ANALOG DEVICES

AHEAD OF WHAT'S POSSIBLE™

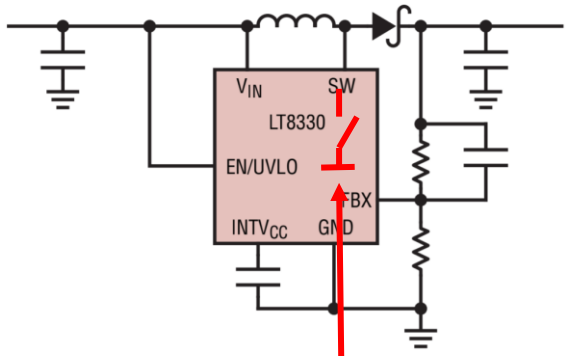
ADI
High Performance Power Solution in Automotive and Industrial Markets

Outline

- Buck/Boost / Buck-Boost / Inverting Basics Overview
- Monolithic high voltage synchronous buck products family
- Monolithic Non-Synchronous/ Synchronous boost products family
- 4-Switch Buck-Boost Controllers/umodule for High Power
- Inverting Converter Design
- Surge Stopper and Protect

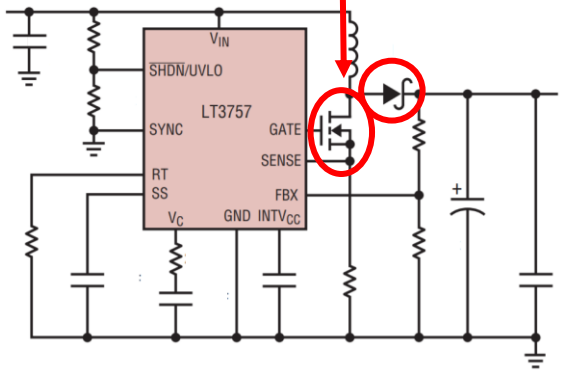
Switch DC-DC Variants

Monolithic – internal Switch(es)



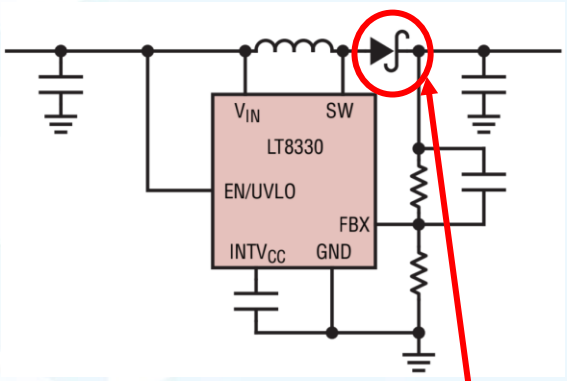
Higher Integration

Controller – external Switch(es)



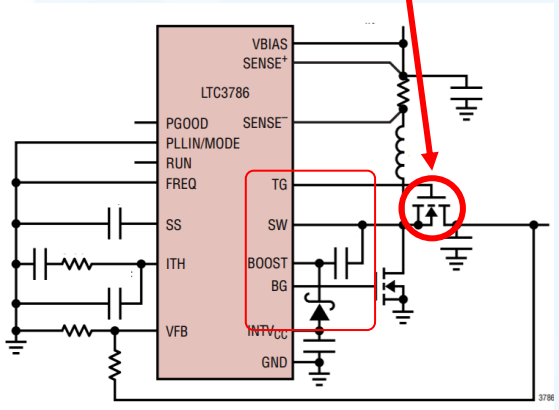
Higher Power

Non-Synchronous Rectification



Simple Control

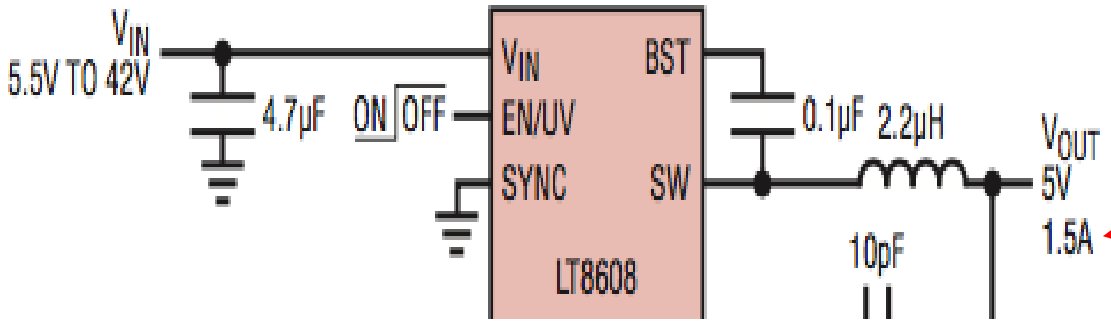
Synchronous Rectification



Higher Efficiency

Buck or Boost Converter Current Rating

- In **bucks**, $I_{OUT} \sim I_{SW}$, so the title of the datasheet reflects **output current capability**:

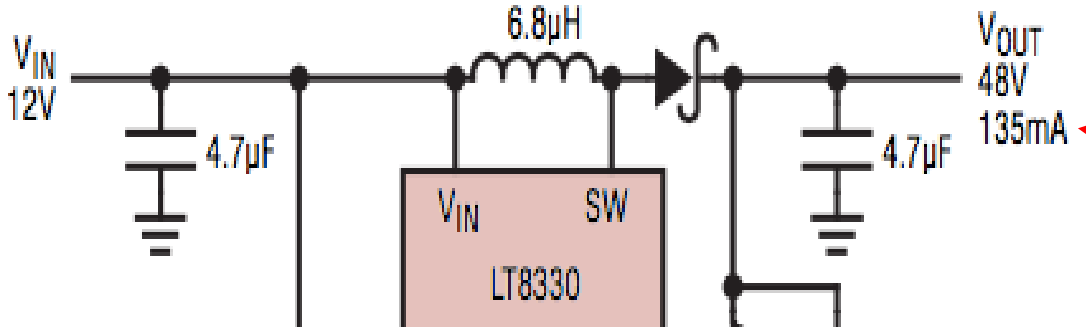


LINEAR TECHNOLOGY

LT8608

42V, 1.5A Synchronous Step-Down Regulator with 2.5µA Quiescent Current

- In **boosts**, $I_{OUT} < I_{SW}$, so the title **shows switch current capability**:



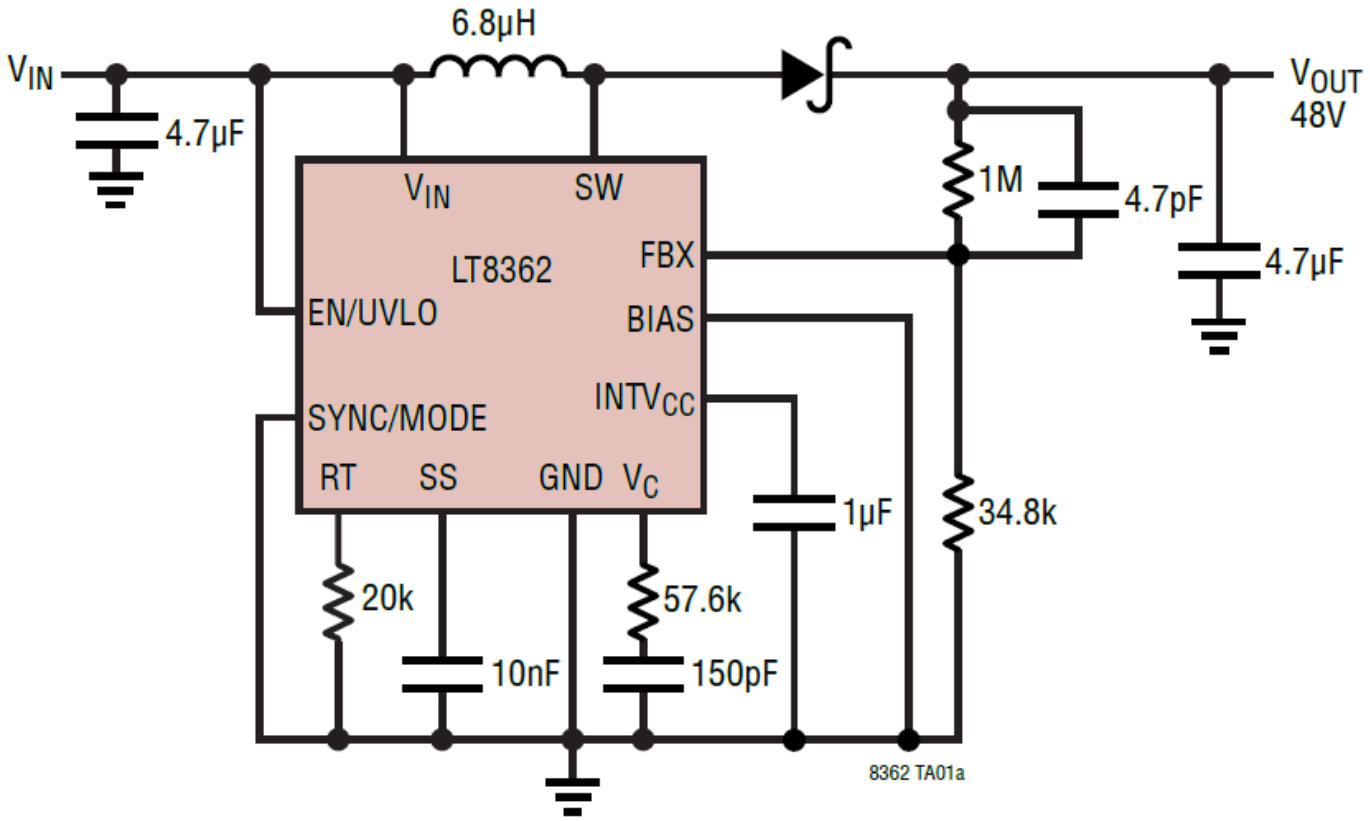
LINEAR TECHNOLOGY

LT8330

Low I_Q Boost/SEPIC/ Inverting Converter with 1A, 60V Switch

Boost Regulator Current Rating – I_{OUT} vs V_{IN}

LT8362 Low IQ Boost/SEPIC/Inverting Converter with 2A, 60V Switch



DEMO MANUAL DC2628A

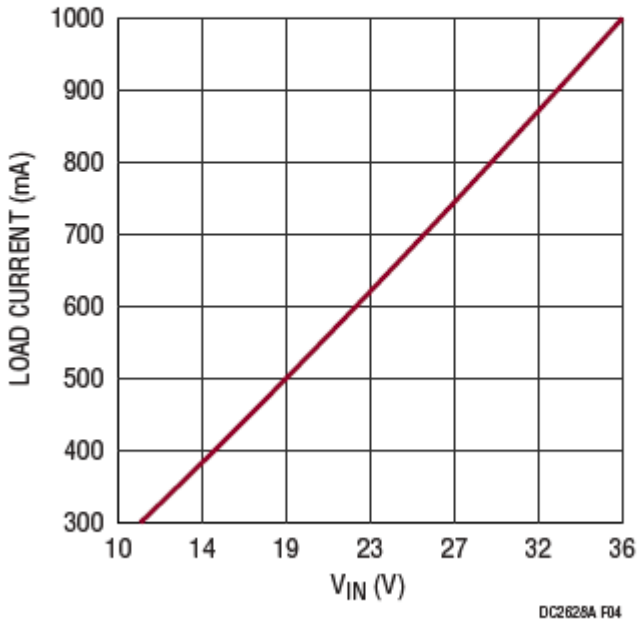


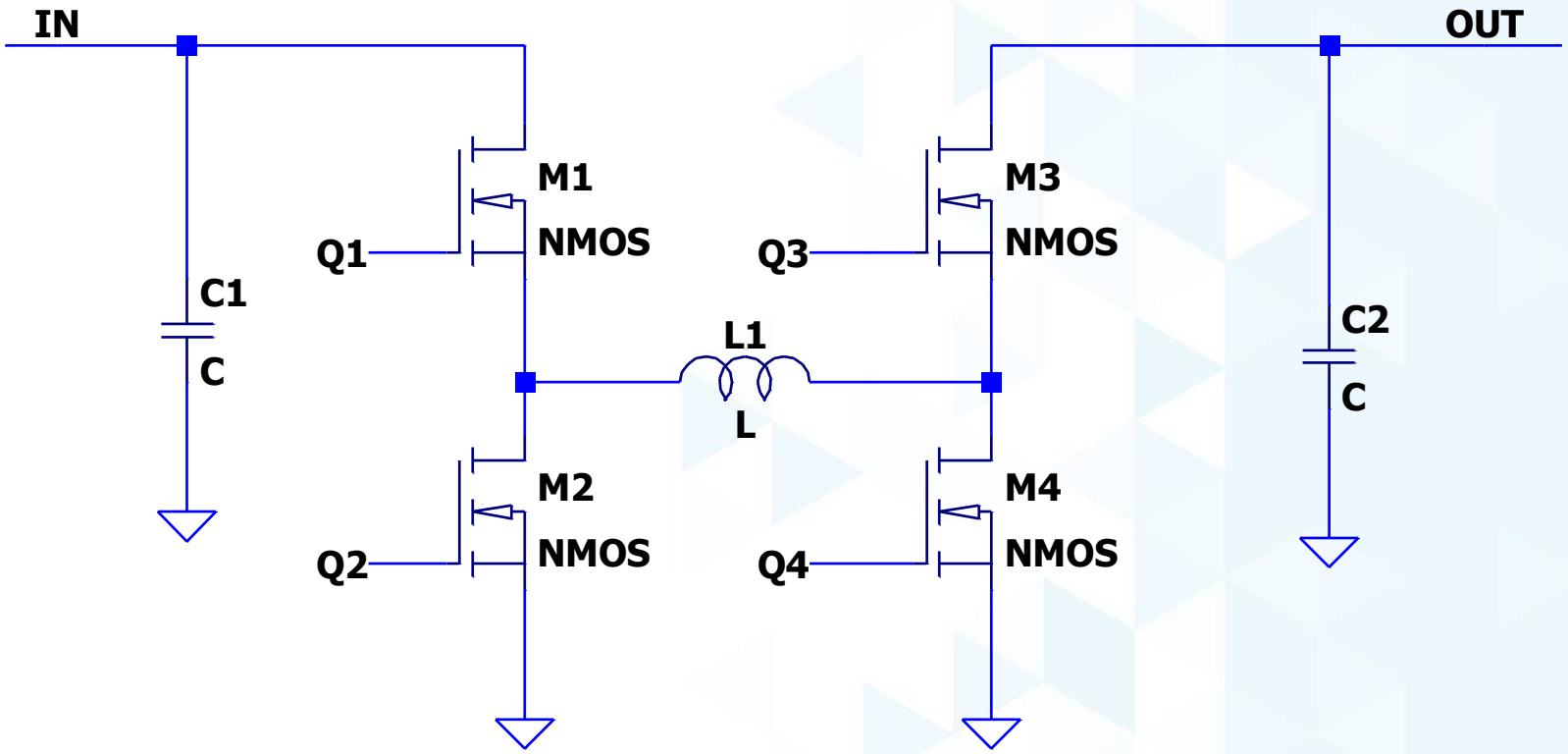
Figure 4. Load Current vs Input Voltage

$$I_{SW} \geq \frac{1.2}{\eta} \frac{V_{OUT}}{V_{IN\,min}} I_{OUT}$$

$$I_{OUT} \propto V_{INmin}$$

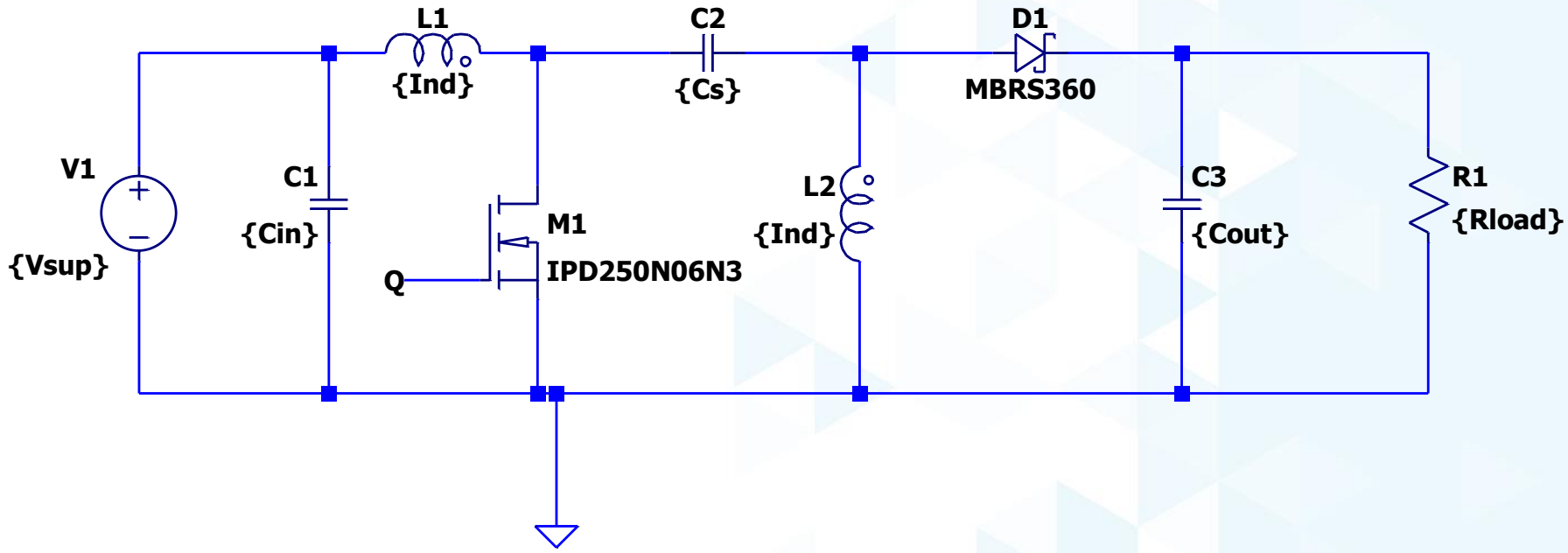
Topology Review : 4-Switches Buck-Boost

- Two half-bridges with an inductor in the middle
- Left half looks like a buck converter, right half looks like a boost converter

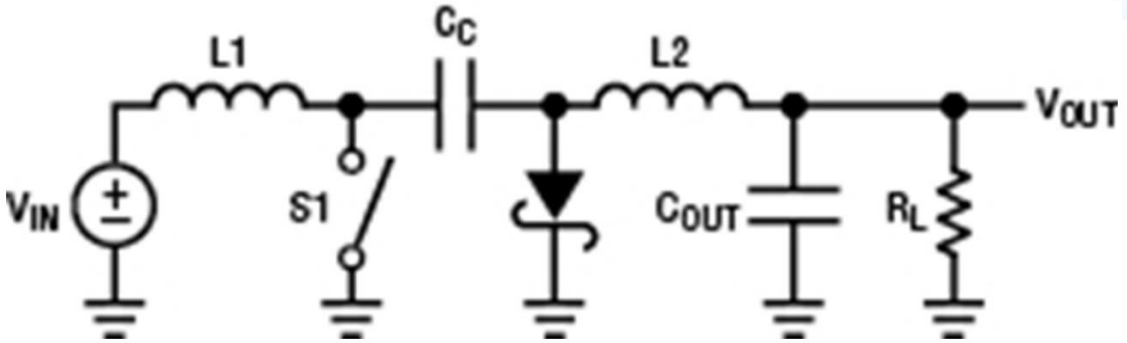


Topology Review – SEPIC

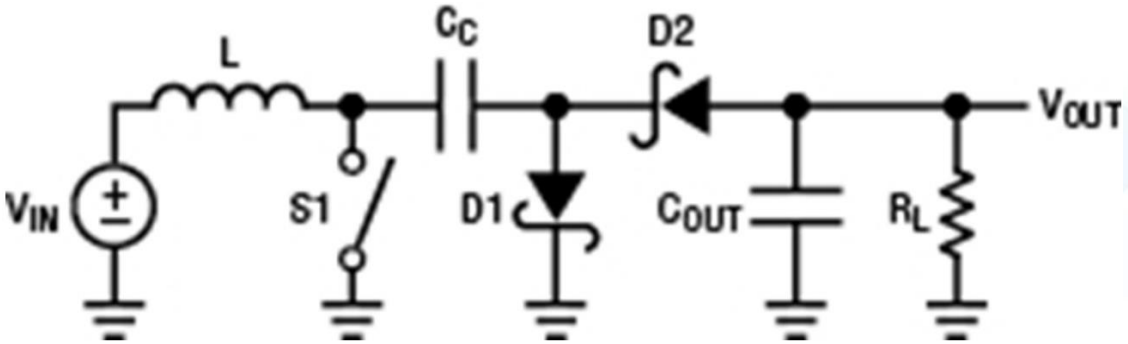
- SEPIC: “Single-Ended Primary Inductor Converter”
- Usually operated asynchronously



Topology Review : Inverting Converter



Cuk Topology



Inverting Charge Pump Topology

- Similar topology:
  - Cuk's second inductor replaced by a schottky diode in inverting charge pump
  - both have a low-side power switch
- The switch node always has a positive voltage applied to it

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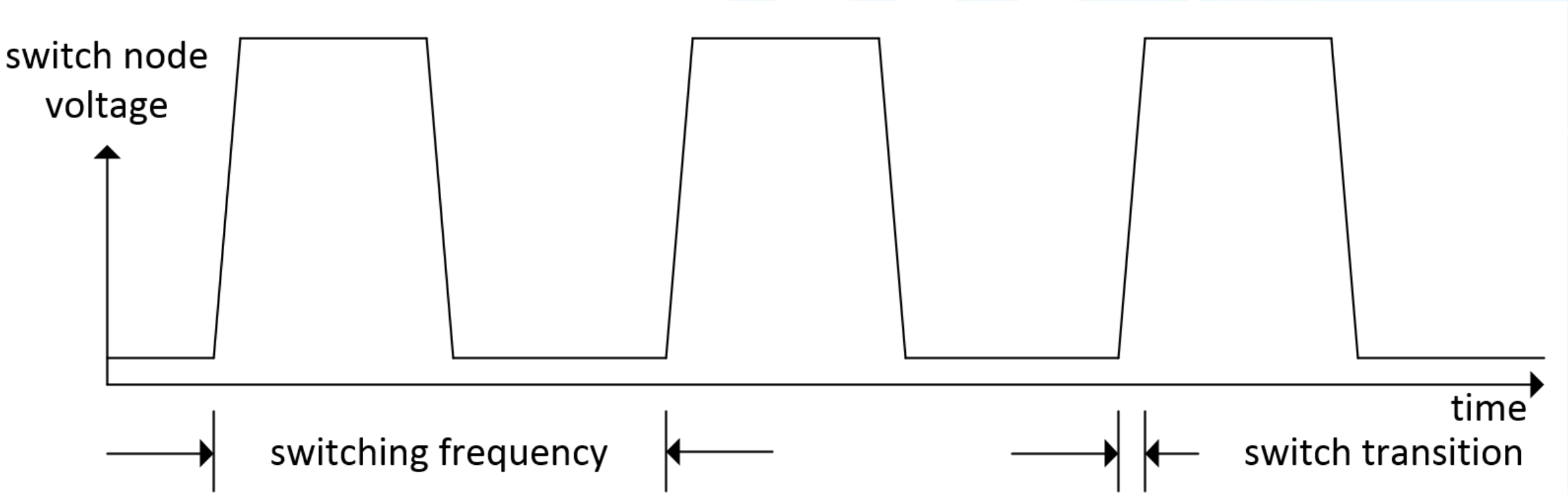
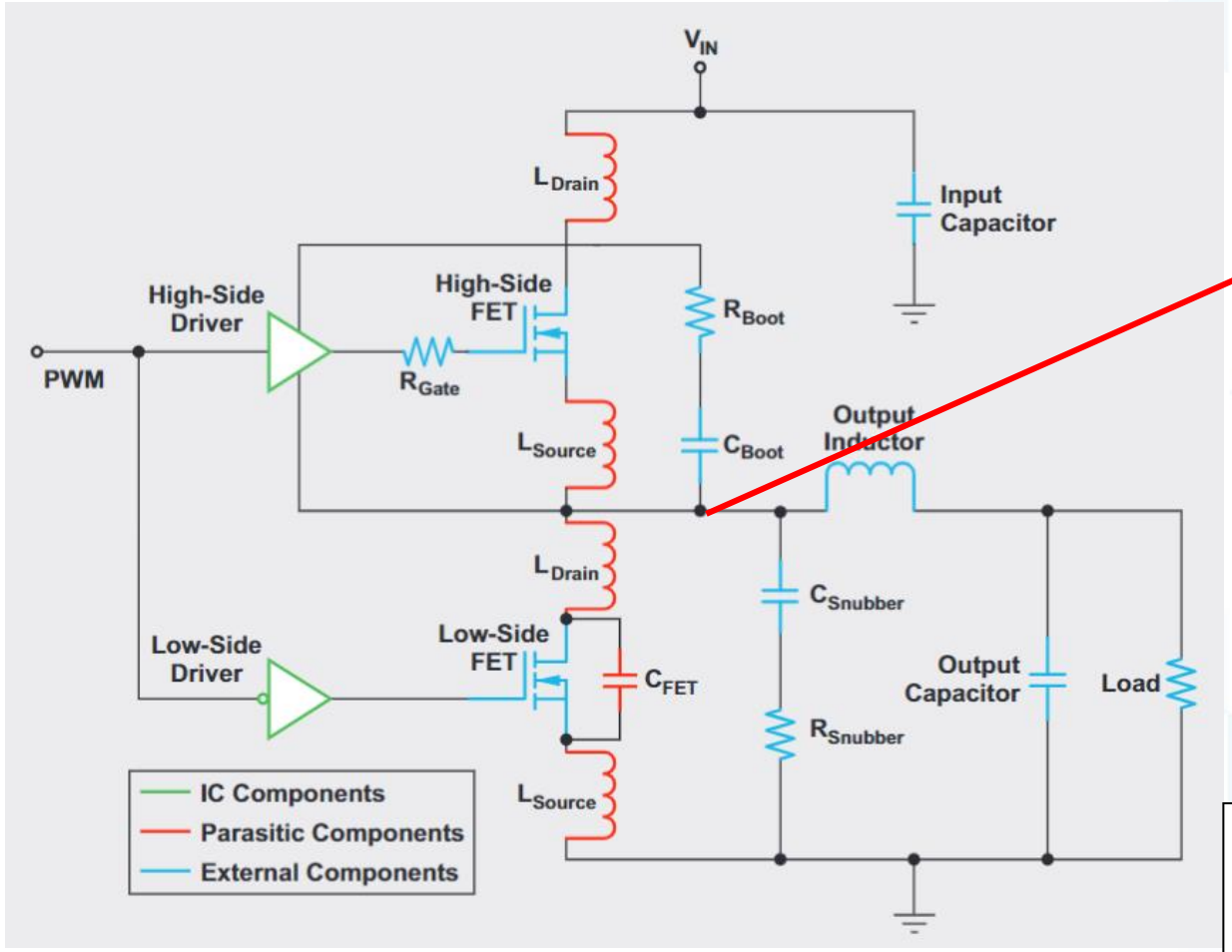
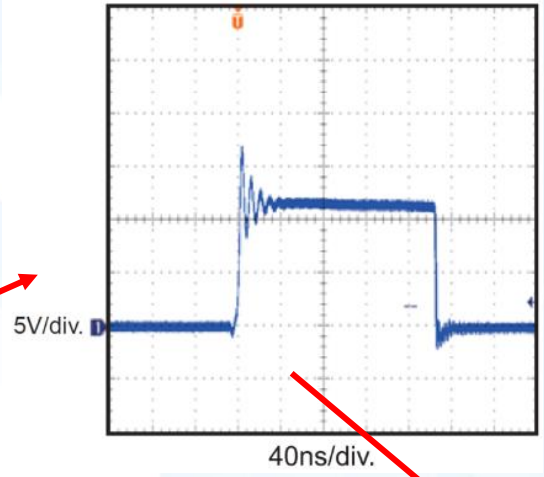
Noise generated by a switch mode power supply



