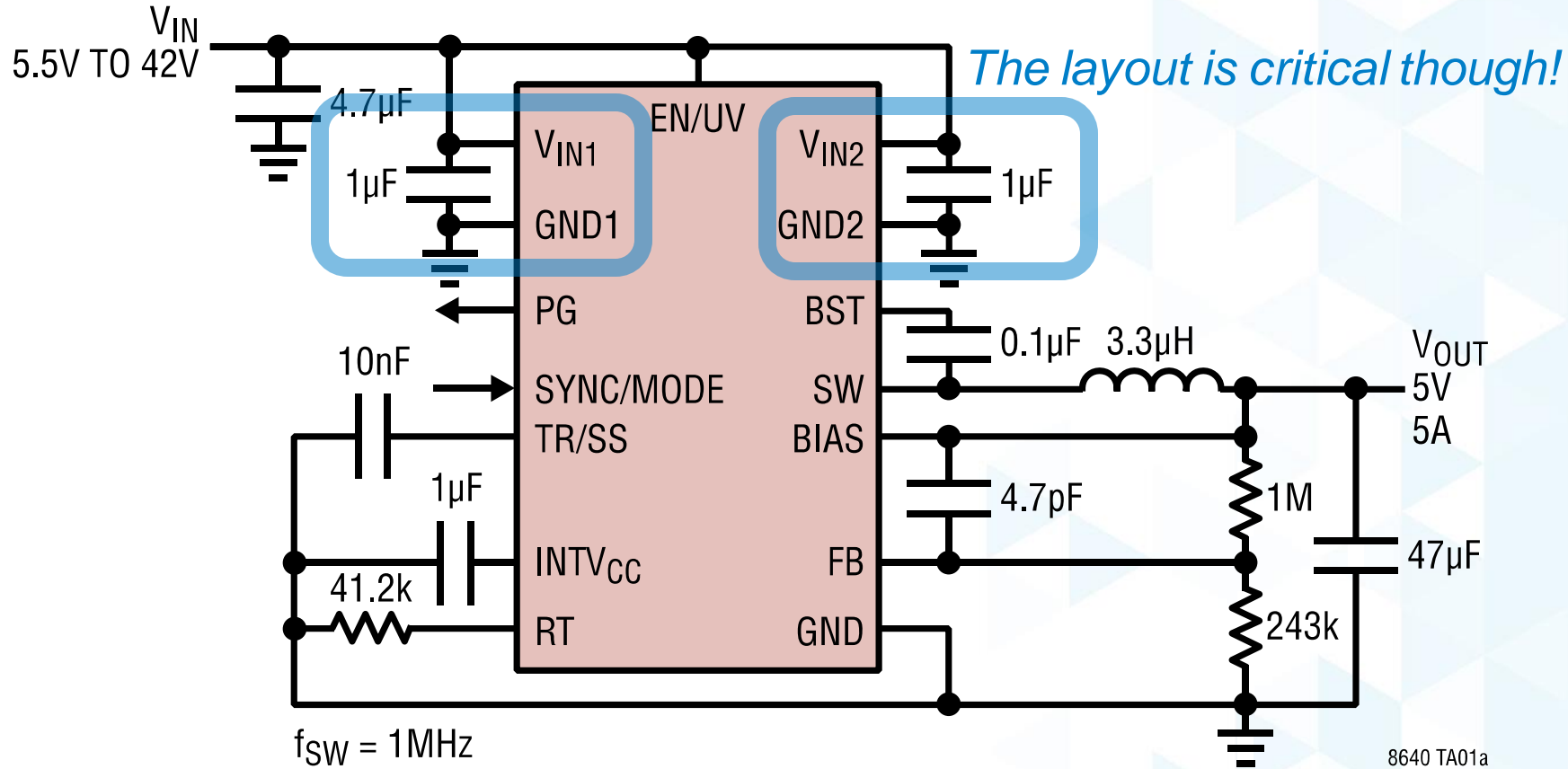
Silent Swither 2

Innovation - Silent Switcher 2

Silent Switcher 1

The layout is critical though!
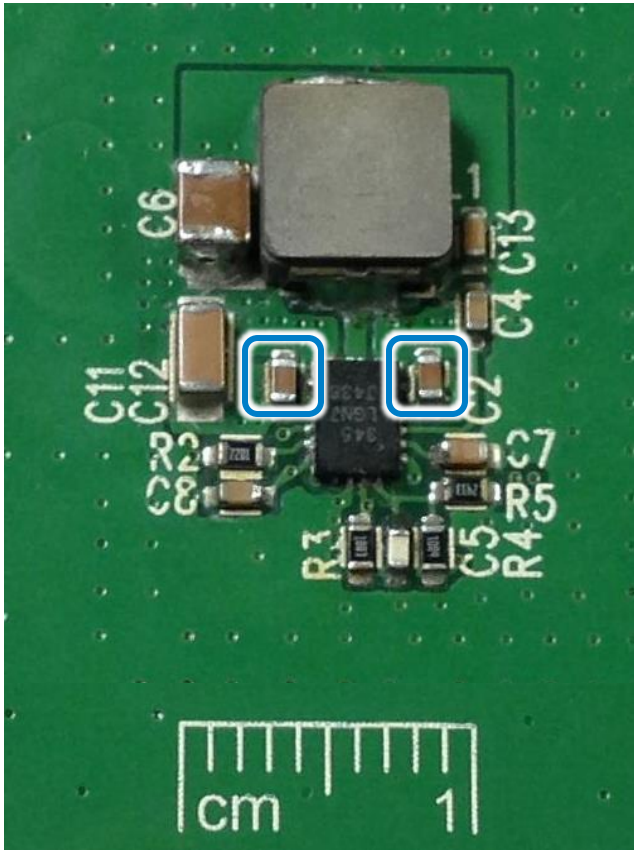
Silent Switcher 2

Flip chip on laminate (FCOL) and Cap-In-Package
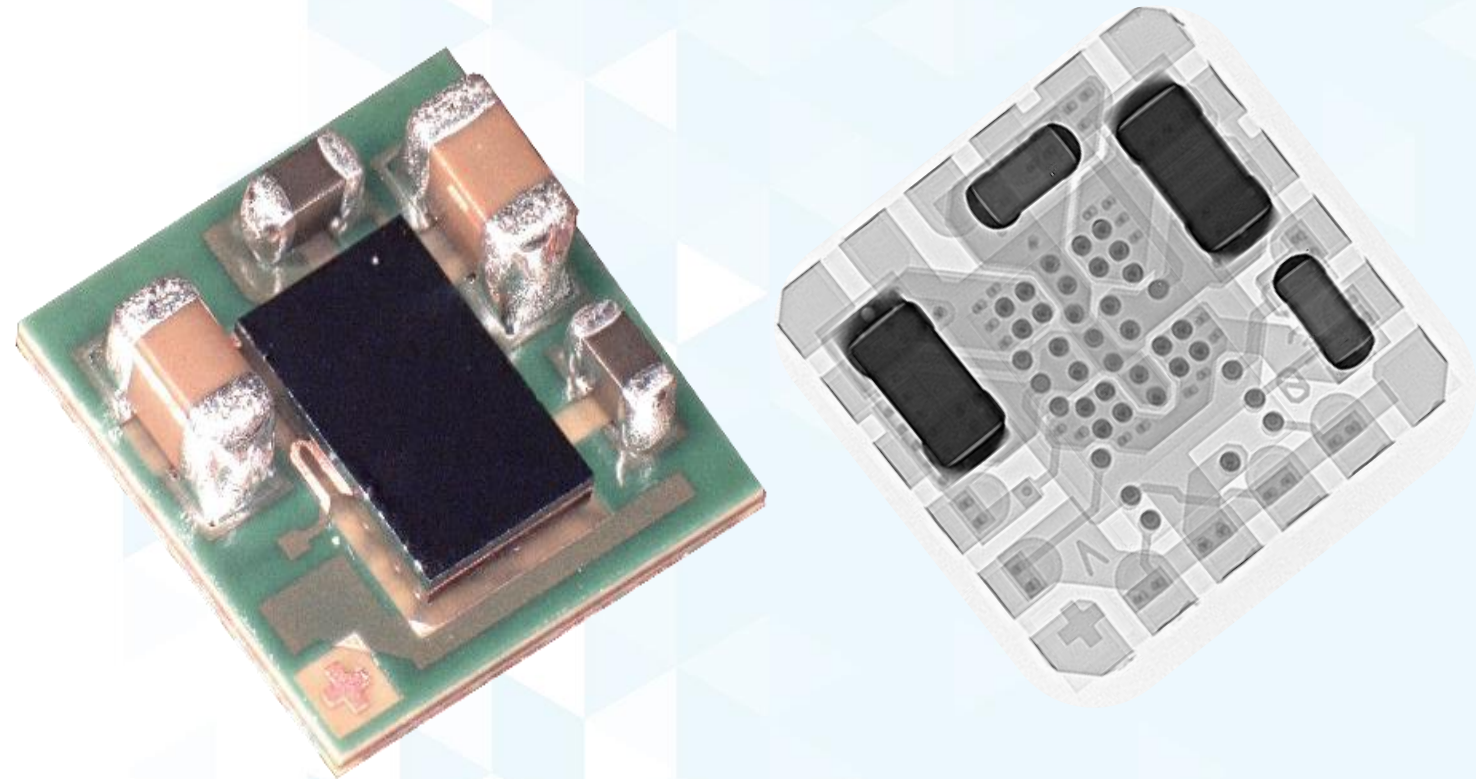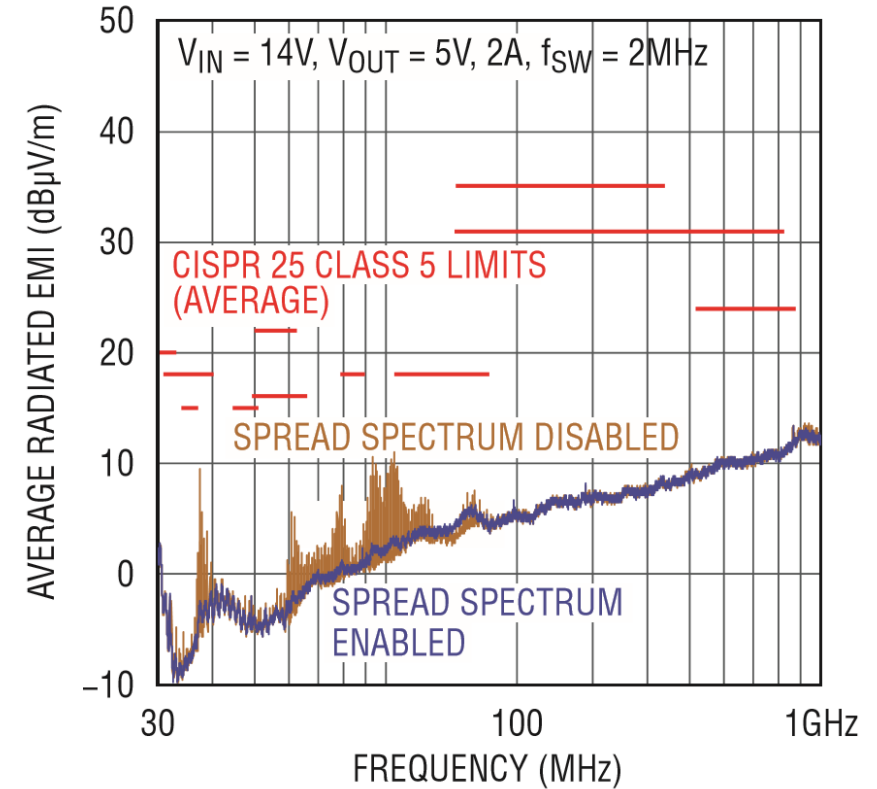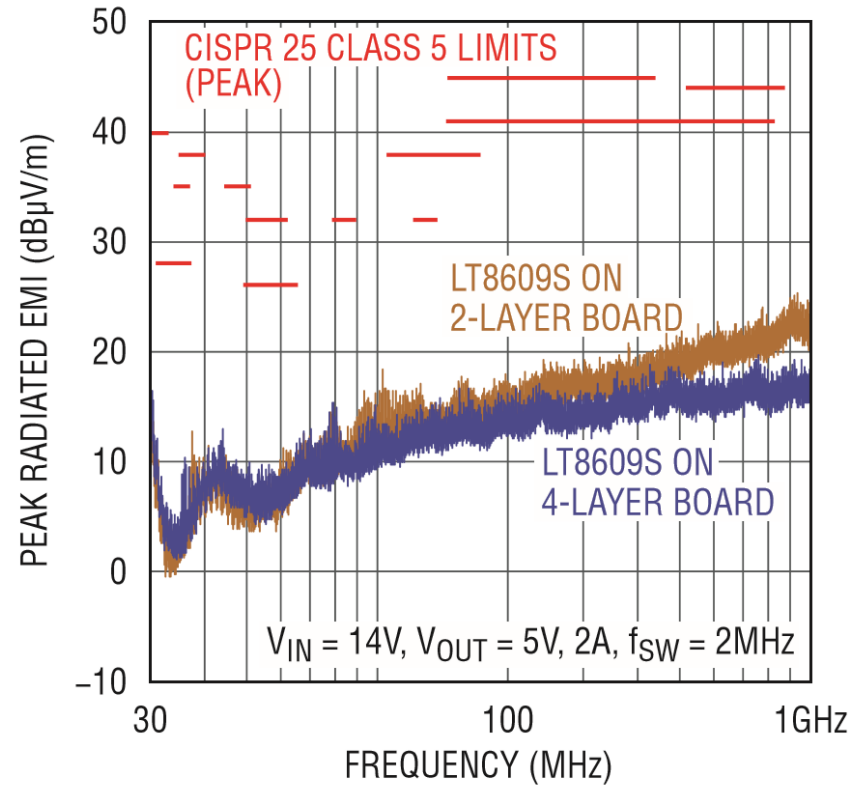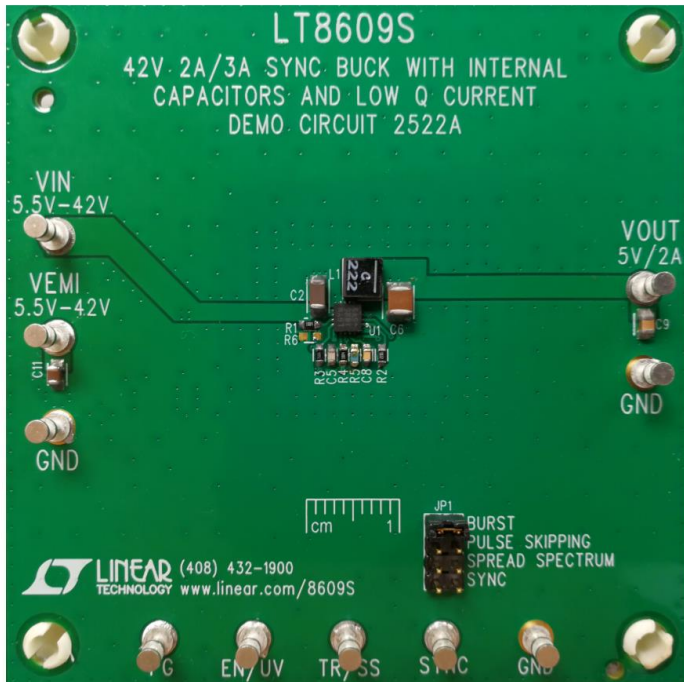
Innovation - Silent Switcher 2

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

V_SW
2V/DIV

1ns/DIV

8650S G40
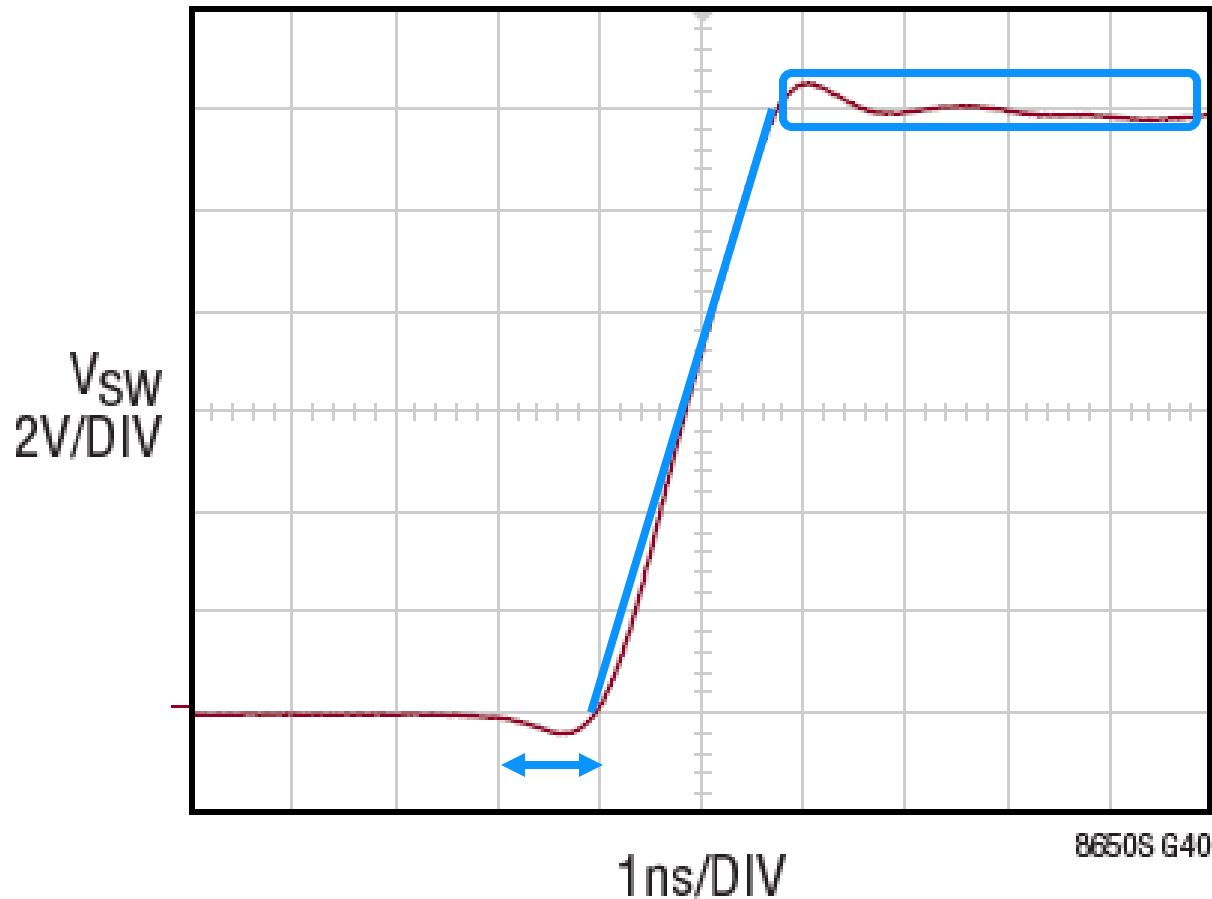
- Hot loop area and inductance virtually zero

- Extremely fast switching

- Neglectable overshoot and no parasitic oscillation on switching node
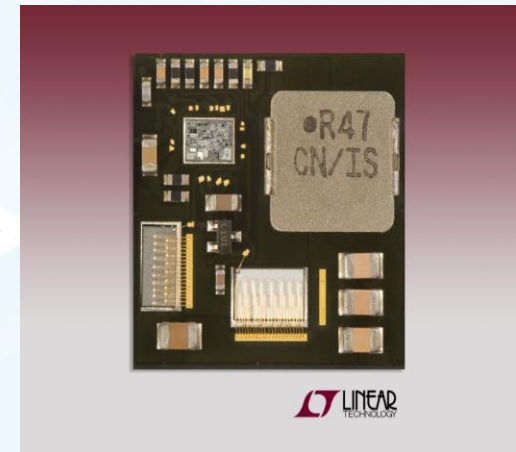
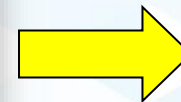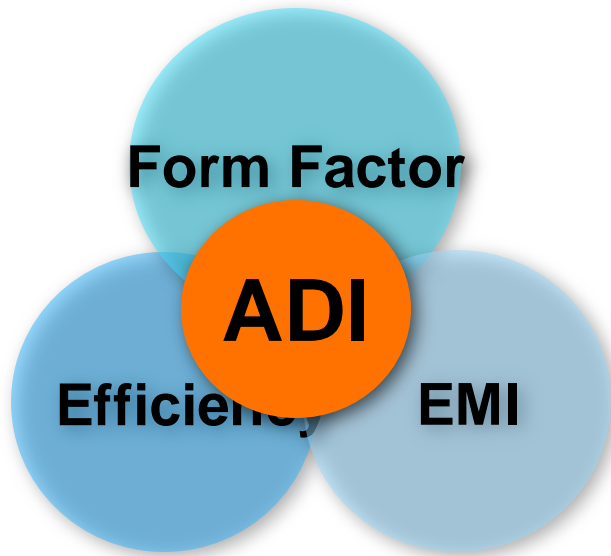- Dead time only 1ns

Unmatched switching performance !
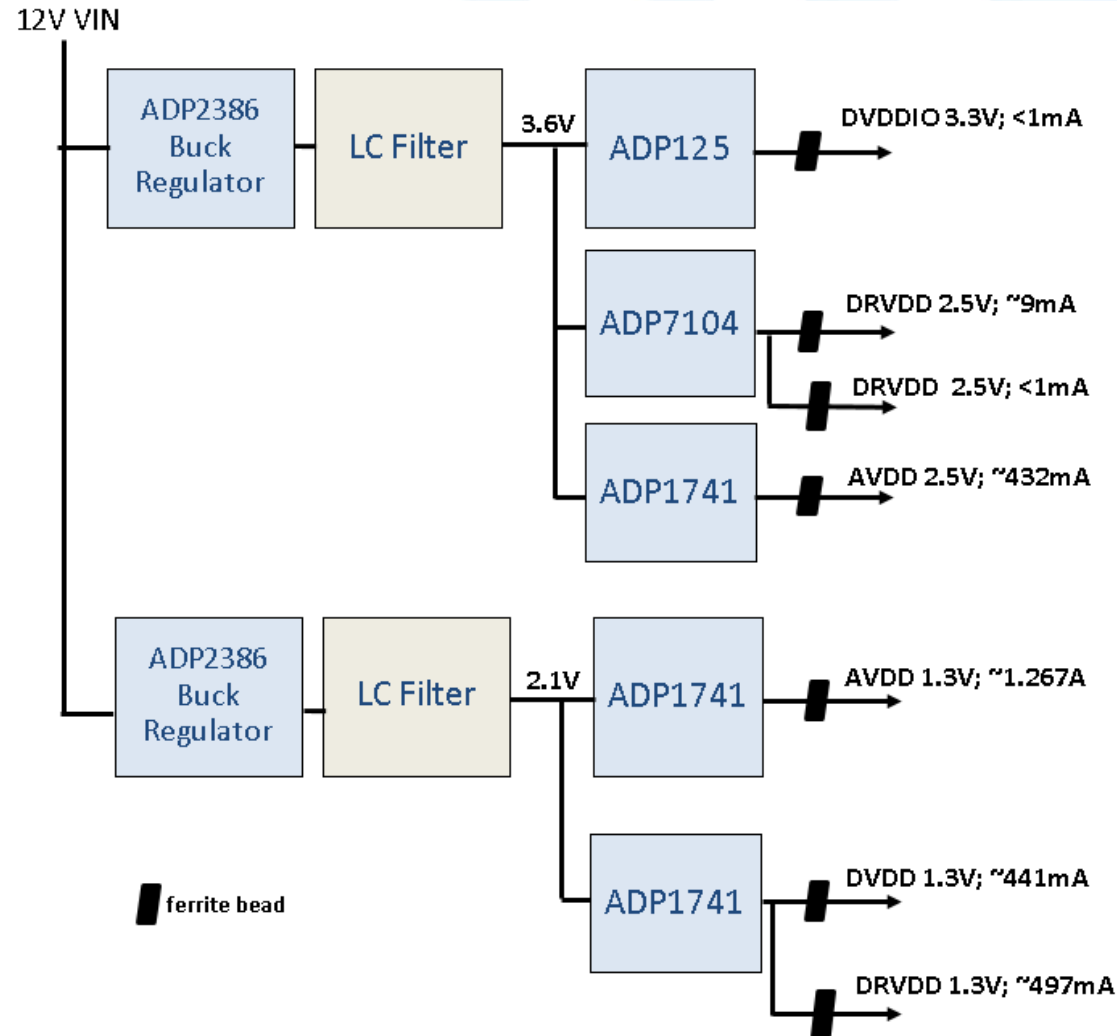
Silent Switcher 2 - Excellent EMI Test Results