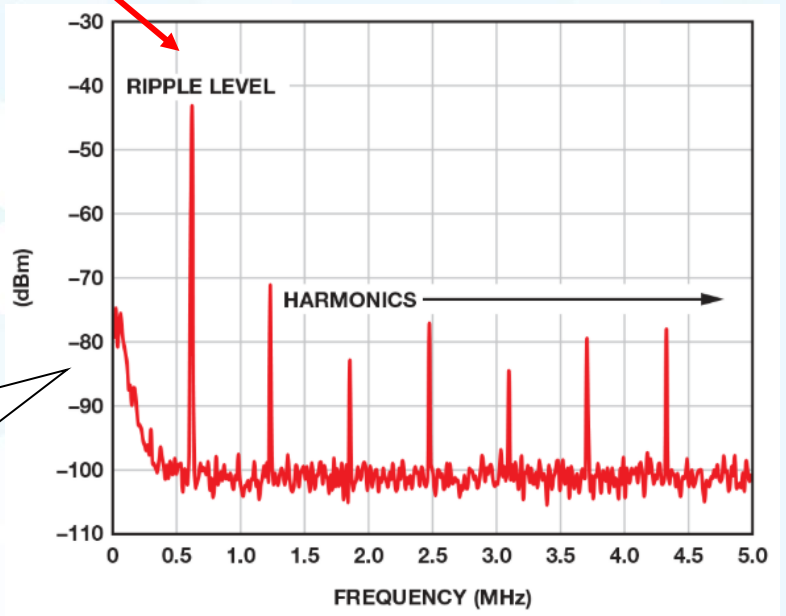
Switching frequency typically **500kHz** to **3MHz**
Switching transition typically **10MHz** to **200MHz** (100ns to 5ns)

Where does high frequency noise come from?





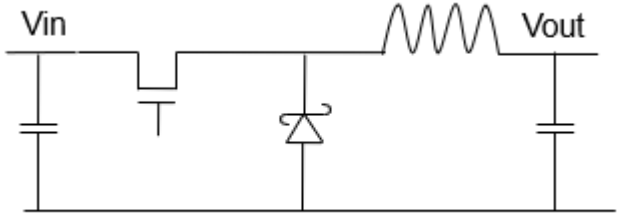
In the time domain, we see ringing on the SW node



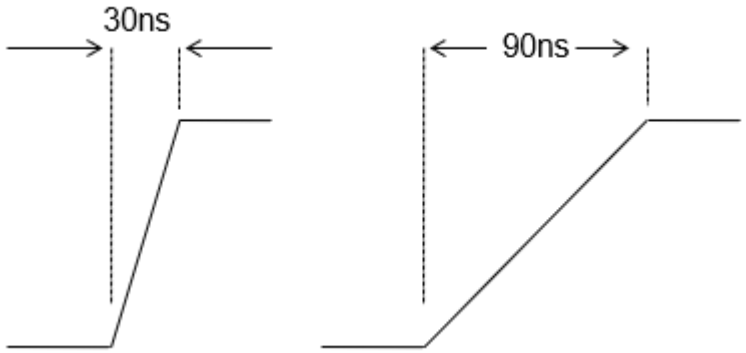
In the frequency domain, we see high frequency harmonics

Layout, a very important ‘external’ component

Basic buck topology



Switch Transition



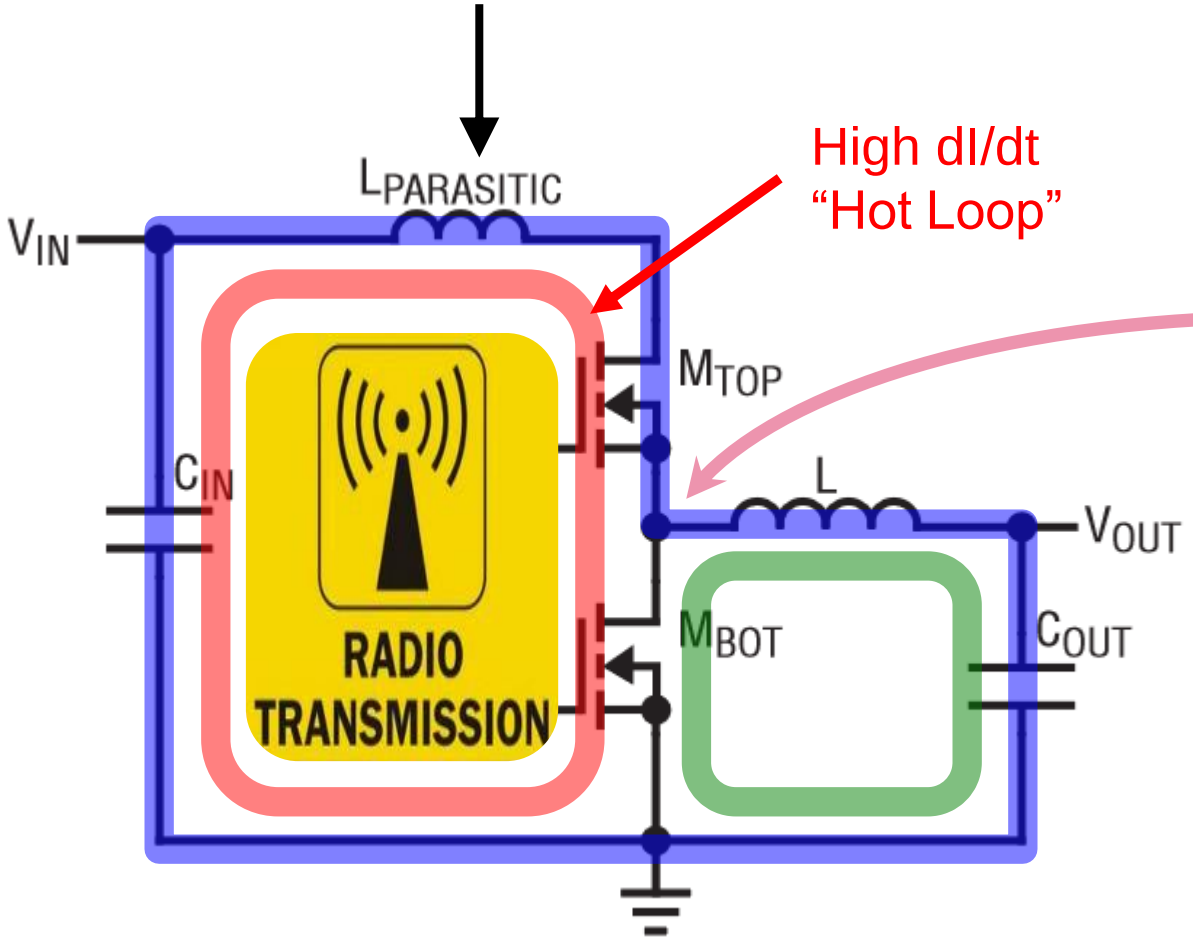
Voltage offset resulting from switch transitions

- Every one inch (2.5cm) of PCB trace has about 20nH of trace inductance
- V = L (di/dt)
- With switch transitions of 30ns, 1 inch of board trace length and 5A of current:
- V = 20nH (5A/30ns) = 3.33V

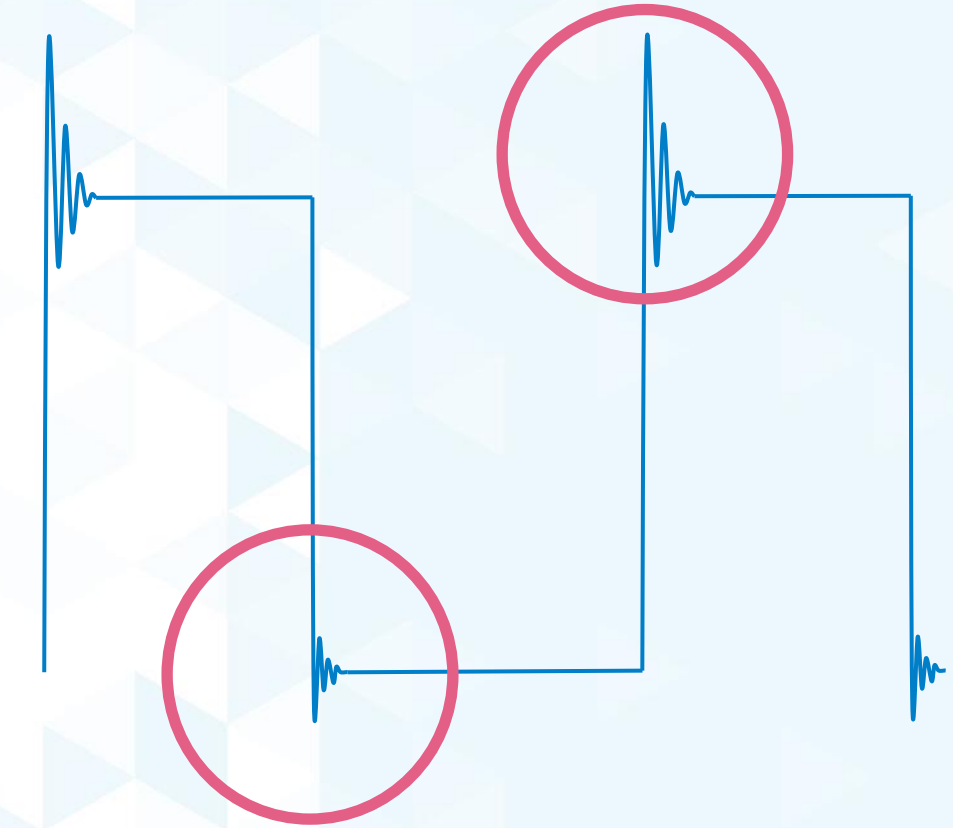
The Problem in Traditional Synchronous Buck Converters

High di/dt Currents in SMPS Hot Loops Create EMI

Parasitic inductance due to copper traces, bond wires, ESL of capacitors and FET internal metal

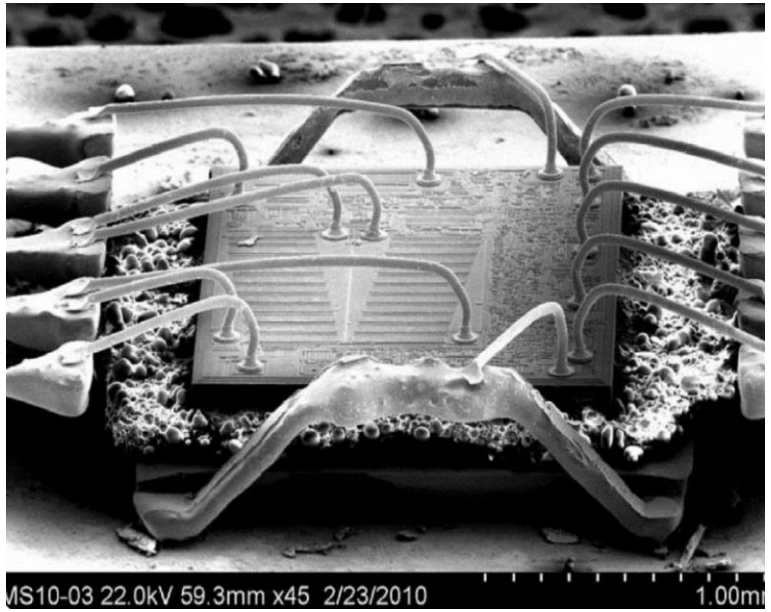


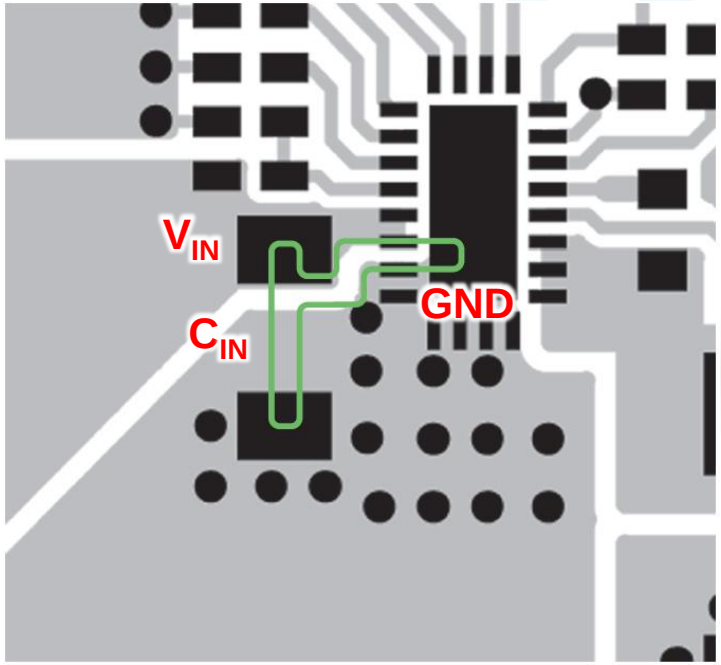
Excessive rings at the switching edges cause conductive noise and radiation

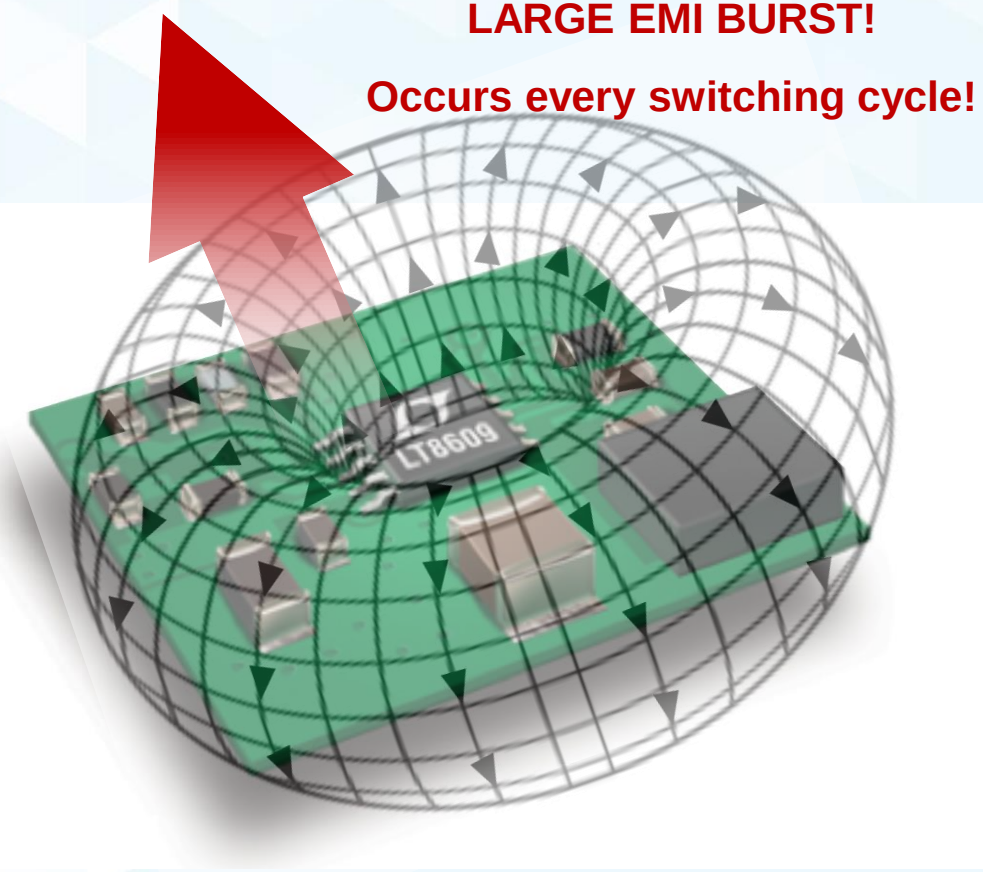


Minimizing Hot Loop

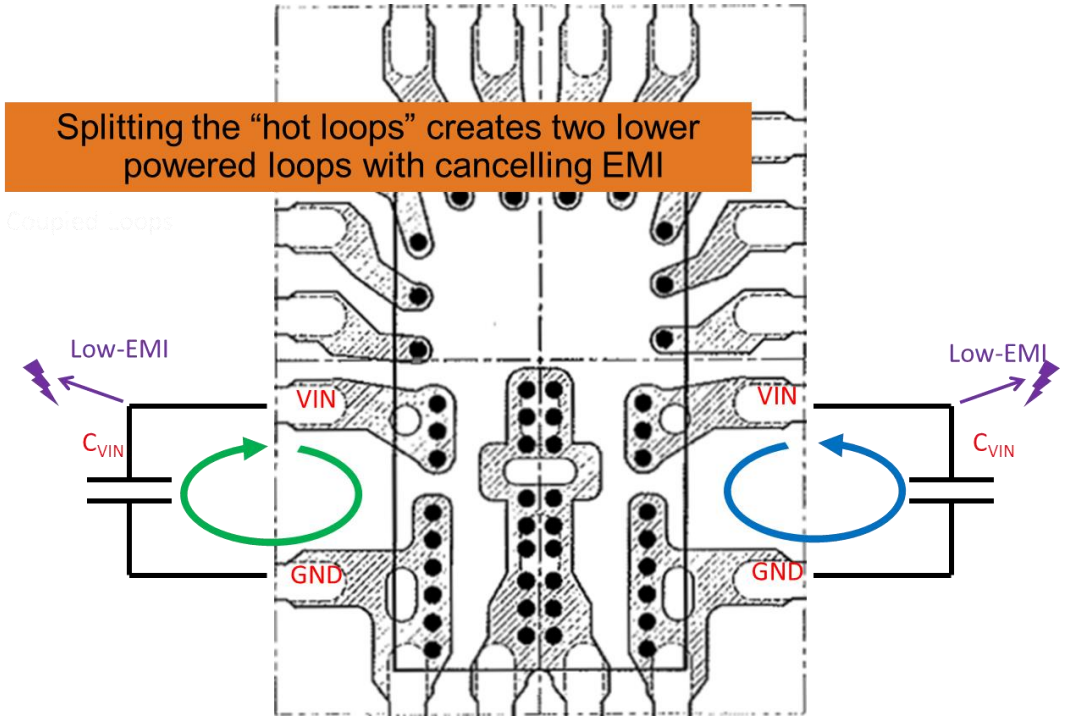
- With monolithic switcher, the best way is to place the low ESL input capacitor as close to the V_{IN} and GND as possible
- A solid GND plane with minimum distance to the hot loop is one of the most effective ways to reduce EMI