Silent Switcher 2 Also Provides Low Output Ripple

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

V_OUT 5mV/DIV

500ns/DIV

DC2522a F06
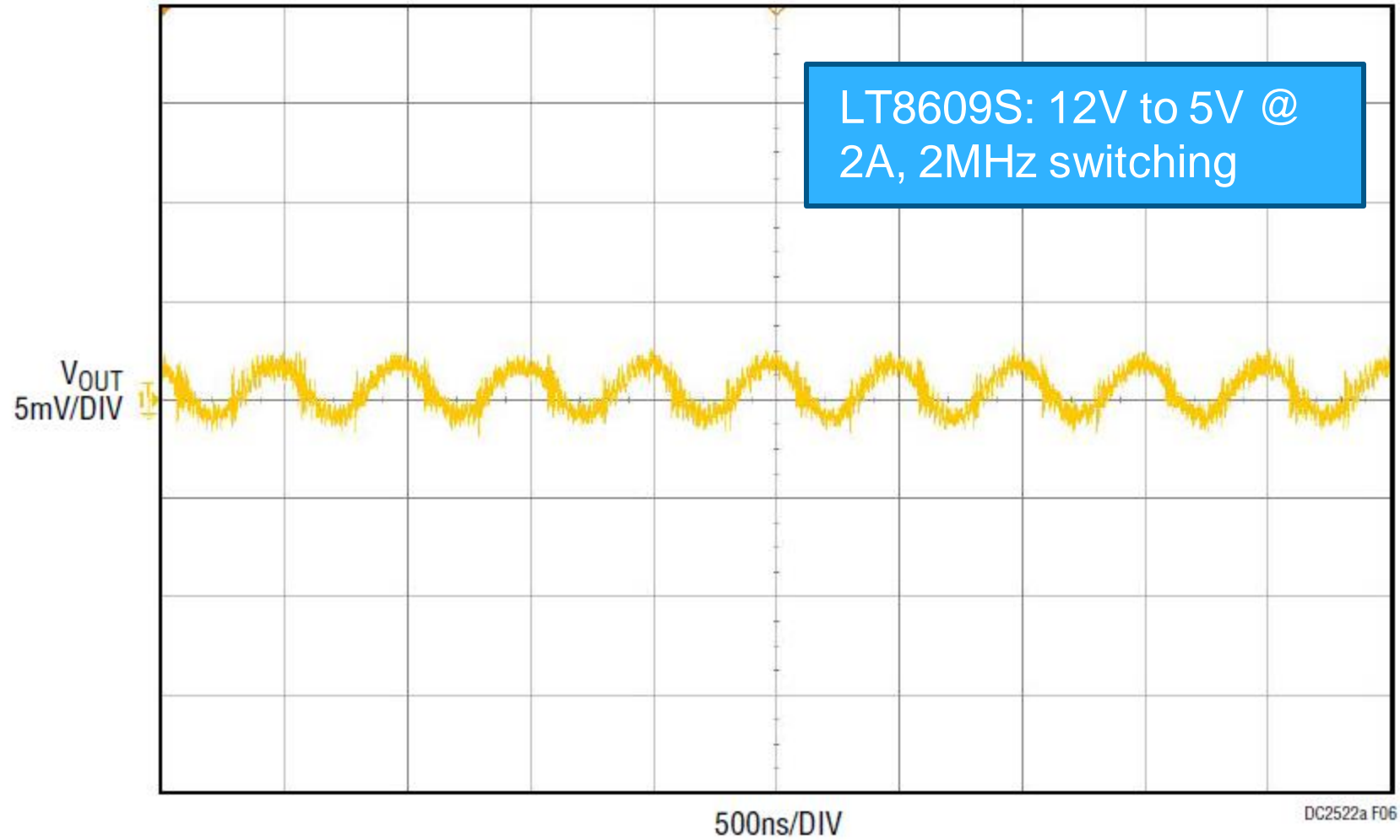
Application 4 – Silent Switch Power Module for High Performance ADC Application

# Application 4 – Silent Switch Power Module for High Performance ADC Application

70 dB SFDR @ 1.8 GHz Ain

ANALOG DEVICES
AD9625
12-Bit
2 GSPS ADC

12V VIN

ADP2386 Buck Regulator → LC Filter → 3.6V → ADP125 → ferrite bead → DVDDIO 3.3V; <1mA

ADP7104 → ferrite bead → DRVDD 2.5V; ~9mA
→ ferrite bead → DRVDD 2.5V; <1mA

ADP1741 → ferrite bead → AVDD 2.5V; ~432mA

ADP2386 Buck Regulator → LC Filter → 2.1V → ADP1741 → ferrite bead → AVDD 1.3V; ~1.267A

ADP1741 → ferrite bead → DVDD 1.3V; ~441mA
→ ferrite bead → DRVDD 1.3V; ~497mA
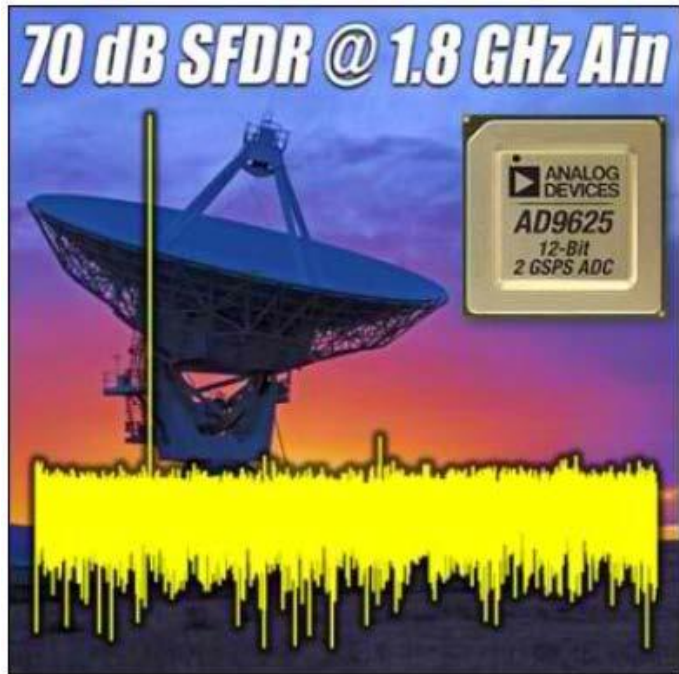
▶ **Good Performance**

▶ **48% efficiency**

▶ **Thermal issue**

▶ **Big power size**

Silent Switcher Technology

Dead time control

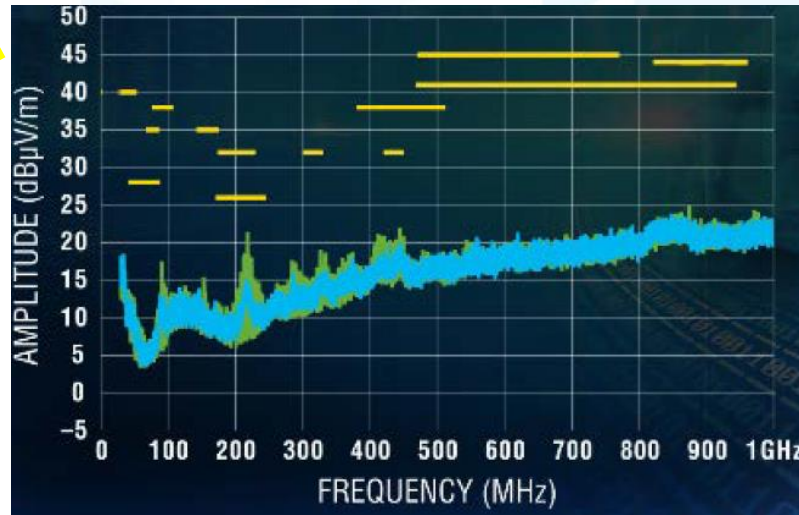## "Hot Loop" Cancellation

**+**

8610

V_SW
2V/DIV

8614

4ns/DIV   an144 F03
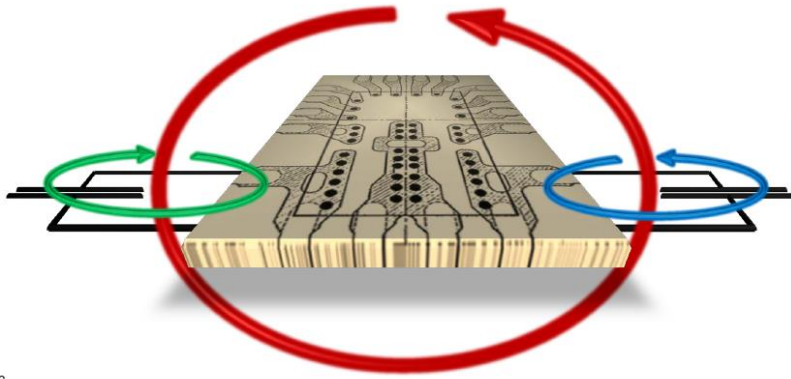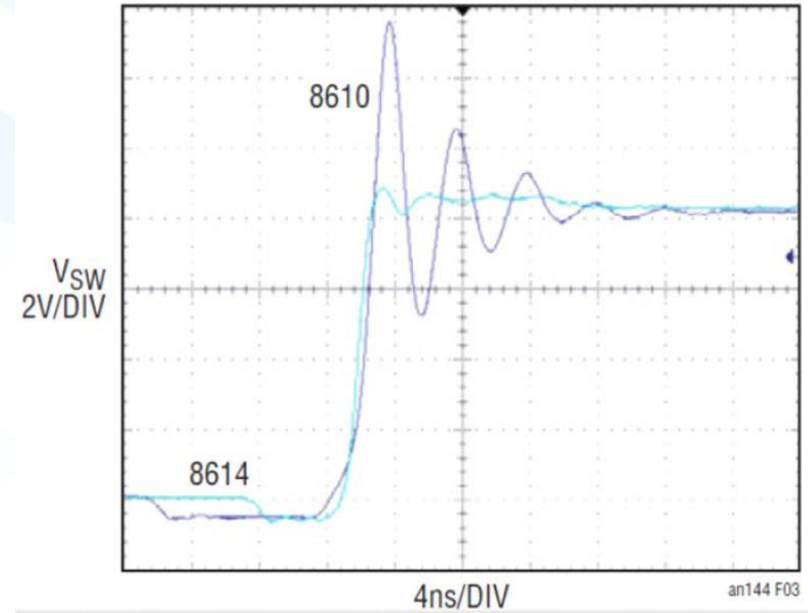
Best EMI performance

40Vin Silent Switcher µModule Regulators

	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

First Generation Silent Switcher uModule
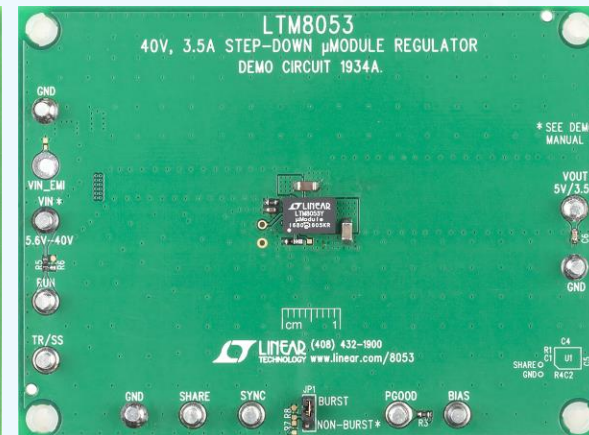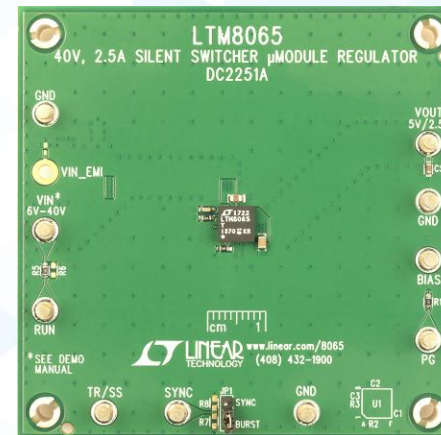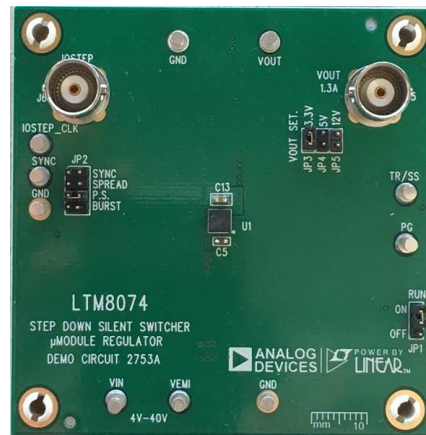
New Power Solution
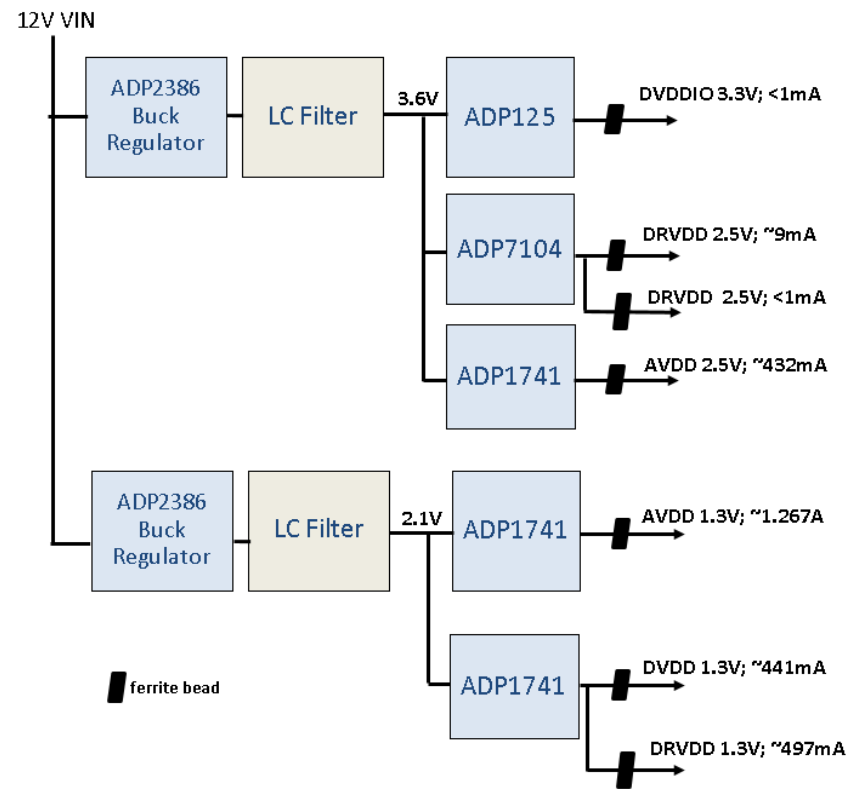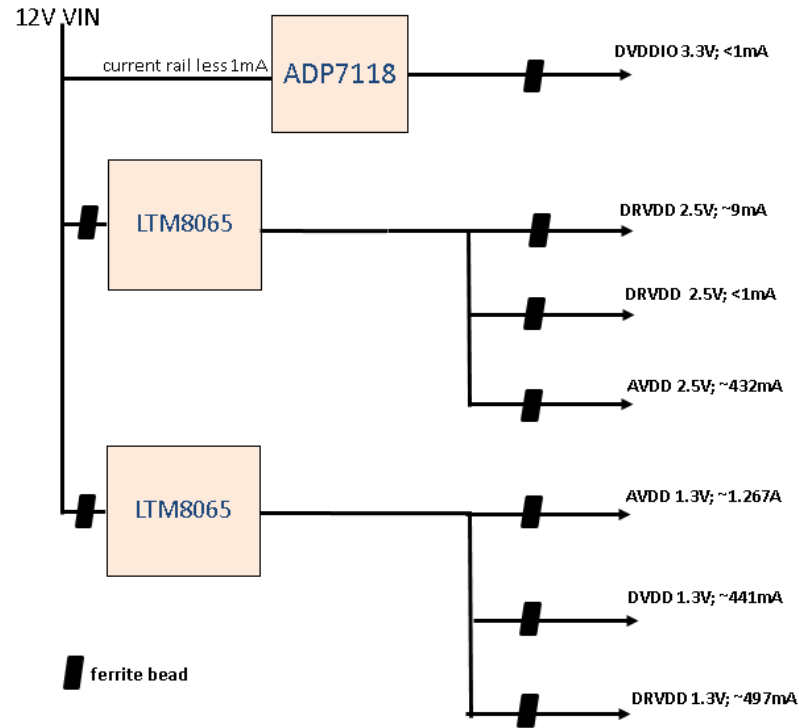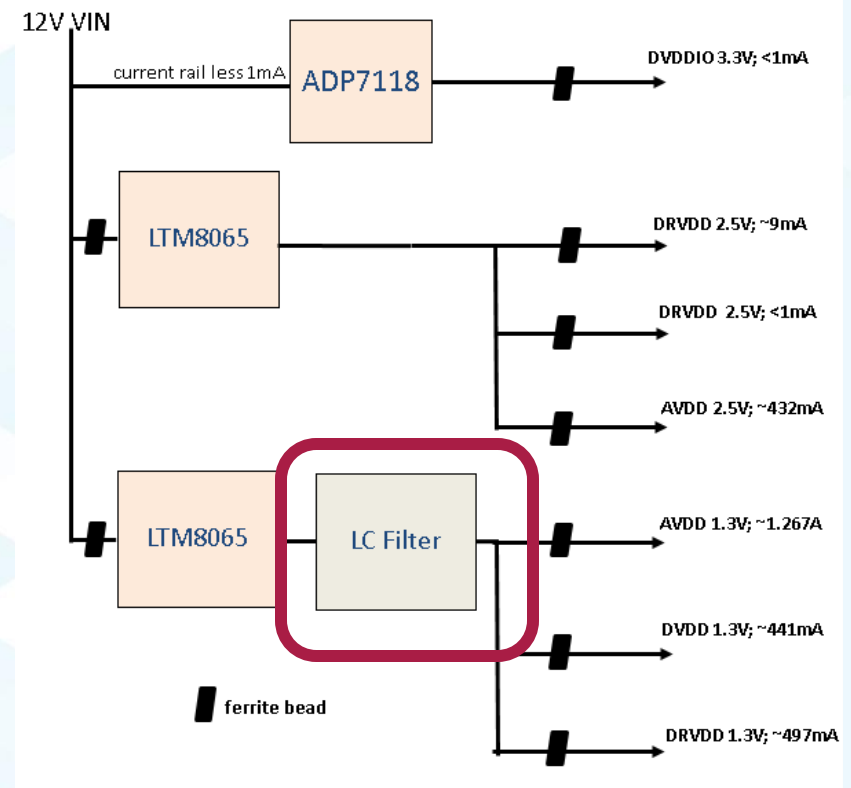
Good Power solution and performance

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

Baseline Power Supply

		Voltage (V)	Current (A)	Power (W)
	PIN	11.729	0.676	7.929
P O U T	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

AD9625 FFT using LTM8065 (AIN = 1349MHz)
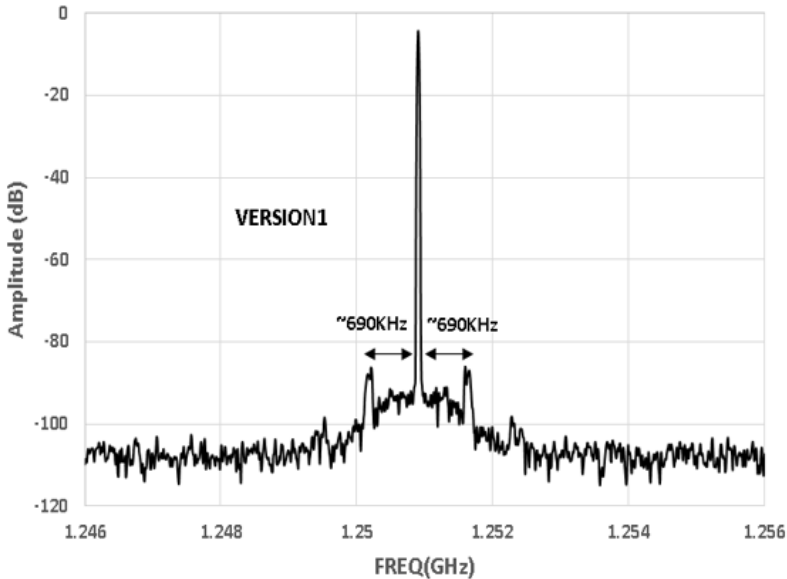
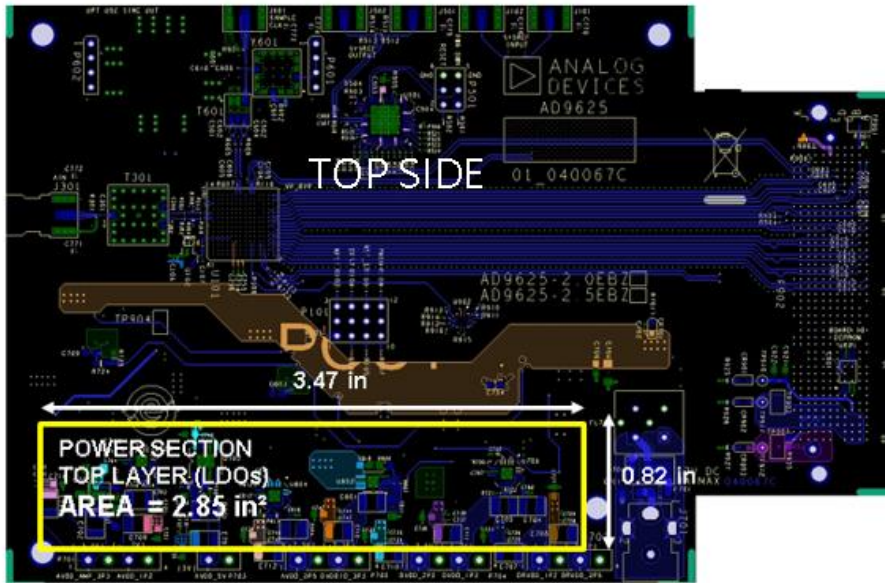AD9625 FFT using LTM8065 + LC Filter (AIN = 1349MHz)
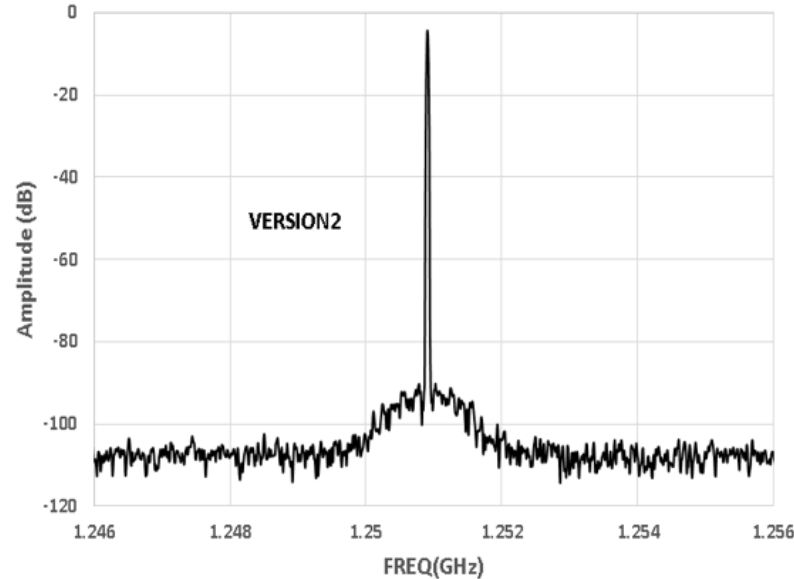
LTM8065 Version 2