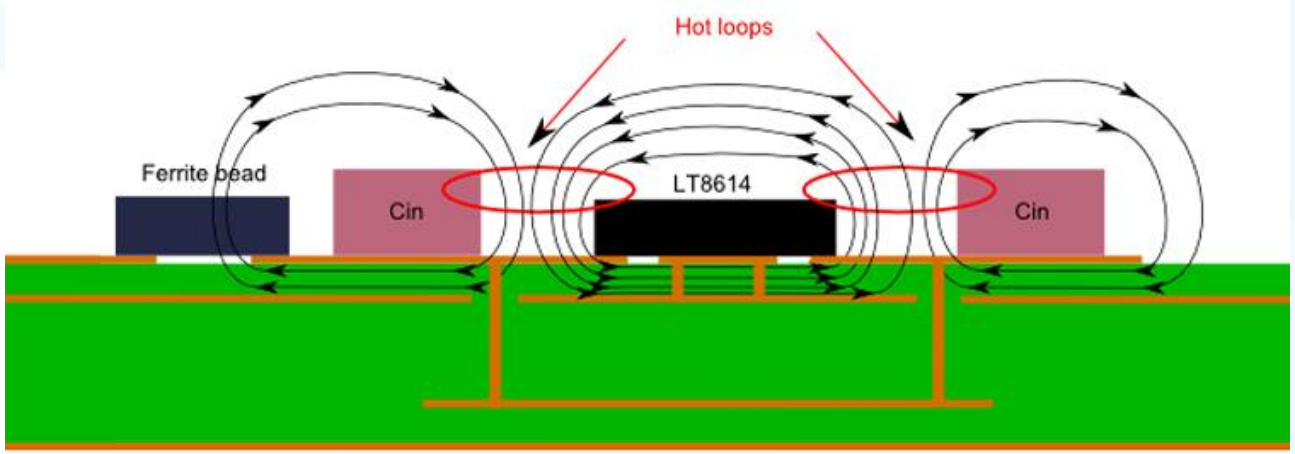


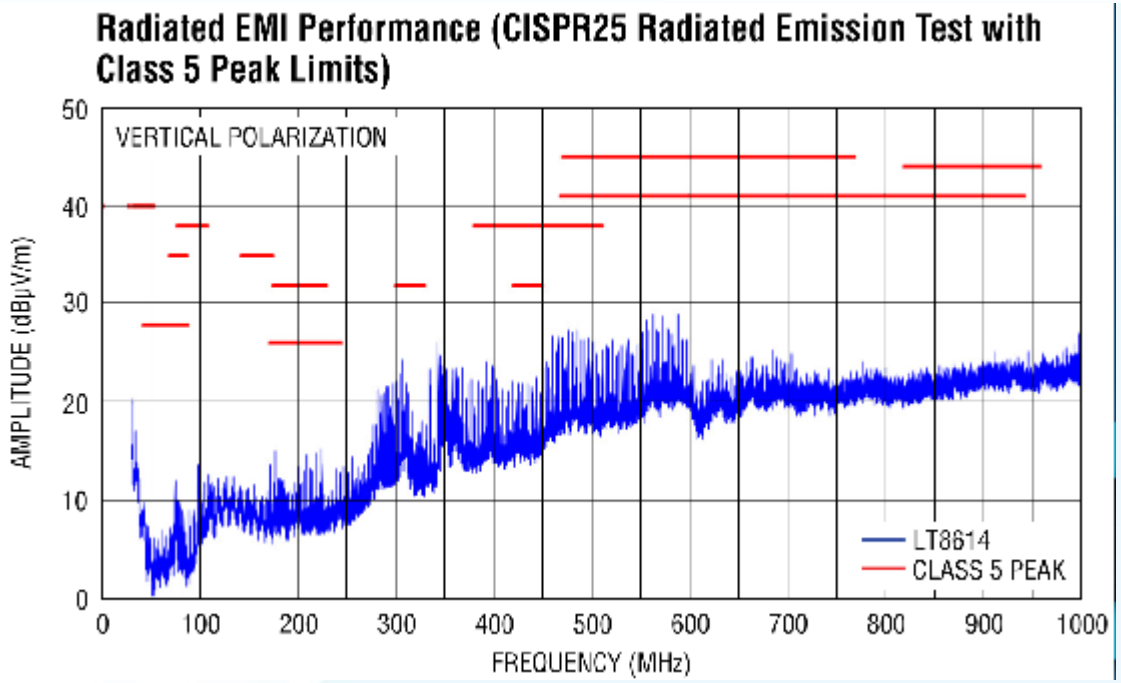




Innovation - Silent Switcher 1



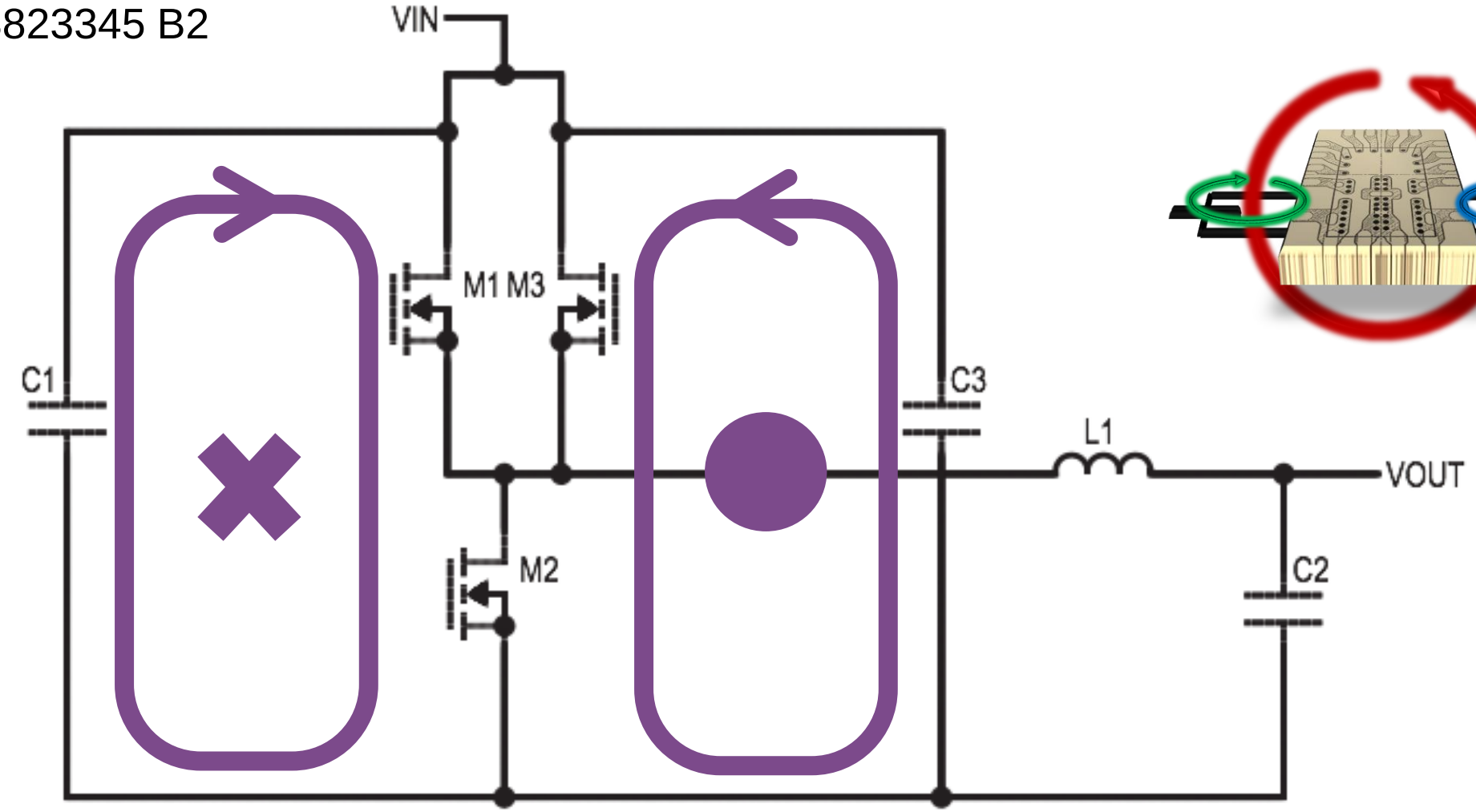




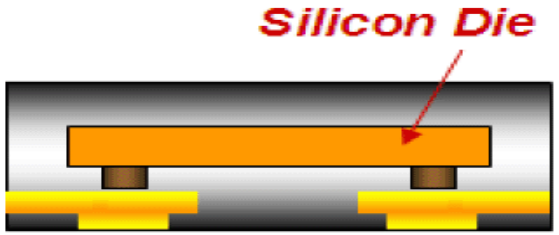
- The two high current loops cancel each others magnetic field, almost like enclosing the circuit in a metal box

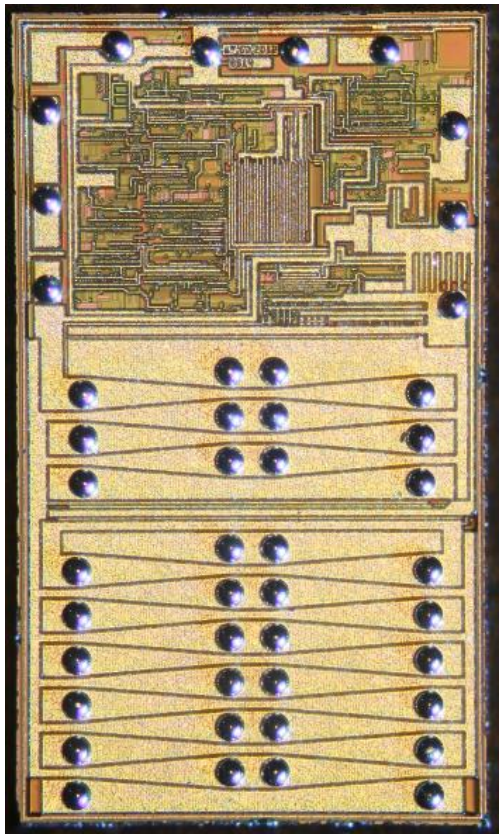
Innovation - Magnetic Field Cancellation

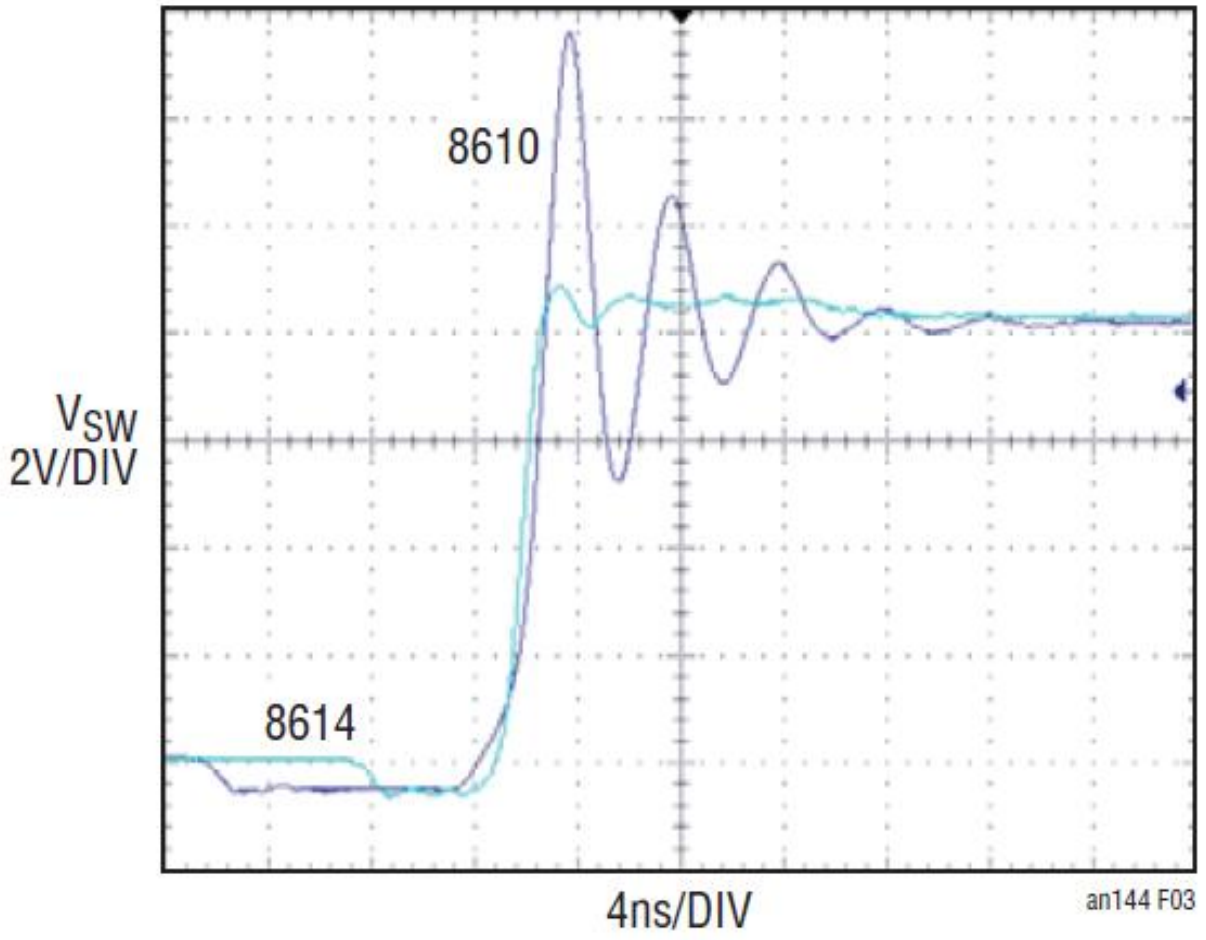
US Patent: 8823345 B2



Silent Switcher 1 Eliminates Switch Ringing





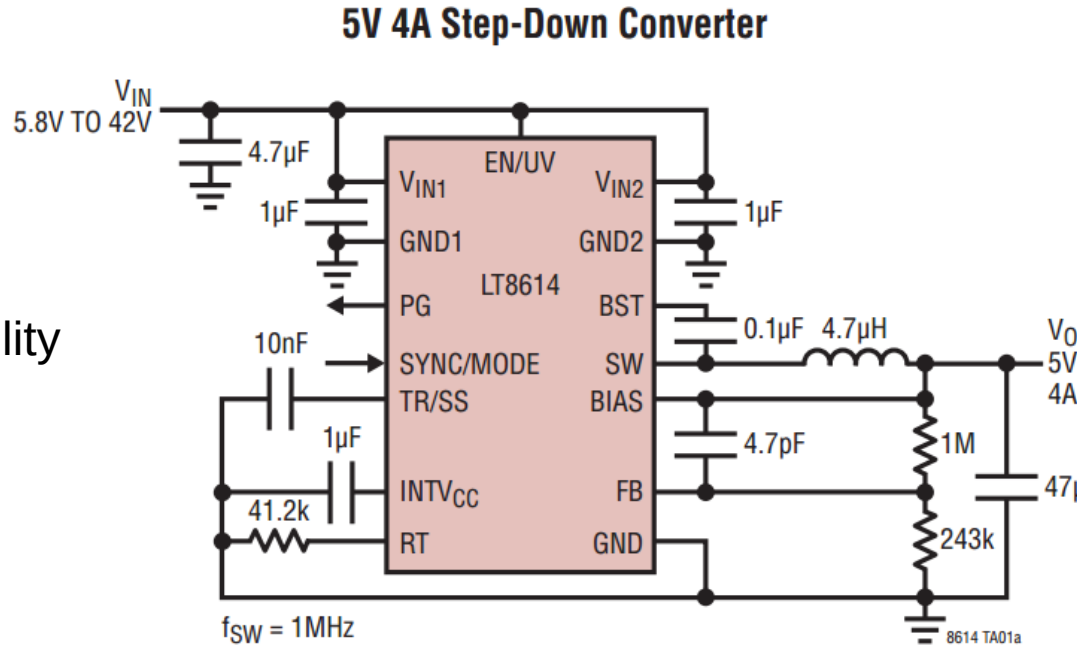


LT8610: Wirebonded in MS16E

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



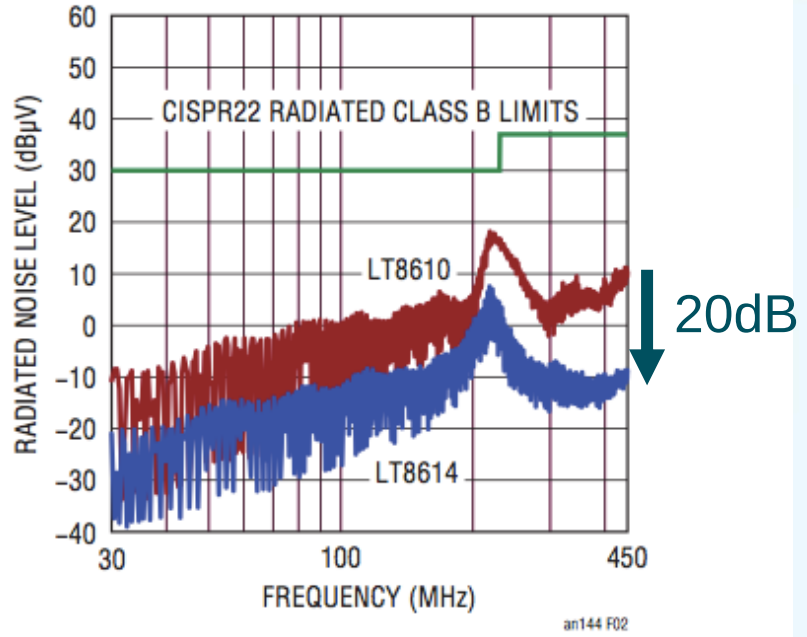
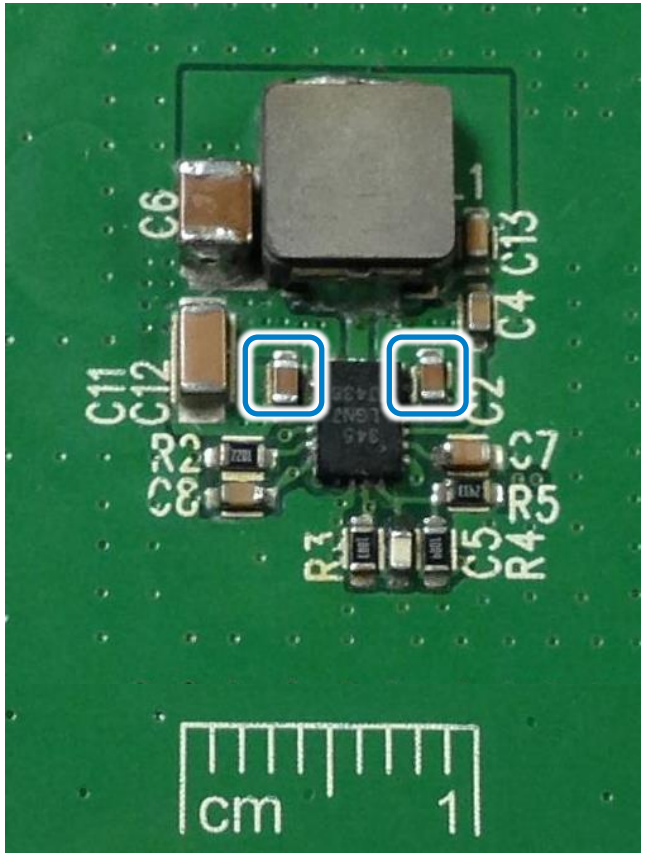


Figure 2. LT8610 and LT8614 700kHz 14V to 3.3V 2A Radiated EMI in GTEM Corrected for OATS

Innovation - Silent Switcher 2

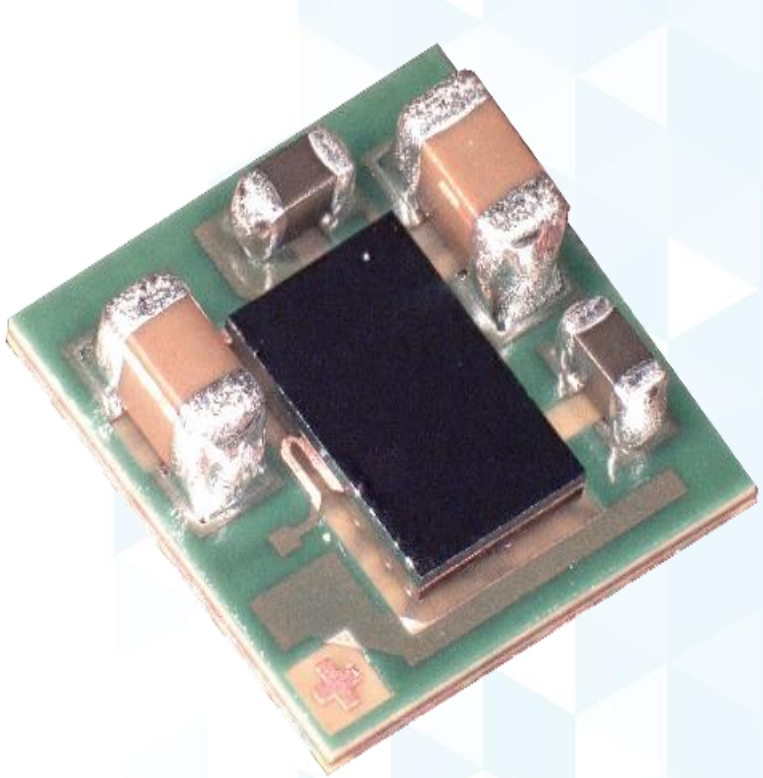
Silent Switcher 1

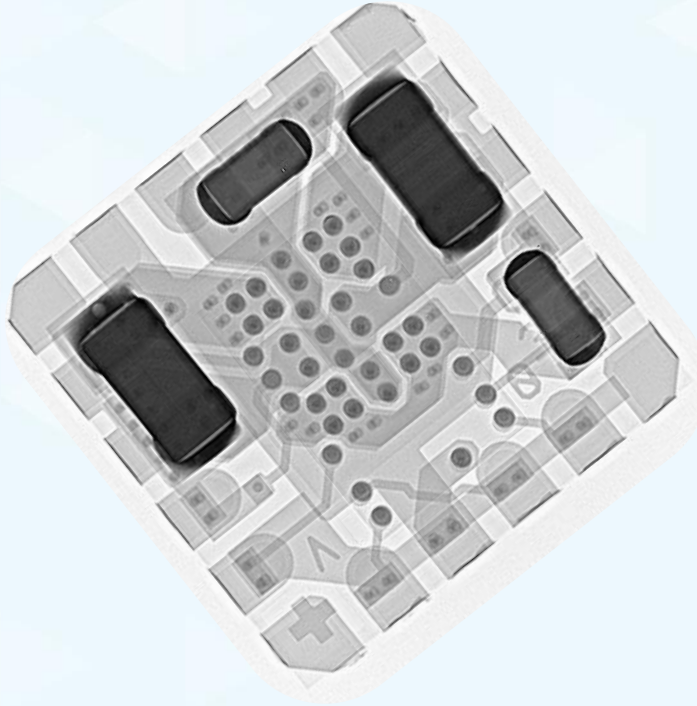
The layout is critical though!



Silent Switcher 2

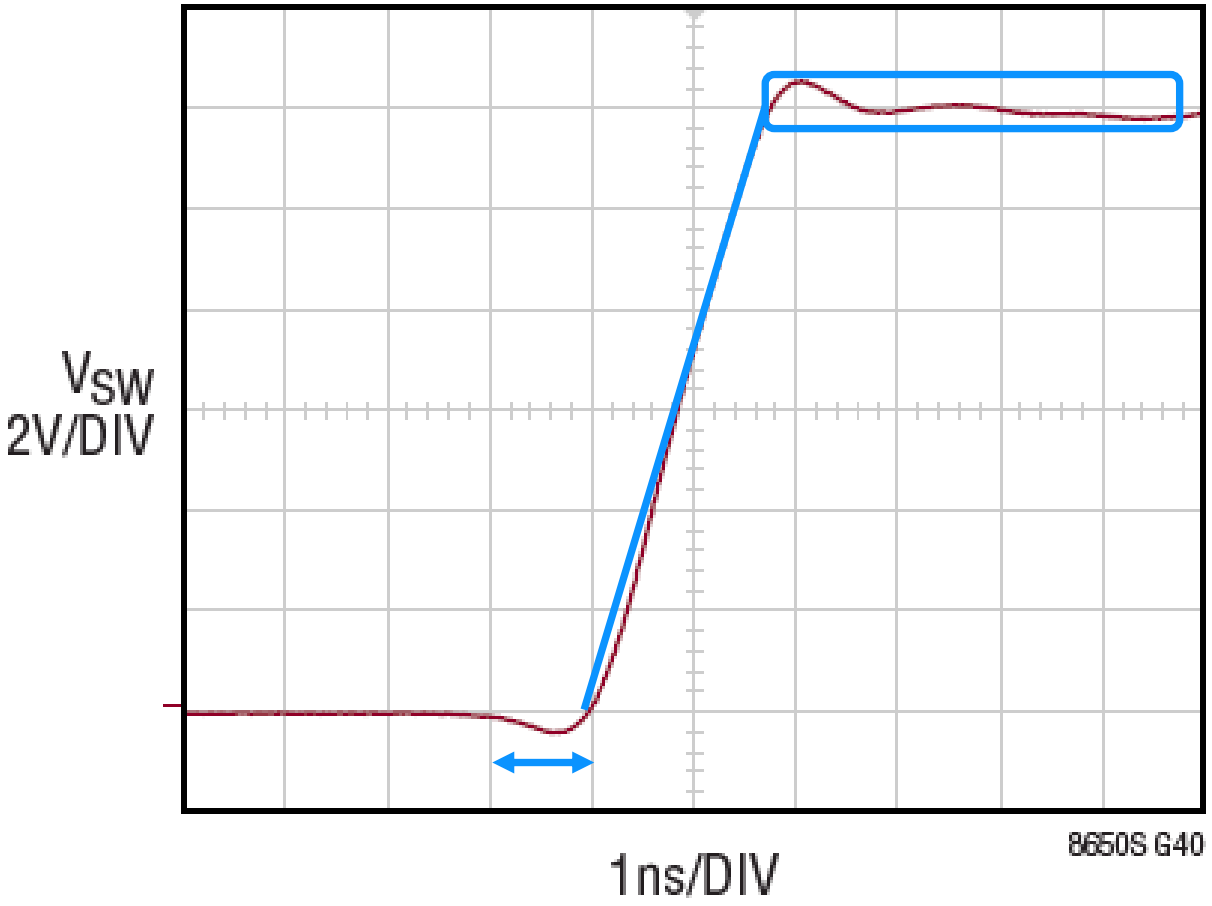
Flip chip on laminate (FCOL) and Cap-In-Package





Innovation - Silent Switcher 2

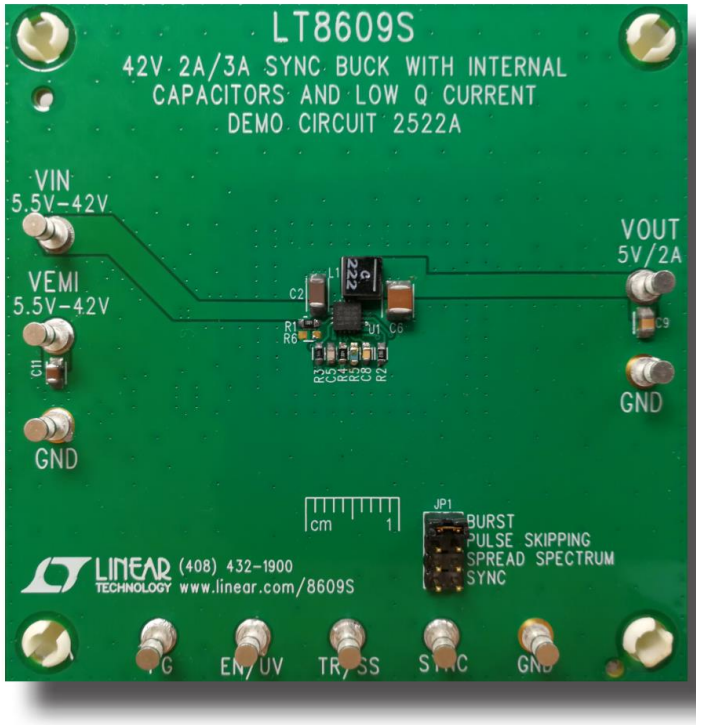
No slew rate limit on switching node necessary to achieve low EMI !