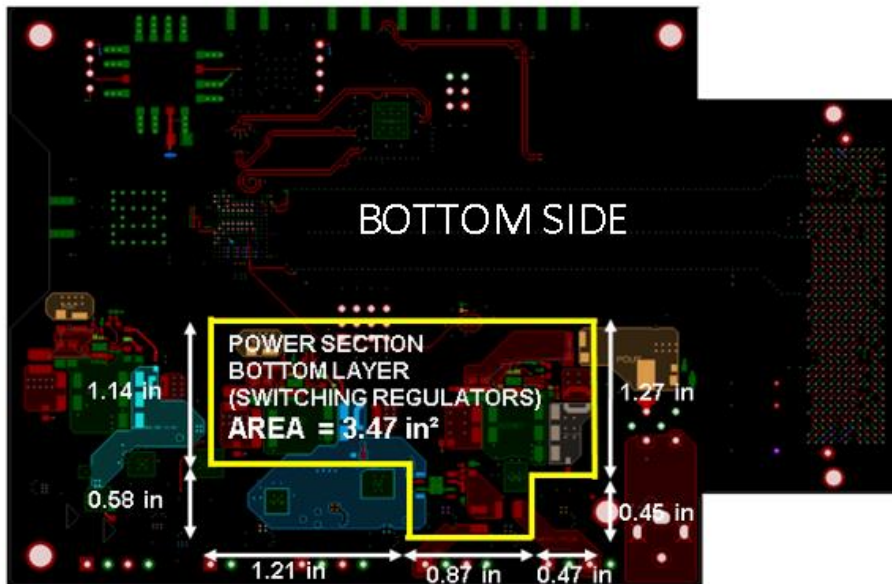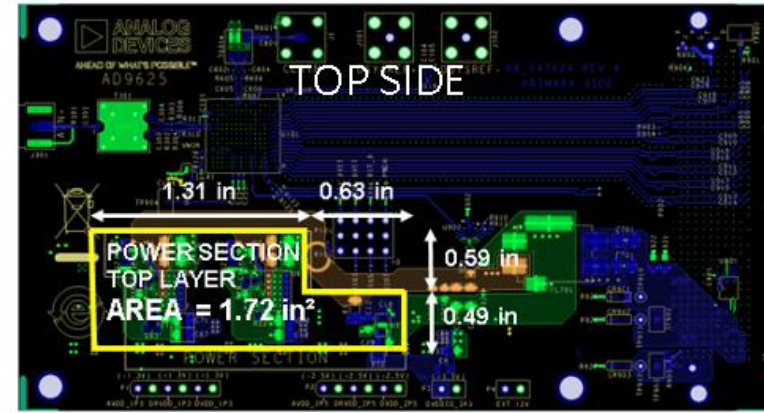|		Voltage (V)	Current (A)	Power (W)
	PIN	11.885	0.442	5.256
P O U T	AVDD_1.3V	1.303	1.308	1.704324
	DRVDD_1.3V	1.302	0.531	0.691
	DVDD_1.3V	1.305	0.459	0.599
	AVDD_2.5V	2.486	0.440	1.094
	DRVDD_2.5V	2.494	0.005	0.012
	DVDD_2.5V	2.496	0.0001	0.0002
	DVDDIO_3.3V	3.301	0.0004	0.0013
	POUT TOTAL:			4.102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

+30%

Silent Switcher uModule - Save PCB size

EVAL-AD9625 Evaluation Board

REVISED Evaluation Board USING LTM8065 POWER SOLUTION

TOP SIDE

POWER SECTION TOP LAYER (LDOs) AREA = 2.85 in²

3.47 in

0.82 in

TOP SIDE

1.31 in   0.63 in

POWER SECTION TOP LAYER AREA = 1.72 in²

0.59 in

0.49 in

BOTTOM SIDE

POWER SECTION BOTTOM LAYER (SWITCHING REGULATORS) AREA = 3.47 in²

1.14 in   1.27 in

0.58 in   0.45 in

1.21 in   0.87 in   0.47 in

PCB Size

6.32in^2 VS 1.72in^2

Understanding High Performance Power Value

Market trend, future demand of MLCC

IHS Markit™
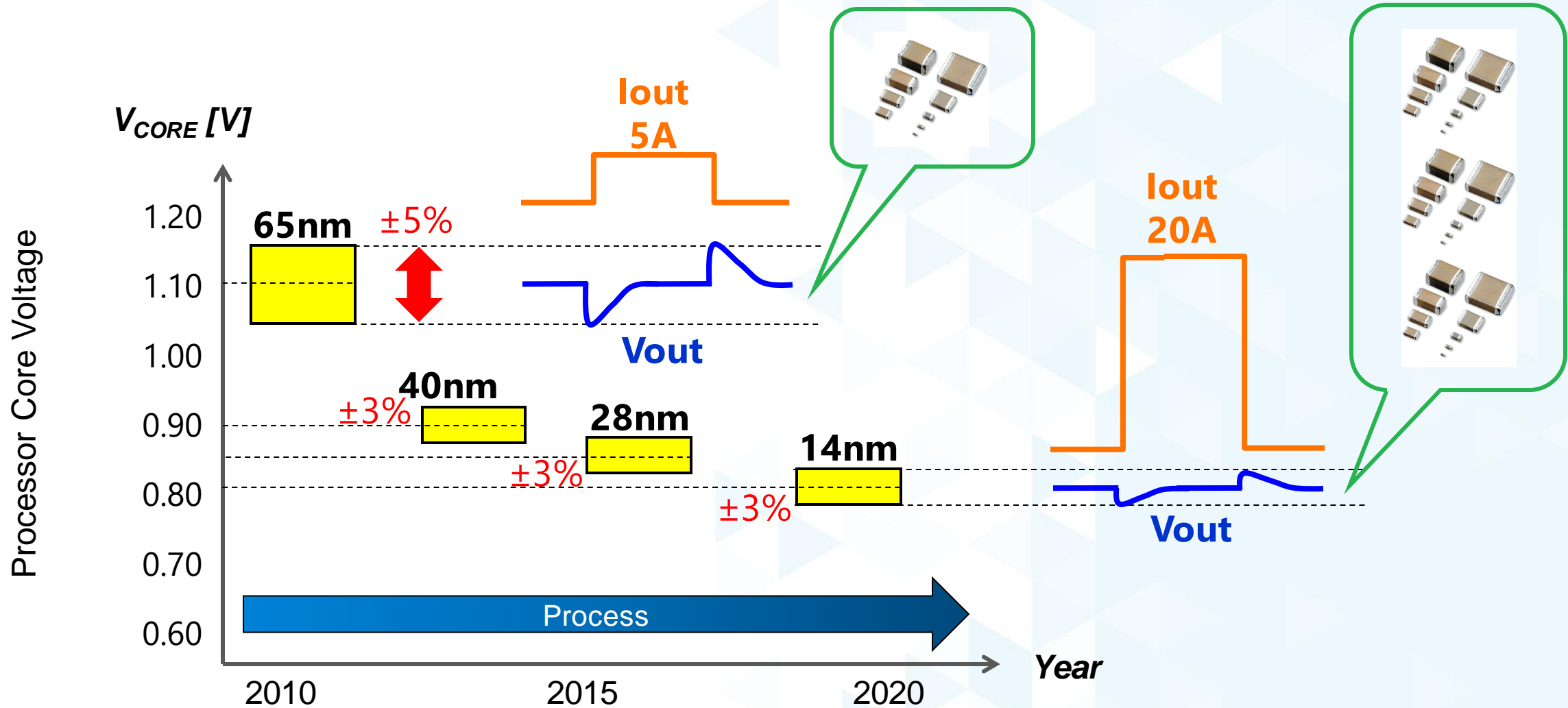
Trend in components demand by vehicle electrification

Quantities per a car

Year	1980	1985	1990	2000	2005	2010	2013	2017	2020	2025
ECU [1]	8	12	17	32	37	45	55	70	100	120
Image Sensor	–	–	–	2	4	7	9	14	19	22
MLCC	100	120	300	500	700	1300	1700	2500	3500	5000
Inductor	3	4	5	6	8	15	50	150	350	500

1) ECU quantities of Medium size car

Trend of MLCC (Multi-Layer Ceramic Capacitor) and Inductor,
ECU and Image sensor will increase due to vehicle features advancing (i.e. ADAS).
MLCC and Inductor will also increase.

How many parts does ADI Power reduce external components

Components Analysis

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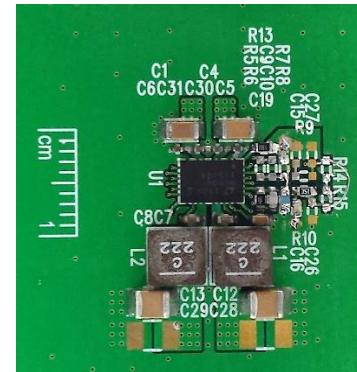
Device	1cs
Capacitor	**14pcs**
Resistor	7pcs
Inductor	2pcs
Total	**24pcs**

Save $ for customer

Size, Simplicity and Flexibility with Multi- Channel Module

LTC3605 x 4
4A Monolithic Regulators

LTM4644
Quad 4A µModule Regulator

15mm

15mm

12mm

20mm
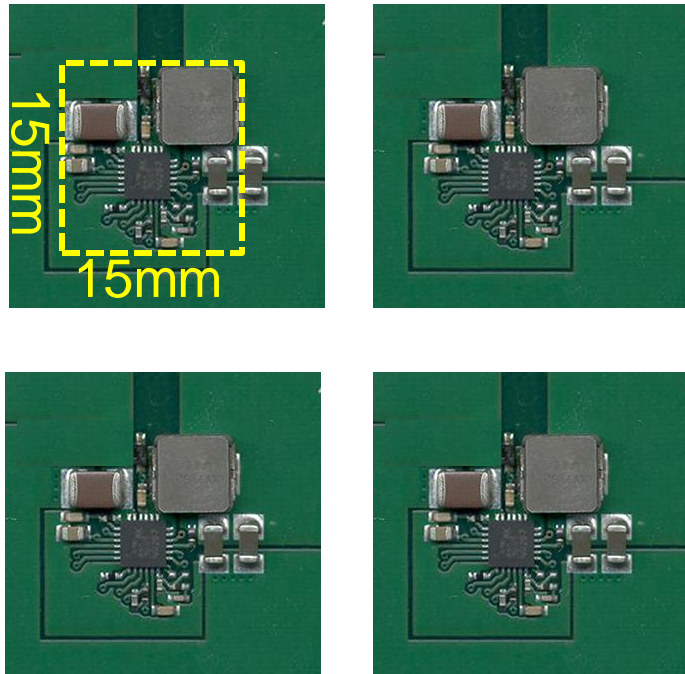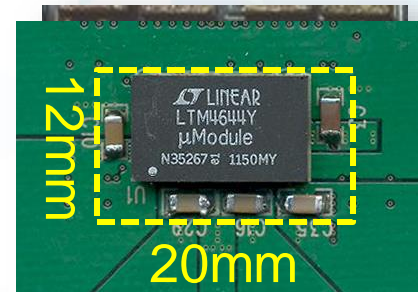
Configurable Output Array*

- 900 mm^2 vs. 240mm^2 = **73% reduction**

Digital Power System Management (Digital PSM) in µModule

- Intelligent POL regulators and system
- **Set, monitor, change and log power parameters via digital bus**
- Remote and on-the-fly modifications without PCB changes
- Fault monitoring and Fault logging of events
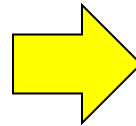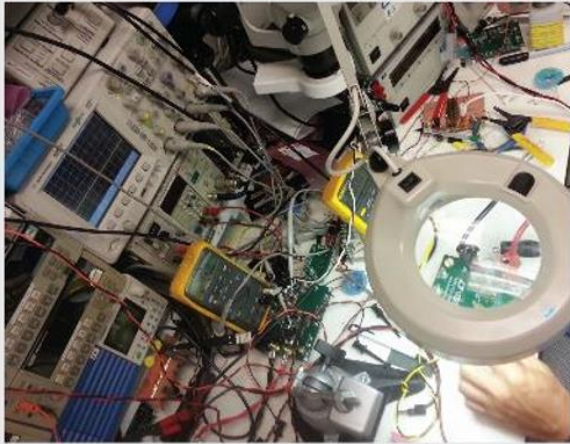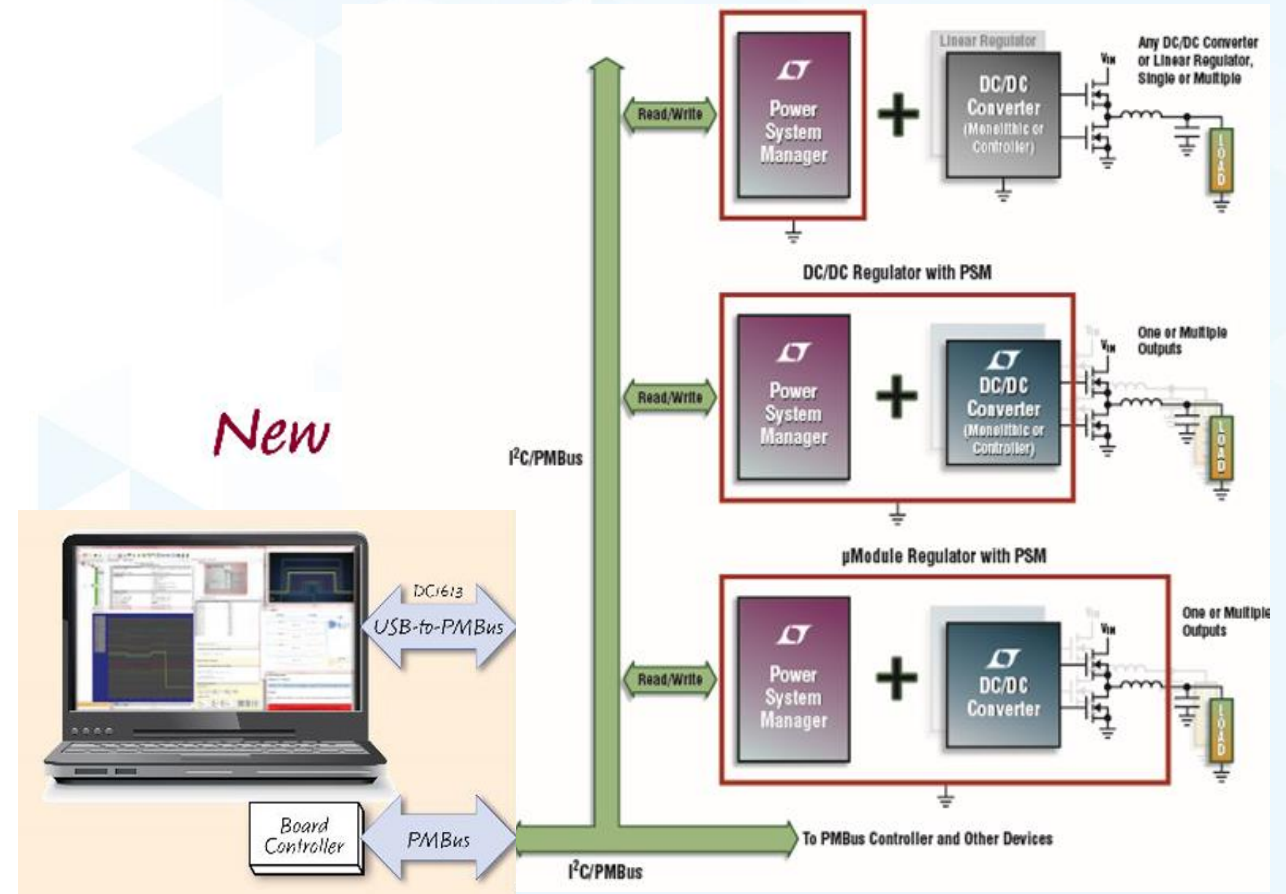
Agenda

► ADI Power Overview

► Applications - How ADI get balance with 3 key matrix

► LTpowerCAD

Power Supply Loop Design / Optimization in the Lab
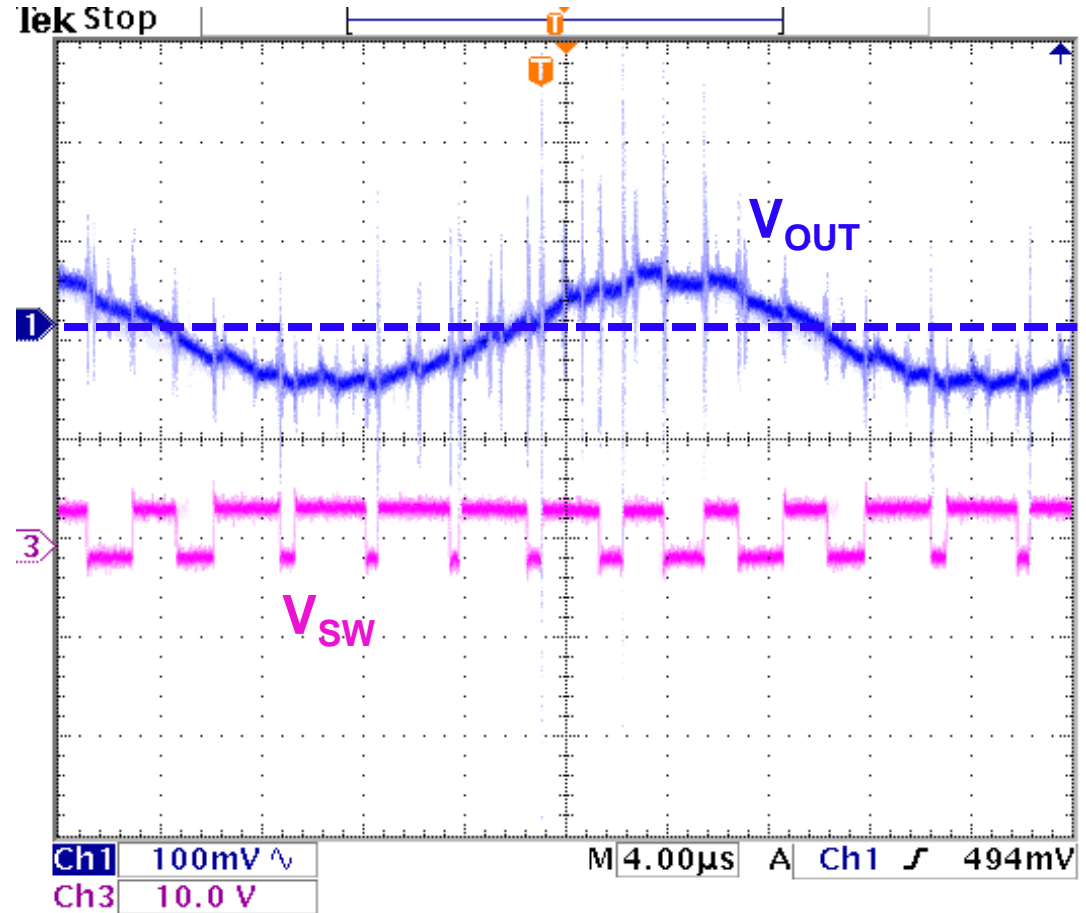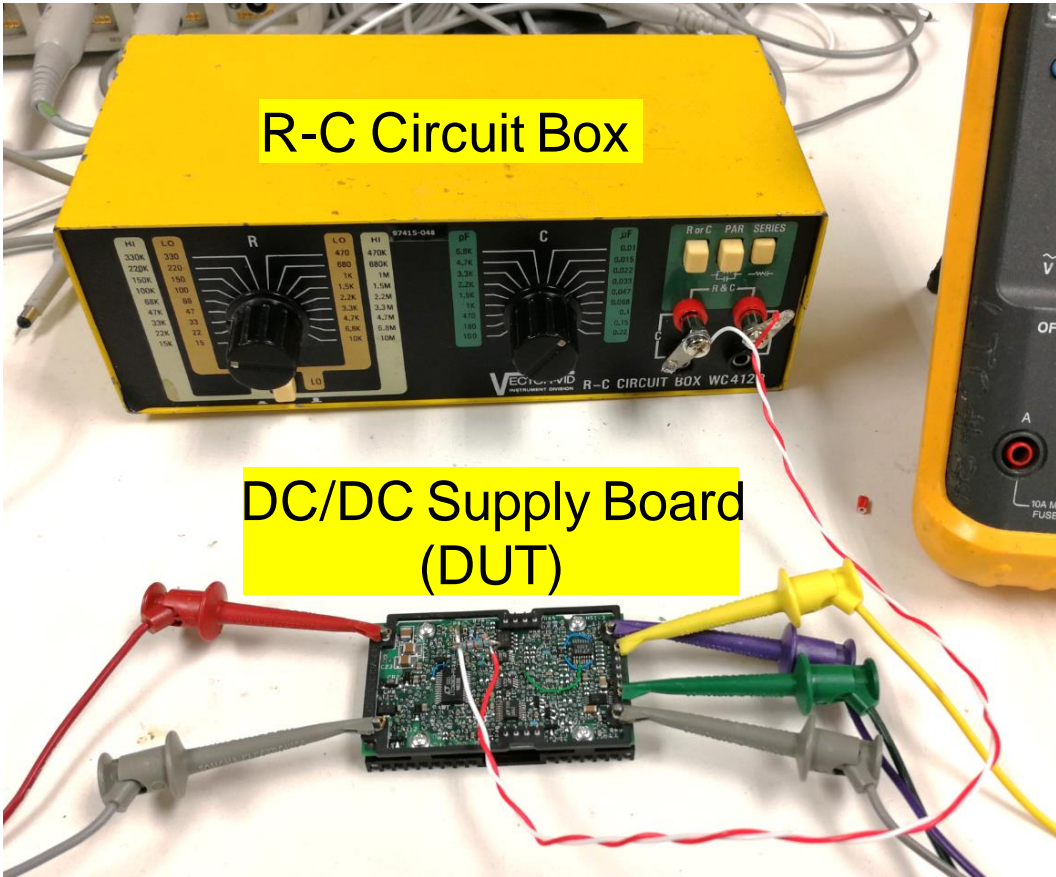
► Manually adjust R and C values. Check loop or load transient.
  ➢ **Accurate, but time-consuming.**
  ➢ **How to support remote customers?**

Complete Power Design Flow with Tools ...