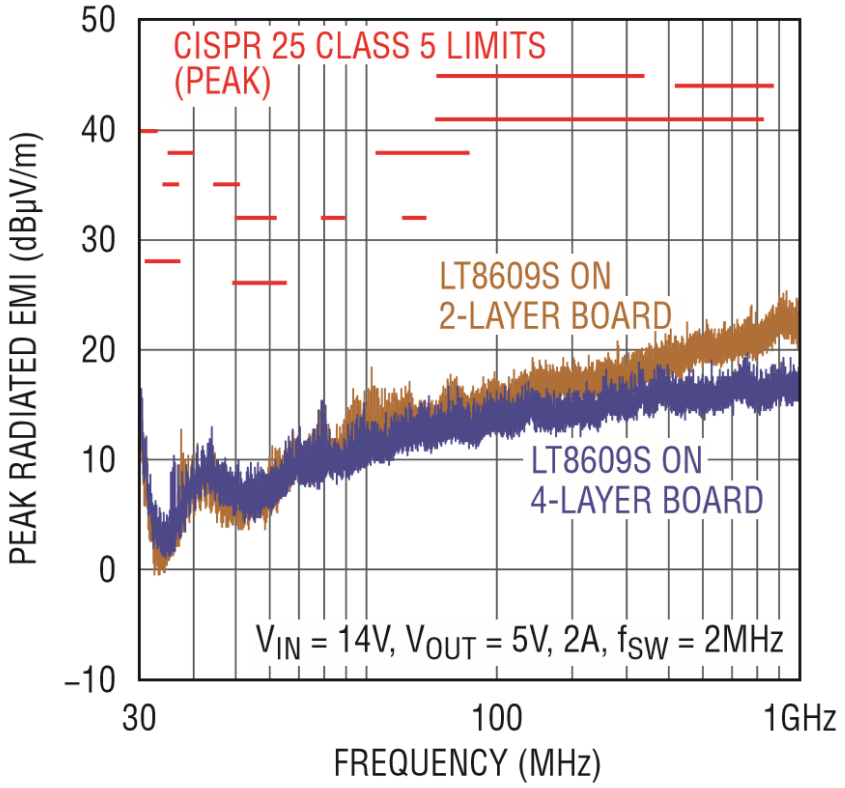


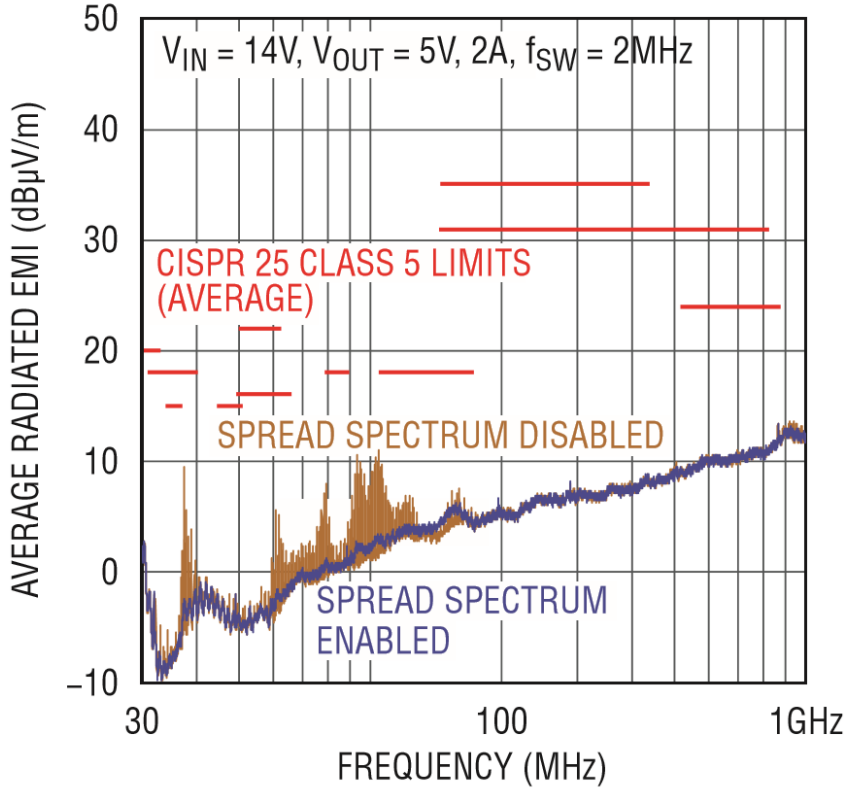
- Hot loop area and inductance virtually zero
- Extremely fast switching
- Neglectable overshoot and no parasitic oscillation on switching node
- Dead time only 1ns

Unmatched switching performance !

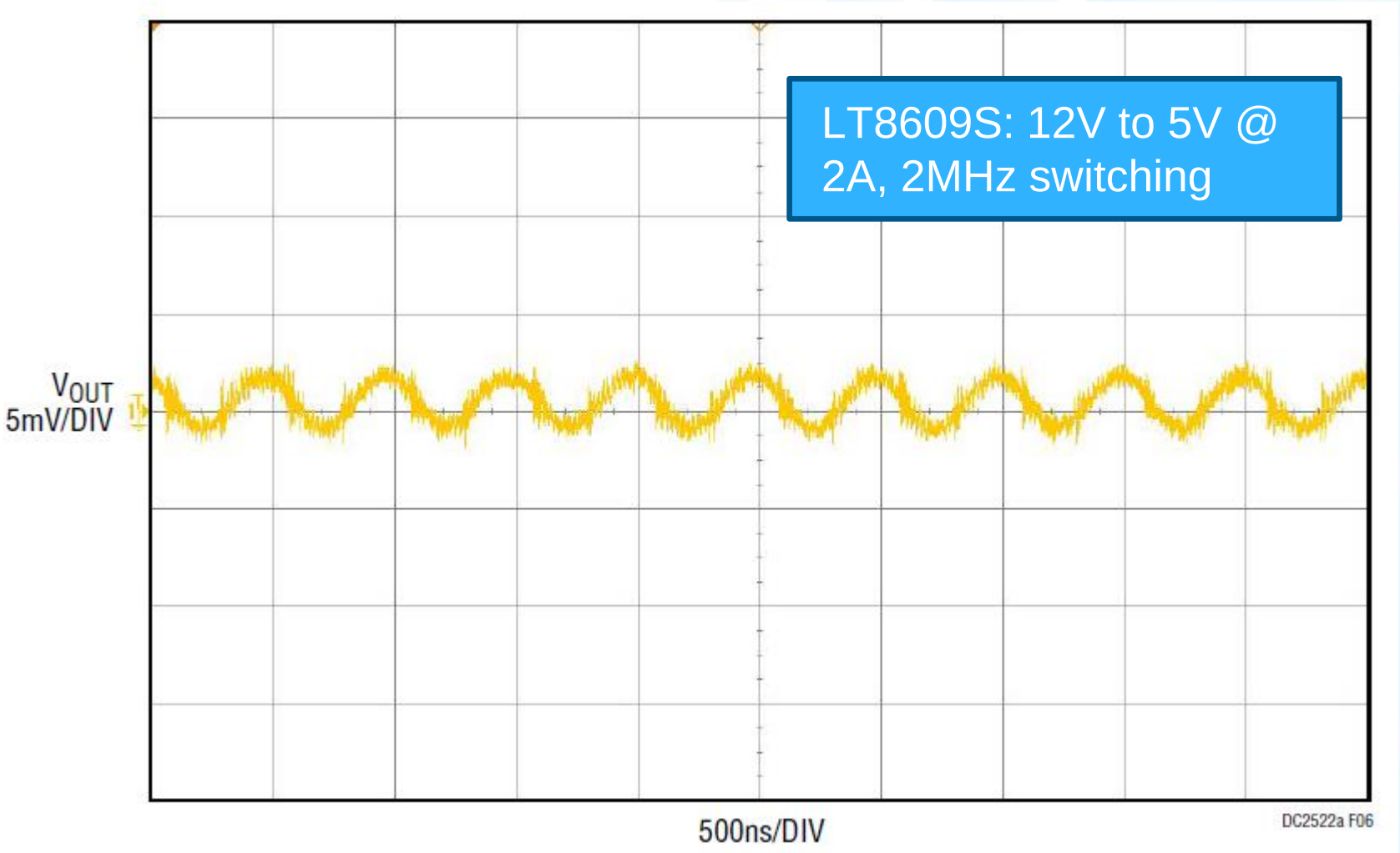
Silent Switcher 2 - Excellent EMI Test Results







Silent Switcher 2 Also Provides Low Output Ripple

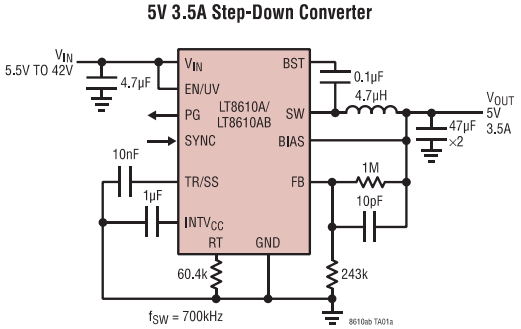


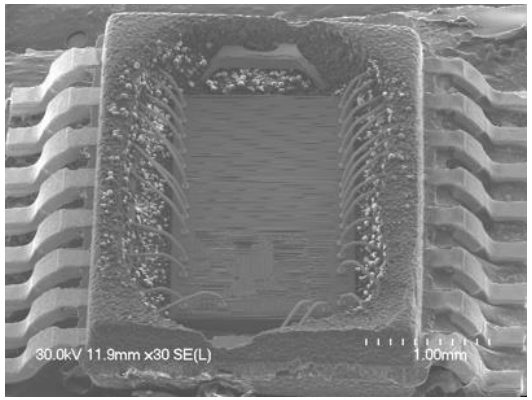
Silent Switcher Family

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

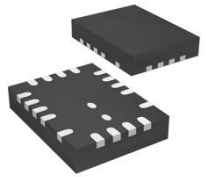
Package technology improves performance

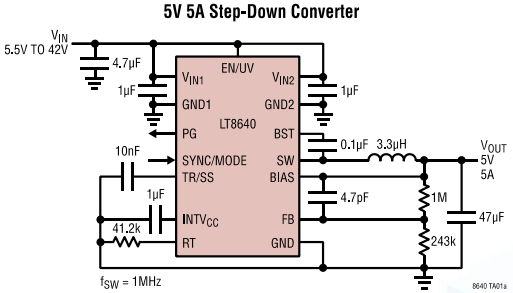
LT8610 MSOP-16

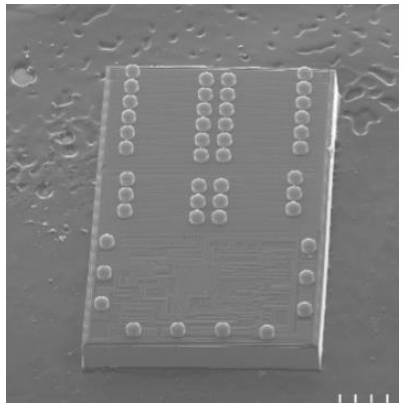




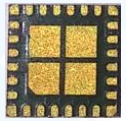
LT8640 QFN

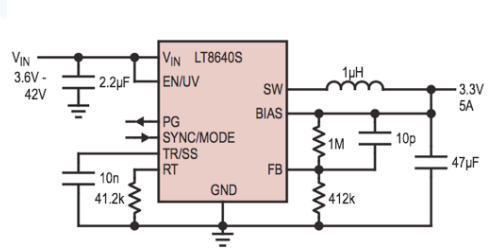


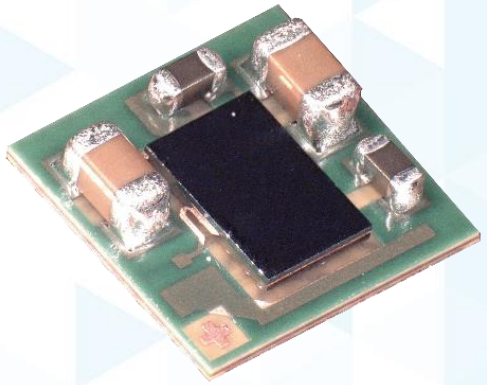




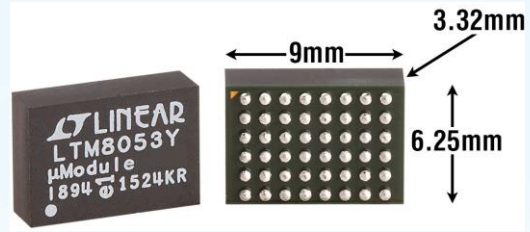
LT8640S (BT laminate LGA)

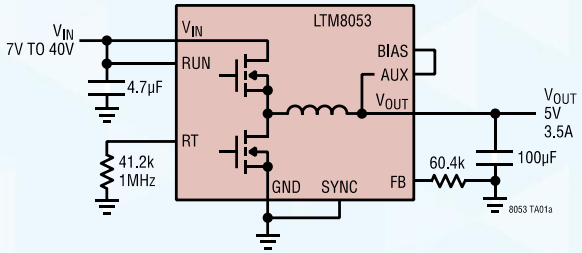


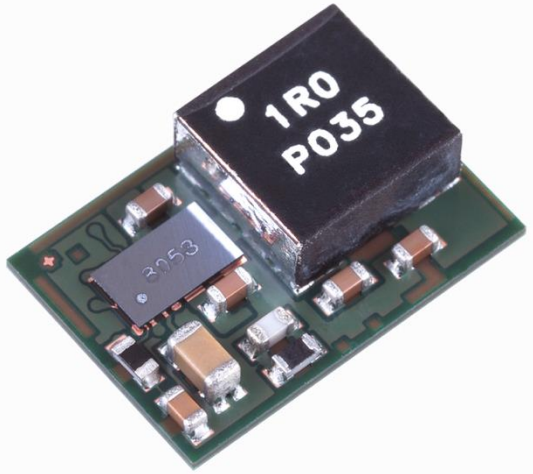




LTM8053 6x9 BGA







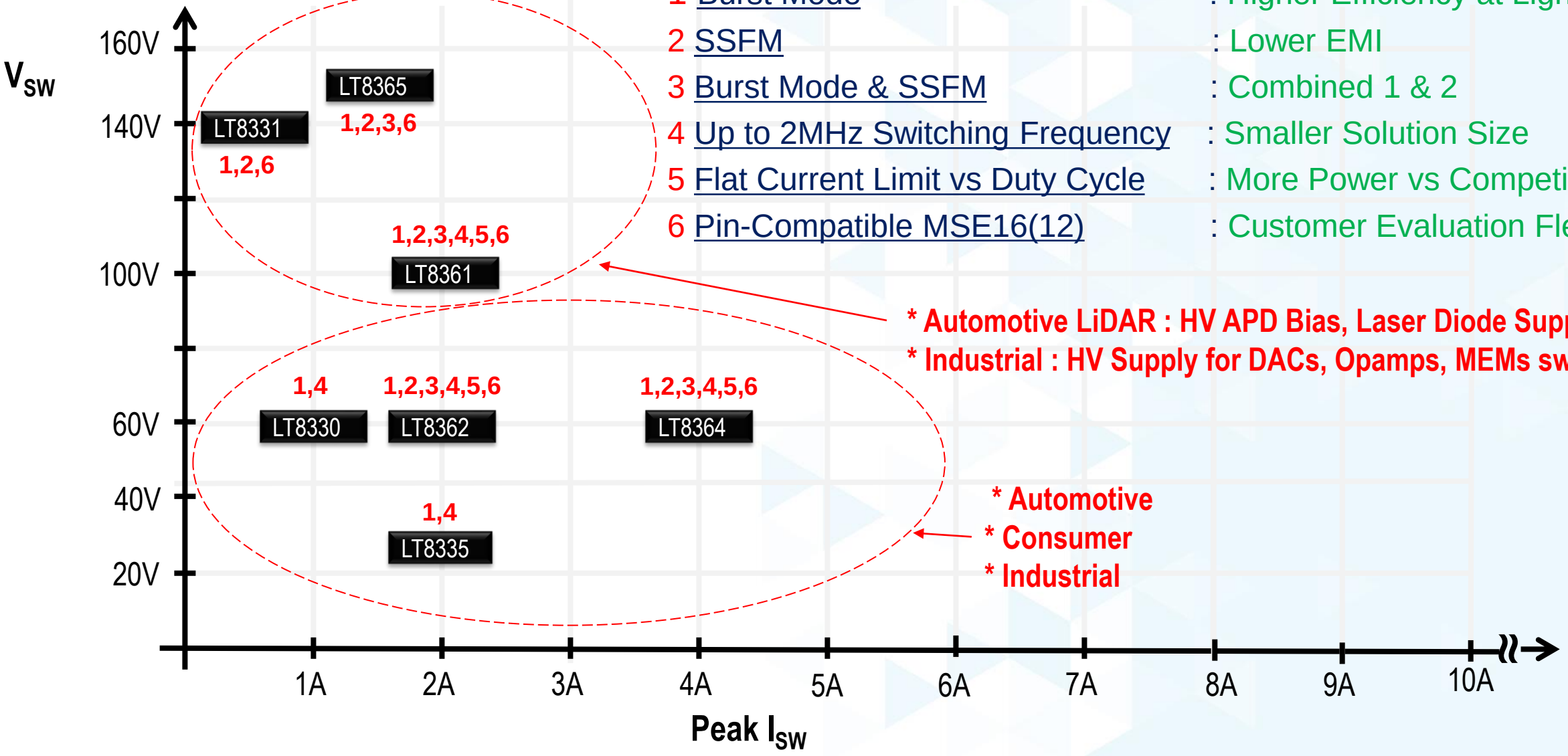
Outline

- Buck/Boost / Buck-Boost / Inverting Basics Overview
- Monolithic high voltage synchronous buck products family
- Monolithic Non-Synchronous/ Synchronous boost products family
- 4-Switch Buck-Boost Controllers/umodule for High Power
- Inverting Converter Design
- Surge Stopper and Protect

Monolithic Micropower Non-Synchronous Boost / SEPIC / Inverting

DMOS power switches

1 Burst Mode : Higher Efficiency at Light Load
2 SSFM : Lower EMI
3 Burst Mode & SSFM : Combined 1 & 2
4 Up to 2MHz Switching Frequency : Smaller Solution Size
5 Flat Current Limit vs Duty Cycle : More Power vs Competitors
6 Pin-Compatible MSE16(12) : Customer Evaluation Flexibility

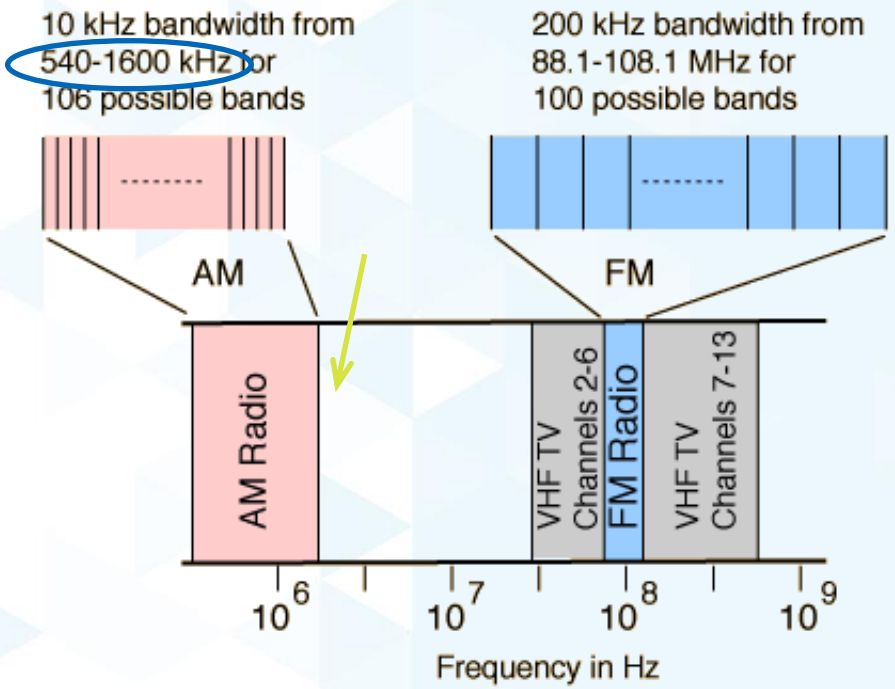


* Automotive LiDAR : HV APD Bias, Laser Diode Supply
* Industrial : HV Supply for DACs, Opamps, MEMs switches

* Automotive
* Consumer
* Industrial

2MHz Switching Frequency

- AM Band presents challenges for DC/DC Converters in an automobile
- Must stay out of 450kHz to ~1.8MHz



- Switching at 2MHz vs 400kHz :
  - smaller values of L and C
  - smaller physical size of L and C
  - better transient response
  - AC losses are higher
  - min and max duty-cycle are challenging
  - ADI's power solutions are able to minimize the challenges at 2MHz operation
  - This provides an excellent opportunity for a superior ADI design to win

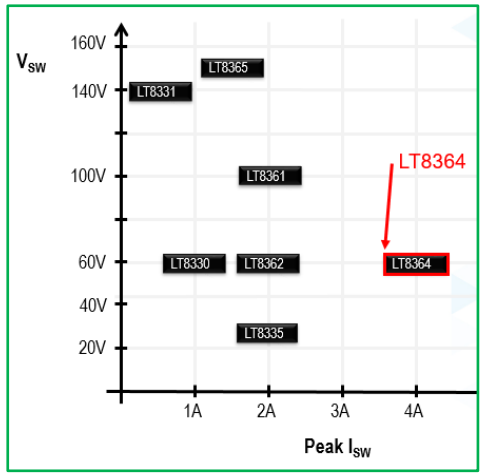
Monolithic Micropower Non-Synchronous Boost / SEPIC / Inverting
LT8364 : 60V/4A

Features

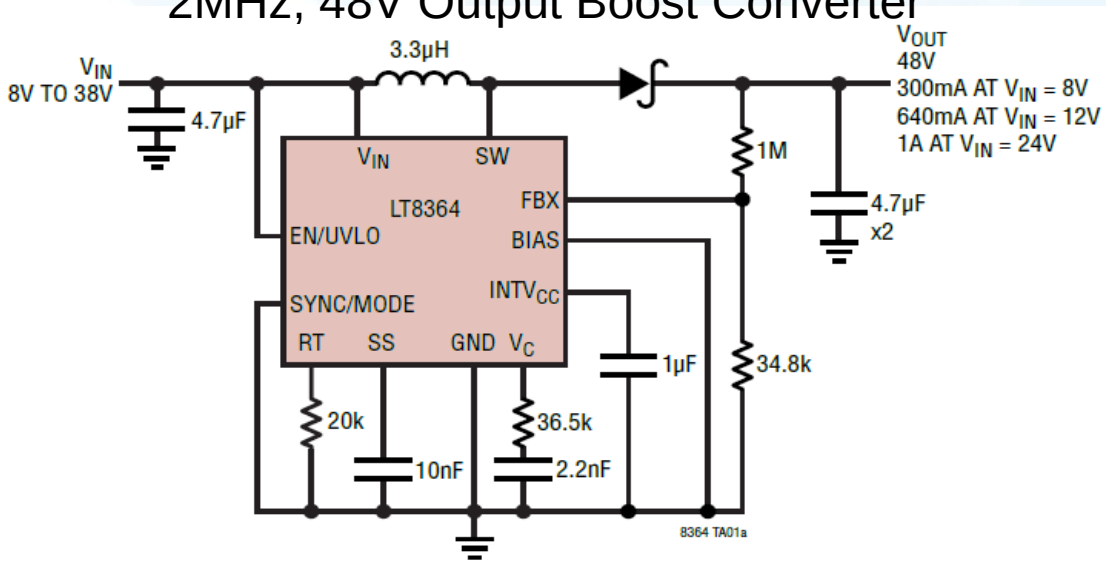
- **60V/4A** Power Switch
- Positive or Negative Output
- Burst Mode : **6uA** Iq, Low Output Ripple
- Wide Vin Range : **2.8V** to **60V**
- SSFM for Reduced EMI
- 4x3 DFN(12), 16(12)-Lead MSOP

Applications

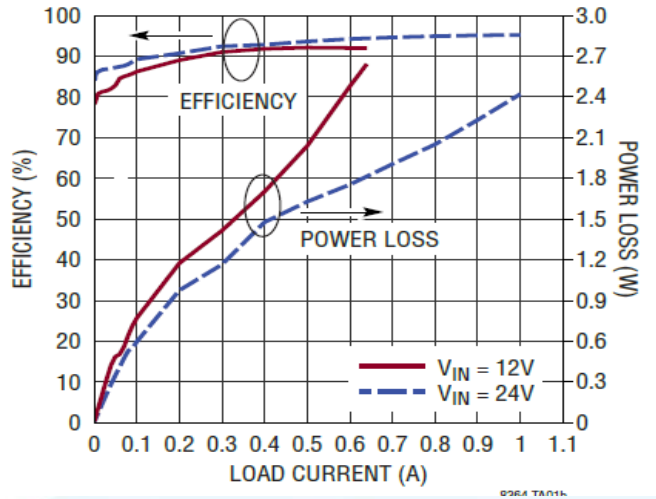
- Automotive
- Industrial
- General Purpose