LTpowerPlanner

LTpowerCAD

LTspice
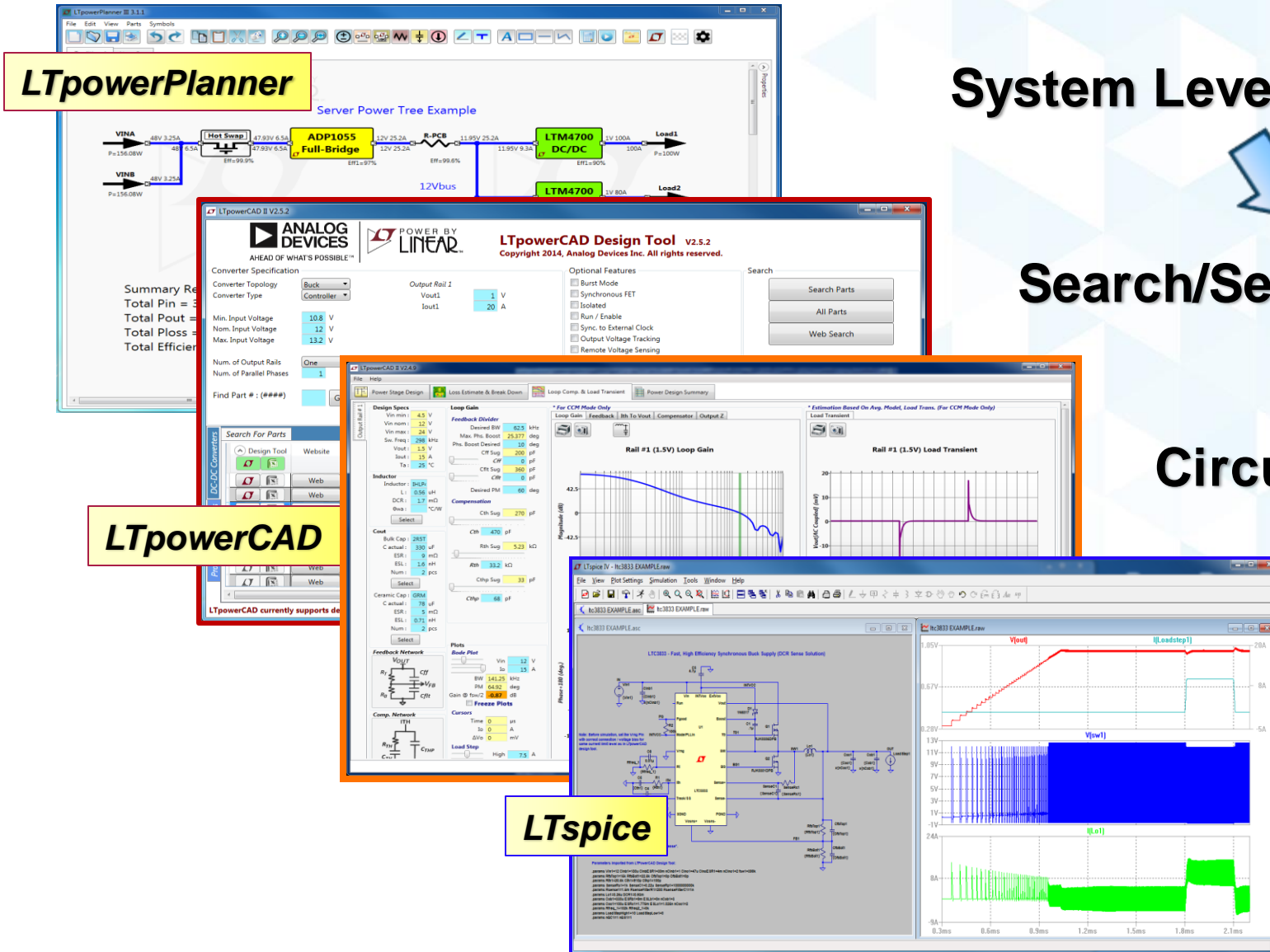
System Level Power Tree

Search/Selection a Solution

Circuit Parameter Design

Simulation

LTpowerCAD - Design Power in 5 Simple Steps!

Step 1 — *Find Solutions*
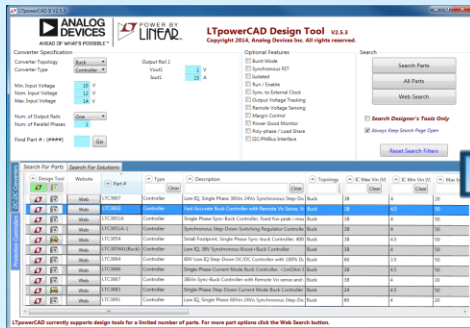
Step 2 — *Power Stage Design*
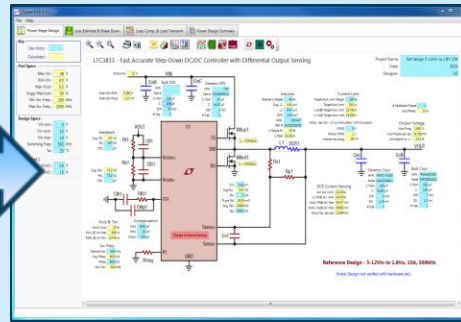
Step 3 — *Efficiency & Loss*
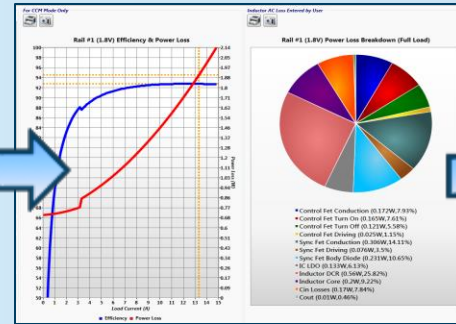
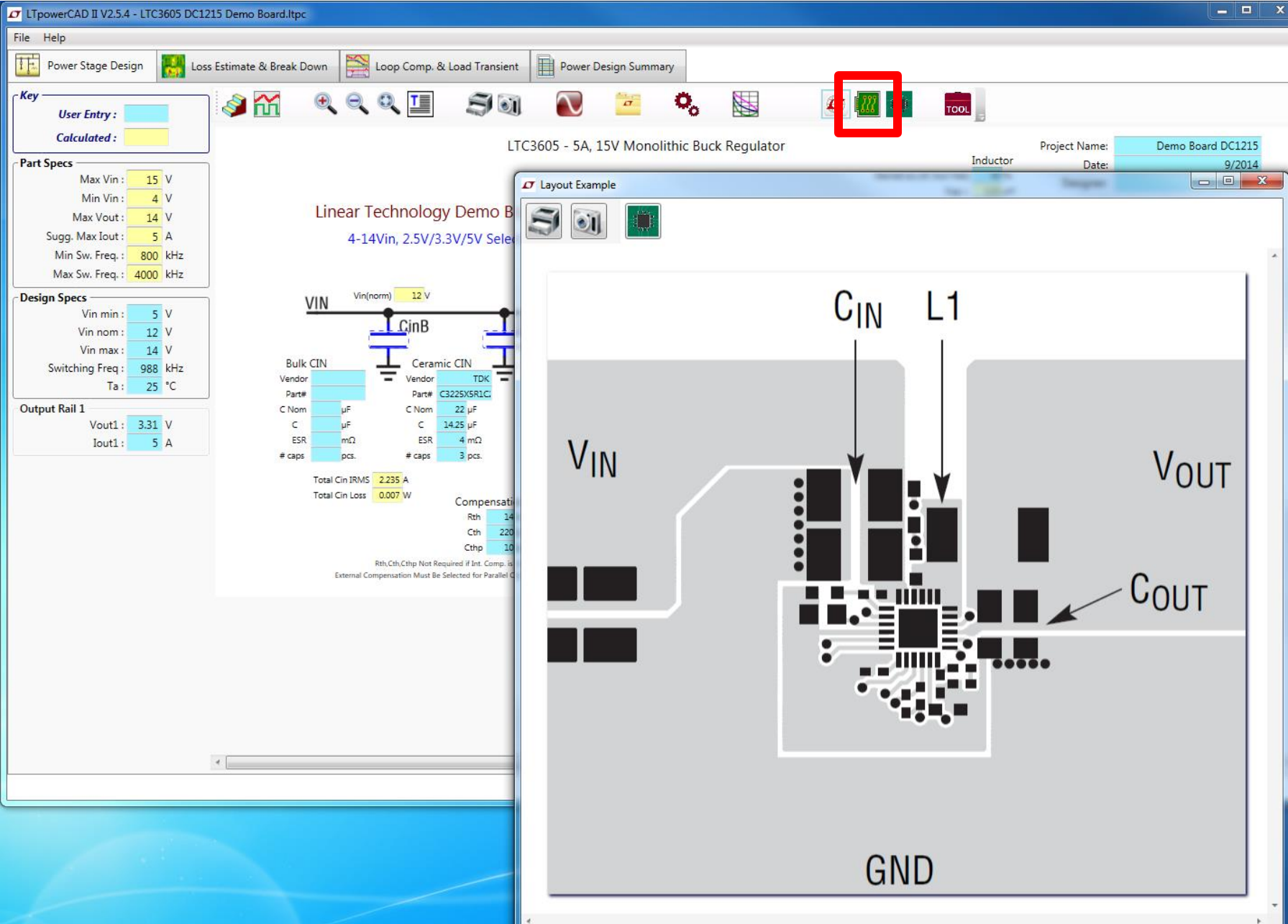**Step 4** — *Loop & Transient*
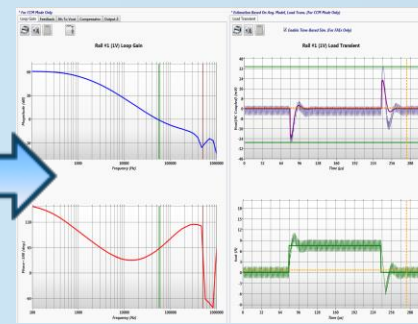
Step 5 — *Summary, BOM, Size*
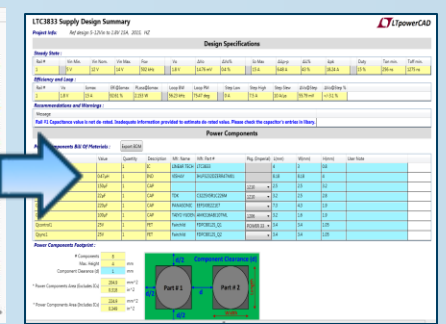
LTspice™
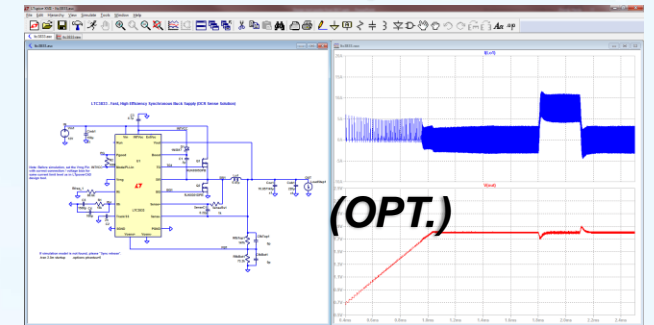
► LTpowerCAD power supply design tool

► Free download @ www.analog.com/LTpowerCAD

► Runs on Windows PC.