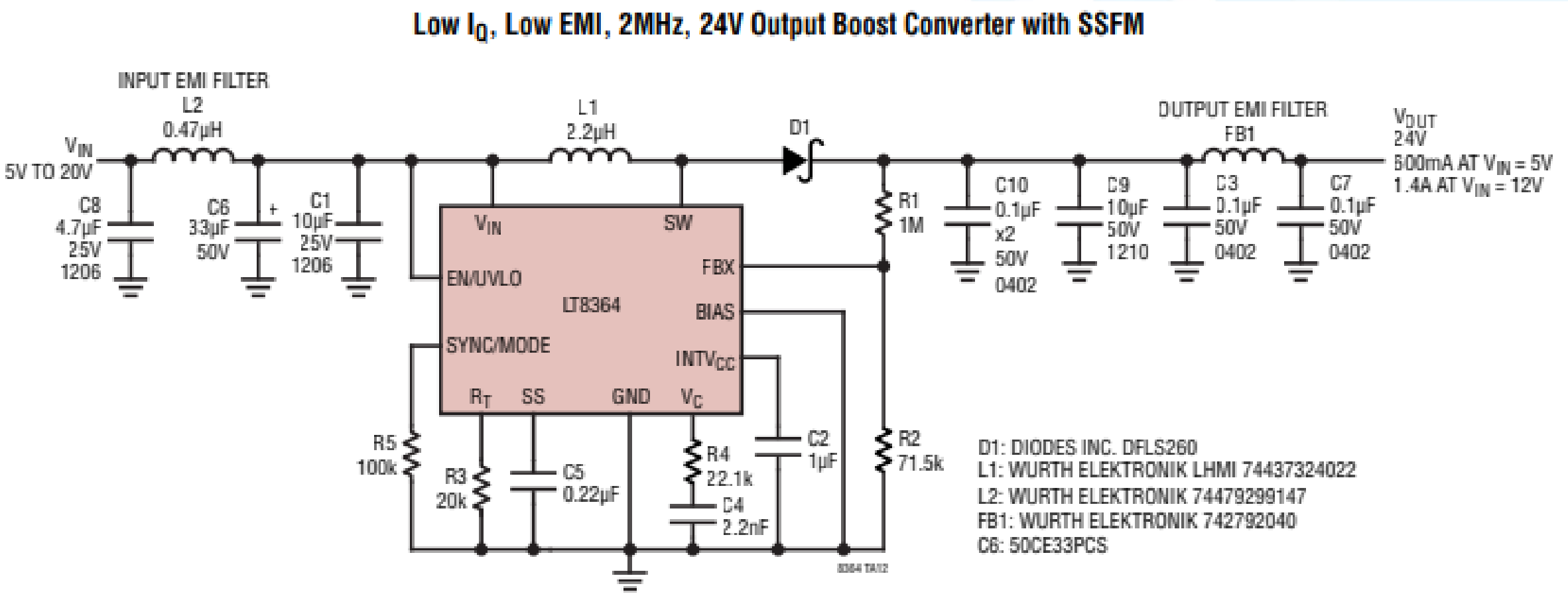
2MHz, 48V Output Boost Converter



Efficiency and Power Loss

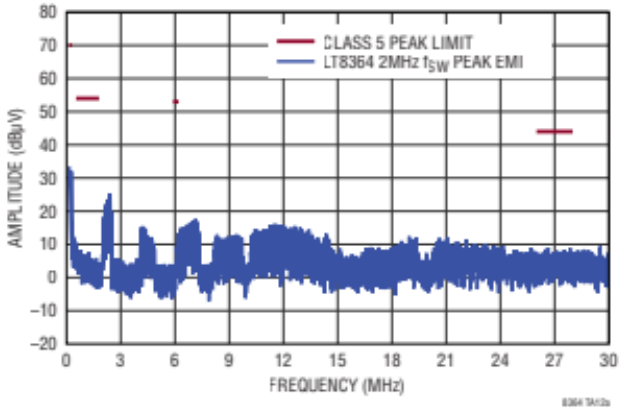


Low EMI Demo Boards DC2716A: An LT8364 Example



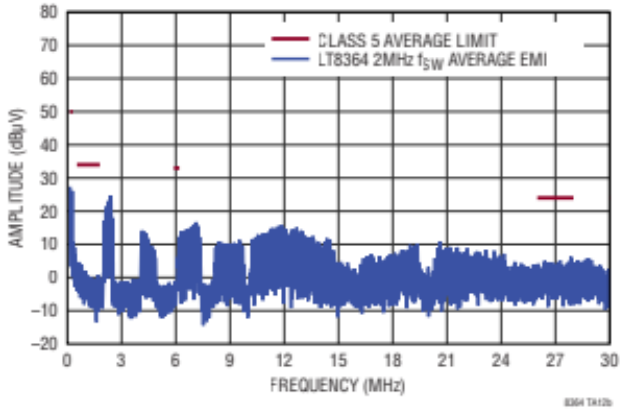
LT8364 – Good EMI Results

Conducted EMI Performance (CISPR25 Class 5 Peak)



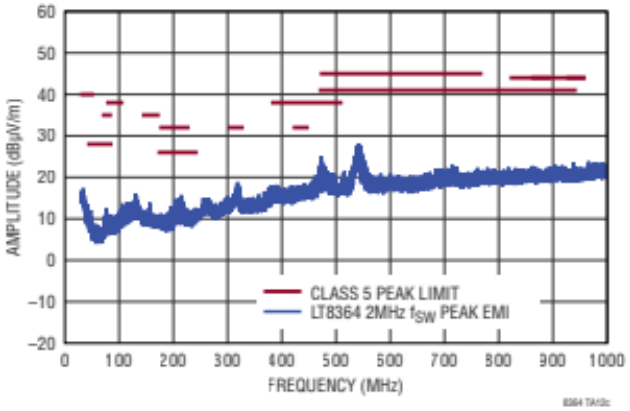
12V INPUT TO 24V OUTPUT AT 1A, f_{SW} = 2MHz

Conducted EMI Performance (CISPR25 Class 5 Average)



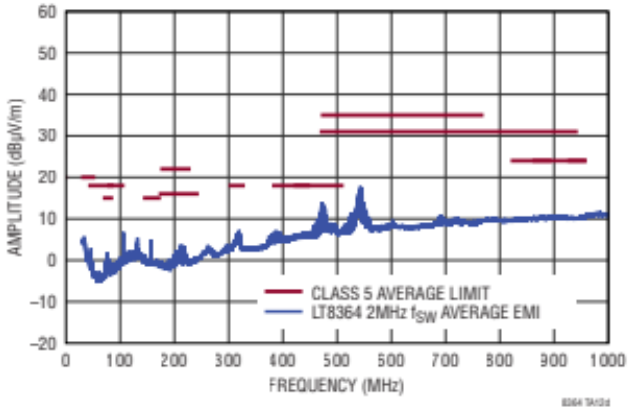
12V INPUT TO 24V OUTPUT AT 1A, f_{SW} = 2MHz

Radiated EMI Performance (CISPR25 Class 5 Peak)



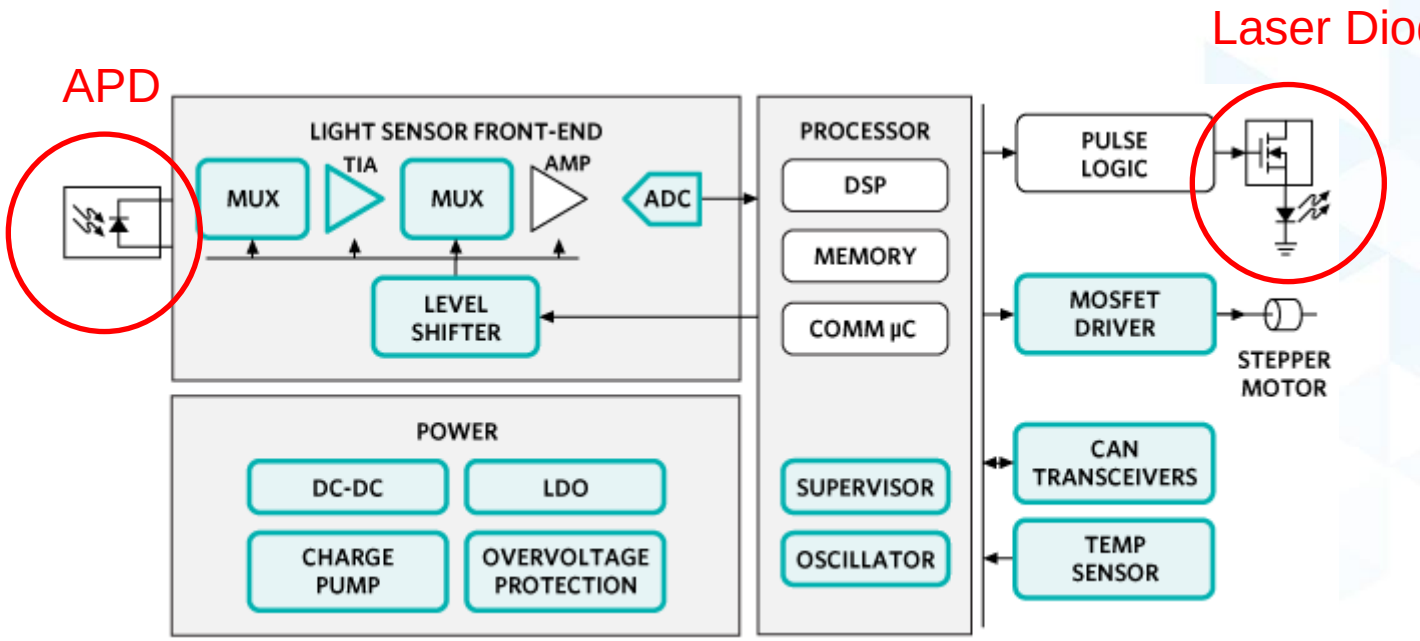
12V INPUT TO 24V OUTPUT AT 1A, f_{SW} = 2MHz

Radiated EMI Performance (CISPR25 Class 5 Average)



12V INPUT TO 24V OUTPUT AT 1A, f_{SW} = 2MHz

ADI's Boost Parts can provide the APD Bias and Laser Diode Supply in Automotive LiDAR



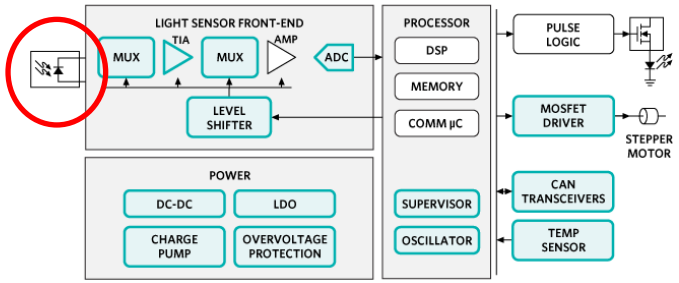
LiDAR Products

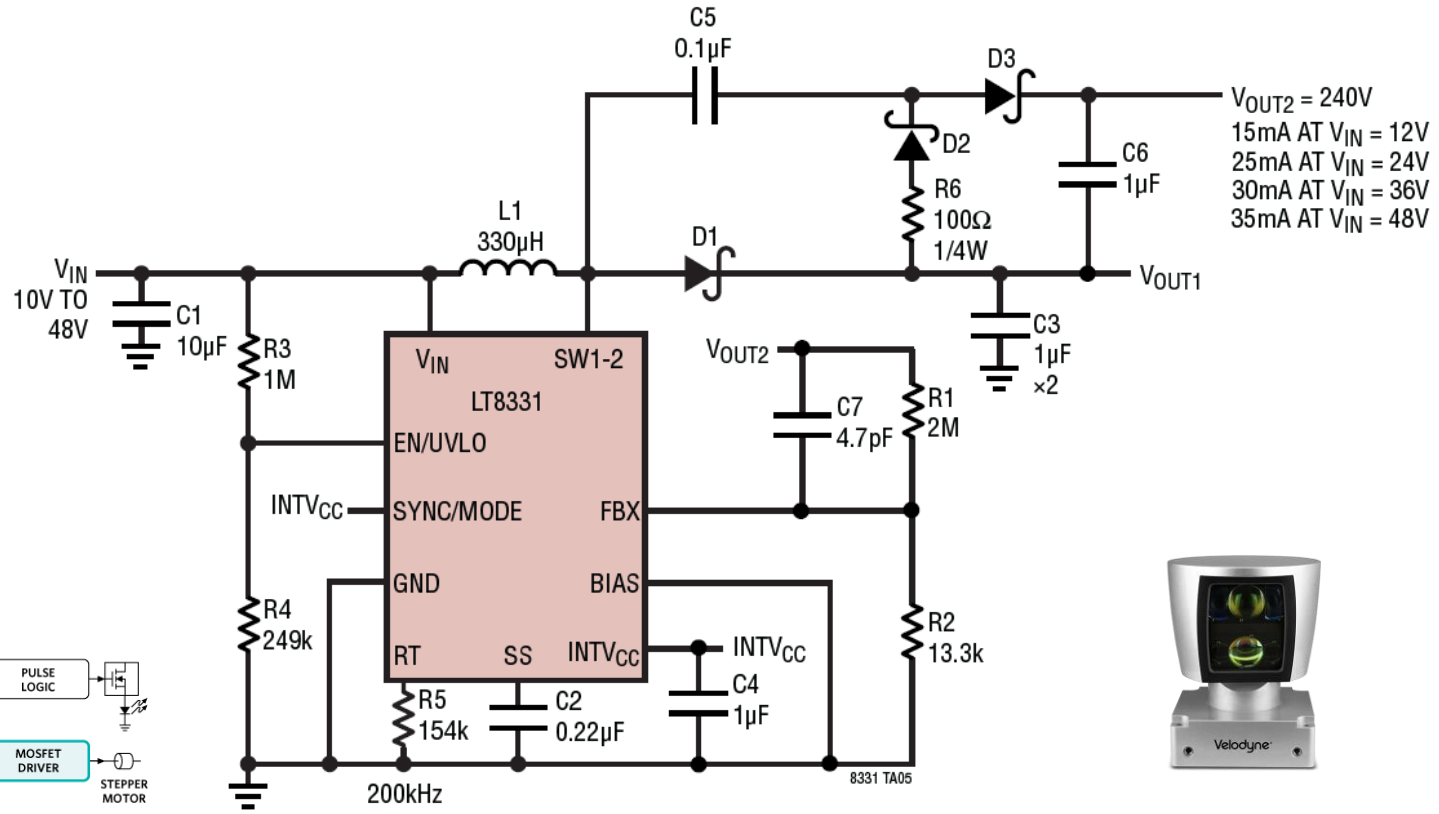
Monolithic Micropower Non-Synchronous Boost / SEPIC / Inverting
LT8331 : 140V/0.5A

Automotive LiDAR : +240V APD Bias

- **Features**
  - **140V/0.5A** Power Switch
  - Positive or Negative Output
  - Burst Mode : **6uA** Iq, Low Output Ripple
  - Wide Vin Range : **4.5V** to **100V**
  - SSFM for Reduced EMI
  - 16(12)-Lead MSOP

- **Applications**
  - Automotive LiDAR : HV APD Bias
  - Industrial HV Supplies

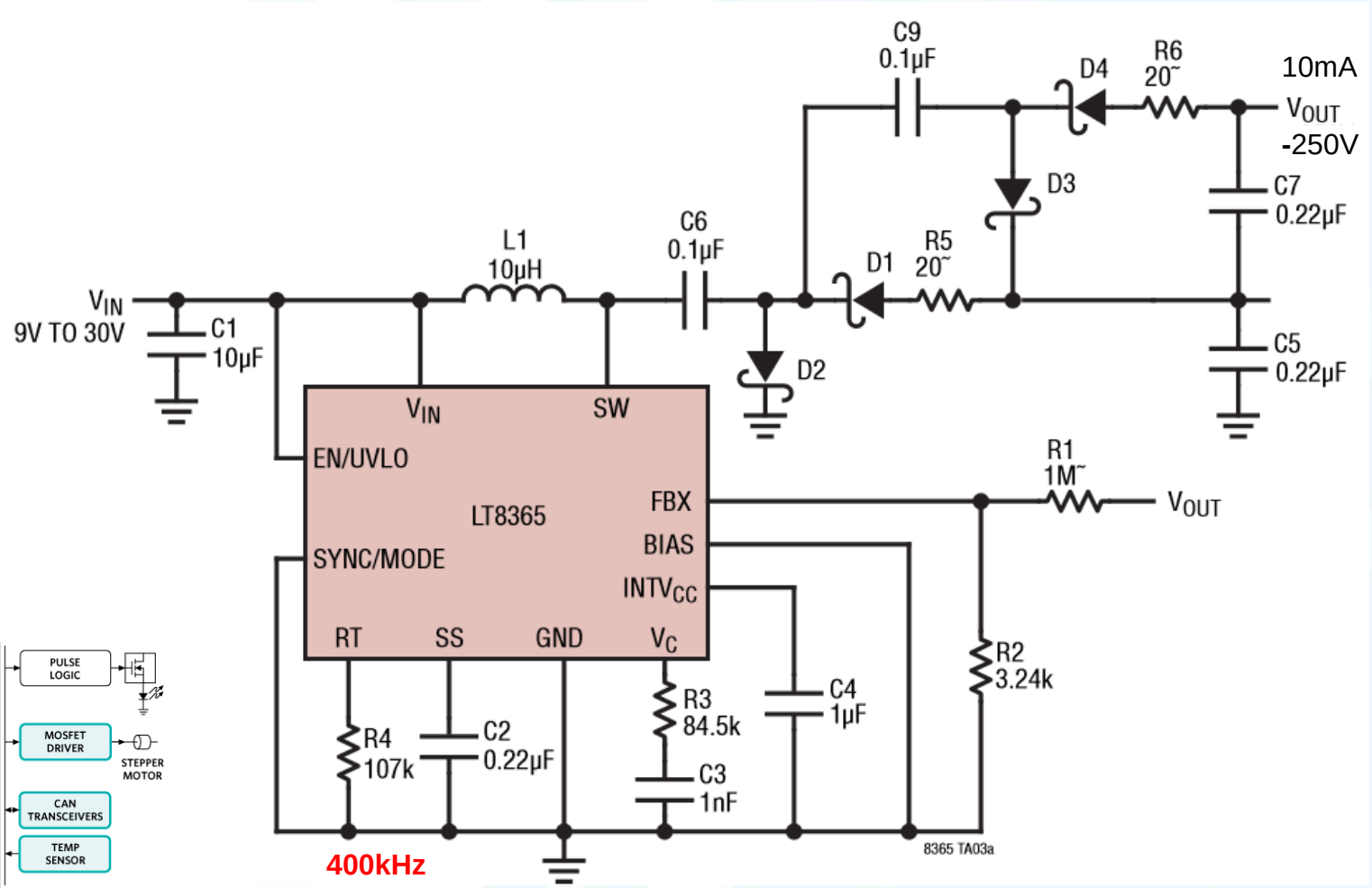




LT8331 can also provide high-voltage **negative** supplies.

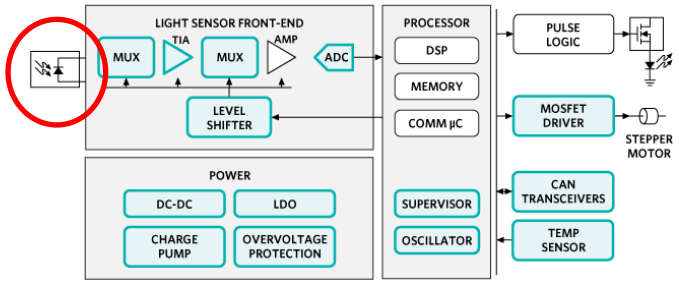
Monolithic Micropower Non-Synchronous Boost / SEPIC / Inverting LT8365 : 150V/1.5A

Automotive LiDAR : -250V APD Bias



- **Features**
  - **150V/1.5A** Power Switch
  - Positive or Negative Output
  - Burst Mode : **9uA** Iq, Low Output Ripple
  - Wide Vin Range : **2.8V** to **60V**
  - SSFM for Reduced EMI
  - 16(12)-Lead MSOP

- **Applications**
  - Automotive LiDAR : HV APD Bias
  - HV DAC Supplies
  - HV MEMs switch supply



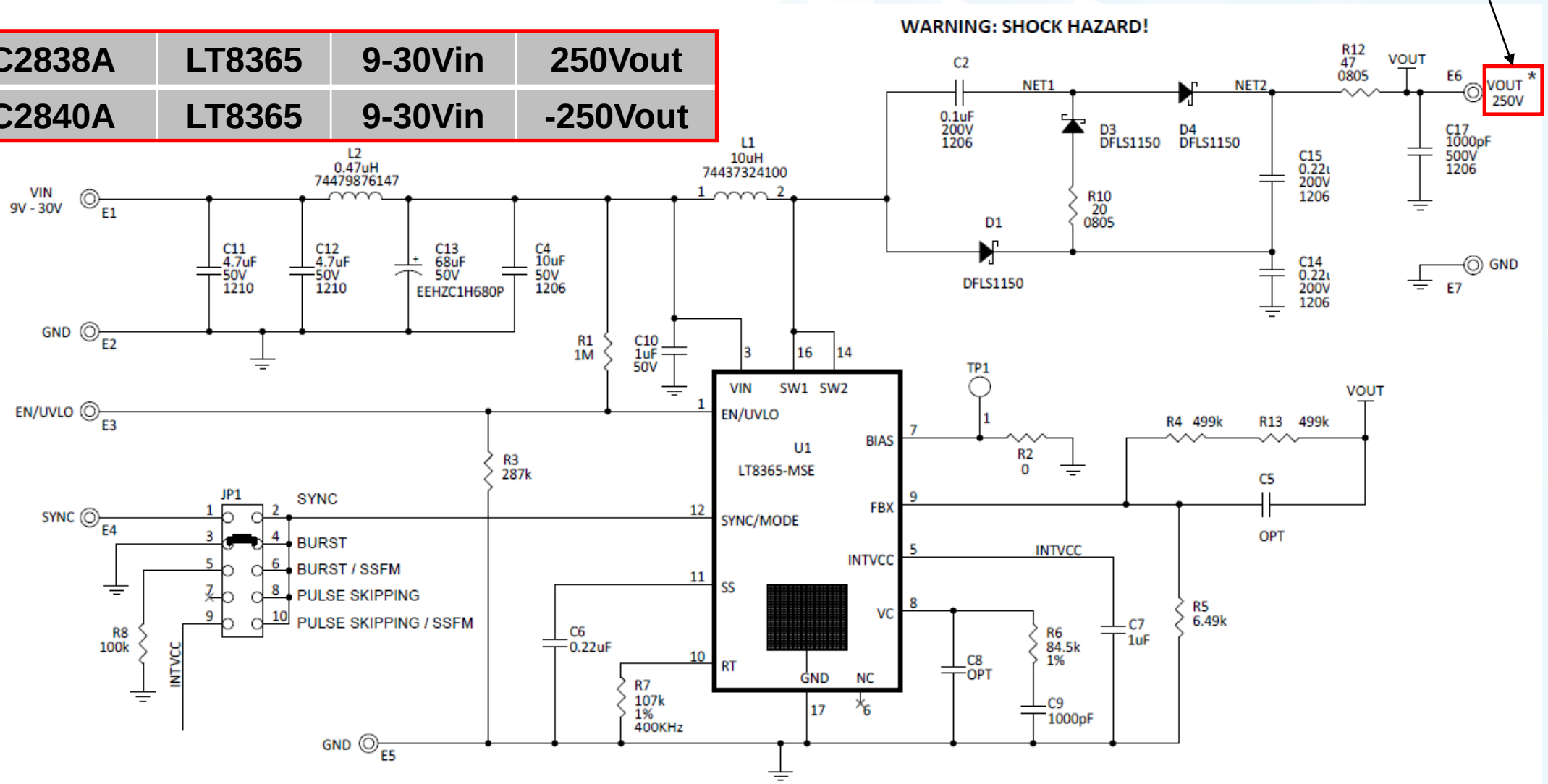
LT8365 can also provide high-voltage **positive** supplies.

LT8365 Demo Boards:
DCM Boost Converter + Charge Pump Circuit

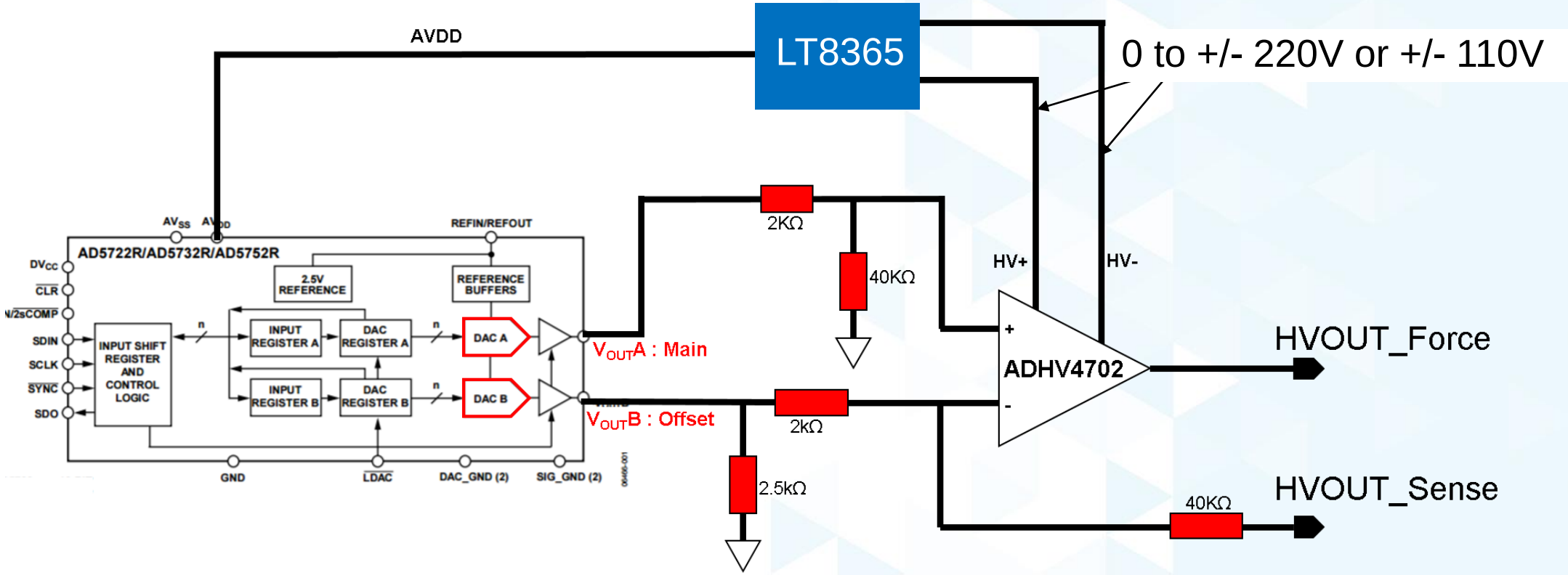
Automotive LiDAR

APD Bias Supply

DC2838A	LT8365	9-30Vin	250Vout
DC2840A	LT8365	9-30Vin	-250Vout



HV DAC Application using LT8365



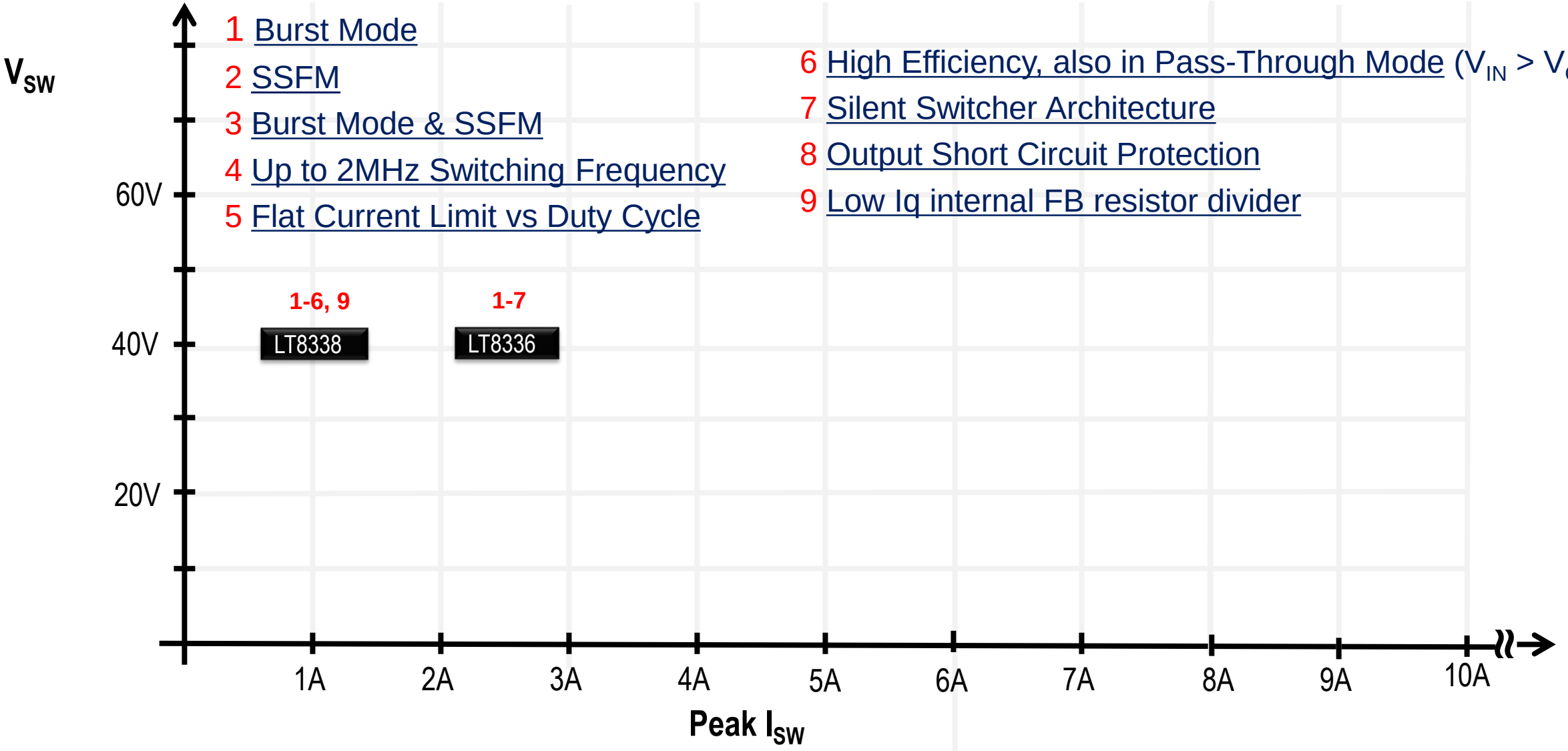
ADHV4702-1 Output Span:

- 200V when AD5752R Gain = 4
- 100V when AD5752R Gain = 2

Monolithic Micropower Synchronous Boosts (V_{IN} > 25V)

1 Burst Mode
2 SSFM
3 Burst Mode & SSFM
4 Up to 2MHz Switching Frequency
5 Flat Current Limit vs Duty Cycle

6 High Efficiency, also in Pass-Through Mode (V_{IN} > V_{OUT})
7 Silent Switcher Architecture
8 Output Short Circuit Protection
9 Low Iq internal FB resistor divider



Monolithic Micropower Synchronous Boost LT8336 : 40V/2.5A, Silent Switcher

Features

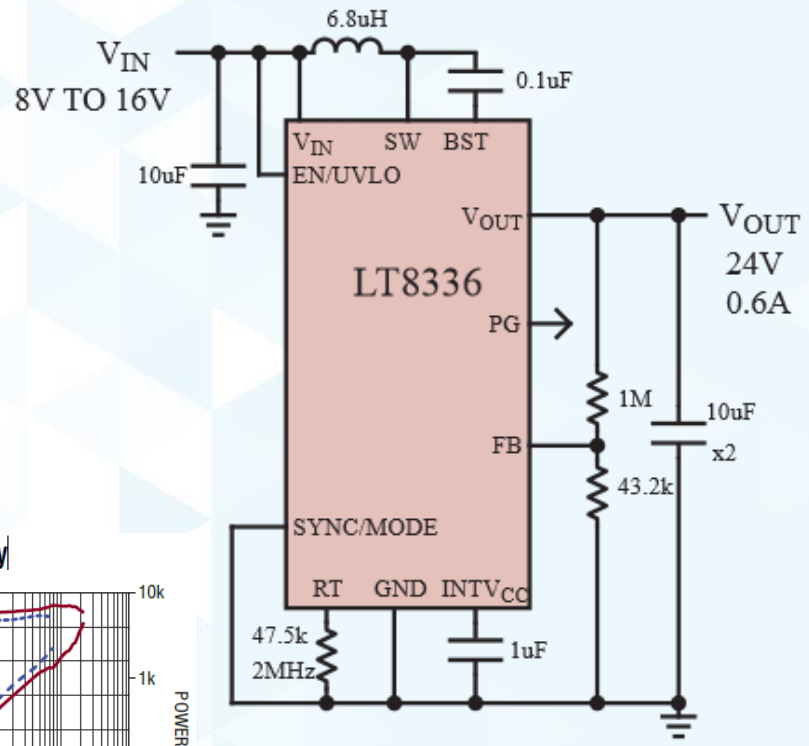
- **Low EMI – Silent Switcher / SSFM**
- **Low 5uA V_{IN} pin Quiescent Current in Burst Mode**
- **High Efficiency, also in Pass-Through Mode (V_{IN} > V_{OUT})**
- Wide Vin/Vout Range : **2.8V** to **40V**
- **40V/2.5A** Power Switches
- Adjustable and Synchronizable: 300kHz to 3MHz
- **3mm x 3mm** LQFN

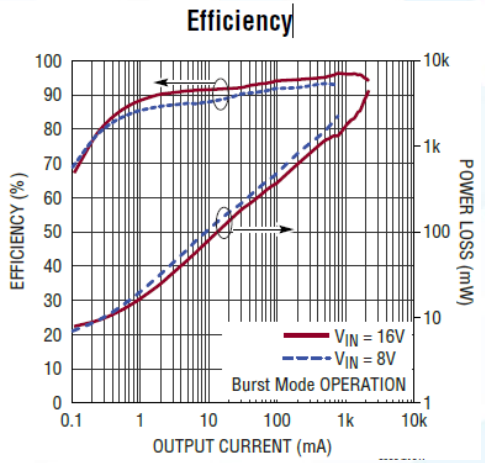
Applications

- Automotive Pre-Boost : Rear and Surround Cameras
- General Purpose High Efficiency, Low EMI Boost

1ST
Micropower Boost
Silent Switcher

Low I_Q, Low EMI, 24Vout 14W Synchronous Boost





Key Tech Feature: Pre-Boost/PassThru (Patented)

V_{IN}

LT8610
Step-Down
Regulator

V_{OUT}

If V_{IN} > V_{OUT} **OK**

If V_{IN} < V_{OUT} **Not OK**

No regulated output in some cases

- Start-up transients

V_{IN}

LT8610
Step-Down
Regulator

V_{OUT}

If V_{IN} > V_{OUT} PassThru™ **OK**

If V_{IN} < V_{OUT} Pre-boost **OK**

Output always OK!!!

Key Tech Feature: Pre-Boost/PassThru (Patented)

If V_{IN} > V_{OUT}

V_{IN}

With PassThru™

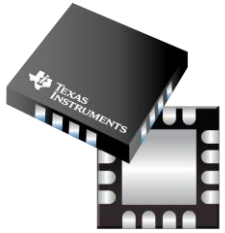
Step-Down Regulator

V_{OUT}

When pre-boost is not active, the LT8336 behaves like a high conductivity wire due to an intelligent **100% duty cycle** high-side synchronous MOSFET

Without PassThru

V_{IN}



Step-Down Regulator

V_{OUT}

When the synchronous MOSFET is not turned on during V_{IN} > V_{OUT}, the parasitic diode of the MOSFET contributes to larger voltage drop in the V_{IN}-to-V_{OUT} conduction path, reducing efficiency

Outline

- Buck/Boost / Buck-Boost / Inverting Basics Overview
- Monolithic high voltage synchronous buck products family
- Monolithic Non-Synchronous/ Synchronous boost products family
- 4-Switch Buck-Boost Controllers/umodule for High Power
- Inverting Converter Design
- Surge Stopper and Protect

Synchronous Buck-Boost Converters

- Applications:
  - Automotive power supply from 12V/24V lead-acid battery
  - Wide V_{IN} applications where V_{IN} and V_{OUT} overlap
  - Emerging narrow-focus applications for LED driver and USB-C PD
  - Industrial / Broad market 5V to 100V

- Core Technology:
  - Low-EMI direct-inductor-current-sense buck-boost architecture for controller solution
  - Silent Switcher architecture for monolithic solution

- Key Features:
  - Low EMI – easy to pass CISPR25 class 5 limits
  - High power efficiency – 95%~98%
  - High switching frequency – up to 2MHz
  - High quality and automotive standard – AEC-Q100

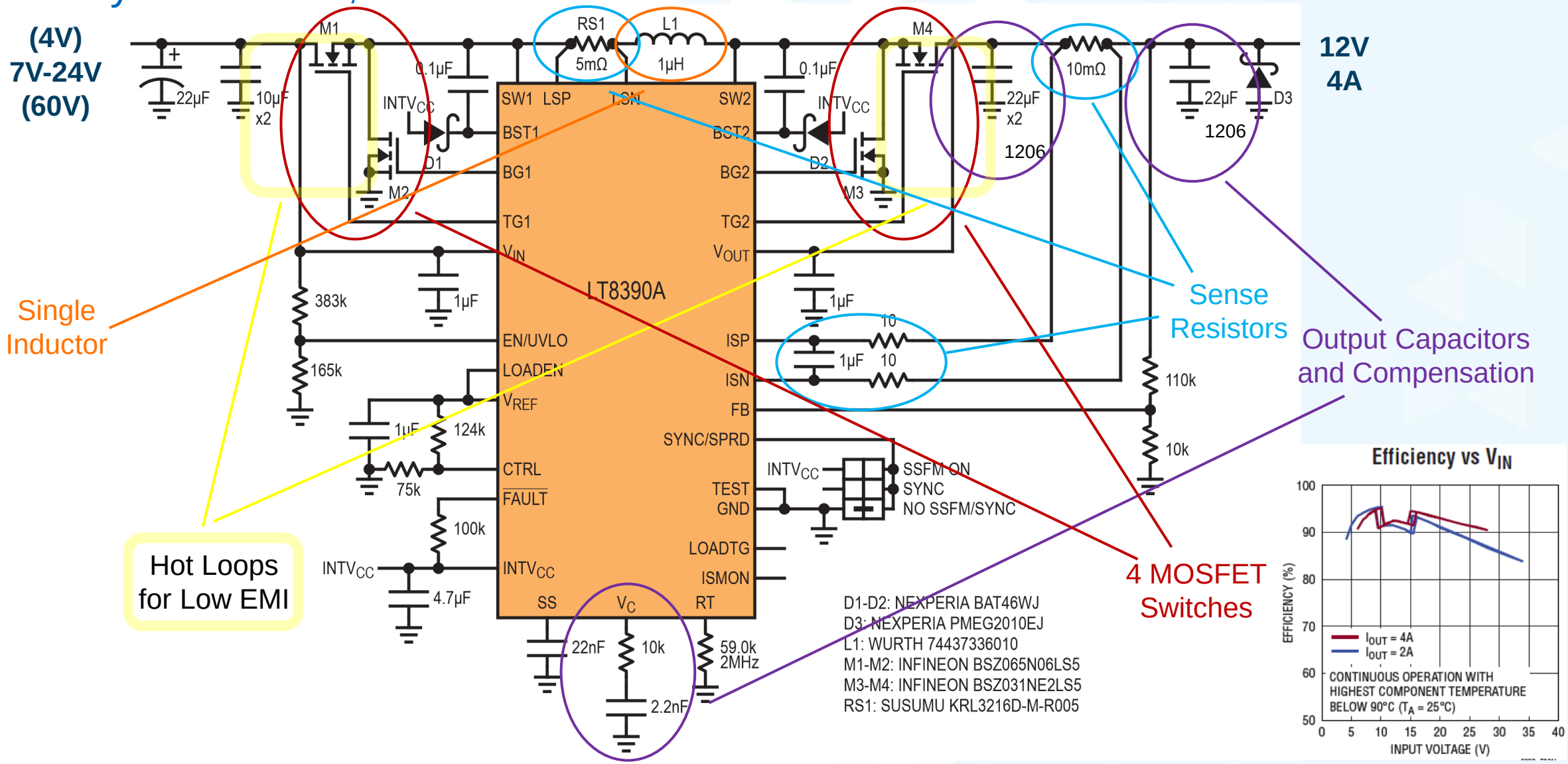
- https://www.analog.com/en/products/power-management/switching-regulators/buck-boost-regulators.html

Buck-Boost Controller Portfolio (40V-60V)

	LT3790	LT8705A	LT8390/90A	LT8210
V_{IN} Range	4.7V~60V	2.8V~80V	4V~60V	2.8V~100V
V_{OUT} Range	1.2V~60V	1.3V~80V	1V~60V	1V~100V
V-Regulation Accuracy	±2%	±2%	±1.5%	±1.25%
I-Regulation Loop	2 (Input and Output)	2 (Input and Output)	1 (Input or Output)	1 (Input or Output)
I-Regulation Accuracy	±6%	±6%	±5%	±5%
Switching Frequency	200k~700k	100k~400k	Non-A: 150k~650k A: 600k~2M	80k~400k
Spread Spectrum	No	No	Yes	Yes
Light Load Operation	CCM	DCM	DCM	DCM
Power Good Flag	No	No	Yes	Yes
Protection	Output Shorted Flags	short-circuit protection	Keep-running, Hiccup, Latch-off in short-circuit condition	-40V Reverse Input Protection
Package	FE38	FE38 & QFN5x7	FE28 & QFN4x5	FE38 & QFN6x6

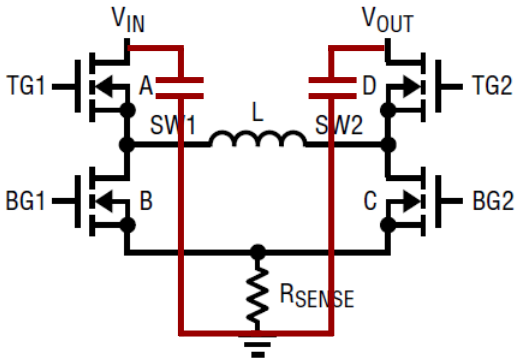
LT8390A 2MHz Buck-Boost Demo Circuit

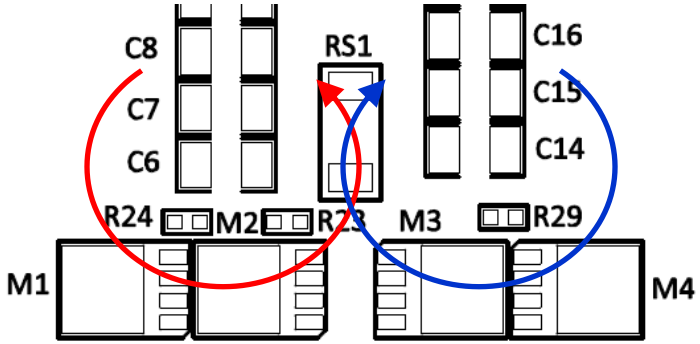
Proprietary Peak Buck, Peak Boost Control Scheme



EMI Performance – LT3790 vs LT8390/90A

LT3790
Ground Current Sense

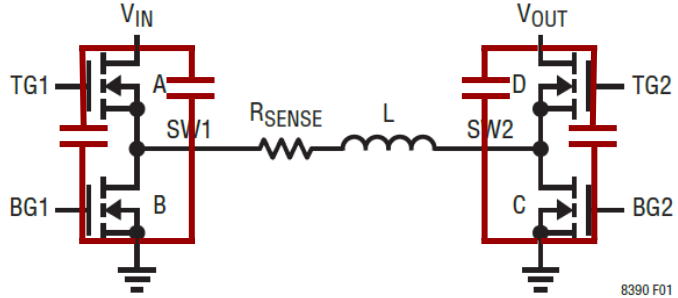


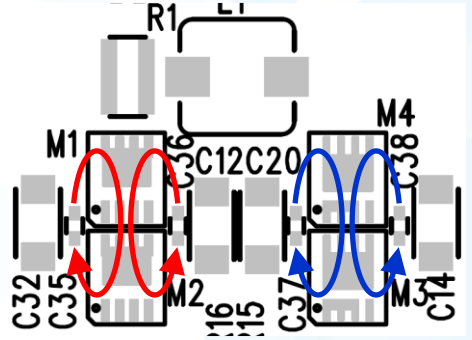


Single big hot loop
for both V_{IN} and V_{OUT}

Low EMI

LT8390/90A
Inductor Current Sense

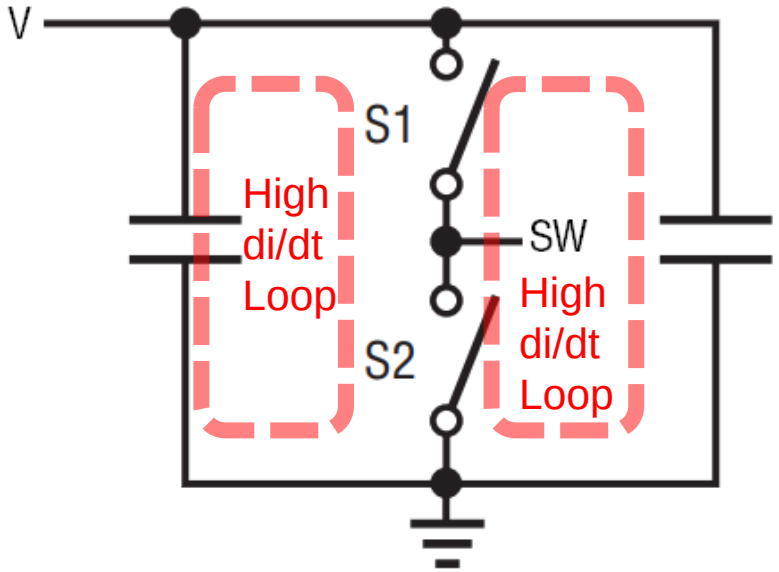




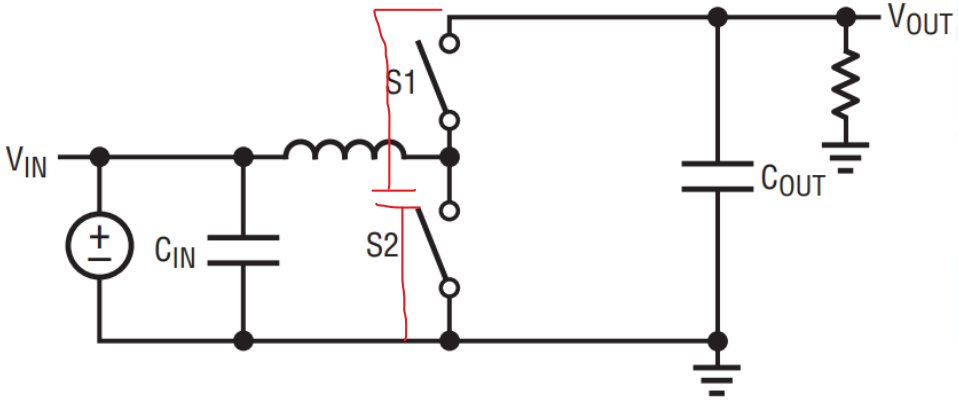
"Silent Switcher" style
small dual hot loops
for both V_{IN} and V_{OUT}

EMI Performance – LT3790 vs LT8390/90A

Dual Split Hot-Loops



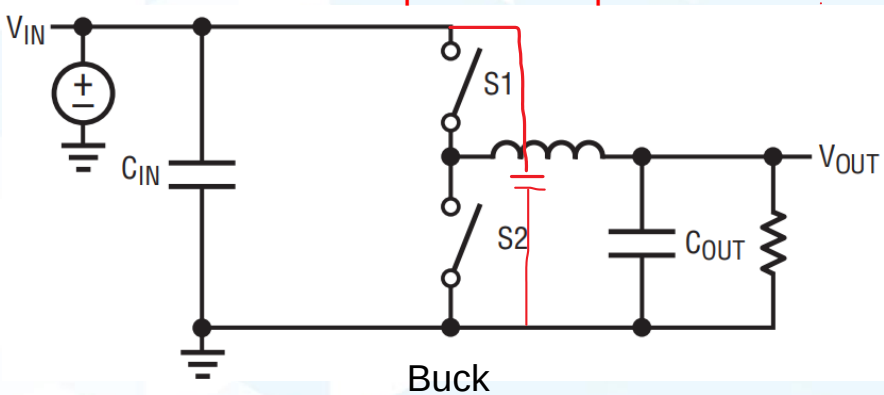
Split Hot-Loop



Boost

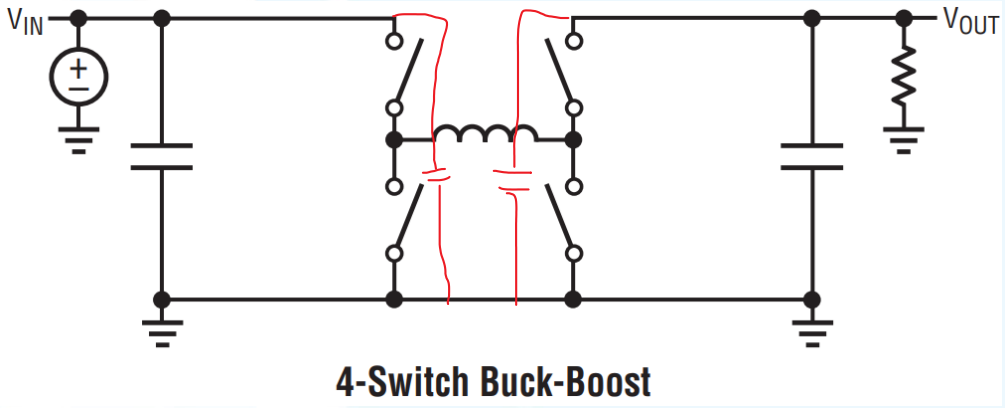
Hot loops should be as small as possible.