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
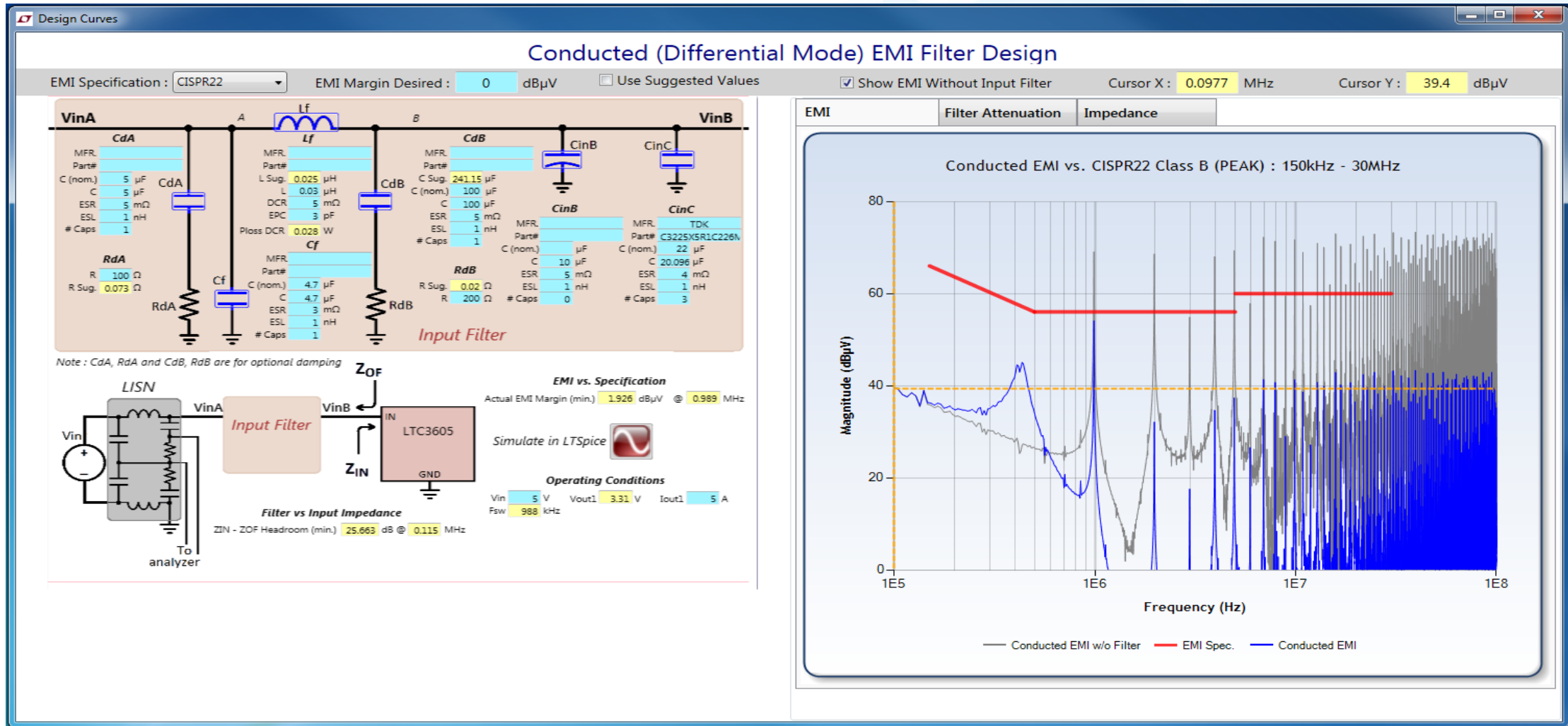
► **First few orders of harmonics determine the filter size.**

DM EMI Noise – Estimated vs. Measured Data

LTpowerCAD EMI Estimation vs. Bench [100k - 30MHz]
No EMI Filter

Fsw=750kHz

Estimated

Measured

Bench Data   LTpowerCAD Exported

LTpowerCAD EMI Estimation vs. Bench [100k - 30MHz]
With EMI Filter

Fsw=750kHz

Estimated

L/C filter resonance

Measured

Bench Data   LTpowerCAD Exported
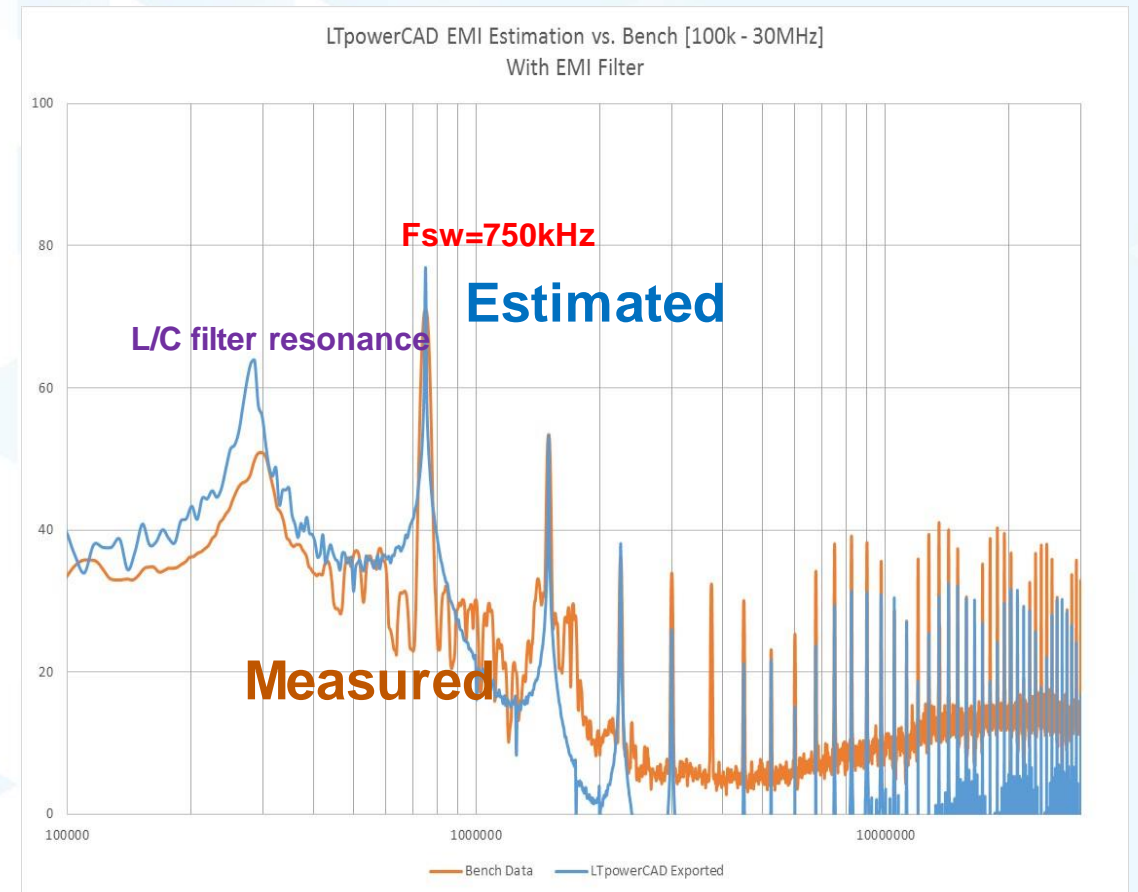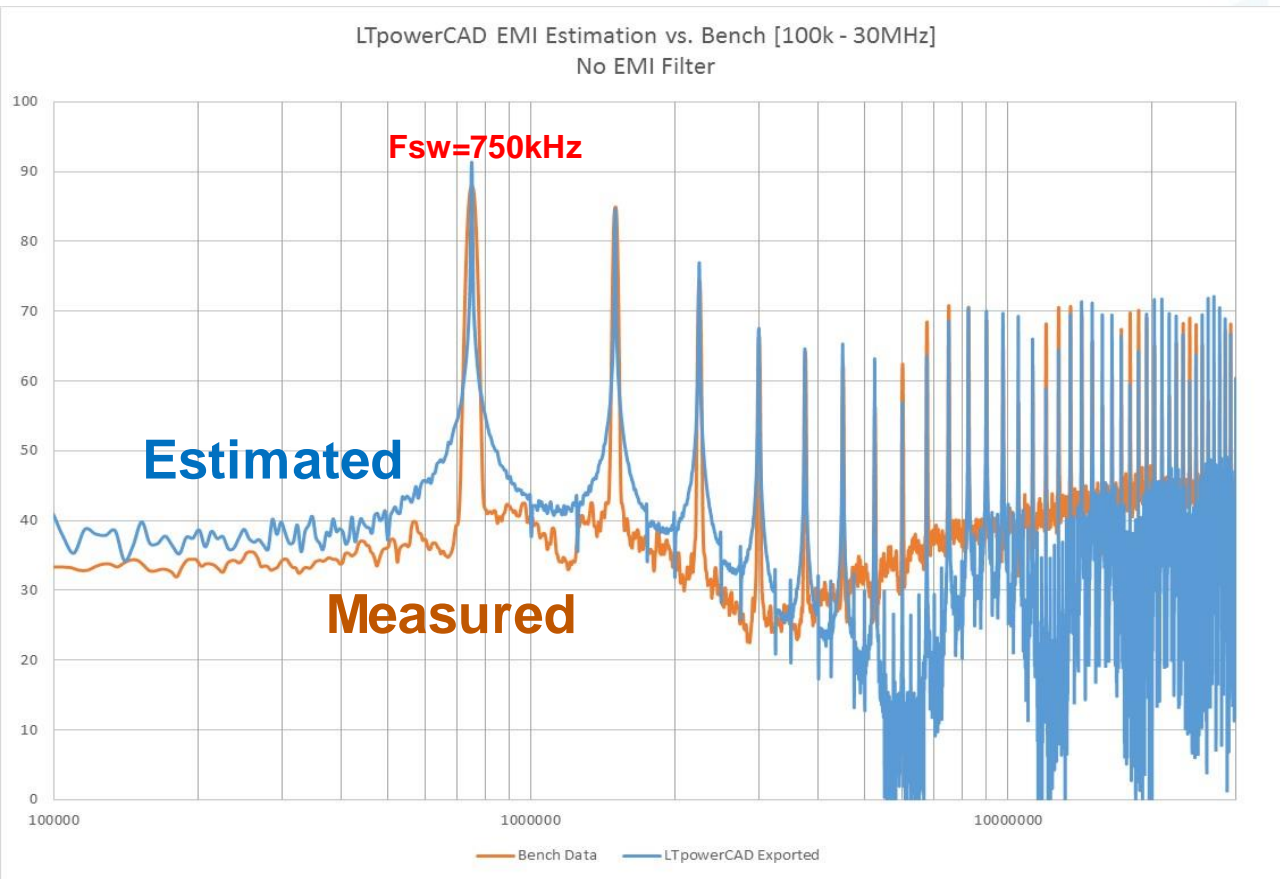
► LTC3851A single phase buck demo board. (12Vin to 1.5Vo/15A, 750kHz).

► **Good matching of peak values.**

ADI Design Center

Search

MYANALOG | MY HISTORY | PRODUCTS | APPLICATIONS | **DESIGN CENTER** | EDUCATION | SUPPORT

Design Center

Circuit Design Tools & Calculators

Get product selection and design assistance using our online and downloadable tools.

- **LTspice**
- **Amplifier & Linear Tools**
- **Clock & Timing Tools**
- **Converter Tools**
- **Power Management Tools**
- **RF & Synthesis Tools**

Simulation Models

Collection of product simulation models used in industry standard simulation tools.

- **SPICE Models**
- **IBIS Models**
- **MathWorks Behavioral Models**
- **BSDL Models**
- **S-Parameters**
- **Sys-Parameter Models for Keysight Genesys**

Evaluation Hardware & Software

Evaluate different components and technologies ADI provides at your bench.

- **LTspice Demo Circuits**
- **Product Evaluation Boards & Kits**
- **Evaluation Platforms**
- **Linduino**
- **Software**
- **Development Platforms**
- **ACE Software**

Reference Designs

Collection of hardware board designs, software drivers, and application algorithms.

- **Circuits from the Lab**
- **Drivers & Reference Code**
- **FPGA and Processors Compatible Reference Designs**

Packaging, Quality, Symbols & Footprints

Find all resources needed for designing and developing a printed circuit board (PCB).

- **Package Index**
- **Package Resources**
- **Quality & Reliability**
- **Symbols & Footprints**

Processors & DSP

From documentation, hardware, software, and more, it's everything you need for processors.

- **Software**
- **Hardware**
- **Technical Library**
- **Third Party Developer Program**

ADI Power Creative Advantage for Customer

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

► **Very wide input range**
- 4V to 42V, 60V, 150V and 650V are all available

► **Broad portfolio**
- LDO, buck, boost, buck-boost, isolated, inverting …..
- >1000 products

► **Low quiescent current**
- critical in always-on systems

► **Low EMI**
- Silent Switchers surely is a superstar
  - With Silent Switchers 2, you don't need to care too much on layout
- Even without silent switcher, our tight frequency control and nicely controlled switching are also good in low EMI applications

► **Small form factor**
- Not only the part itself but the overall solution size
- µModule provides the best power density

► **Good power supply quality**
- Low output ripple
- Fast transient response – high bandwidth and stable
- High efficiency over wide range of loading
- High reliability, robust by design
- Lots of protection (OV, OC, OT etc.)

► **Innovation**
- Silent Switchers
- No-opto flyback
- 4-switch buck-boost
- Surge stopper
- Fast ideal diodes
- High voltage, high power charge pump

► **Great customer support!!!**
- We are always your power supply consultants

The End!

ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™