Split Hot-Loop



Buck

Split Hot-Loop

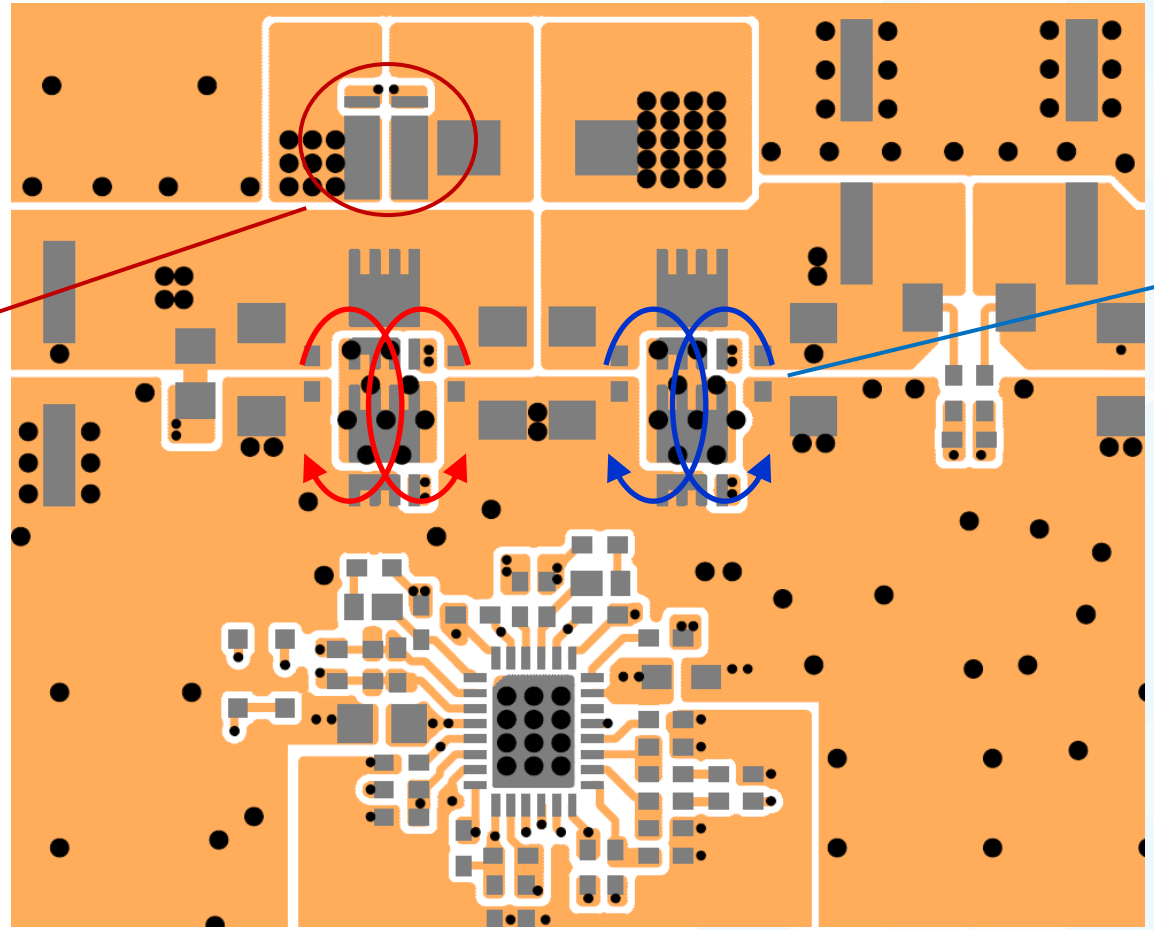


4-Switch Buck-Boost

Sense Resistor Layout – Hot Loops Can Be Small and Duplicated for Low EMI

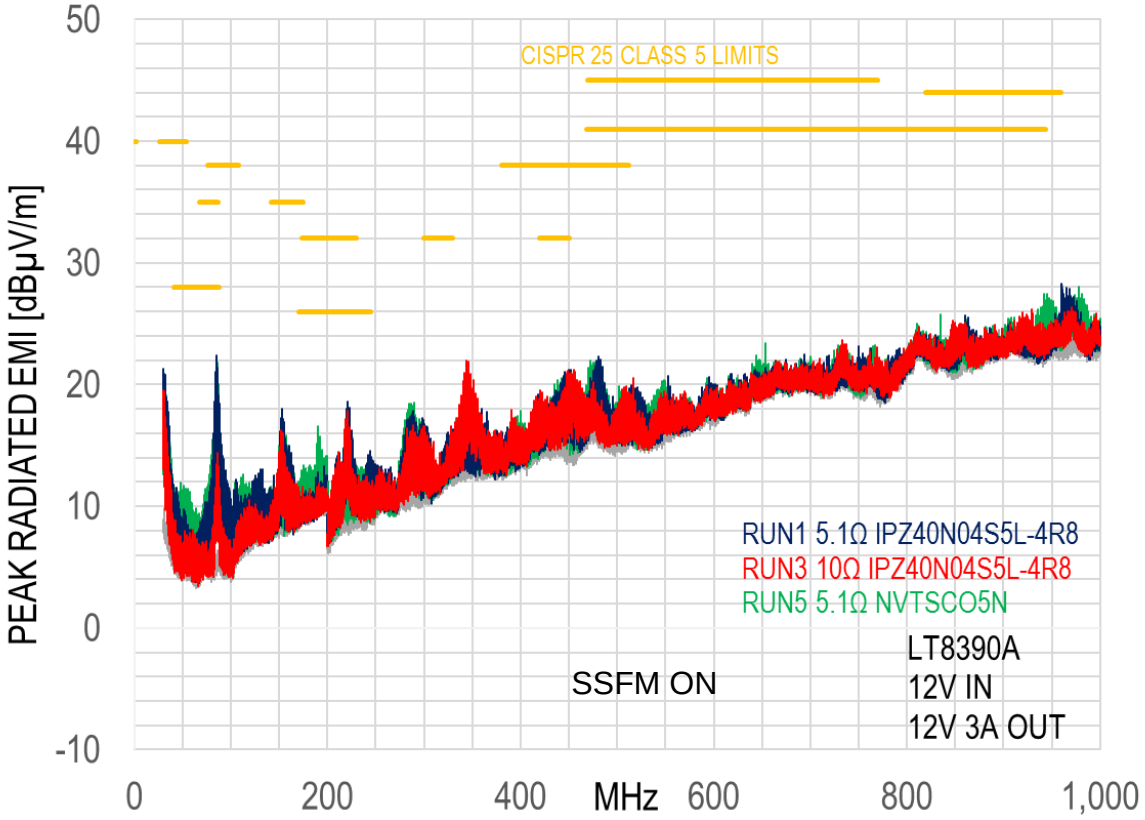
Discrete “Silent Switcher” Layout With Unique Sense Resistor Architecture – R_S Not in Hot Loops

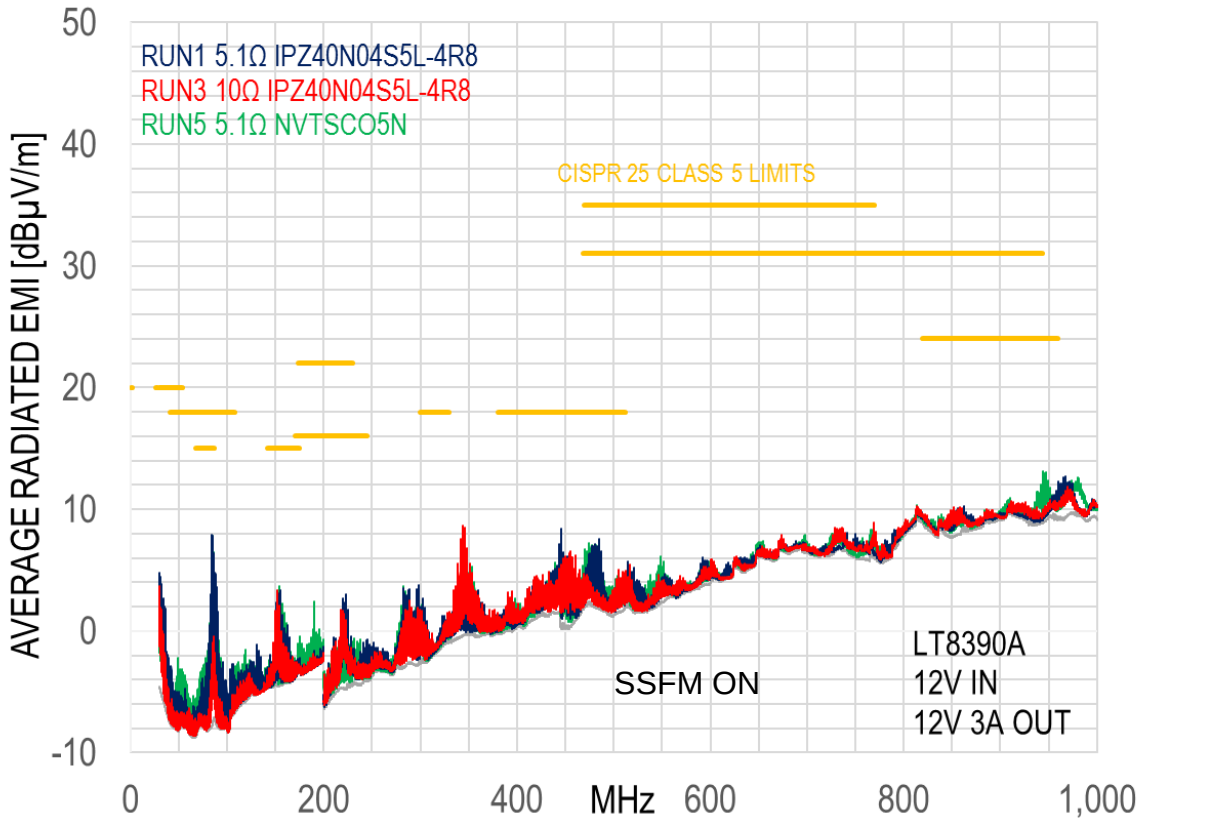
- Peak boost, peak buck low EMI sense resistor (R_S) architecture
- 4-terminal sense resistor layout for highest accuracy.



- Small switching hot-loop is smaller without sense resistor in path
- Opposing hot-loops are possible with this architecture, giving lower EMI with cancelling magnetic fields –
- “Discrete Silent Switcher”

LT8390A Type C USB Power Delivery CISPR 25 Radiated EMI
EMI Filters, Gate Resistors, Automotive Components, SSFM, Layout



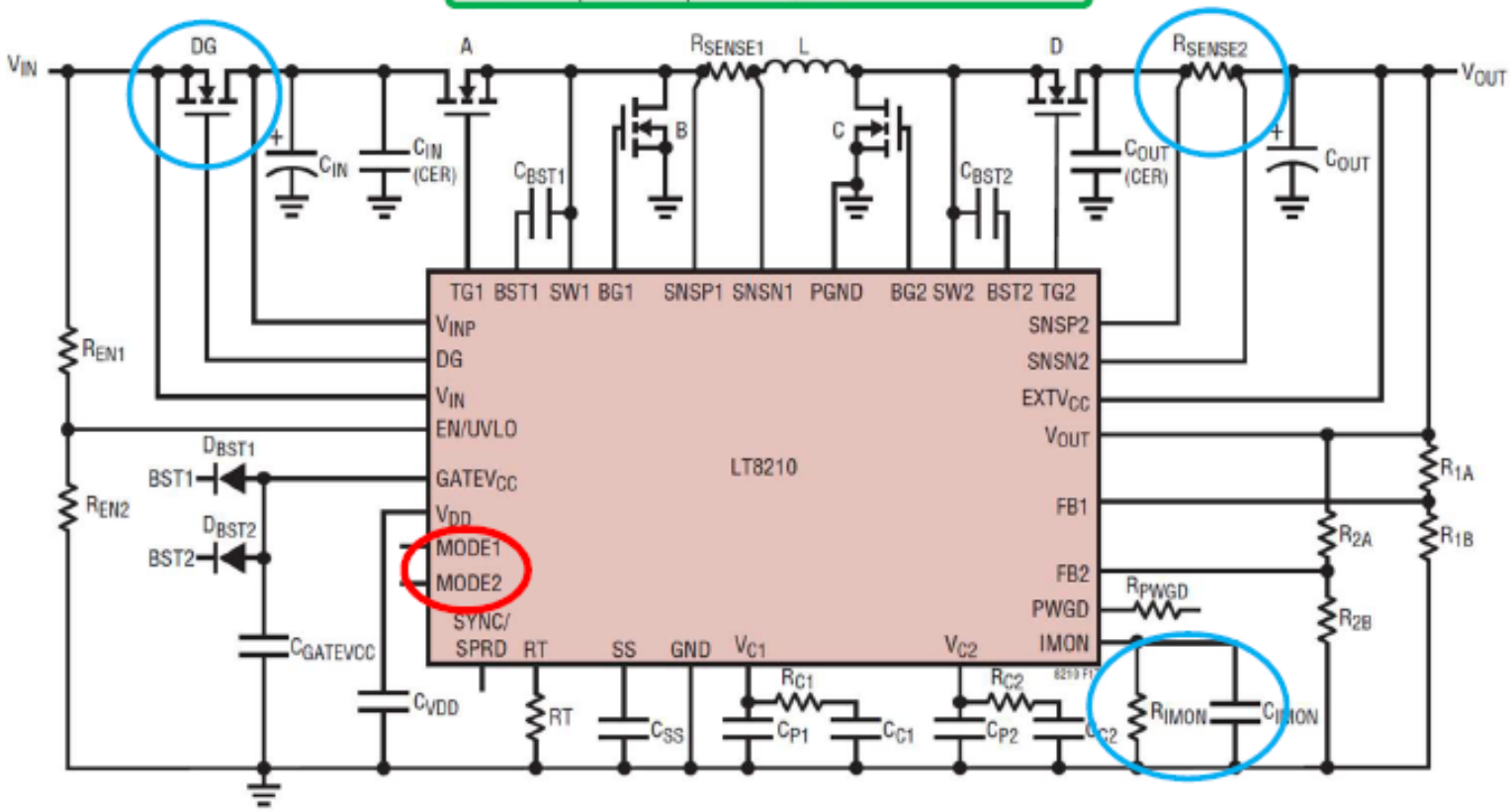


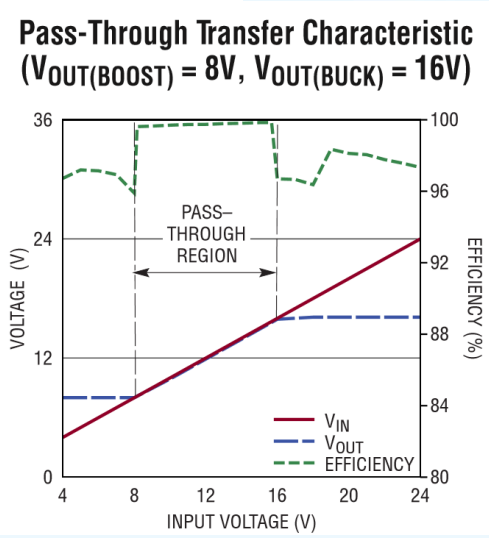
LT8210: 100V Buck-Boost Controller With Pass-Through

Buck-Boost Regulation
Fixed V_{OUT}
FB1 and V_{C1} control Buck and Boost

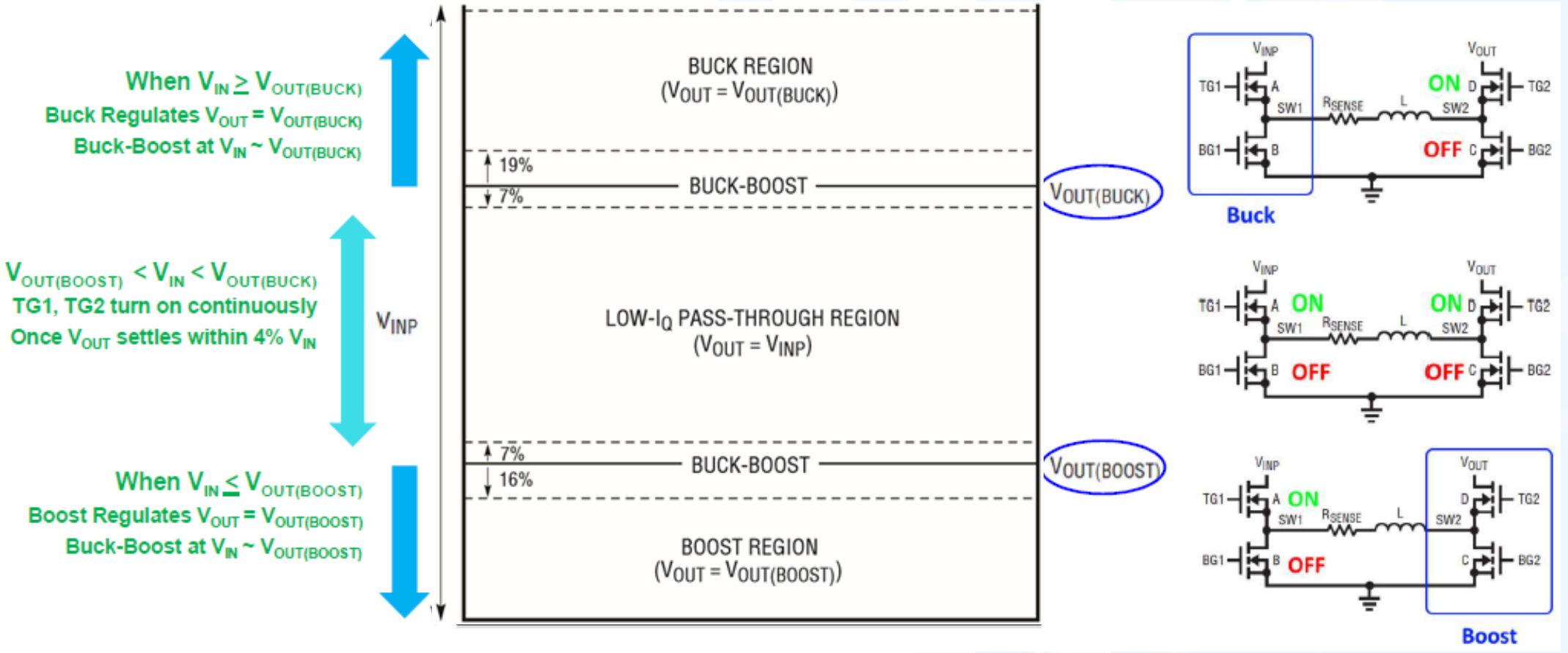
MODE2	MODE1	OPERATING MODE
LOW	LOW	Continuous Conduction Mode (CCM)
LOW	HIGH	Discontinuous Conduction Mode (DCM)
HIGH	LOW	Burst Mode Operation
HIGH	HIGH	Pass-Through Mode

Pass-Through Regulation
V_{OUT} window regulation
FB1 sets bottom, FB2 sets top
V_{C1} controls Boost, V_{C2} controls Buck



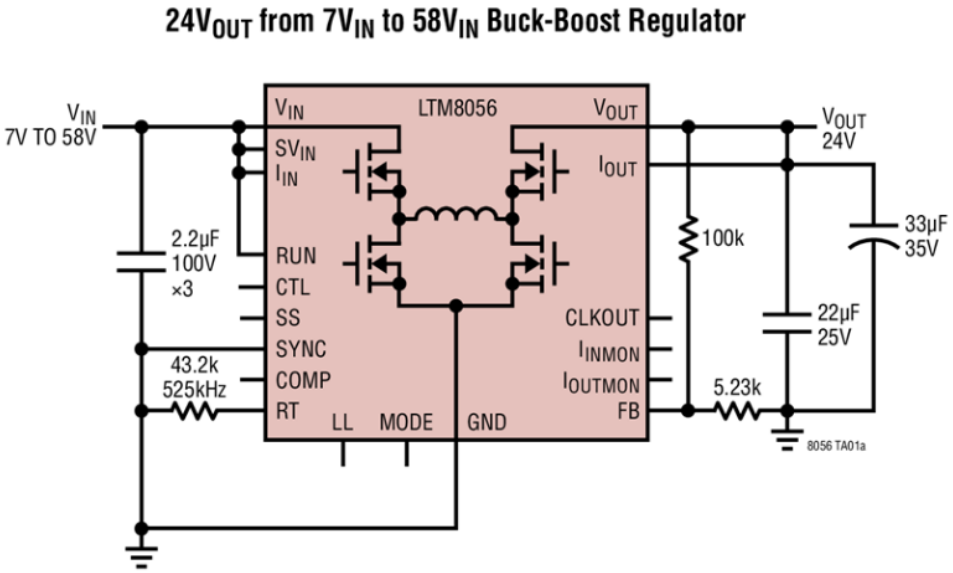


Pass-Through Mode Overview



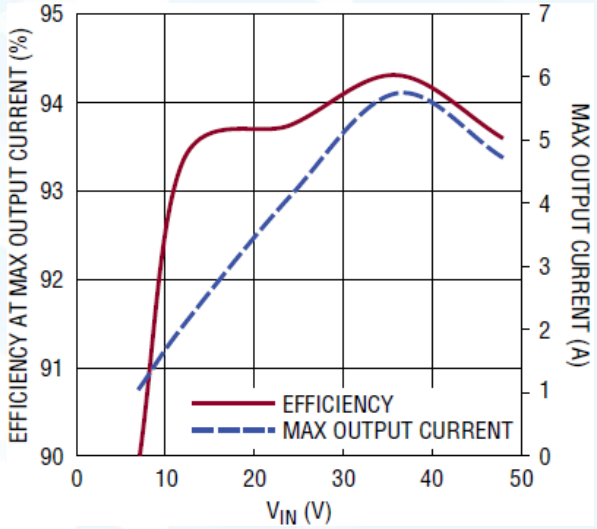
Further Integration

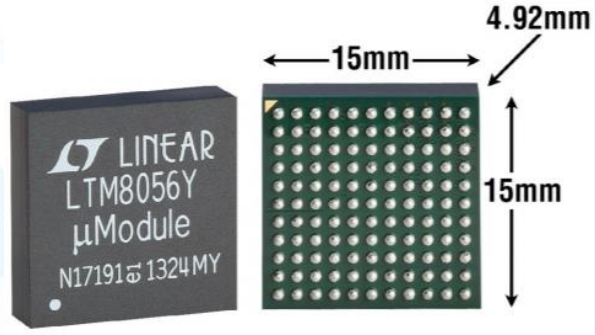
µModule 4 SW Buck-Boost



- **Features**
  - Wide input and output voltage ranges:
    5 V ≤ VIN ≤ 58 V
    1.2 V ≤ V_{OUT} ≤ 48 V
  - Switching Frequency: 100kHz to 800kHz
  - Up to 96% Efficient
  - Parallelable for Increased Output Current

Max Output Current and Efficiency vs VIN





Buck-Boost Charger+Power Path controller--Macnica Cytech

- Target Market / Customers
  - Industry
  - Automation
  - On-board equipment
- Key Features
  - Sync Buck-Boost Charger+Power path control.
  - Li-Ion and Lead-Acid Charge Algorithms.
  - Wide input voltage :Vin:4.5-55V,Vout:4.5-55V.Iout:6-12A.
  - High Efficiency.

VIn	Iin	Pin	Vout	Iout	Pout	Eff	Ploss	散热片
17.49	10.05	175.77	25.93	6.50	168.42	95.81%	7.36	铝散热片
17.52	9.23	161.71	25.93	5.99	155.24	96.00%	6.47	铝散热片
25.13	6.99	175.66	25.93	6.59	170.96	97.32%	4.70	铝散热片
31.83	5.50	175.07	25.93	6.55	169.84	97.02%	5.22	铝散热片
51.20	3.47	177.66	25.93	6.59	170.96	96.22%	6.71	铝散热片
40.68	4.34	176.55	25.93	6.58	170.62	96.64%	5.93	大散热背板
49.80	5.04	250.99	25.93	9.31	241.28	96.13%	9.71	大散热背板
24.42	9.90	241.76	25.93	9.05	234.54	97.01%	7.22	大散热背板
19.57	9.91	193.94	25.93	7.23	187.34	96.60%	6.59	大散热背板

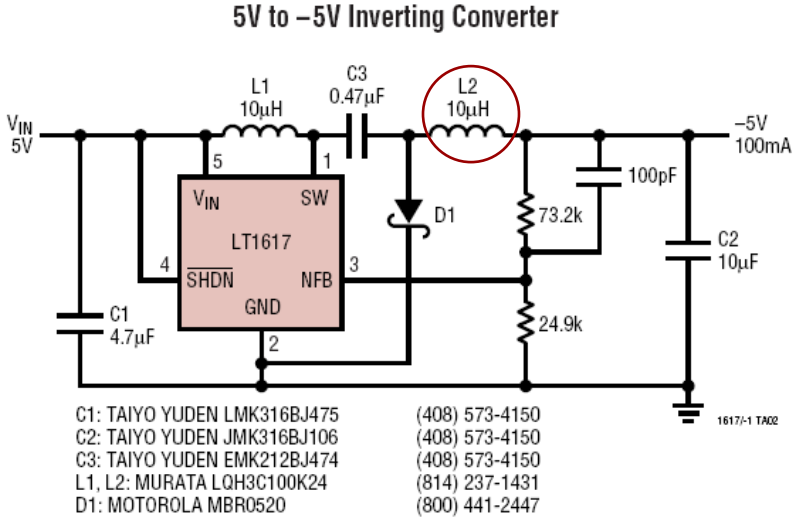
Outline

- Buck/Boost / Buck-Boost / Inverting Basics Overview
- Monolithic high voltage synchronous buck products family
- Monolithic Non-Synchronous/ Synchronous boost products family
- 4-Switch Buck-Boost Controllers/umodule for High Power
- Inverting Converter Design
- Surge Stopper and Protect

Basic Inverting Topologies

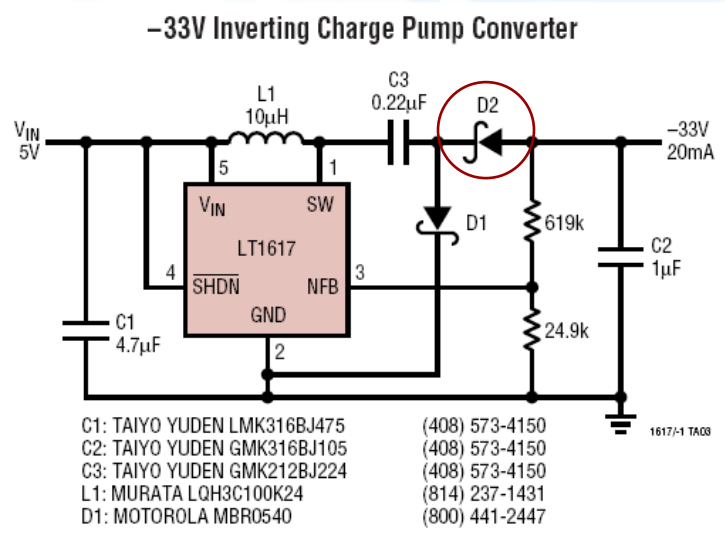
Inverting Cúk

- slightly larger solution size
- max output voltage slightly lower SW pin sees (V_{IN} + $|V_{OUT}|$)
- lower output ripple voltage
- typical efficiency of 75% - 80%

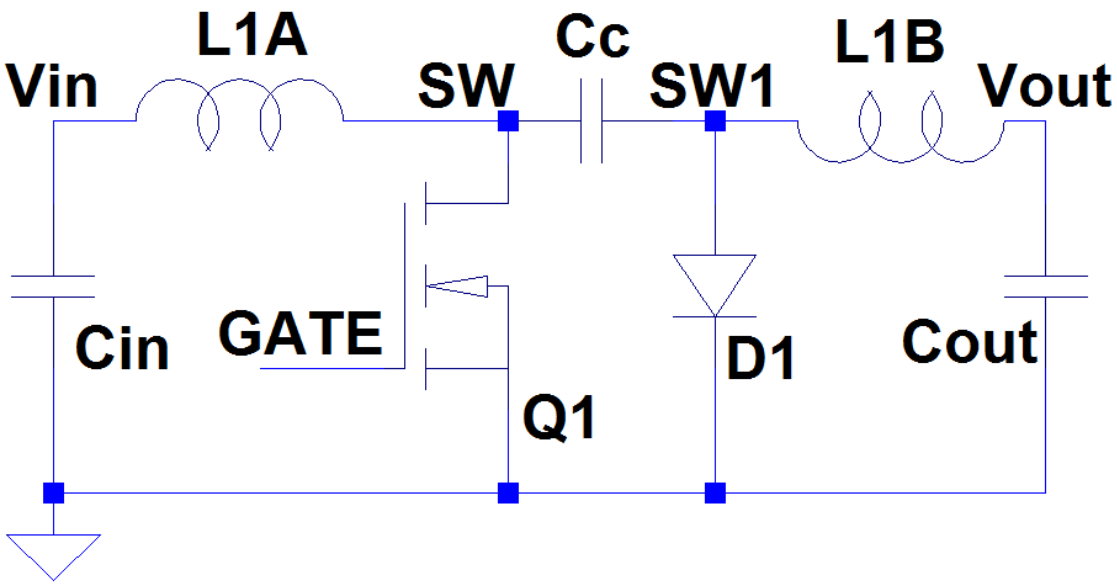


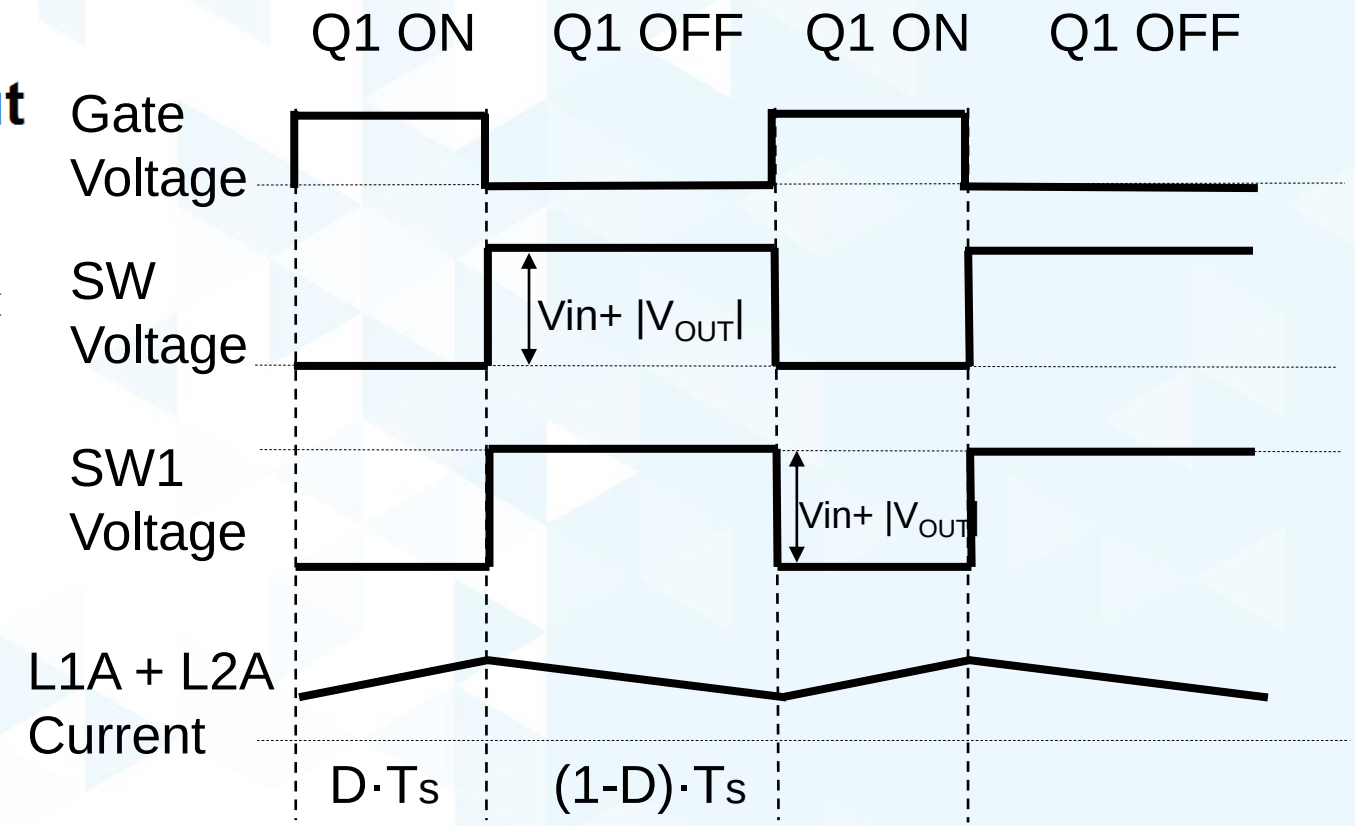
Inverting Charge Pump

- smallest solution size
- larger output voltages
  SW pin sees $|V_{OUT}|$
- slightly larger output ripple voltage
- typical efficiency of 75% - 80%



Cuk Converter Waveforms





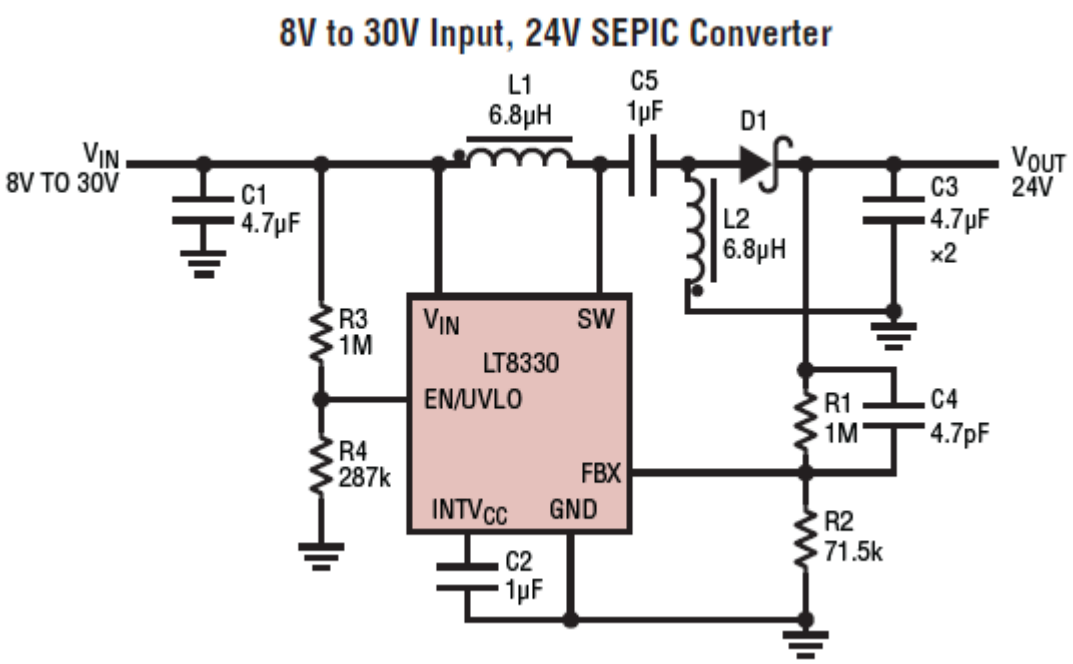
$$V_{OUT} / V_{IN} = - D / (1-D)$$

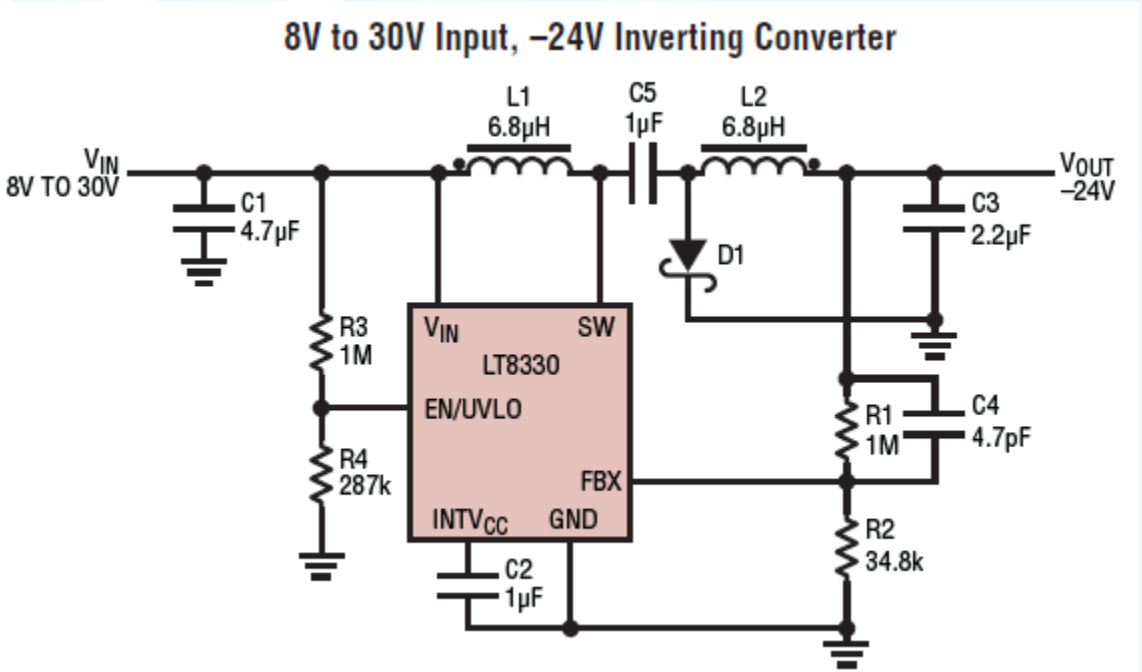
For example: Vout = -12V

Vin (V)	D
6	0.67
12	0.5
24	0.33

T_S : Switching Period

New LT833X / LT836X Non-Synchronous Boosts can also be configured as SEPIC or Inverting (Cuk) Converters





Topology	Main Difference
Boost	Vin < Vout
SEPIC	$V_{INmin} < V_{OUT} < V_{INmax}$
Inverting (Cuk)	V_{OUT} is Negative

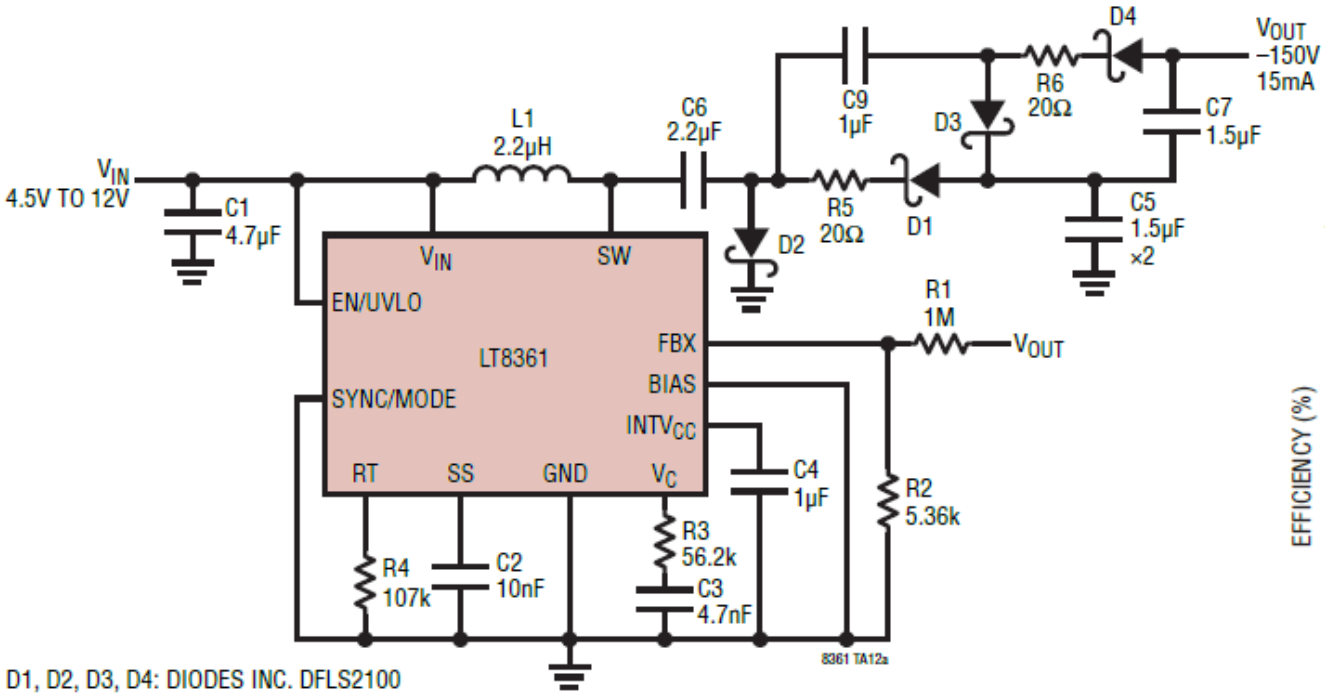
FBX:
Voltage Regulation Feedback Pin
Allows Positive or Negative Outputs

Inverting Charge Pump for High Negative Voltage (e.g. -150Vout) Application

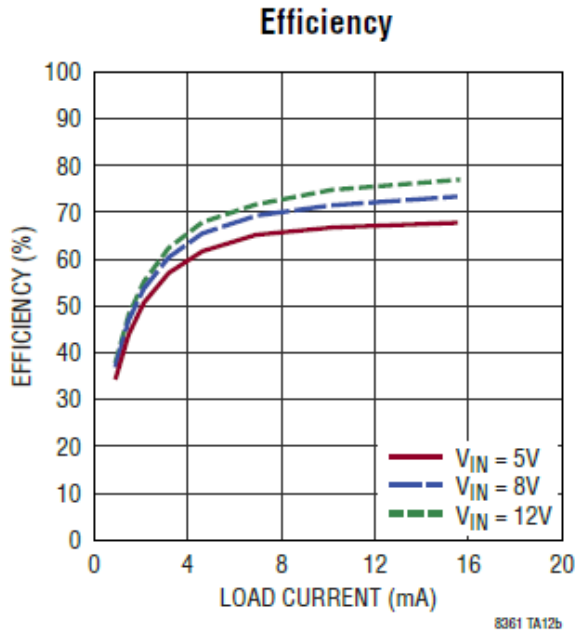
LT8361

TYPICAL APPLICATION

450kHz, 4.5V to 12V Input, –150V Output, Automotive LiDAR APD Bias Power Supply



D1, D2, D3, D4: DIODES INC. DFLS2100
L1: WURTH ELEKTRONIK WE-PD 7345 7447779002
C5: NIPPON CHEMI-CON KTS101B155M32N0T00



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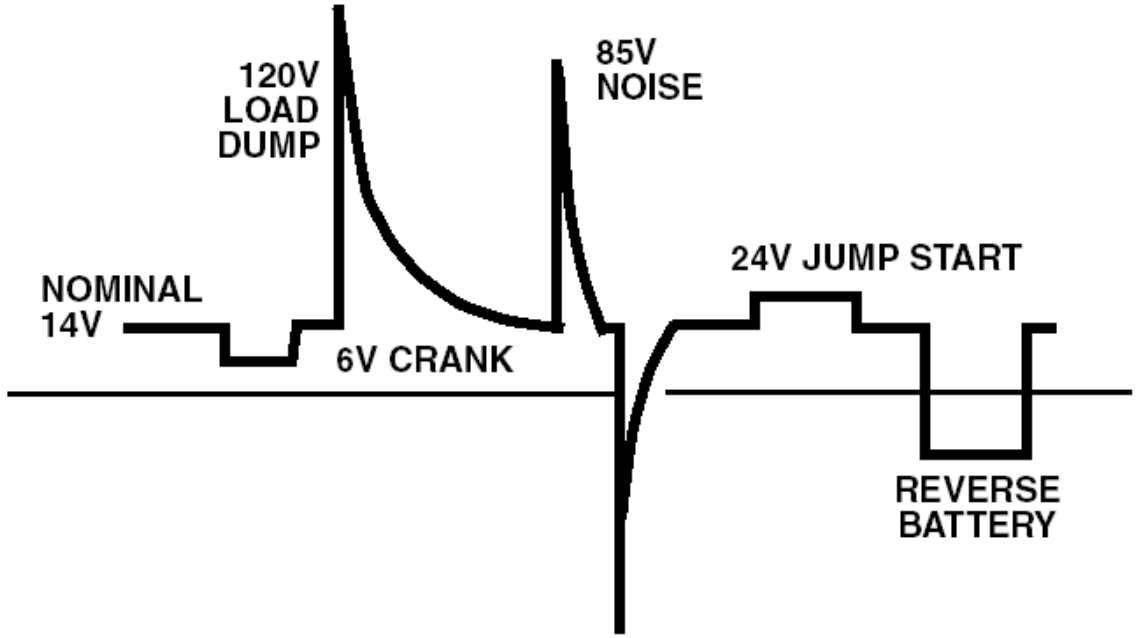
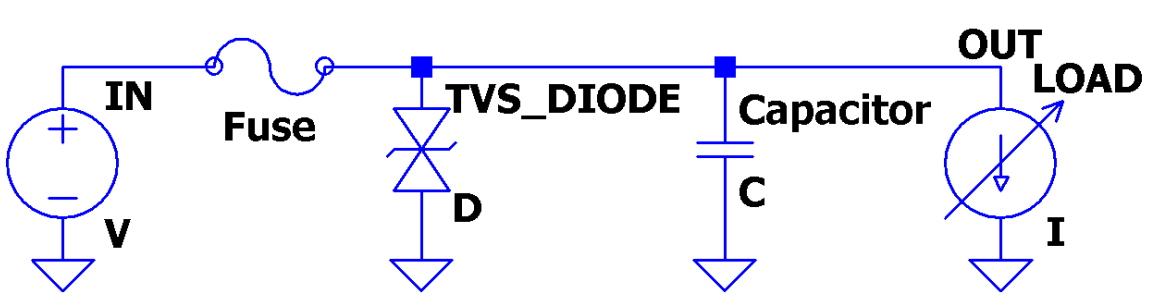
Automotive & Transport: Design Challenges

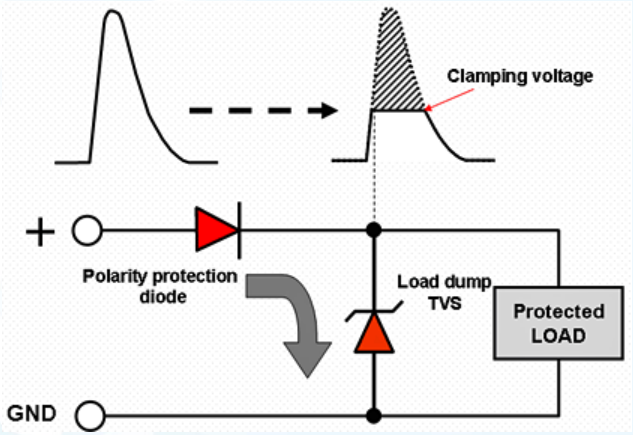


- High voltage spikes & surges (load dump)
- Dual battery jump-start
- Cold crank
- Low quiescent current for always-on systems
- High temperatures, small space
- Demanding quality and reliability requirements

Traditional Solution

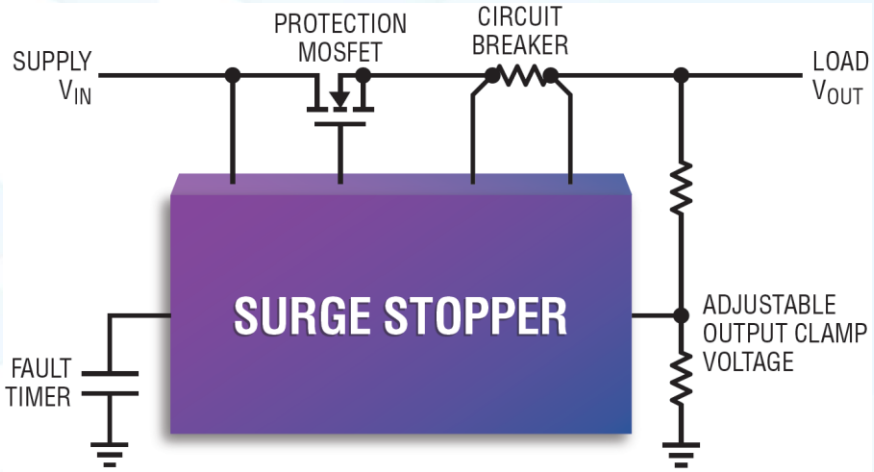
- Consists of
  - Transient voltage suppressor (TVS) for overvoltage protection
  - Inline fuse for overcurrent protection
  - Capacitors and inductors for filtering low energy spikes
  - Series diode for reverse battery protection
- Cons
  - Large size to absorb load dump energy
  - Sloppy, for example, select SMBJ28A to be above dual-battery jump start of 26 V
    - This TVS breaks at 33 V but clamps 13 A at 45 V, so need 45 V downstream circuits
  - Sustained or dc transients can blow fuse or TVS, requiring repairs
  - Reverse protection diode drops voltage, dissipates power

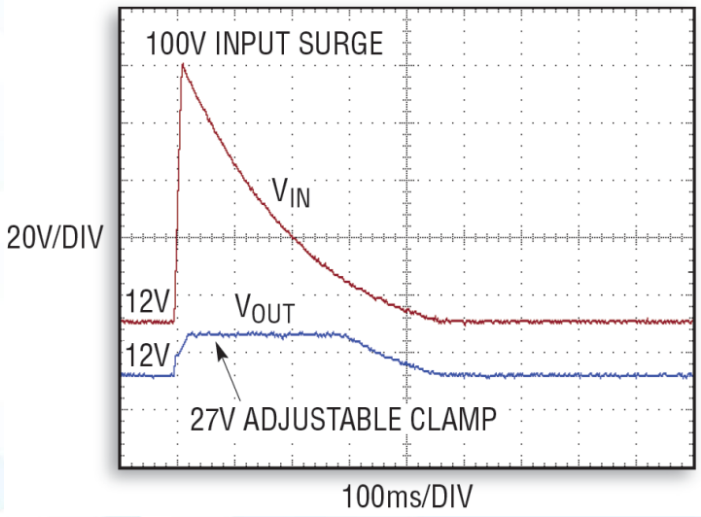




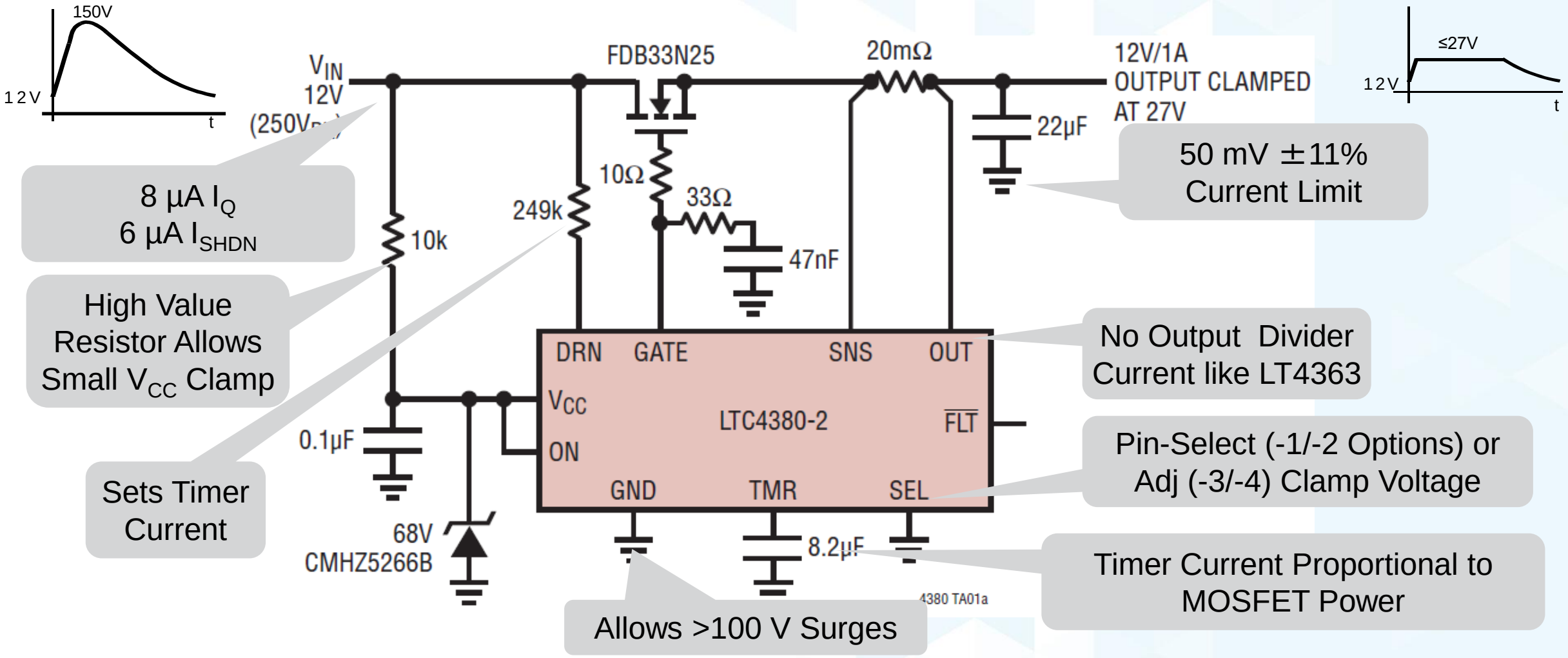
Our Solution: Surge Stopper

- Uninterrupted system operation through V_{IN} or I_{LOAD} surges
- Protects load from input OV and supply from overload/short-circuit
- Disconnects load from supply for sustained/dc faults
- Adjustable clamp voltage eases design changes and reuse
- Tight accuracy minimizes overdesign and reduces cost
- Low profile, surface-mount solution enables compact form factor





LTC4380: 8 µA Quiescent Current Surge Stopper



Thank you

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